

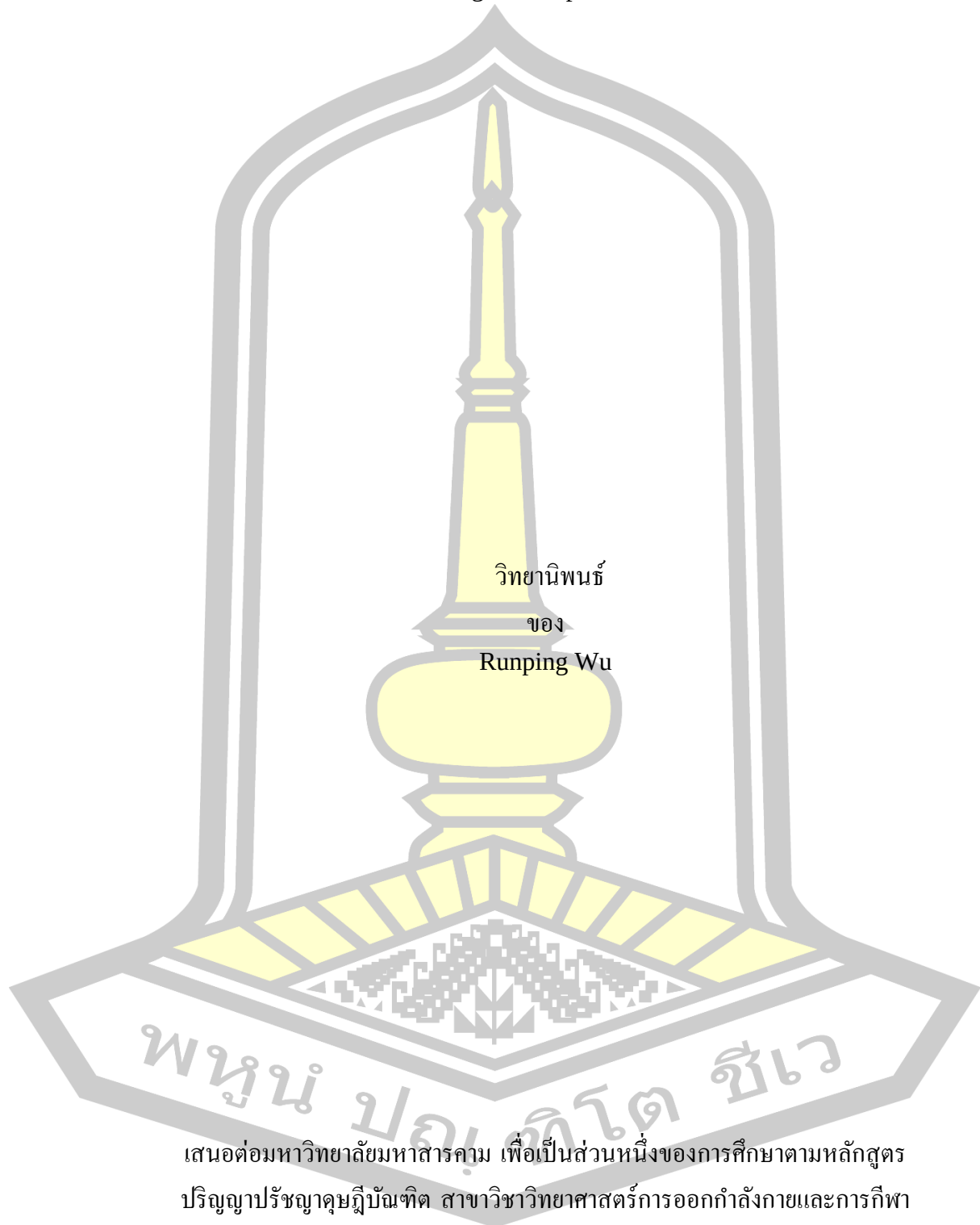
Biomechanical Characteristics Analysis of Upper Limb Muscle Groups of Athletes
during Push Up Exercise

Runping Wu

A Thesis Submitted in Partial Fulfillment of Requirements for
degree of Doctor of Philosophy in Exercise and Sport Science
May 2024

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Biomechanical Characteristics Analysis of Upper Limb Muscle Groups of Athletes
during Push Up Exercise



เสนอต่อมหาวิทยาลัยมหาสารคาม เพื่อเป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
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May 2024

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The examining committee has unanimously approved this Thesis, submitted by Mr. Runping Wu , as a partial fulfillment of the requirements for the Doctor of Philosophy Exercise and Sport Science at Mahasarakham University

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ABSTRACT

One of the main purposes of biomechanics in the study of motion technology is to reveal the principle of motion technology. There are many differences between different athletes in completing different technical movements. The biomechanical causes and principles of these differences can be studied from the perspective of biomechanics and biology, and a reasonable movement pattern mechanism can be extracted through the technical diagnosis and analysis of excellent athletes, and advanced movement technology principles can be established to guide sports training and physical education. Most of the technical movements of competitive gymnastics need double support to complete, push-ups is a typical double-support technical movement, and has long been used as a means to evaluate the local muscle endurance of the upper body. Using biomechanical test method to study the biomechanical characteristics of push-ups with different postures and different loads is of great significance for guiding teaching and training.

Twelve volunteers from Xi'an Physical Education University participated in this study, including 4 high-level athletes, 4 intermediate level athletes and 4 ordinary athletes. They are between the ages of 21-26 and have been involved in sports training for 1-11 years. Through the participation of volunteers, the biomechanical characteristics of Chinese gymnasts in different positions and different loads of push-ups were studied.

High-speed photography, 3D force measurement and wireless surface electromyography were used to test the gymnasts of three sports levels to complete 4 postures and 5 kinds of load push-ups. The kinematic data, force value and surface EMG data obtained from the test were selected, and the data analysis of the selected values were carried out, such as mean value, standard deviation and T-test. This paper summarizes the time characteristics, speed characteristics, Angle to Angle, mechanical characteristics and surface myoelectric characteristics of the three levels of athletes to complete the push-up movement, such as kinematics, dynamics and myoelectric characteristics, and makes a comparative analysis of each other. Combined with the theory of sports biomechanics and education and training theory, the factors affecting

the completion of the push-up technical movement and teaching and training methods are discussed. The main conclusions are as follows:

(1) The complete time of push-ups in the same posture is different among athletes at different sports levels, and there is a significant difference between each other, and the complete time of high-level athletes is less than that of medium-level and ordinary athletes.

(2) Athletes of the same athletic level take different time to complete push-ups with different loads, and there are significant or very significant differences between each other, and the time of advanced athletes is less than that of intermediate and ordinary athletes.

(3) The complete time for athletes at the same level to complete push-ups with different loads has a rule of U, that is, the time for completing push-ups with feet 25 cm and 30 cm above the ground is slightly less than that for feet on the ground, while the time for completing push-ups with feet 40 cm and 50 cm above the ground is longer than that for feet 25 cm and 30 cm above the ground. Push-ups with feet 50 cm above the ground took the most time.

(4) When the same level athletes complete push-ups with different loads, the ground vertical reaction force in the upward pushing stage is greater than that in the downward bending arm stage.

(5) When athletes of the same level complete push-ups with different loads, the speed of the left shoulder joint and the right shoulder joint is inconsistent in the downward flexion stage and the upward push stage, and there is a certain difference.

(6) When athletes at different levels complete push-ups in different positions or different loads, there are differences in the Angle of the elbow joint at the lowest point of the bending arm of the downward flexion, and the Angle of the elbow joint of high-level athletes is smaller than that of intermediate level and ordinary athletes.

Keyword : Biomechanical characteristics, Push up exercise

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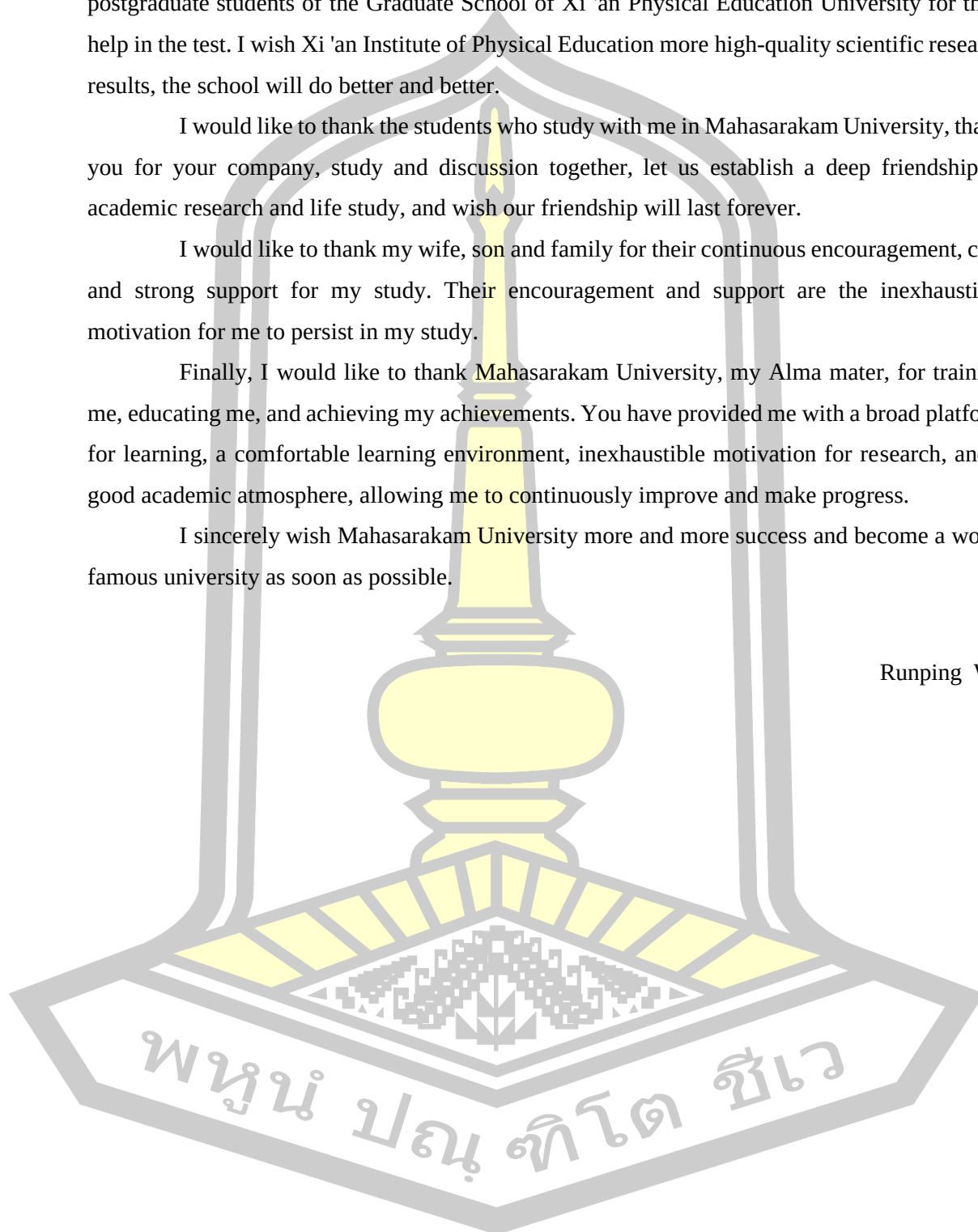
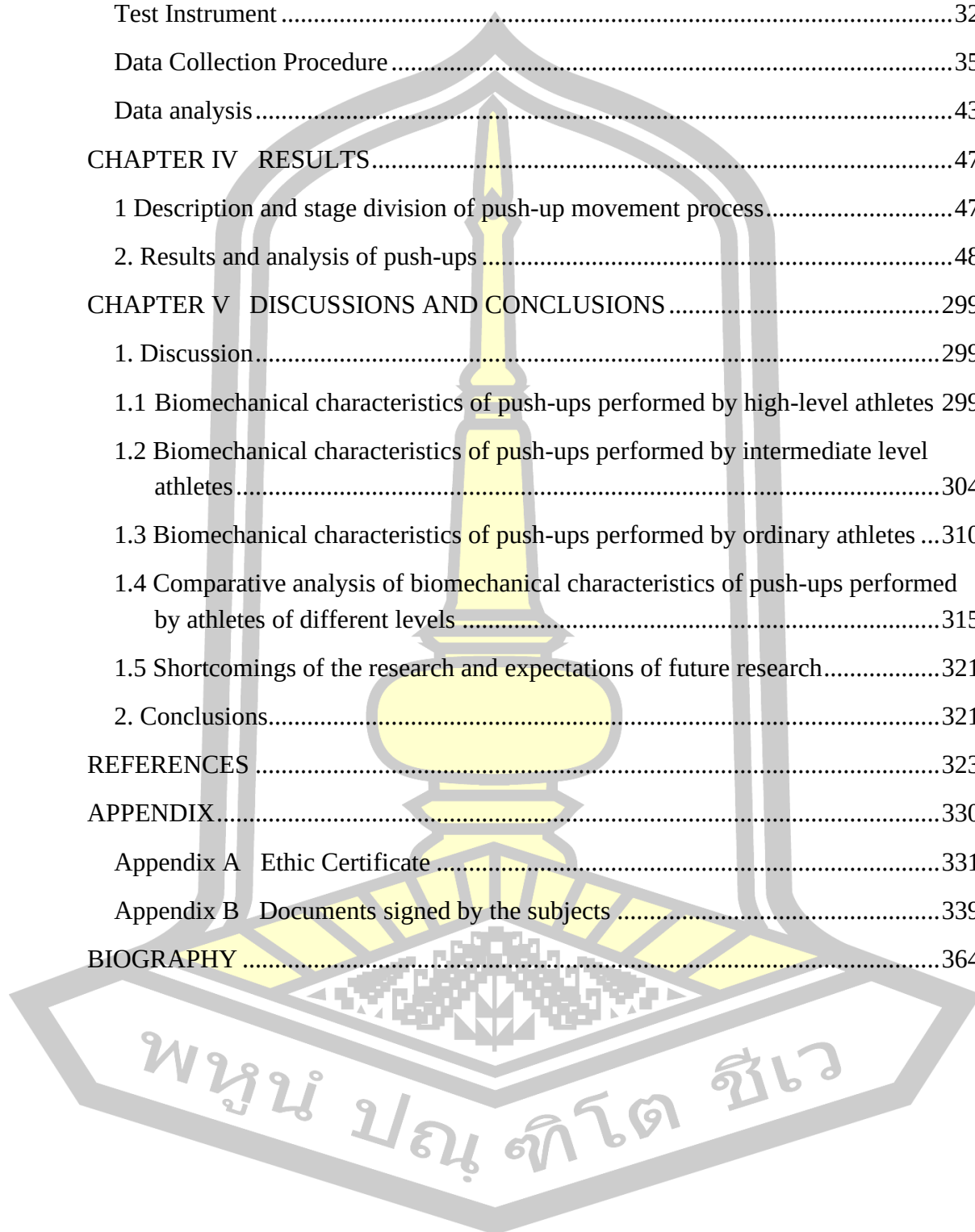


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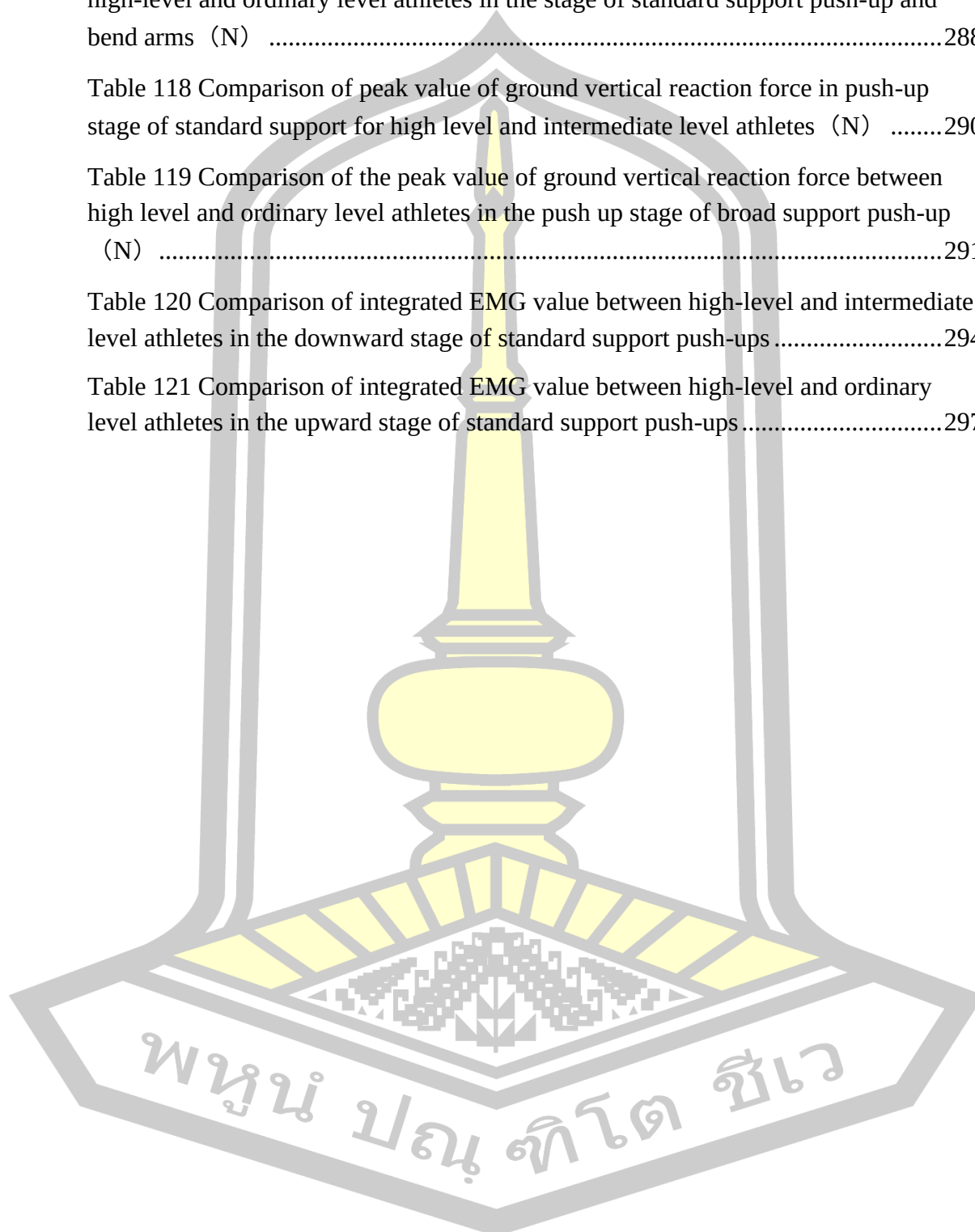
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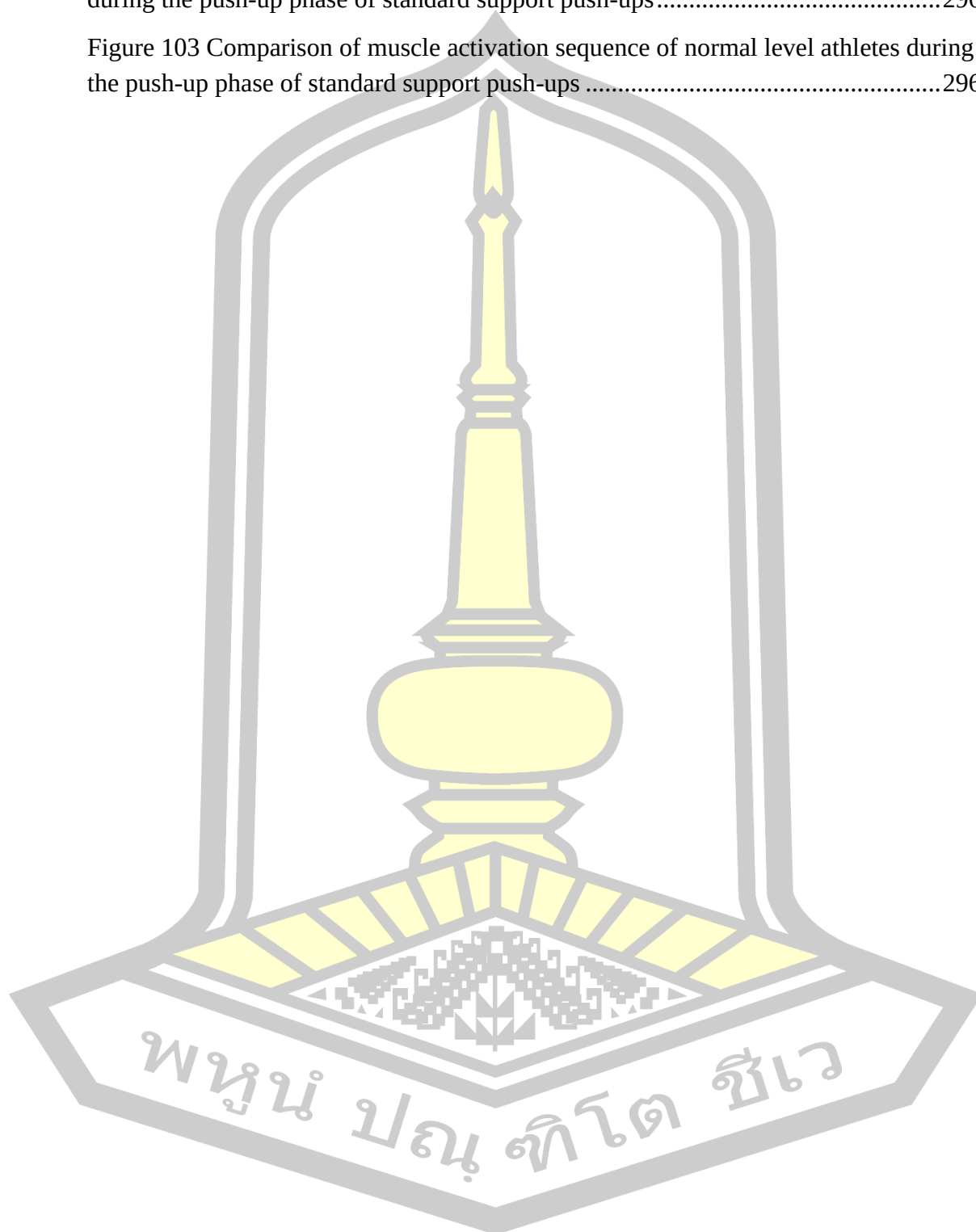
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CHAPTER I

INTRODUCTION

Background

Biomechanics is an interdisciplinary subject that combines biology and mechanics. "Biomechanics is a science that studies the structure and function of biological systems by using the principles and methods of mechanics" (Hatze, 1974). Sports biomechanics is an important branch of biomechanics, which is the science of studying the laws of human mechanical motion in sports. It is a subject that combines the complex movement forms and changes of the human body (or equipment) in sports with the principles of mechanics and biology (Lu, 2010). Sports ergonomics and sports engineering are also emerging interdisciplinary disciplines closely related to sports biomechanics. Sports ergonomics refers to a comprehensive and practical discipline that studies the relationship among the three in the system of worker, sports equipment and sports environment to achieve coordination and unity (Reilly T. 1984). Sports biomechanics is a science that discusses the forces acting on the human body and their effects (Hay, 1993). Because of understanding the mechanism of sports injury, there are many ways to prevent sports injury. Because most of the damage has its mechanical reasons, force and related factors (such as energy) are the basic factors that determine the occurrence and severity of the damage (Zatsiorsky, 2000). As an important part of sports science, sports biomechanics has two main tasks: one is to improve sports ability (sports performance), including competitive sports, national fitness and leisure sports; The second is to prevent sports injury. Its essence is to apply the principles and methods of mechanics to study the forms, laws and principles of human movement. Its scope mainly focuses on sports movement technology, sports training, sports injury and physical fitness, sports equipment and other aspects. The principles and methods of sports biomechanics are the main means to analyze and diagnose the technical and tactical characteristics of athletes, and the main methods to improve sports performance, explore technical rules and improve sports skills and tactics (Lu, 2010). One of the main purposes of sports technology research is to reveal the principles of sports technology, especially in the field of competitive sports. The

principles and methods of sports biomechanics are the main means of analyzing and diagnosing the technical and tactical characteristics of athletes, as well as the main methods of improving sports performance, exploring technical rules, and improving sports technical and tactical levels (Zhang, 2012). With the development of science and technology, the research methods of sports biomechanics continue to innovate, the level of measurement technology gradually improves, and the research of various sports technologies continues to deepen, thereby promoting the improvement of various sports technology levels and sports achievements. Through the study of the application status of sports biomechanics in the analysis of martial arts sports technology, we found that martial arts researchers have not yet analyzed sports technology, there is a great potential for utilization and development (Yang&Yang, 2006).

Through combining relevant literature, it is found that scholars have paid extensive attention and conducted a lot of research as the key technology of gymnastics, aerobics, martial arts routines, figure skating, skiing and other difficult sports. The main research methods include video observation, 3D video analysis, infrared high-speed motion capture, 3D force measurement, and surface electromyography testing. At present, there is research on the surface electromyography of push up movements, but there is relatively little synchronous research on the three elements of push up movements: surface electromyography, movement trajectory, and three-dimensional force. The kinematics, dynamics and surface electromyography indexes selected in the test and analysis of each project are relatively similar. The commonly used kinematics indexes are center of gravity height, center of gravity distance, center of gravity, horizontal velocity, center of gravity, vertical velocity, center of gravity lift angle, rotational angular velocity, airtime, etc. The dynamic indicators are ground reaction force value; Surface electromyographic indicators include muscle activation timing, integrated electromyographic value, and median signal of electromyographic frequency.

Competitive gymnastics is a traditional sport in China, which has made an important contribution to winning gold and silver MEDALS for the Chinese sports delegation at the Olympic Games. Continuous innovation is the life of the development of competitive gymnastics, and a series of innovative technical moves have played a

vital role in enabling Chinese gymnasts to win MEDALS in major competitions such as the Olympic Games and world Championships, making China a world power in competitive gymnastics.

The practice of competitive gymnastics cannot be separated from theory and scientific research. In the past 30 years, many scholars have conducted extensive research from different angles, different methods and different contents to improve the competitive level, strength and training level of competitive gymnasts and promote the healthy and sustainable development of competitive gymnastics. They have also obtained relatively rich research results. The research focus of competitive gymnastics mainly focuses on the kinematics analysis of individual difficult movements, the development characteristics and trends of competitive gymnastics and various sports, the innovation of competitive gymnastics, the development and arrangement of men's gymnastics, the competition analysis, the training characteristics and training level of athletes, the trend and countermeasures of technical development, etc. The physical quality and physical ability of athletes, the training of reserve talents, the selection of athletes, the development of human resources, the evolution of rules and so on.

With the development of science and technology, high-end instruments and equipment are more advanced, and sports biomechanics testing methods are more advanced and scientific, which continuously promotes the great improvement of sports technology. At present, video analysis, high-speed photography, sensor measurement, infrared high-speed motion capture system, laser tester, three-dimensional dynamometer, etc. are used for sports technology and tactics analysis, mainly focusing on two-dimensional and three-dimensional video analysis of technical actions and combining various sports biomechanical test methods to analyze technical actions. In track and field, taekwondo, tennis, table tennis and other events, the two-dimensional and three-dimensional video analysis methods are used to conduct quantitative analysis of technical movements, find out the advantages and disadvantages of movement techniques, and provide a basis for improving sports training and performance. The rapid development of sports biomechanics research methods and instruments provides a platform for the improvement of various sports technologies. In practice, the study of various sports technology principles needs

sports biomechanics, which can be used as a theoretical indicator for the judgment of sports technology and the improvement of training methods (Zhao, 2022).

With the continuous innovation of the research methods of sports biomechanics, the level of test methods and measurement technology has been gradually improved, and the research of various sports technologies has been deepened, which has promoted the improvement of various sports technology levels and sports achievements. Sports technology diagnosis is the mainstream in sports biomechanics research, the research method has been further improved, and the accuracy level of test instruments has also been continuously improved (Su, 2012). The biomechanical characteristics of the lower limbs of the Chinese men's gymnastics team were compared by testing the backward somersault and vertical landing movements of six athletes (Wu, 2022). Two high-speed cameras (JVC GC-px100), three-dimensional dynamometer (AMTI, USA), and bioelectricity measurement and analysis system (Biovision, Germany) are used to synchronously collect the kinematics data, dynamics data and surface EMG signals of the athletes' backhand turn movement. Through the general means of sports biomechanics, the characteristics and principles of the technical movements in the upper limb support stage of the backhand turn movement are analyzed from the aspects of kinematics, dynamics, and surface EMG, based on the anatomical characteristics of the upper limb motor system, the location and mechanism of the injury prone to occur during the support stage were explored. (Lu, 2017). Through the establishment of sports biomechanical model and the human body experiment of gymnastics landing, the load changes of lower limb joints, bones, muscles and other tissues of gymnasts during the landing process are studied, and the biomechanical mechanism of ankle injury during the landing process of gymnastics is discussed (Liu, 2016).

The straightening of the body is accompanied by the movement of the upper limbs up and down. Upper limb movement can be divided into two stages: downward bending and upward pushing. Johnson and Nelson (1986) and Fitness grams (Cooper Institute for Aerobics Research, 1992) indicate the hands should be shoulder width apart with the fingers pointed forward. Push up used by strength and conditioning professionals to train athletes in sports such as baseball (Hammer C. 2009), boxing

(Wallace M. and Flanagan S., 1999), and martial arts (La Bounty, 2011), and they play a prominent role in the basic training programs of the U.S. Military (Popovich RM, 2000). Plyometric push-ups are considered essential for optimizing stretch shortening cycle-induced adaptations for the upper body (Vossen J., 2000). Weede (2002) and Kraemer (2002) and Khazel (1994), Schuler (2004), Voight (2000) suggest that performing push-ups from a narrow base (NB) hand position will better isolate the triceps brachii. Other sources advocate the wide base (WB) push-up for isolating the pectoralis major as well (Hendel. 2004, 1994). Many studies have examined muscle activation responses in a variety of shoulder strengthening programs (Anderson. 1984, Lear. 1998, Signoeile. 2002, Uhl. 2003). Signorile et al. (2002) compared muscle activation patterns during the lateral pulldown exercise performed from varying hand placement positions. They reported that changes in handgrip position affect electromyographic (EMG) activation levels in certain muscle groups. Donkers et al. (1993) examined mechanical demands at the elbow during standard push-ups performed from the shoulder width (SW), WB, and NB hand positions. They found that the flexion torque at the elbow during push-ups is greatest when the exercise is performed from a NB, hands together position. The claims in popular literature (Geiger. 2004, Hendel. 2004) that hand position changes may elicit different muscular recruitment responses appear to be unsubstantiated empirically. Weede and Kraemer (2002) and Geiger (2004) and the empiric evidence of Donkers et al. (1993), we hypothesize that greater muscle activation will be elicited in the triceps brachii from the NB hand position and in the pectoralis major from the WB hand position. Push-ups have also been evaluated as an upper body strength test (Mayhew, 1991) and are often included on standardized fitness tests including those used for school children (Lloyd, 2003) and military recruits (Knapik, 2006). Training with traditional and plyometric push-ups produces increased upper body strength and power (Vossen, 2000). Push-ups are also commonly used to evaluate muscular endurance and can be modified to yield similar results between men and women (Laughlin, 2007). Thus, push-ups are used, and their quantification can be of value for programs designed for youth, general fitness, and military recruits. Unfortunately, the quantification of this exercise in a training program is difficult compared to traditional resistance training exercises. Aerobic gymnastics is the ability to perform continuous complex and high intensity aerobic

movement patterns to music, which originates from traditional aerobic exercises (FIG, 2021). It is a combination of basic aerobic steps together with arm movements, to create dynamic, rhythmic, and continuous sequences of high and low impact movements (Chayun et al., 2020), all performed at an adequate level of intensity (FIG, 2021). The exercises are classified in four different groups (FIG, 2021), A (Dynamic Strength), B (Static Strength), C (Jumps and Leaps), D (Balance and flexibility). In Aerobic Gymnastics a fundamental technique is the Push-Up which is one of the difficulties of group A (Dynamic Strength), it consists in pushing with the arms with hands and feet in contact with the ground and body straight. Another fundamental technique is the Explosive Push-Up which involves the detachment of the hands from the ground and is the starting technique for other difficulties. The Push-Up represents a fundamental position since it is used as a starting or finishing position during the execution of other difficulties, in particular the Free Fall, belonging to group C (Jumps and Leaps) and consists in landing from a flight phase in Push-Up position. Strength in the upper limbs, therefore, is very important in Aerobic Gymnastics, and particularly the strength expressed in this specific position. There are currently not many studies on upper limb strength in Aerobic Gymnastics, most studies have focused more on workload, cardiovascular effort (Alves et al., 2015) and injuries (AbaloNúñez et al., 2018; 2013a; 2013b; Núñez, 2015) resulting from practice, some that have analyses explosive strength have been conducted on the lower limbs through jump tests (Mihaela & Dragomir, 2021; Ol'ga& Erika, 2010). There are studies in the literature that have analyses the execution of the push up and its variants using strength platforms (Dhahbi et al., 2017a; 2017b; Waller, 2016; Koch et al., 2012; Ebben et al., 2011), even if not in relation to Aerobic Gymnastics. However, most of these studies focused only on the performance aspect and there is no research aimed at injury prevention through the execution of these tests. In any case, the evaluation of the push-up movement through force platforms seems to be valid and reliable (Parry et al., 2021; 2020; Bohannon et al., 2020; Zalleg et al., 2020; Gillen et al., 2018; Hogarth et al., 2013).

The vast majority of gymnastics movements need double support to complete. Push-ups are a kind of exercise to exercise the strength of the chest, shoulders and upper limbs. The push-up movement is a typical double-supported movement and the most

representative gymnastic movement, which requires the combination of shoulder retraction and elbow extension. In addition, long-term practice of push-ups can also slow down the speed of muscle aging, improve cardiopulmonary function and maintain good ability and body shape. In this study, push-ups were selected as the starting point to study the double support movement of gymnastics, to explore the kinematics, dynamics, body surface myoelectric biomechanical characteristics and movement rules of gymnasts at different exercise levels who completed push-ups with different exercise loads and different postures, and to provide theoretical basis and scientific training suggestions for optimizing the upper limb double support movement technique of gymnasts.

Objectives

- (1) To test the biomechanical characteristics of push-ups with difference loads and postures in high-level athletes.
- (2) To test the biomechanical characteristics of push-ups with difference loads and postures in intermediate level athletes.
- (3) To test the biomechanical characteristics of push-ups with difference loads and postures in ordinary level athletes.
- (4) To compare analysis of the biomechanical characteristics of push-ups performed among high-level, intermediate level athletes and level athletes under different loads and postures.

Hypothesis of the Research

- (1) There are significant biomechanical characteristics in different levels of people completing push-ups with different loads.
- (2) There are significant biomechanical characteristics in different levels of people completing push-ups with different postures.
- (3) There are significant differences in biomechanical characteristics among people of different levels in completing push-ups.

Significant of Study

Theoretical Significance

(1) Break through the previous research defects, condensing the biomechanical characteristics and movement rules of upper limb and trunk muscle groups when gymnasts complete double support exercises in a closed manner.

(2) It enriches and improves the biomechanical characteristic system of upper limb and trunk muscles when gymnasts complete double support exercises and provides theoretical guidance for scientific training of gymnasts.

Practical Significance

(1) To construct the biomechanical characteristic system of upper limbs and trunk muscles when gymnasts complete double support exercise, which provides a cognitive path for the establishment of gymnastics teaching and training content, especially for the balanced development of upper limbs.

(2) The conclusion and analysis of the biomechanical characteristics of the upper limb and trunk muscle groups of gymnasts when they complete the double support exercise provide inspiration for the optimization of gymnastics training means and the innovation of training means.

Related concepts and definitions

1. Biomechanics

Biomechanics is a branch of biophysics that applies the principles and methods of mechanics to the quantitative study of mechanical problems in living organisms. The research scope ranges from the whole organism to the system and organ (including blood, body fluid, viscera, bone, etc.), from bird flight, fish swim, flagella and cilia movement to the transport of plant body fluid, etc (Yan,2012) .

2. Biomechanical characteristic

Dynamic and kinematic characteristics are involved in this study.

Kinematic test. The researchers used high-speed cameras to collect data on the push-up kinematics of volunteers performing different positions and different loads at a sampling rate of 100 frames per second. All volunteers were asked to successfully complete two push-ups with different positions and loads. Each time a volunteer completes a move, there will be three first-level gymnastics judges on site to judge it as successful. After an action fails, they need to complete the same action again until data is collected for two successful actions. In the follow-up study, the group with complete exercise data collection and the highest exercise quality will be selected for data analysis. A high-speed camera was positioned in front of the volunteers' heads as they performed the action. High-speed cameras have a sampling rate of 100 frames per second. After the video shooting was completed, SIMI 3D moving image analysis system and Matsui Hideji human body model were used to calculate the data, and second-order filtering method was used to smooth the data, and the interception frequency was 6Hz. Use Excel software to calculate the data and statistics.

Dynamic Testing. The three-dimensional force measurement platform collected the ground reaction force of the subjects (high-level, intermediate and ordinary gymnasts) when they completed the push-ups under different positions and different loads in the push-down and push-up stages. The sampling frequency was 500Hz. In the push-up test, the subjects need to complete the push-up movement with their hands on a three-dimensional force measuring platform. The sampling frequency of the 3D force measuring table is set to 500Hz. Combined with the kinematic data, the ground reaction (N) in different directions [left and right (X axis), front and back (Z axis), up and down (Y axis)] is obtained. Including: different positions and different loads of push-ups, the vertical force peak value in the downward flexion stage and the upward push up stage. The characteristics of vertical ground reaction peak value of push-ups in downward bending stage and upward pushing stage were analyzed under different posture and load collected by 3D force measuring platform.

3. Definition of surface EMG related indicators

Surface electromyographic signal (EMG): The bioelectrical signal emitted when neuromuscular activity is recorded by electrodes from the surface of human bones, which reflects the functional state of nerves and muscles (Tian, 2012). Time domain analysis: It is an evaluation index reflecting the changing characteristics of the EMG curve in the time dimension, including root mean square amplitude, average

amplitude, integrated EMG, etc. Root means square amplitude refers to the root mean square value of all amplitude of myogram in the time period. It is generally believed that the root mean square amplitude is related to the number of motor units recruited and the synchronization of muscle fiber discharge. The average amplitude is related to the intensity of muscle electrical signals, the number of exercise units involved and the degree of synchronization of discharge frequency and reflects the average level of muscle discharge during the time period (Sui, 2012). Integrated electromyography: refers to the sum of the area under the curve within a unit time after rectification and filtering of the obtained electromyography signal, which represents the total discharge of the motor unit involved in muscle activities within a certain time, and to a certain extent reflects the number of working motor units and the discharge size of each motor unit (Wang, 1996) (Guo et al., 2009).

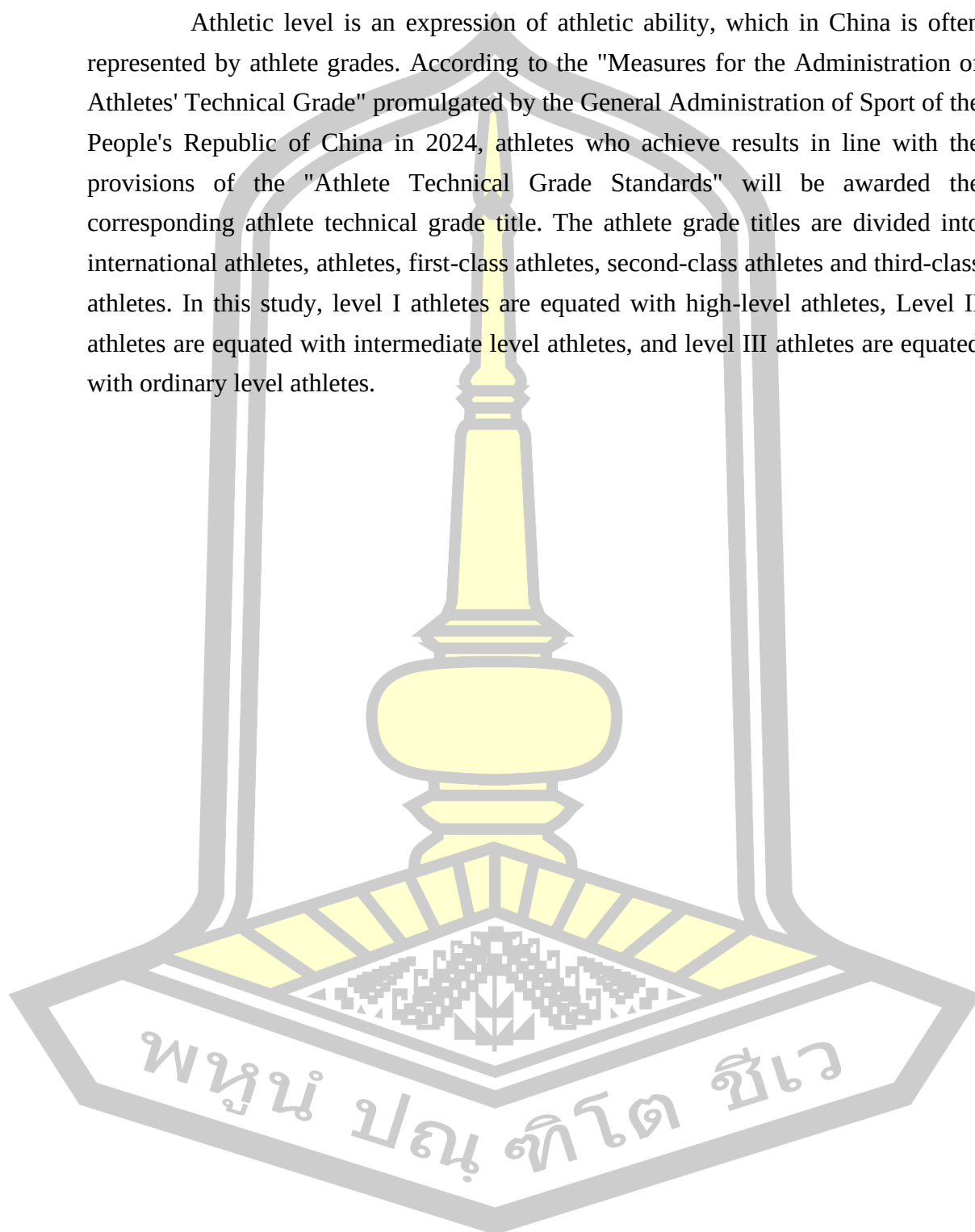
Set the sampling frequency of wireless telemetry EMG signal to 2000Hz, and the filtering frequency to 20 ~ 500hz. The surface electromyography test indexes selected in this study were integrated electromyography and muscle activation timing. The electromyograph of the selected muscle of the subject was collected by wireless telemetry surface electromyograph during the completion of the movement. The sampling frequency was 2000Hz, and the filtering frequency was 20-500Hz. At the end of the test, the raw data was imported into the Noraxon analysis software to obtain the raw integral electromyography and muscle activity duration of each tested action muscle. The duration of muscle activation is based on the characteristics of the discharge of action muscles in this study. The integrated electromyography that is greater than 20% of the maximum value of electromyography and lasts for more than 0.05s is taken as the muscle activation area, and the duration of muscle activation is further converted into the percentage of the total time of the action stage.

4. Push-up

This test selected 4 different postures and 5 different loads of push-ups to test. The four different positions are the standard support push up, the wide support push up, the standard support high-five push up and the wide support high-five push up. The five different loads are feet placed on the ground, feet 25 cm above the ground, feet 30 cm above the ground, feet 40 cm above the ground and feet 50 cm above the ground.

5. Exercise level

Athletic level is an expression of athletic ability, which in China is often represented by athlete grades. According to the "Measures for the Administration of Athletes' Technical Grade" promulgated by the General Administration of Sport of the People's Republic of China in 2024, athletes who achieve results in line with the provisions of the "Athlete Technical Grade Standards" will be awarded the corresponding athlete technical grade title. The athlete grade titles are divided into international athletes, athletes, first-class athletes, second-class athletes and third-class athletes. In this study, level I athletes are equated with high-level athletes, Level II athletes are equated with intermediate level athletes, and level III athletes are equated with ordinary level athletes.



CHAPTER II

REVIEW OF RELATED LITERATURE

In the past, mainly used the Internet, such as www.cnki.net, bbs.chinatofit.com and Baidu Academic. The research literature and relevant data of gymnastics, competitive gymnastics, competitive gymnastics sets of movements, gymnasts' strength training, sports quality-related concepts, core strength training, rapid telescopic compound training, etc. were retrieved. Watched the 31st and 32nd Summer Olympic Games and consulted the rules of international gymnastics competition. Read books related to sports anatomy, sports physiology, sports biomechanics and sports training to provide reference materials and theoretical basis for the topic selection and writing of this study.

Theoretical

The sequence principle of muscle activity

This principle is also known as the principle of the sum of internal forces, the principle of continuous activity and the principle of angular momentum transfer along the chain of motion. The principle points out how the body can mobilize all parts of the body to participate in the movement at the right time. The large muscle groups, usually the penniform muscles, work first. These muscles contract to overcome the inertia of the whole body and parts of the body. The muscles then work in turn until the fast muscle activity at the end of the limb ends. These activities not only increase the range and speed of motion, but also increase accuracy due to the gradual decrease in the number of muscle fibers innervated by each motor neuron; The sequence of movements of the proximal link before the distal link also ensures that the distal link muscles are moderately elongated before contracting. For this reason, gymnasts use a large amount of upper limb strength, especially dynamic and static support, in completing single and complete movements of competitive gymnastics, such as Thomas full rotation of pommel horse, swing handstand of double arm support of parallel bars, and inverted cross support of rings, all of which are inseparable from the large participation of upper limb muscle group and trunk muscle group.

Principle of energy saving

This is about the rational use of metabolic energy in specific tasks, also known as the "muscle excitation limitation principle". Some studies believe that the adaptive mechanism in the process of motor skill learning reflects this principle (Bartlett. RM, 1992). This principle is widely used in gymnastic movement technology. The existence of human large joint muscles shows that the principle of energy conservation plays an important role in sports.

Post Activation Potentiation (PAP)

In the research literature of post activation enhancement effect, researchers have similar specific interpretations. The term post activation enhancement was first proposed by Hamada, Sale and MacDougall. However, Verkhoshansky (1983) was the first person to carry out relevant research. He mentioned this potential mechanism in his research on compound training in 1983. In the study, Docherty ^{et al.} described the post activation enhancement effect as a neuromuscular phenomenon of muscle strength and explosive force enhancement immediately after heavy load resistance training, while Robbins called it a phenomenon of muscle contraction trace after random contraction with maximum or near maximum strength, which significantly enhanced the working ability of muscles. It can be seen that the academic community has a more consistent view on the post activation enhancement effect.

At present, the research is relatively unified that the enhancement of muscle contractility is caused by the enhancement of light chain protein phosphorylation after the maximum and sub maximum stimulation (Rassier D E (2000); Zhou Tong (2017); Paasuke M. (1996); Sale DG. (2002).

Manning D R (1982), Moore R L (1984), Vandenboom R (1993), in many animals skeletal muscle experiments, it has been found that when specific efferent nerve fibers are directly stimulated, significant increase in light chain phosphorylation regulation and muscle tension occurs. A similar reaction was found in human skeletal muscle. Stuart D S. (1988) et al. found that after 10 seconds of equal length maximum

voluntary contraction, the content of light chain phosphate in the lateral thigh muscle was significantly increased and the muscle strength of the knee extensor group was significantly increased. But Smith JC (2007) et al. found no significant changes in the regulation of light chain phosphorylation and muscle strength 7 minutes after 10 seconds of equal length maximum random contraction.

Tillin N (2009) believed that enhancing the activation of motor units and acting on the nervous system may be one of the mechanisms of post activation enhancement, but the change of muscle structure also contributed to this effect. Earp J. (2010) believed that the larger feather angle was related to the enhancement of explosive force. However, Mahlfeld K. (2004) said in the study that the feather angle decreased after 3-6 minutes of maximum random contraction. Kamagai M. (2010) also believed that the smaller feather angle was related to the sprint speed. Baudry S. and Duchateau J. (2007) studied the post activation enhancement effect and the decline of post activation enhancement with time in the load speed relationship. For this purpose, this paper tested the angular velocity of thumb adduction after a single electrical stimulation and the performance of 10-50% of the maximum torque load in the terminal release random shortening contraction after 6 seconds of maximum voluntary contraction. Hamada T. (2000) et al. tested the post activation enhancement effect after 10 seconds of maximum random isometric contraction. In addition, some studies were conducted on independent muscle. These experiments have fully confirmed the effect of post activation enhancement effect. The experimental results mainly focus on the effect of low-frequency contraction of muscle fibers.

Principle of extending acceleration distance

By the principle of functional relationship between $\Delta E = F \Delta r = F |\Delta r| \cos \theta$ (F represents the force, Δr represents the displacement, an Angle between the F and Δr θ , ΔE for mechanical energy) in force, the formula shows that the larger mechanical energy (ΔE) by increasing the average force (F) or increase range (s), and when F and $|\Delta r|$ must be, When $\cos \theta = 1$, ΔE is the maximum, and the mechanical energy (ΔE) is the maximum when both the force (F) and the motion displacement (Δr) are in the same direction (Zhou, 1979). For example, in the completion of elbow flexion and extension action, the elbow flexion and extension increase the effective distance, and the direction of force and displacement should be as consistent as possible. Research and practical experience show that push-

ups, high-five push-ups, etc., have more power. The reason is that the force of the latter is longer than that of the former, so that the increment of mechanical energy is larger than that of the former.

Myofilament gliding theory

Huxley et al. found that the length of A-band remained unchanged while the length of I-band and H-band narrowed when the muscle was shortened. When the muscle is lengthened, the length of the A-band remains unchanged, and the I-band and H-band become wider. At the same time, it was found that the length of thick and thin myofilaments remained unchanged when the sarcomere was shortened or lengthened, but the overlapping degree of the two myofilaments changed. Based on the above findings, Huxley et al. proposed the sliding theory. According to the gliding theory, the shortening of muscle is caused by the gliding of the thin filaments in the sarcomere between the thick filaments. That is, when the muscle contracts, the thin muscle filaments from the Z line slide towards the center of the A belt under the action of a certain force. As a result, the adjacent Z lines are close to each other, and the length of muscle segments becomes shorter, resulting in the shortening of myofibrils, even the whole muscle fiber and the whole muscle (Wang, 2002).

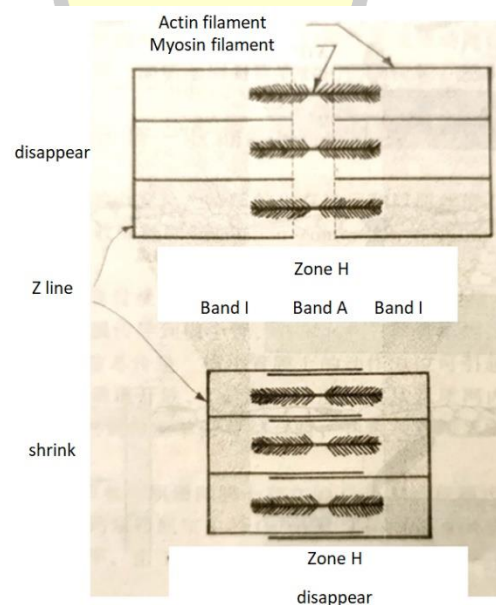


Figure 1 Skeletal muscle contraction diagram

Research Evident

Sports Training Methods

Sports training methods refer to the general name of the basic ways and means that play a universal role in improving athletes' function, quality, technology, tactics and other training levels in specific sports training activities.

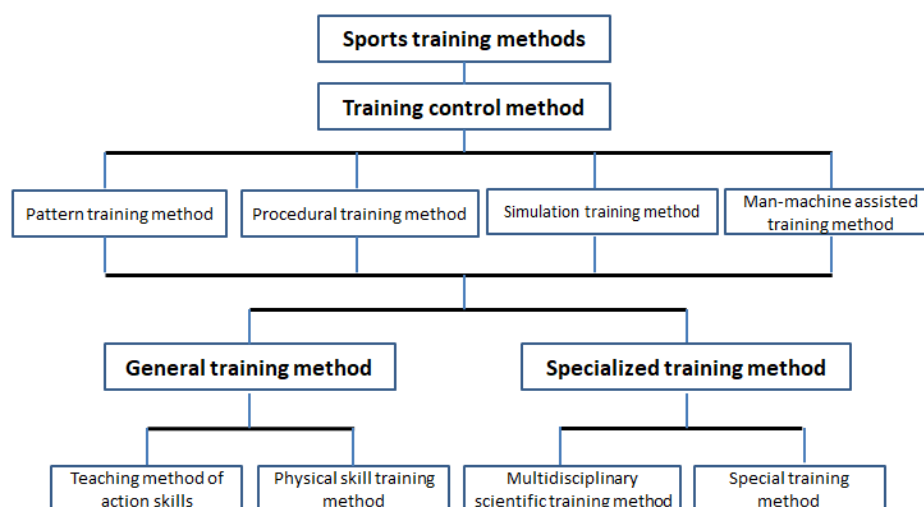


Figure 2 The overall system of modern sports training methods

A multi-level training method proposed by Chinese scholar Xu (1999) constitutes the overall system structure. In the overall sports training method system, the training control method is a method system to guide the training process, including four basic training methods, such as model training method. In training practice, the repeated training method, intermittent training method, continuous training method, transformation training method, cycle training method, competition training method, altitude training method, etc. commonly used by coaches and athletes are all basic training methods considered from the perspective of training factors.

Tian (2000) proposed in Sports Training that "strength quality refers to the ability of the human neuromuscular system to overcome or resist resistance during work. Strength quality is an important basic sports quality. The physiological factors that affect strength quality include nerve excitability, ratio of fast muscle to slow

muscle, initial length of muscle, muscle stretching speed, etc; The individual factors affecting strength quality include age, sex, weight, etc; The training factors affecting strength quality include training methods, movement completion, load intensity and load, recovery methods, etc. According to different classification methods, strength quality can be divided into general strength, special strength, fast strength, etc.

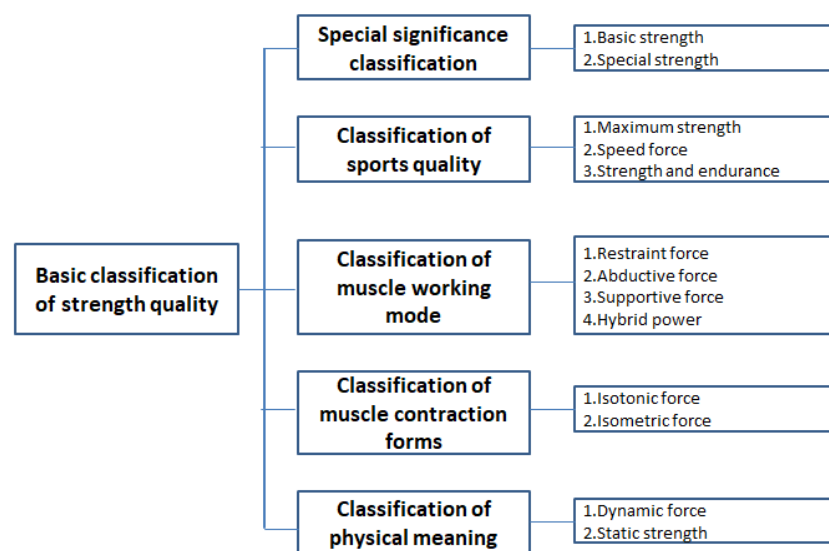


Figure 3 **Strength quality classification**

Liu (2011), through surface electromyography telemetry technology, believed that according to the size of contribution, the medial femoral muscle, the lateral femoral muscle, the biceps femoris, the soleus muscle, and the gastrocnemius muscle play a major role in the takeoff, while the rectus femoris, the gluteus maximus, and the anterior tibial muscle play a relatively small role. During special training, the strength of the above five muscles should be mainly developed, and attention should be paid to strengthening the strength of the quadriceps femoris pedal extensor muscle group and the triceps calf and other posterior calf muscles.

Reaction Force

Chen (2001) et al. believed that the stretch shortening cycle and the "plyometric contract" used in previous studies are two names of a concept, both of which refer to the form of muscle contraction in which the muscle is stretched centrifugally and then retracted centripetally.

In this continuous muscle stretching and contraction movement, the human body moves under the action of periodic impact or tension, and the muscles participating in the movement first undergo centrifugal contraction followed by centripetal contraction, forming a complete muscle contraction form (Komi P V. 2000). Many concepts have been derived from lengthening and shortening the cycle, such as shock training, response strength training, ultra-isometric strength, and rapid telescopic composite training. The reaction force is consistent with the concept of super-equal-length force, which means the force generated when the muscles contract in a lengthening and shortening cycle.

The concept of "plyometric" predates naming. In the 1960s, the Soviet Union and Eastern European countries had already adopted plyometric for training, and it was first used in jumping events. Verkhoshanski summarized and refined this training in 1969, and then introduced it to the United States. In 1975, American track and field coach Fred Wilt named it plyometrics.

Skeletal muscle is connected with bone through tendons, and the length and velocity changes of musculoskeletal complex determine the changes of joint angle and angular velocity. When the muscle fibers shorten to produce greater strength, the tendon is lengthened, which means that the speed of muscle contraction is the sum of the elastic retraction of the tendon and the contraction speed of the muscle fibers (Lv, 2013).

Huxley et al. pointed out in the study that elastic energy can also be obtained through the swing of the elastic neck of the actin transverse bridge when myofibril bridging (Huxley A F, 1971).

Training Methods of Reaction Strength

Donald A. CHU (2011), Lundin (1991), Robert U (1994), Sun (2013) studied the reaction strength training method. Most of the domestic literature translated it into rapid expansion and contraction compound training, which refers to the exercise to maximize muscle strength in the shortest possible time.

Lees A (1994), Waller M A (1999), Fletcher IM (2004), SaezSaez d V E (2010), Lockie RG (2014) Research found that reaction strength training was initially only used in track and field events. Since the 1970s, other sports have gradually added this training method to training. Since the 1990s, many researchers have studied the effectiveness and safety of response strength training. The sports events concerned by these studies are quite different from the athletic ability of athletes, so the conclusions drawn are not completely consistent. The design and implementation of response strength training need to consider many factors, such as the athlete's gender, age, sports level, injury history and sports specialty.

In summary. Training should fully reflect the specificity. As a basic item, track and field training methods are often borrowed from other items. Reaction strength training was first introduced by jumping training in track and field sports, but it has a good effect on the development of strength and explosive force of lower limbs. When designing training plans, special characteristics of different projects should be considered. If the project requires the development of lower limb explosive force in the horizontal direction, it is obviously inappropriate to add the reaction force training of developing vertical explosive force in the training, and vice versa. Coaches should have a deep understanding of the characteristics of sports events, and design response strength training that conforms to the characteristics of events can achieve twice the result with half the effort.

Sports biomechanics research

1. Analysis of sports skills and tactics

Sports biomechanics is a discipline that applies the knowledge of biology and the principles and methods of physics and mechanics to study the movement laws of human body (or equipment) in sports. In the study of sports technology, one of its main purposes is to reveal the principles of movement technology, especially in the field of competitive sports. The principles and methods of sports biomechanics are the main means to analyze and diagnose the characteristics of athletes' skills and tactics, and also the main methods to improve sports performance, explore technical rules and improve movement skills and tactics. With the development of science and technology, the high-end instruments and equipment are more advanced, and the sports biomechanics testing means are more diverse, which makes the sports technology has been greatly improved. In this conference, video analysis, high-speed photography, sensor measurement, infrared high-speed motion capture system, laser tester, three-dimensional force measuring table and so on are used to analyze sports techniques and tactics, mainly two-dimensional and three-dimensional video analysis of technical movements, at the same time combined with a variety of sports biomechanical testing means to analyze technical movements have also emerged. Zhou Haoxiang et al. used two methods of video point shooting analysis and real ship dynamics test system analysis to diagnose the technical movements of different individual combinations of excellent men's double scullers, so as to provide reference for optimal pairing. The women's air rifle was of great significance as the first event of the Olympic Games. The SCATT laser tester was used by Geng and his team to measure six indicators, including aiming performance and shaking speed one second before firing, of four elite women athletes in the world to determine the key factors affecting the athletes' shooting performance. In track and field, taekwondo, tennis, table tennis and other events, two-dimensional and three dimensional video analysis methods are often used for quantitative analysis of technical movements to find the advantages and disadvantages of movement techniques, and provide a basis for improving sports training and performance (Zhao, 2022).

Zhou Jihe et al. used virtual reality technology to conduct 3D reconstruction

demonstration of the sliding movement technology of short track speed skating in Wudajing 500m out of curves; Du Chuanjia et al. used Signal-TEC 3D V1. OC video analysis system to analyze the two-pole push technique of 8 male cross-country skiers. Guo Tianlong et al. used the wireless inertial motion capture analysis system to collect and analyze the leg movements of three U-slot double-board skiers, providing efficient visualization and data support for the training process.

2. Sports injury and sports rehabilitation

The occurrence, development and rehabilitation of sports injuries are all related to the stress on the injured site. Sports biomechanics provides test means and research methods for exploring the causes and mechanisms of sports injuries and evaluating the rehabilitation effects, and serves the fields of competitive sports, public health and special groups. The biomechanical diagnosis and analysis of sports injury and rehabilitation training mainly focuses on the field of competitive sports. Xu Yongxin et al. established the injury model of international elite athletes on snow by analyzing four key parameters, including injury rate, severity, injury site and type, injury factors and causes, of elite athletes in major international level snow events. It is suggested that relevant scholars further explore the influence of internal and external factors on injury and establish a comprehensive and localized injury detection system by injury and trauma model reconstruction. Ren Yuanyuan et al. simulated the visual tracking task of soccer players in real games with 3D-MOT task and found that sports fatigue under the visual tracking task increased the risk of non-contact ACL injury. With the increase of fatigue degree, the athletes' landing mode changed from "soft" to "hard", prone to joint instability. Biomechanical diagnosis and analysis of sports injury and rehabilitation training mainly focus on the field of competitive sports (Wang et al., 2016).

Public health has broadened the new field of sports biomechanics research, and the research content has expanded from the "technical diagnosis" of competitive sports to human health. Liu Dan used the method of literature to summarize the injury factors related to overweight people and discussed the impact of jumping mode on the kinematics, dynamics and sports injuries of the lower limbs of overweight people. Qi Xuan used Zebris FMM-System planar pressure gait analysis System to test patients

with a history of ankle joint injury and discussed the characteristics and influencing factors of balance ability of patients with a history of ankle joint injury under four postures. With the proposal of the concept of sci-tech Winter Olympics and the rapid development of competitive sports for the disabled, sports for the disabled are developing in a comprehensive and diversified direction (Sun et al.,2020). At the same time, biomechanical research on sports injuries of the disabled is also on the rise. Zhou Titian et al. comprehensively studied how wheelchair athletes change the performance of wheelchairs under the influence of various conditions, so as to understand the injury mechanism of wheelchair athletes in a more comprehensive way. According to the investigation of 17 professional players of the Chinese Disabled table tennis team, Yuan Lingwei learned: The injury sites were shoulder (92.86%), waist (85.71%) and neck (50%). The injury causes were fatigue injury (88%), other injury (12%) and acute injury (4%). After sports injury, massage, acupuncture combined with acupoint, cupping therapy was effective.

3. Application and development of sports equipment, training equipment and testing instruments

With the development of modern science and technology, competitive sports become more and more necessary for high-tech equipment, and the development and application of sports biomechanics in equipment and training equipment become more and more important. He Xiao used Isomed2000 dynamometer to test the muscle strength of the extensor and flexor muscles of bilateral knee joint of 24 excellent table tennis players (12 male and 12 female). The test found that the peak moment and relative peak moment of flexor and extensor muscles on both sides of the knee joint of Chinese table tennis players decreased with the increase of angular speed. Test the theory that the tension of muscles is inversely proportional to the rate of contraction. Xiong Jun et al. used Vicon system and DaeDo electronic protection to study the sensitivity rule of whirlwind kick of 12 professional taekwondo athletes, and found that the higher the competition level, the greater the score threshold, and the greater the impact force required. In the field of mass sports, sports biomechanics has become more and more targeted, scientific and practical in the development of equipment and instruments. Wu Hao from Beijing Institute of Sports Science developed autonomous

stepping test equipment to improve the situation in aerobic endurance module of the elderly's physical fitness test, increasing the accuracy and safety of the elderly's physical fitness test data.

Research on the Kinematics of Push Ups

Bret Contreras, MA (2012) and other studies believe that in the fitness environment, pushups are widely used to develop upper body strength, strength and muscle endurance. Pushups are used by strength and physical training professionals to train athletes in baseball (Hammer C., 2009), boxing (Wallace M and Flanagan S., 1999) and martial arts (La Bounty P, 2011) and other sports, and play an important role in the basic training plan of the United States military (Popovich RM, 2000).

TYson A.C. et al. (2008) studied the contribution of muscles to low back load and stiffness in standard push-ups and suspension push-ups.

Most of the biomechanical studies of push-ups mainly focus on the joints and muscles of the upper limbs (An, Korinek, Kilpela and Edis, 1990; Donkers, An, Chao and Morey, 1993; Gouvali and Boudolos, 2005; Lear and Gross, 1998; Lou, Lin, Chou, Chou and Su, 2001; Ludewig, Hoff, Osowski, Meschke and Rundquist, 2004).

According to the activation level of trunk muscles reported in scientific literature, push-ups also seem to provide an effective means to challenge abdominal muscle tissue (Juker, McGill, Kropf and Steffen, 1996), especially when the hand contacts with unstable support surface (Freeman, Karpowicz, Gray and McGill, 2006)^[60]. Although the above findings provide a neuromuscular load index, attempts to quantify the internal mechanical consequences of such observations during push-ups are rare.

Different push-up positions can produce different muscle exercise patterns.

Push-ups can be performed with a multitude of variations to bring about different muscular recruitment patterns. The knee push-up shortens the lever, which reduces bodyweight loading to 54% in the top position and 62% in the bottom position

(Suprak DN, 2011) and substantially reduces prime mover (Gouvali M, 2005) and core musculature requirements (Juker D, 1998).

Electromyography (EMG) research and evaluation of muscle recruitment patterns during push-ups showed that different support methods had different effects on the activation of triceps brachii muscle EMG. Compared with the wide support position of the hand, the narrow support of the hand not only caused greater activation of triceps brachii muscle, but also promoted higher activation of sternum head of pectoralis major muscle (Cogley R, 2005, Gouvali M and Boudolos K., 2005). Moving the trunk backward relative to both hands will slightly increase the activity of pectoralis major and triceps brachii (Gouvali M and Boudolos K., 2005).

Ebben et al. (2011) assessed the peak vertical ground reaction forces of pushup variations including the standard push-up and those performed from the knees, with feet elevated on a 30.5-cm box and a 61.0-cm box, and with hands elevated on these boxes. Push-ups with the feet elevated produced a higher ground reaction force than all other pushup variations. When expressed as a percentage of total body mass, the order from least to greatest load progressed from the hands elevated on a 61.0-cm box (41% of bodyweight), to the knee push-up (49%), to the hands elevated on a 30.5-cm box (55%), to the regular push-up (64%), to the feet elevated on a 30.5-cm box (70%), and finally to the feet elevated on a 61.0-cm box (74%).

Different hand support methods can produce different biomechanical characteristics of push-ups.

Exercises performed on labile support surfaces have been shown to elicit greater levels of trunk muscle activation compared to the same activities performed on stable support surfaces (Anderson & Behm, 2005a, 2005b; Behm & Anderson, 2006; Behm, Leonard, Young, Bonsey, & MacKinnon, 2005; Vera-Garcia, Grenier, & McGill, 2005). Performing pushups with hands on basketballs, for example, results in abdominal activation levels up to 2.5 times greater than those documented during the execution of standard push-ups with the hands on the ground (Freeman et al., 2006). Marshall and Murphy (2006) made similar observations when comparing abdominal activation levels measured while participants maintained static push-up postures on stable and unstable support surfaces. Although these findings demonstrate a

neuromuscular response to the presence of labile support surfaces during exercise, the effects that such responses have on resultant tissue loads and joint stiffness are not always quantified. It is important to consider the biomechanical implications of increased muscle activation levels when deciding to incorporate more challenging exercises into one's training regimen, as potential benefits to be gained must be weighed against the risk of tissue overload. It should be noted that Freeman et al. (2006) did report increases of about 1 kN in lumbar intervertebral joint (IVJ) compressive load magnitudes when comparing push-ups performed on labile support surfaces to those performed on a stable surface. However, the influence of increased abdominal activation levels on lumbar IVJ shear loading and rotational stiffness was unexplored by the aforementioned authors.

When exercises are performed on labile support surfaces, increased muscle activation levels may reflect an attempt by the neuromuscular system to augment the stiffness of a joint (or system of joints). Muscle stiffness rises with an increase in activation (Cholewicki & McGill, 1995), and increased muscle stiffness can lead to an overall stiffening of the joint(s) spanned (Lee, Rogers, & Granata, 2006). The degree to which joint stiffness is enhanced by muscle stiffness is also dependent on the magnitude, orientation, and point-of-application of muscle force vector(s) with respect to the joint(s) in question (Brown & Potvin, 2007; Potvin & Brown, 2005). It is well established that trunk muscles play a critical role in stiffening IVJs of the lumbar spine (Bergmark, 1989; Cholewicki & McGill, 1996; Gardner-Morse, Stokes, & Laible, 1995); however muscular contributions to IVJ stiffness during exercise are often inferred based on qualitative interpretations of trunk muscle activation profiles without considering mechanical and geometric characteristics of the muscles. This limits the ability to justify the inclusion of an exercise in lumbar spine stabilization training programs, as improving one's ability to actively stiffen lumbar IVJs can assist in reducing the likelihood of spinal buckling when loaded under some conditions (Reeves, Narendra, & Cholewicki, 2007). Both voluntary and reflexive trunk muscle contribution to IVJ stiffness is considered the primary mechanisms of spine stabilization (Bergmark, 1989; Cholewicki & McGill, 1996; Gardner-Morse et al., 1995; Granata, Slota, Bennett, & Kang, 2004).

Different movement speeds can produce different biomechanical characteristics of push-ups.

The explosive push-ups are compared in terms of peak strength, strength development speed and peak impact force. Garcia Masso et al, and anti-motion push-ups (a kind of fast push-ups with fast eccentric, reverse and concentric phases, but not involving leaving the ground), and found that the anti-motion push-ups performed at the maximum speed showed the highest peak force and force development speed. Considering that this is the only variant that will not encounter impact, if you want to maximize the upper body strength, anti-motion push-ups seem to be a safe and effective choice of explosive variants. The clapping push-ups have been proved to be superior to the standard, slow eccentric, one-hand on the medicine ball, two-handed staggered, two-handed on two balls, two-handed on one ball, rapid reaction, one-arm and alternating enhanced push-ups in the activities of pectoralis major and triceps brachii (Freeman S, 2006). For individuals with back problems, advanced forms of enhanced push-ups may be problematic, because alternate enhanced push-ups using medicine balls have been proven to produce 6224 N compression on the lumbar spine (Freeman S, 2006).

From the point of view of training, compared with putting both hands on the stabilizer ball and feet on the ground for push-ups, shoulder strap stabilizers lift both feet on the bench and put both hands on the ground for push-ups are more challenging and demanding.

To sum up, with the improvement of people's living standards, sports biomechanics play an increasingly important role in improving people's physical fitness. Applying biomechanical methods to study various fitness activities can reveal the biomechanical characteristics of fitness and the biomechanical effects of human movement, guide sports participation, choose scientific fitness methods, effectively improve health and avoid sports injuries.

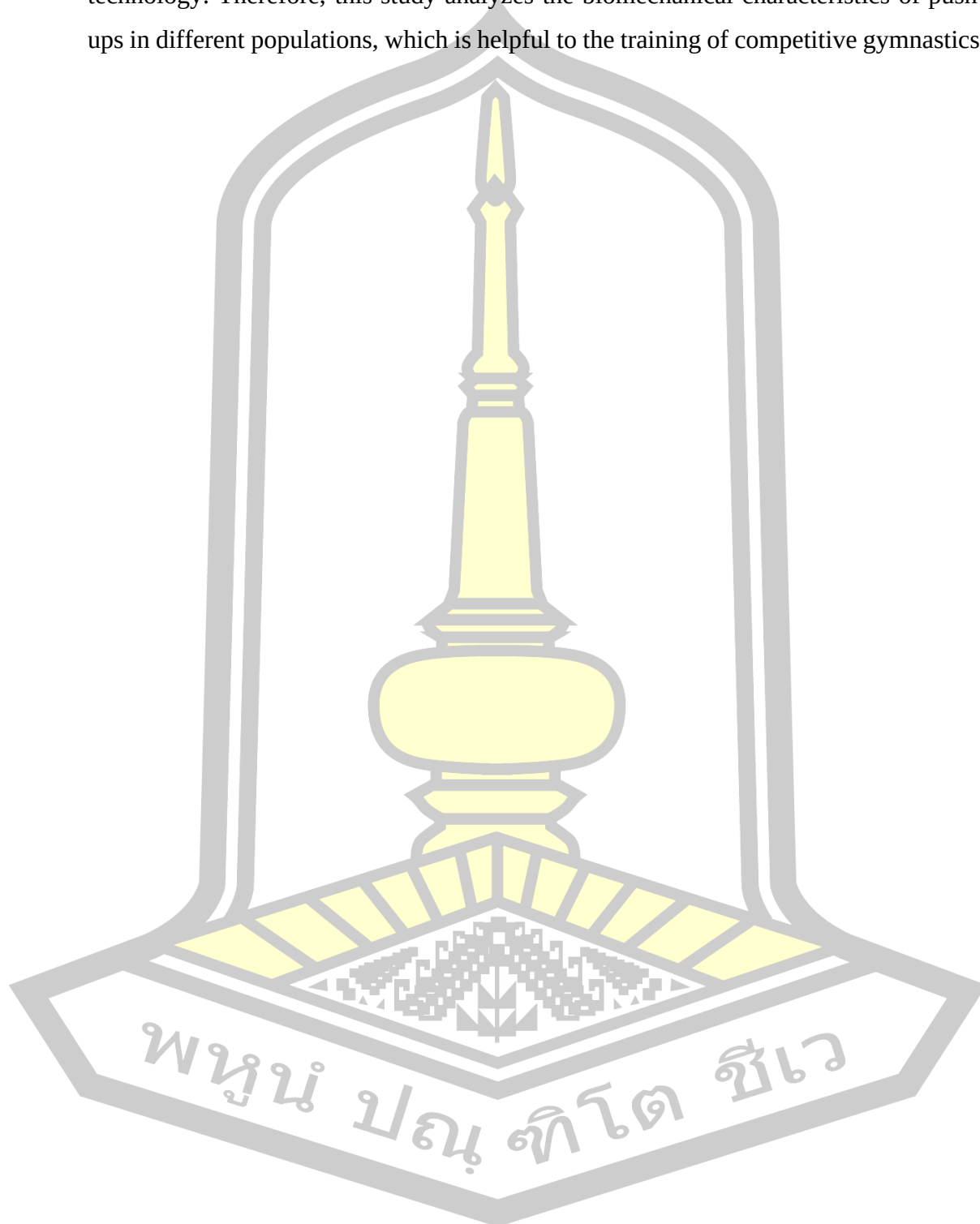
The previous studies of relevant experts on relevant issues are mainly reflected as follows. In terms of the selection of sports for research, previous studies and practices mainly focus on track and field events, providing a variety of training means and methods for developing the strength needed for the long jump. However, due to the inadequate analysis of the specificity of the neuromuscular system in the long jump takeoff process, there is still room for improvement in the requirements of strength training methods to guide the training practice of the special development of the long jump takeoff. After years of research, the theory of sports training methods has formed a set of systems. The training practice is guided by theory, and the practical effect is obtained. From the point of view of exercise physiology, in studying the mechanism of muscle stretching and contraction, the reaction strength of muscle in the period of lengthening and shortening is affected by four aspects: first, the storage of elastic potential energy in the stage of centrifugal contraction and the utilization rate in the stage of centripetal contraction; The second is the power generated by central reflex regulation; Third, the force generated by the stretching reflex; Fourth, the power of active muscle contraction during centripetal systole. The reaction strength training was first proposed by the jump training in track and field, and the particularity of different events should be considered when designing the training plan. Coaches should deeply understand the characteristics of different sports, design in line with the characteristics of different sports reactive strength training, in order to get twice the result with half the effort.

The research focus of relevant scholars on push-ups mainly focuses on three aspects. First, different push-up positions can produce different patterns of muscle exercise; Second, different hand support methods will produce different biomechanical characteristics of push-ups; Third, different movement speeds can produce different biomechanical characteristics of push-ups. Muscle activation was assessed during push-ups exercises with three different hand positions: normal, wide, and narrow. Muscles studied included the triceps, pectoralis major, serratus anterior, and deltoid posterior muscles. Emg analysis did not show any significant differences between the two groups, and the study concluded that the perfect push-up grip did not appear to increase muscle replenishment compared to a standard push-up. Relevant experts have a certain

basis for the research of push-ups, but in China, there is no research on the biomechanical characteristics of push-ups so far, and the research on the biomechanical characteristics of gymnasts completing push-ups is a blank. The aim of this study is to explore the biomechanical characteristics and movement rules of upper limb and trunk muscle groups when athletes complete push-ups with static closure with the increase of exercise load. To explore the biomechanical characteristics and movement rules of upper limb and trunk muscle group when athletes complete push-ups with the increase of exercise load; To explore the neuromuscular innervation patterns of upper limb and trunk muscle groups of athletes at different levels during push-ups. To explore the neuromuscular innervation patterns of upper limb and trunk muscle groups of athletes in different sports during push-ups. To explore the neuromuscular cooperative mode of the upper limb muscle groups of the dominant side and the non-dominant side when the athletes complete the push-up exercise with different loads and different power modes; To explore the synergistic relationship and biomechanical characteristics of muscle kinematics, dynamics and surface myoelectric activities in each link of upper limbs when athletes complete push-ups. This paper probes into the training enlightenment of gymnasts completing the double support movement technique.

With the promulgation of the "National fitness Plan" in China, the application of biomechanics theory to study national health has become a hot spot in the field of sports research. Sports biomechanics researchers focus primarily on health issues in older adults, while other groups are less involved. Therefore, in the future research process, Chinese scholars should expand the research group and focus on the field of national fitness. We will promote science and fitness for all. The changes of The Times promote the development of competitive gymnastics training to depth. Modern science and technology integrate advanced teaching media, advanced ideas and scientific methods into competitive gymnastics training. With people's continuous exploration, the competition rules of competitive gymnastics are constantly improving and changing, and the training system is constantly improving and supplementing. Athletic gymnastics training also follows the above rhythm, constantly adjusting the training content, training methods and training ideas. With the development of science and technology, high-end instruments and equipment are more advanced, and sports

biomechanical test methods are more diversified, which greatly improves sports technology. Therefore, this study analyzes the biomechanical characteristics of push-ups in different populations, which is helpful to the training of competitive gymnastics.



CHAPTER III

RESEARCH METHODS

This chapter describes the overall design of the study, including test subjects, instruments, data collection process, and statistical analysis. This study will adopt the test method to obtain the biomechanical data of push-ups performed by gymnasts with different exercise levels and different loads and obtain the biomechanical characteristics of the movement through analysis. The overall research framework is shown in Figure 4.

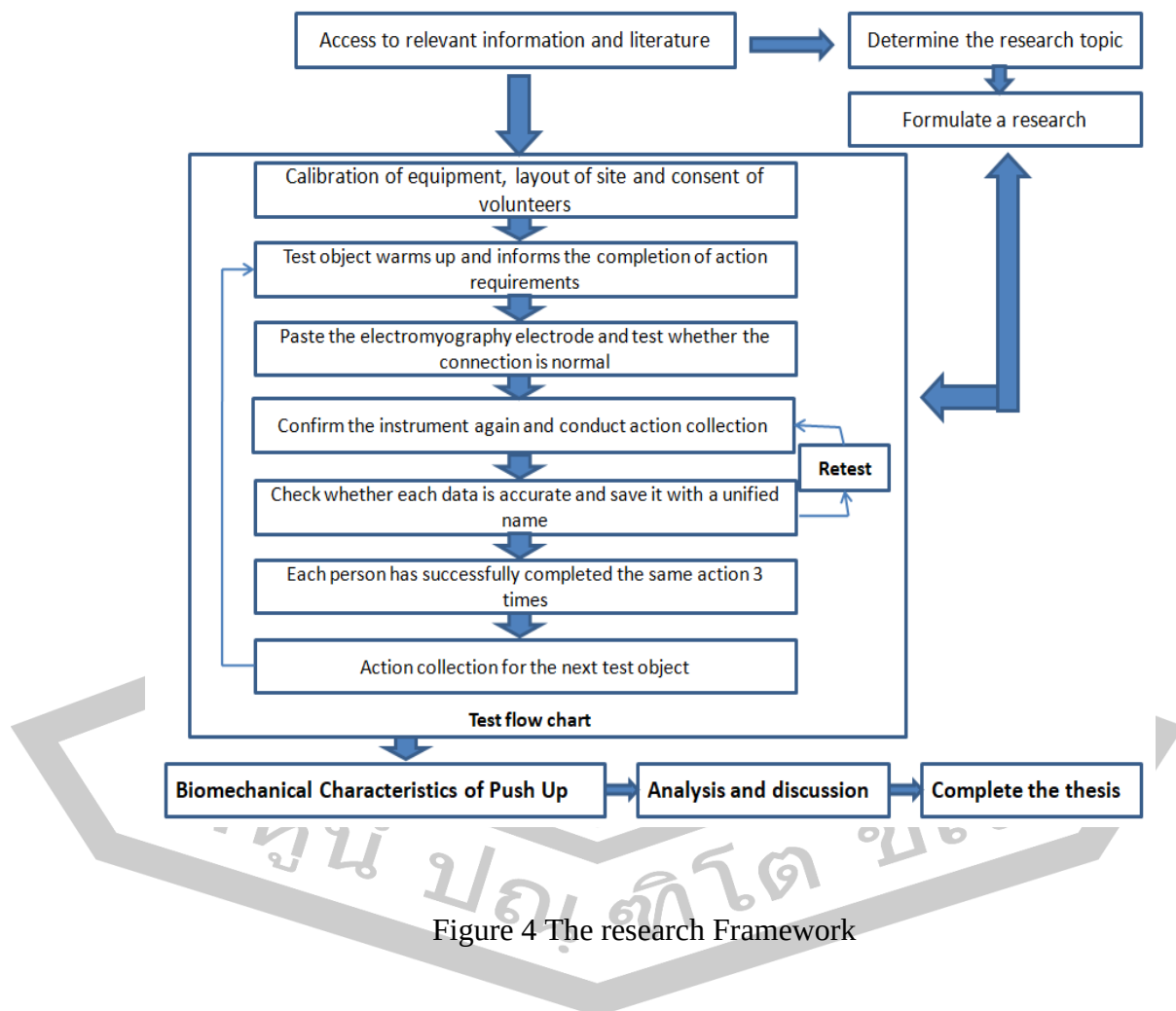


Figure 4 The research Framework

Participants

The students in Xi 'an Sport University who met the test conditions were given a lecture, which mainly introduced the experimental purpose, experimental test method, test content, test precautions, etc. After obtaining the consent of the test volunteers, 12 test volunteers who were all over 18 years old were recruited. After the recruitment of test volunteers is successful, the relevant information of the test is informed again. After the test volunteers fully understand the complete situation of the test, the volunteer informed consent is signed with the test volunteers. The experimental subjects were 4 high-level athletes, 4 intermediate level athletes and 4 ordinary level athletes. The subjects were in good health and had no history of sports injury. After being informed about the content of the experiment, the subjects volunteered to participate in the experiment. They did not engage in high-intensity exercise in the 24 hours prior to the test and did not experience muscle fatigue. At the same time, they recorded various parameters. The participation of volunteers in the test is shown in Table 1.

Table 1 Basic statistics of athletes participating in the test

N0.	Name	Sex	Age	Height	Weight	Sports level	Training Years
1	A1	M	26	165	64	High level	10
2	A2	M	25	173	76	High level	11
3	A3	M	26	165	64	High level	10
4	A4	M	25	173	70	High level	11
5	B1	M	21	180	67	Intermediate level	4
6	B2	M	22	173	71	Intermediate level	4
7	B3	M	21	173	64	Intermediate level	4
8	B4	M	22	175	64	Intermediate level	4
9	C1	M	21	178	78	Ordinary level	2
10	C2	M	22	177	68	Ordinary level	1
11	C3	M	22	172	60	Ordinary level	2
12	C4	M	22	181	70	Ordinary level	1

The experimental testing was conducted by a professional testing team from the Experimental Center of Sports Biomechanics, Xi'an Sports University, of which the author of this study was also a member. This professional testing team often participated in the research and testing of sports physiological and mechanical characteristics of several sports projects initiated by Shaanxi Provincial government and obtained a lot of research results in sports biomechanics. During testing, the test team's responsibilities for each person are clear and fixed to ensure the accuracy of the test data.

Test Instrument

(1) The Wireless surface electromyography (EMG) system

American NORAXON surface myoelectric wireless telemetry system, with up to 4000HZ EMG acquisition frequency, USB power supply and connected to the PC end, transmission range of 30m, sampling frequency is optional 2000Hz or 4000Hz, sensor size 37*24.5*16.5mm length, width and height, weight 14g; Sensor base size 174*92*169mm length, width and height, weight 545g; Signal receiver size 261*36*29mm, weight 185g, with 16 channels.

The wireless surface electromyography test system can simultaneously collect 16-channel electromyography signal, real-time wireless data transmission, support the analysis of common indicators in the time domain and frequency domain of electromyography, such as mean value, maximum value, minimum value, root mean square amplitude (RMS), integrated electromyography (IEMG), power spectrum (PSD), and customized analysis. The wireless electromyography test system can obtain data such as the order of muscle work done, and the amount of work done when athletes perform difficult movements without affecting their performance. Through data analysis, the surface EMG characteristics of athletes performing the technical movements can be obtained.

In addition to the professional equipment for sports biomechanics testing, we also need to use some common tools, such as laptops, during the testing process. Two computers, including Ariel 3D motion image analysis system, 3D force measuring table data analysis software, electromyography data analysis system, electromyography

and force measuring table synchronization system, and an external synchronizer are installed. The surface electromyography test instrument is shown in Figure 5.



Figure 5 Schematic diagram of EMG equipment

(2) 3D force measuring table

One 3D force measuring table (Swiss KISTLER). Kistler 3D force bench test system is mainly used in the field of gait and balance analysis. It can accurately obtain the ground force, friction force, pressure and other parameters of different gait and posture. In this study, the ground force, friction force and pressure parameters of athletes' take-off action are mainly tested, and the ratio of push off force to body weight is calculated by combining with the athletes' body weight, so as to construct the mechanical characteristics of athletes' push off take-off stage. The test instrument of a three-dimensional dynamometer is shown in Figure 6.



Figure 6 Three-dimensional dynamometer

(3) 3D High-Speed Camera system

Three Japanese SONY-RX10IV cameras, a set of SIMI Motion software of SIMI company, calibration frame using Agger 3D DTL framework calibration. 3D high-speed camera system can be used in the study of human movement, which can truly reproduce the movement and movement trajectory of athletes and output the movement data of each link of athletes at any time, such as displacement, speed, angular speed, etc., so as to facilitate quantitative analysis. Combined with the principles of human physiology and physics, the research and improvement methods can make the observation of human movement get rid of the state of relying purely on experience. Enter the theoretical, digital era. 3D high-speed camera is a non-contact measurement, which has the advantages of not imposing extra load on the human body, not interfering with the body movement and measuring close to the actual condition. The detection and processing of human motion information takes human motion as the research object. Measure and analyze the displacement, velocity, acceleration and joint Angle of each part of the human body in the process of movement. 3 D high speed camera system is mainly used to study the kinematic characteristics of motion technology. High-speed camera test instrument is shown in Figure 7.



Figure 7 Schematic Diagram of High-Speed Camera

Data Collection Procedure

This study has been carried out with the approval of MahaSarakhm University under the Ethic code : 511-359/2023.

1. Composition and responsibilities of the test team

The test work and data process of this study was completed by a high-level professional test team, each member of which held a fixed test position and could not be replaced during the whole test process to ensure the stability of the test process and the accuracy of the test data. The composition of the test team and its testing responsibilities are presented in Table 2.

Table 2 Composition and responsibilities of the test team

Name	Employer	Major	Title	Test task
Zhou	Xi 'an Sports University	Sports Biomechanics	Professor	EMG test
Liu	AnKang University	Sports human science	Lecturer	EMG test
Yan	Xi 'an Sports University	Sports Biomechanics	Professor	High speed photography
Guo	AnKang University	National traditional sports science	Associate professor	High speed photography
Ma	Xi 'an Sports University	Sports Biomechanics	Lecturer	Force table
Wu	ChengDu Normal University	Sports training science	Professor	Force table
Chen	Xi 'an Sports University	Sports Biomechanics	Student	Test order arrangement

2. Test time and test team

Test location: Laboratory of Sports biomechanics, Xi 'an Sport University.

Exam time: Pre-exam (December 2, 2023), formal exam (December 8, 2023). The official test time was one full day, and 12 test volunteers completed all the tests in one day.

3. Test method

3.1 Kinematic test

The researchers used high-speed cameras to collect data on the push-up kinematics of volunteers performing different positions and different loads at a sampling rate of 100 frames per second. All volunteers were asked to successfully complete two push-ups with different positions and loads. Each time a volunteer completes a move, there will be three first-level gymnastics judges on site to judge it as successful. After an action fails, they need to complete the same action again until data is collected for two successful actions. In the follow-up study, the group with complete exercise data collection and the highest exercise quality will be selected for data analysis.

3.2 Dynamic Testing

The three-dimensional force measurement platform collected the ground reaction force of the subjects (high-level, intermediate and ordinary gymnasts) when they completed the push-ups under different positions and different loads in the push-down and push-up stages. The sampling frequency was 500Hz. In the push-up test, the subjects need to complete the push-up movement with their hands on a three-dimensional force measuring platform.

3.3 Surface electromyography test

A wireless electromyography test system was used to collect the surface electromyography data of high, intermediate and ordinary gymnasts in different positions and different loads of push-ups, and the electromyography was analyzed. According to the movement characteristics of different push-ups and different loads, different test muscles were selected in different exercise stages, respectively, the right and left biceps, the right and left triceps, the right and left deltoid anterior bundle, the right and left pectoralis major, the right and left trapezius, the right and left latissimus dorsi, and the right and left forearm muscle groups, etc.

4. Instrument installation method

4.1 High-speed camera system

In this experiment, a Japanese SONY-RX10IV camera was used for synchronous point-shooting. The camera frequency is 100Hz. The calibration frame was calibrated by Agger 3D DTL frame.

4.2 3D force table measuring

The Swiss KISTLER three-dimensional force measuring platform is installed in the installation slot of the force measuring platform at the test site to ensure the accuracy of the test data of the force measuring platform. The whole test area forms a horizontal plane, which does not affect the subjects to complete different positions and different loads of push-ups (see Figure 8). The X-axis direction of the measuring table is set perpendicular to the center of the subject's head.

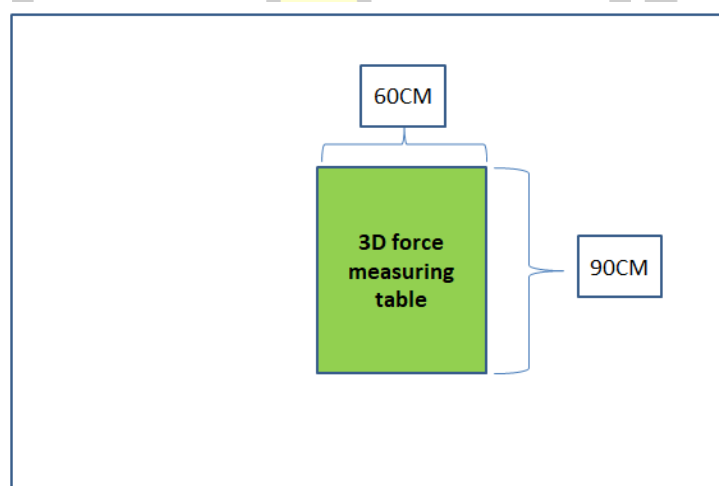


Figure 8 Installation diagram of force measuring table

4.3 Wireless telemetry myoelectric system

4.3.1 Selection of muscles

According to the movement characteristics of push-ups with different postures and different loads, the same test muscles were selected in different exercise stages, which were respectively left and right biceps, right and right triceps, right and right pectoralis major and right and right trapezius. Major muscle starting and ending points and major functions (Table 3).

Table 3 The starting and ending points and main functions of muscles

Muscle Name	Muscle Start and end Point	The main function of a muscle
Triceps brachii	It is divided into a long head, inner head and outer head. The long head starts from the glenoid nodule of the scapula, the lateral head starts from the outer upper part of the radial nerve groove of the humerus body, the medial head starts from the lower part of the humerus body, and the three heads form a muscle belly and end at the olecranon of the ulna.	The forearm is extended at the elbow joint when the close fixation is contracted, and the upper arm is extended at the shoulder joint when the long head is contracted. When the distal fixation contracts, make the upper arm extend at the elbow joint.
The biceps brachii	It is located in the shallow layer of the front of the upper arm, and the upper part is covered by the deltoid muscle and pectoralis major muscle, including the long and short heads. The long head starts from the supraglenoid tubercle of the scapula, the short head starts from the coracoid process of the scapula and ends at the radial tuberosity and forearm fascia after the combination of the two heads.	Near fixed contraction, the upper arm flexes and contracts at the shoulder joint and elbow joint to make the upper arm close forward.
The deltoid	It is located at the shoulder in a triangular shape, divided into three parts: front, middle and rear. It starts at the lateral end of the clavicle, the acromial peak and the spine of the scapula, and ends at the tuberosity of the deltoid muscle on the lateral side of the humerus body.	Near fixed contraction, anterior muscle fibers make the upper arm bend, adduct and pronate; The posterior muscle fibers make the upper arm extend, adduct and rotate outward; The middle muscle fiber makes the upper arm abduce to the horizontal position; The contraction of the whole muscle causes the upper arm to abduce.
Pectoralis major muscle	It is located under the chest. It starts from the medial half of the clavicle, the lateral edge of the sternum, the upper 6 ribs, and the anterior wall of the rectus abdominis sheath, and ends at the greater tuberosity ridge of the humerus.	When near fixed contraction, make the upper arm bend, adduction and pronation; When retracting from the distal fixation, pull the torso closer to the upper arm.
The trapezius muscle	It is located under the neck and upper back. It starts from the external occipital protuberance, the nuchal ligament, the seventh cervical vertebra and the spinous process of all thoracic vertebrae, and ends at the lateral third	The upper muscle fiber raises, retracts and gyrates the scapula when it contracts in close fixation; The middle muscle fiber makes the scapula shrink back; The lower muscle fibers make the scapula fall, shrink back, and swing up; The three parts of muscle fibers contract to make the scapula retract and rotate upward.

of the clavicle, the acromion and the spine of the scapula.

In the case of distal fixation and contraction, the head and spine bend to the same side and turn to the opposite side in the case of unilateral contraction; Both sides contract at the same time to straighten the head and spine.

4.3.2 EMG test electrode placement

Before the test, the electrode placement of the muscle to be measured was determined according to the anatomical marks on the body surface and by hand inspection. Shave the hair on the skin surface of the preset electrode and wipe with 75% alcohol. The two recording electrodes were attached to the highest point of the muscle abdominal bulge during the contraction of each muscle to be measured and in the same direction as the muscle fibers. The center distance of the two electrodes was 2cm, and then the elastic bandage was wrapped and fixed.

5. Instrument synchronization method

The synchronization between the electromyography and the force measuring table relates to the synchronization software in the way of internal synchronization. The synchronization between the high-speed photography and the electromyography and the force measuring table is achieved by the way of external synchronization.

6. Instrument sampling frequency

6.1 High-speed Camera

A high-speed camera was positioned in front of the volunteers' heads as they performed the action. High-speed cameras have a sampling rate of 100 frames per second.

6.2 Three-dimensional force measuring table the sampling frequency of the 3D force measuring table is set to 500Hz.

6.3 Wireless telemetry of electromyography Set the sampling frequency of wireless telemetry EMG signal to 2000Hz, and the filtering frequency to 20 ~ 500hz.

7. Test preparation

7.1 Methods for collecting and recording the movement technical data of subjects must be fully warmed up before the test. After warming up, all subjects will complete 2 push-ups according to different positions and different loads. Three Level I judge will be invited to evaluate the completion of the movements.

7.2 Information Collected during Test Preparation

General information: subject height, weight, gender, training years, sports grade, competition experience, injuries, etc.

Environment and instrument installation reference data: investigate the factors affecting the environmental safety of athletes completing movements, debug test instruments and equipment, improve the test environment, and lay the foundation for the smooth conduct of formal tests. For example, the tightness of the myoelectric electrode fixation, the impact of site safety measures on the athletes' completion of the movement, the installation of the force measuring table in a special experimental tank does not affect the test accuracy of the force measuring table and reduces the impact of site conditions on the accuracy of the test instrument.

8. Formal testing

8.1 Preparation for the testing

According to the problems found in the preparation stage of the test, all the hidden dangers that may affect the accuracy of the test should be eliminated, the equipment should be installed and adjusted, and the test preparation should be done well. All subjects were asked to bare their upper body, wear high-stretch tight shorts, and wear their usual training sneakers. All subjects were numbered and recorded before the test began. Warm up activities are performed before the test starts and EMG electrodes are used after a full warm-up.

The electrode pastes personnel and test athletes remain neutral, fixed with double-sided tape along the longitudinal axis of the muscle in the most prominent position of the muscle abdomen, and fixed with elastic bandages to prevent the electrode from slipping or falling off during exercise. Take the left limb (left biceps brachii, left triceps, left deltoid anterior bundle, left pectoralis major, left trapezius, etc.). Turn on the electrodes attached to the test athlete. Verify that the computer can be connected to the electrodes and perform signal detection.

8.2 Test Process

The test volunteers completed two push-ups with different positions and different loads in numbered order. Three first-level judges were invited to evaluate the completion of movements in the test venue, and the one with complete movement data collection and the highest movement quality was selected for data preservation. After the first subject completes the test and saves the test data, the second subject starts the test and completes the test for all subjects in turn, and properly saves the test data. The test is complete. The test instrument should be arranged and returned as soon as possible after the test. The flow chart of push-up test is shown in Figure 9.

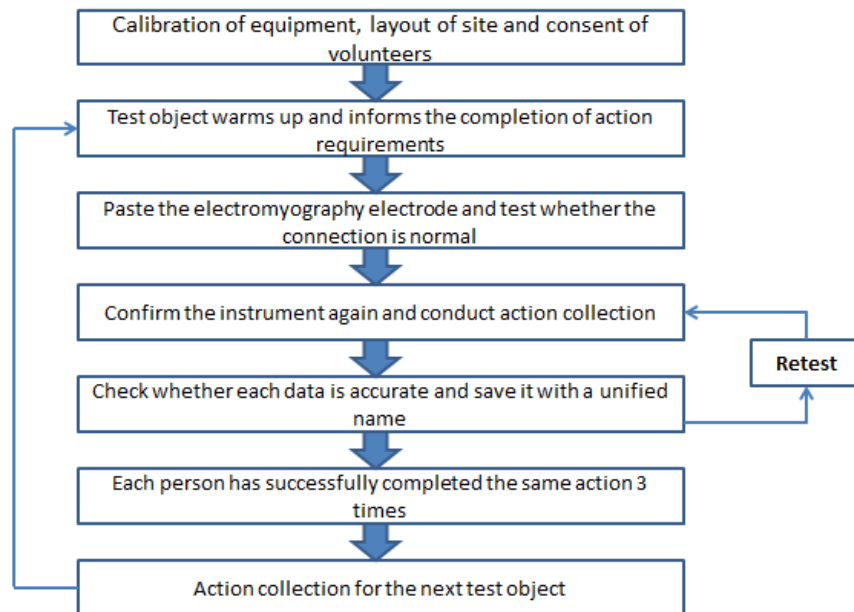


Figure 9 Test flow chart

Test steps: The first step is to arrange a force measuring table, a camera, and a surface EMG measuring instrument. Participants will do a 30-minute warm-up stretch and a 5-minute rest.

Step 2: After warming up, the tester found the muscle position of each part of the subject's body, wiped with alcohol, and pasted the sensor.

Step 3: The subjects put their palms on the force measuring table to adapt to the changes of the force measuring table, sensing film and field environment, and perform 7 push-ups with different positions or loads until they find the feeling of completing the standard movement (there is 1-2 minutes of adjustment time between the completion of each movement).

Step 4: After acclimatization, the subject can prepare for the ongoing test.

Step 5: After one subject completes the test, the EMG is removed and installed on the next subject due to limited EMG modules in the laboratory. Repeat (steps 1 to 4).

Step 6: After the test, save the collected data and restore the experimental instrument for subsequent data processing.

8.3 Precautions

Ensure that subjects are fully aware of the test requirements and procedures and ensure that athletes are fully warmed up before the test to avoid sports injuries. Test equipment hire professional operators to operate, to ensure the safety of the instrument. After the test, test data everywhere and back it up to ensure the safety of the test data.

8.4 Push Up Posture

The four different positions and five different combinations of push-ups are shown in Figure 10, Figure 11, Figure 12, Figure 13, Figure 14, Figure 15, Figure 16, Figure 17.

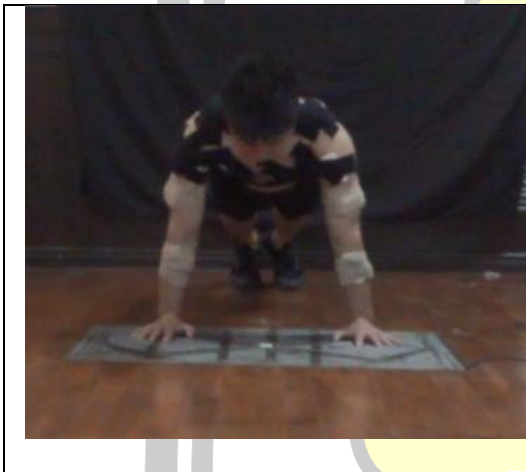


Figure 10 Push up exercise (Pose 1)

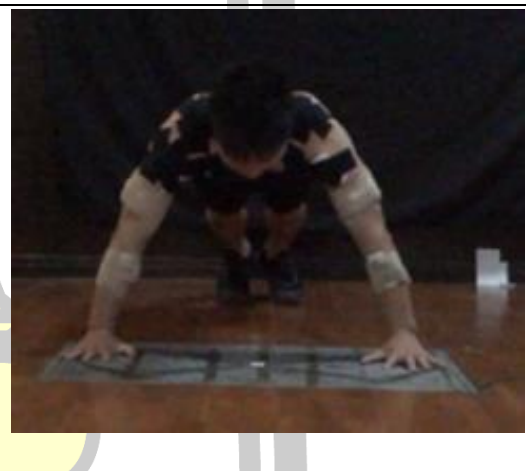


Figure 11 Wide support push up exercise (Pose 2)

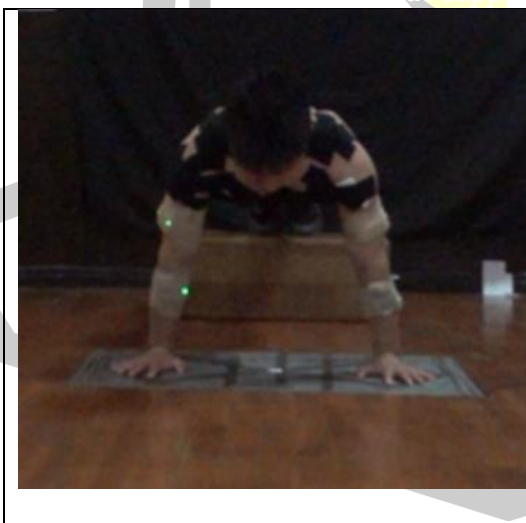


Figure 12 Standard push-ups (25 cm) (Pose 3)



(Pose 4)

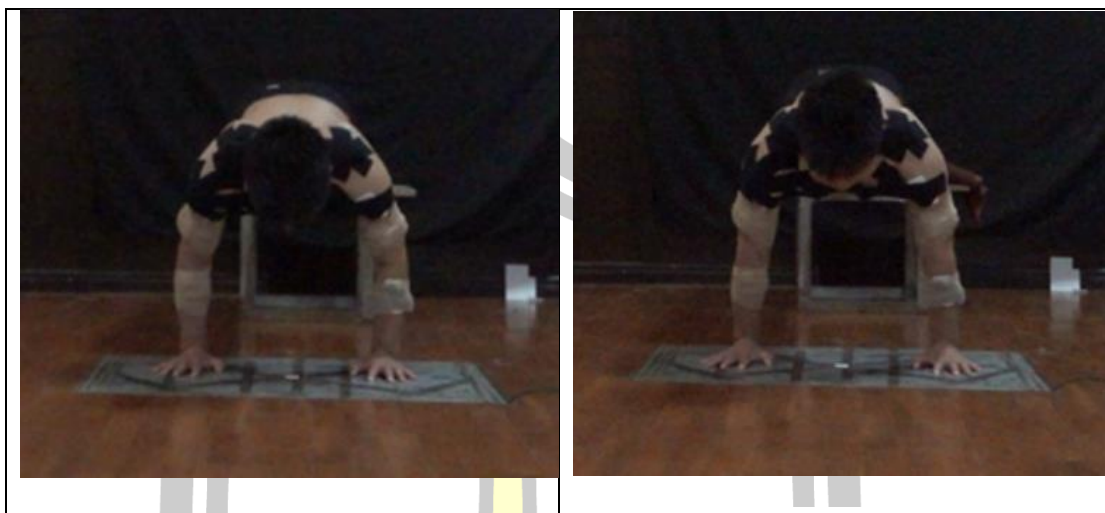


Figure 14 Standard push-ups (40 cm) (Pose 5) Figure 15 Standard push-ups (50 cm) (Pose 6)

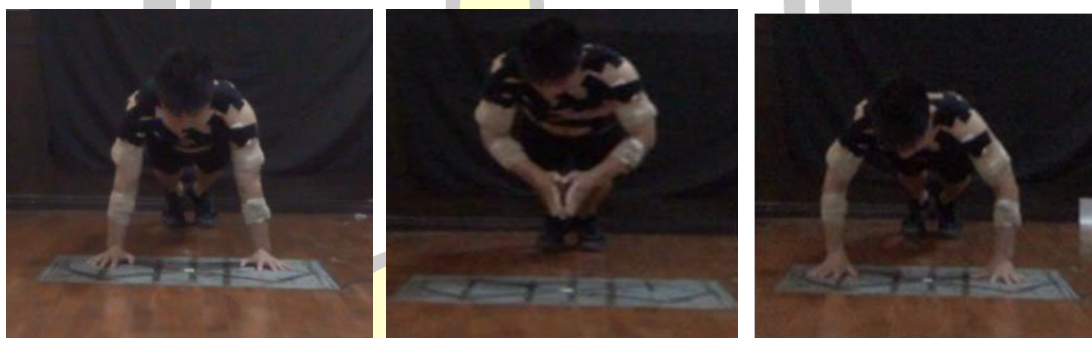


Figure 16 Standard Support High-five push-ups (0 cm) (Pose 7)



Figure 17 Wide Support high-five push-ups (0 cm) (Pose 8)

Data analysis

1. Data analysis of 3D high-speed camera system

1.1 Data method of 3D high-speed camera images

After the video shooting was completed, SIMI 3D moving image analysis system and Matsui Hideji human body model were used to calculate the data, and second-order filtering method was used to smooth the data, and the interception frequency was 6Hz. Use Excel software to calculate the data and statistics.

1.2 Data selection and analysis of 3D high-speed camera system

1.2.1 Complete the time characteristics analysis of push-ups with different positions and different loads

(1) The total time of push-ups in different positions and different loads

The total time of push-ups with different posture and different load was selected to analyze the characteristics.

(2) Time analysis of the bending arm stage in the downward flexion

The characteristics of different posture and different load of push-ups are analyzed.

(3) Time analysis of the upward pushing stage

The characteristics of different postures and different loads of push-ups are analyzed

(4) Time analysis of vacating stage

The time data of different postures and different loads of high-five push-ups in the air stage were selected for characteristic analysis.

1.2.2 Complete the characteristics analysis of push-ups in different positions and different loads

(1) Analysis of the Angle characteristics of the lowest elbow joint in the downward flexion stage of push-ups with different positions and different loads.

(2) Shoulder joint speed peak characteristics of push-ups with different positions and different loads in the downward bending arm stage and the upward pushing stage.

(3) The peak angular velocity characteristics of shoulder joints in different positions and different loads of push-ups during the downward flexion stage and the upward pushing stage.

2. Data analysis of 3D force measuring table

2.1 Data method of 3D force measuring table

Combined with the kinematic data, the ground reaction (N) in different directions [left and right (X axis), front and back (Z axis), up and down (Y axis)] is obtained. Including: different positions and different loads of push-ups, the vertical force peak value in the downward flexion stage and the upward push up stage.

2.2 Selection and analysis of 3D force measuring table data

The characteristics of the vertical ground reaction peak value were analyzed in the downward flexion stage and upward push up stage of push-ups with different posture and load collected by loading platform.

3. Data analysis of wireless EMG system

3.1 Wireless EMG datatization method

The surface electromyography test indexes selected in this study were integrated electromyography and muscle activation timing. The electromyograph of the selected muscle of the subject was collected by wireless telemetry surface electromyograph during the completion of the movement. The sampling frequency was 2000Hz, and the filtering frequency was 20-500Hz. At the end of the test, the raw data was imported into the Noraxon analysis software to obtain the raw integral electromyography and muscle activity duration of each tested action muscle. The duration of muscle activation is based on the characteristics of the discharge of action muscles in this study. The integrated electromyography that is greater than 20% of the maximum value of electromyography and lasts for more than 0.05s is taken as the muscle activation area, and the duration of muscle activation is further converted into the percentage of the total time of the action stage.

3.2 Data selection and analysis of wireless EMG system

(1) Analysis of EMG characteristics of athletes completing push-ups with different positions and different loads in downward flexion stage and upward push stage.

(2) The activation time and EMG integral value of relevant muscle groups collected by wireless EMG system were analyzed when athletes completed push-ups with different positions and different loads in the downward flexion stage and the upward push stage.

4. Comprehensively analyze the technical characteristics of athletes of different levels completing different positions and different loads

4.1 Comprehensively analyze the technical characteristics of athletes at different sports levels completing push-ups with different positions and different loads.

4.2 Comprehensively analyze the technical characteristics of athletes at different sports levels completing push-ups with different positions and different loads.

5. Data statistics and calculation

According to the research needs, statistical software SPSS25 and Excel 2021 were used to establish the kinematic data, push-up and push-up force data and EMG data database obtained by the experiment. The test data in this study were divided into three groups. The first group is the data of high-level athletes who complete different positions and different loads of push-ups; The second group is the data of intermediate level athletes who complete different positions and different loads of push-ups; The third group is the push-ups data of ordinary athletes in different positions and under different loads. The mean value and variance analysis of push-up data of the same group of athletes under different positions and different loads were carried out. The T test was used to compare the data of the two groups of athletes in different positions and different push-up loads, and the difference of the data between the two groups was judged by the P-value. Analysis of variance was used to compare the three groups and above data for analysis and comparison. When analyzing the EMG data of each group of athletes, it was found through individual value analysis that the EMG characteristics of each person who completed different positions and different loads of push-ups were more effective.

CHAPTER IV

RESULTS

1 Description and stage division of push-up movement process

1.1 Description of the push-up movement process

A standard push-up involves spreading your hands slightly wider than shoulder width apart, bringing the front soles of your feet together, and supporting four points on the ground, forming a straight line from head to foot. Keep your elbows straight, your arms perpendicular to the floor, and the Angle between your elbows and your torso should be about 45 degrees. Clamp your shoulder blades and bend your arms until your elbows are slightly higher than your torso, then straighten your arms to return.

1.2 Stage division of push-ups

1.2.1 Standard push-up action stage division

According to the main technical links of the push-up, the upper limb movement of the push-up can be divided into two action stages: the arms down and the arms bent, and the arms pushed up. (Figure 18)

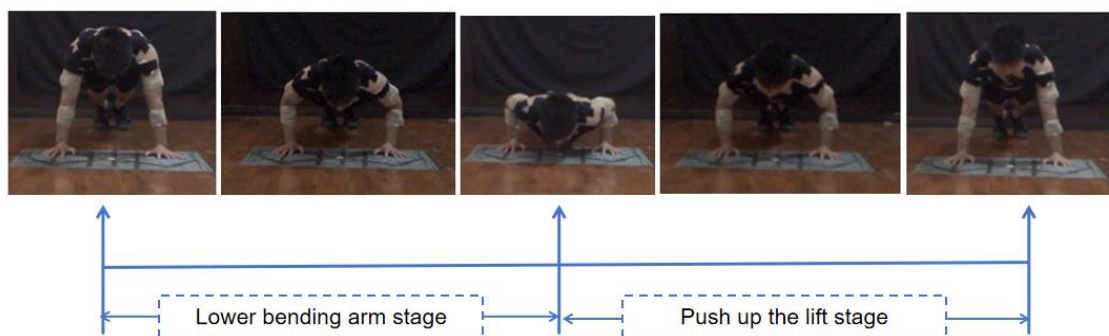


Figure 18 Standard push-up action stage division diagram

1.2.2 Standard high-five push-ups movement stage division

Because this study also involves other posture push-ups besides standard push-ups, the high-five push-ups are divided into three stages, namely, the downward push-up stage, the upward push-up stage and the air stage. (Figure 19)

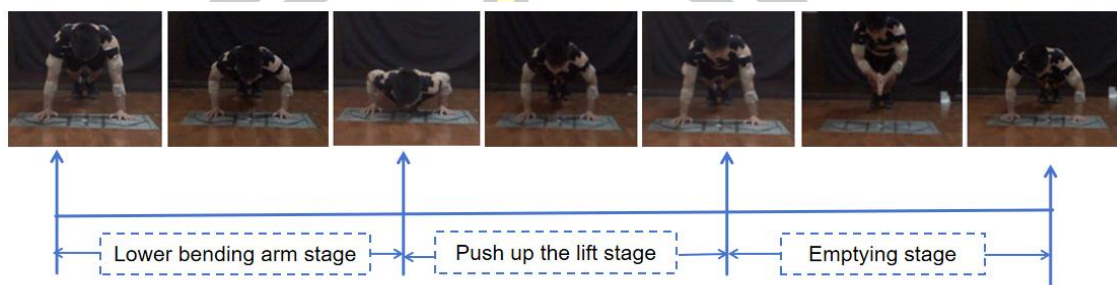


Figure 19 Standard high-five push-up action stage division diagram

2. Results and analysis of push-ups

2.1 Biomechanical characteristics of push-ups performed by high-level athletes

2.1.1 Time characteristics

2.1.1.1 Complete motion time characteristics

(1) The total time of standard push-ups supporting different loads

Standard support means that the hands supported on the ground are shoulder-width apart (Figure 20). Push-ups with different loads are push-ups in which the feet are placed at different heights. (Figure 21, Figure 22, Figure 23, Figure 24, Figure 25)



Figure 20 Standard push-up support diagram (hands slightly wider than shoulders)

Table 4 Statistical table of total time taken to complete standard support push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.96	0.95	0.96	1.1	1.13
A2	0.95	0.94	0.94	1.12	1.19
A3	0.95	0.96	0.95	1.15	1.12
A4	0.97	0.93	0.96	1.13	1.2
$\bar{X} \pm S$	0.96 $\pm$ 0.01	0.95 $\pm$ 0.01	0.95 $\pm$ 0.01	1.13 $\pm$ 0.02	1.16 $\pm$ 0.04



Figure 21 Standard support push-up diagram (0 cm)

Judging from the total time of standard support push-ups (with both feet on the ground) (table 4 and Figure 21), the average time of high-level athletes to complete standard support push-ups is 0.96s, and the standard deviation is 0.01s. The total time of the four athletes who participated in the test to complete the standard support push-ups (flat ground) was very close, and the total time of athletes A2 and C to complete the standard support push-ups (feet on the ground) was 0.95s, which was the shortest among the four athletes. The total time for athlete D to complete the standard support push-up (with both feet on the ground) was 0.97s, which was the longest among the four athletes.



Figure 22 Standard support push-up diagram (25cm)

Judging from the total time of standard support push-ups (feet 25 cm above the ground) (table 4 and Figure 22), the average time of high-level athletes to complete standard support push-ups (feet 25 cm above the ground) is 0.95s, and the standard deviation is 0.01s. The total time of the four athletes participating in the test to complete the standard support push-up (feet 25 cm above the ground) is very similar, and the total time of athlete D to complete the standard support push-up (feet 25 cm above the ground) is 0.93s, which is the shortest among the four athletes. Athlete C's total time to complete the standard support push-up (feet 25 cm above the ground) was 0.96s, which was the longest time of the four athletes.



Figure 23 Standard support push-up diagram (30cm)

Looking at the total time of standard support push-ups (feet 30 cm above the ground) (table 4 and Figure 23), the average time of high-level athletes to complete standard support push-ups (feet 30 cm above the ground) is 0.95s, and the standard deviation is 0.01s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 30cm above the ground) is very similar, and the total time of athlete A2 to complete the standard support push-ups (feet 30cm above the

ground) is 0.94s, which is the shortest among the four athletes. The total time of athletes A1 and D to complete the standard support push-up (feet 30 cm above the ground) was 0.96s, which was the longest time of the four athletes.



Figure 24 Standard support push-up diagram (40cm)

From the total time of standard support push-ups (feet 40 cm above the ground) (table 4 and Figure 24), the average time of high-level athletes to complete standard support push-ups (feet 40 cm above the ground) is 1.13s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 40cm above the ground) is very similar, and the total time of athlete A1 to complete the standard support push-ups (feet 40cm above the ground) is 1.1s, which is the shortest among the four athletes. Athlete C's total time to complete the standard support push-up (feet 40 cm above the ground) is 1.15s, which is the longest time of the four athletes.

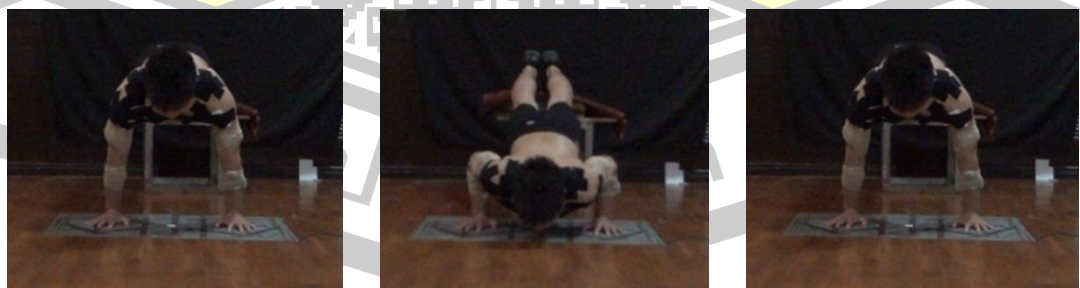


Figure 25 Standard support push-up diagram (50cm)

From the total time of standard support push-ups (feet 50 cm above the ground) (table 4 and Figure 25), the average time of high-level athletes to complete standard support push-ups (feet 50 cm above the ground) is 1.16s, and the standard deviation is 0.04s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 50cm above the ground) is very close, and the total time of athlete C to complete the standard support push-ups (feet 50cm above the ground) is 1.12s, which is the shortest among the four athletes. The total time of athlete D to complete the standard support push-up (feet 50 cm above the ground) is 1.2s, which is the longest time of the four athletes.

(2) The total time of push-ups with different loads of wide support

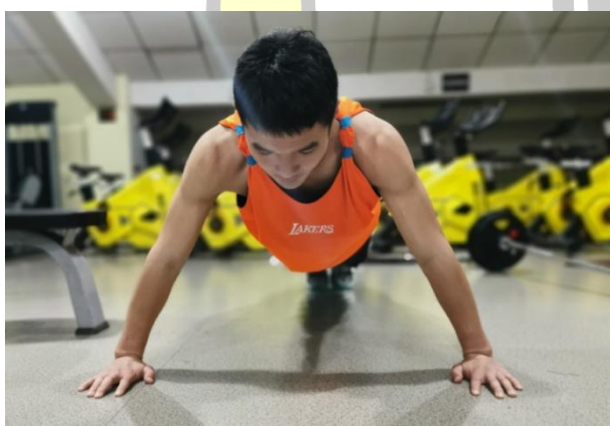


Figure 26 Wide support diagram (hands are longer than shoulders)

Table 5 Complete wide support push-ups total time statistics table (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.98	0.93	0.95	1.08	1.28
A2	0.98	0.94	0.94	1.06	1.26
A3	0.97	0.95	0.93	1.12	1.3
A4	0.93	0.93	0.95	1.11	1.32
$\bar{X} \pm S$	0.97±0.02	0.94±0.01	0.94±0.01	1.09±0.03	1.29±0.03

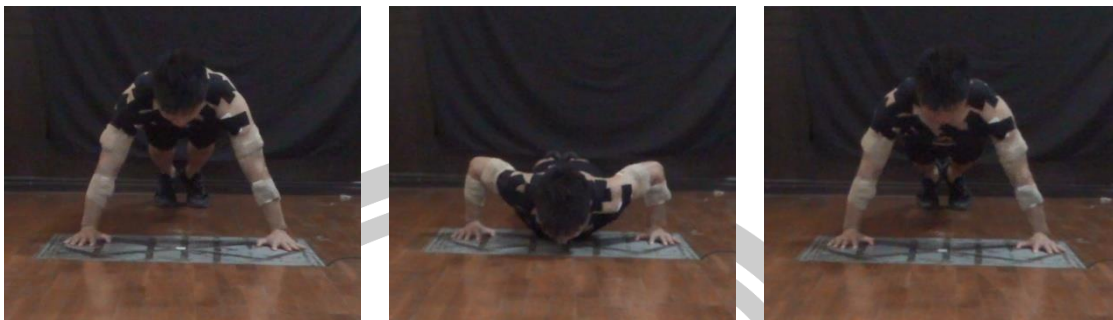


Figure 27 Wide support push-up diagram (0 cm)

In terms of the total time spent in wide-supported push-ups (with both feet on the ground) (table 5 and Figure 27), the average time for high-level athletes to complete wide-supported push-ups is 0.97s, with a standard deviation of 0.02s. The total time of the four athletes participating in the test to complete the wide support push-up (flat ground) is very close, and the total time of athlete D to complete the wide support push-up (feet on the ground) is 0.93s, which is the shortest among the four athletes. The total time of athletes A1 and A2 to complete the wide support push-up (feet on the ground) was 0.98s, which was the longest time of the four athletes.



Figure 28 Figure 28 Wide support push-up diagram (25cm)

In terms of the total time required for wide-supported push-ups (feet 25 cm above the ground) (table 5 and Figure 28), the average time for high-level athletes to complete wide-supported push-ups (feet 25 cm above the ground) is 0.94s, with a standard deviation of 0.01s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 25 cm above the ground) is very similar, and the total time of athletes A1 and D to complete the wide support push-up (feet 25

cm above the ground) is 0.93s, which is the shortest among the four athletes. Athlete C's total time to complete the standard support push-up (feet 25 cm above the ground) was 0.95s, which was the longest time of the four athletes.



Figure 29 Wide support push-up diagram (30 cm)

In terms of the total time required for wide-supported push-ups (feet 30 cm above the ground) (table 5 and Figure 29), the average time required for high-level athletes to complete wide-supported push-ups (feet 30 cm above the ground) is 0.94s, with a standard deviation of 0.01s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 30cm above the ground) is very similar, and the total time of athlete C to complete the wide support push-up (feet 30cm above the ground) is 0.93s, which is the shortest among the four athletes. The total time of athletes A1 and D to complete the wide support push-up (feet 30 cm above the ground) was 0.95s, which was the longest time of the four athletes.



Figure 30 Wide support push-up diagram (40 cm)

In terms of the total time required for wide-supported push-ups (feet 40 cm above the ground) (table 5 and Figure 30), the average time for high-level athletes to complete wide-supported push-ups (feet 40 cm above the ground) is 1.09s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 40cm above the ground) is very similar, and the total time of athlete A2 to complete the wide support push-up (feet 40cm above the ground) is 1.06s, which is the shortest among the four athletes. The total time of Athlete C to complete the wide support push-up (feet 40 cm above the ground) is 1.12s, which is the longest time of the four athletes.



Figure 31 Wide support push-up diagram (50 cm)

In terms of the total time required for wide-supported push-ups (feet 50 cm above the ground) (table 5 and Figure31), the average time required for high-level athletes to complete wide-supported push-ups (feet 50 cm above the ground) is 1.29s with a standard deviation of 0.03s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 50cm above the ground) is very close, and the total time of athlete A2 to complete the wide support push-up (feet 50cm above the ground) is 1.26s, which is the shortest among the four athletes. The total time of athlete D to complete the wide support push-up (feet 50 cm above the ground) is 1.32 seconds, which is the longest time of the four athletes.

(3) The total time used for standard high-five push-ups with different loads

Table 6 Total time required to complete standard support high-five push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	1.33	1.18	1.14	1.17	1.32
A2	1.12	1.14	1.06	1.24	1.35
A3	1.29	1.24	1.25	1.24	1.31
A4	1.33	1.27	1.13	1.08	1.35
$\bar{X} \pm S$	1.27±0.10	1.21±0.06	1.15±0.08	1.18±0.08	1.33±0.03

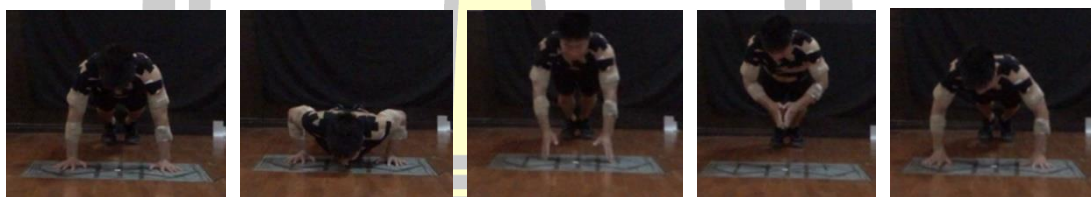


Figure 32 Standard support high-five push-ups schematic (0 cm)

Judging from the total time of standard supported high-five push-ups (with both feet on the ground) (table 6 and Figure 32), the average time for high-level athletes to complete standard supported high-five push-ups is 1.27s, and the standard deviation is 0.10s. The total time of the four athletes participating in the test to complete the standard supported high-five push-ups (flat ground) is very close, and the total time of athlete A2 to complete the standard supported high-five push-ups (feet on the ground) is 1.14s, which is the shortest among the four athletes. The total time of athlete D to complete the standard support push-up (feet on the ground) is 1.27s, which is the longest time of the four athletes.



Figure 33 Standard support high-five push-ups schematic (25 cm)

From the total time of standard supported high-five push-ups (feet 25 cm above the ground) (table 6 and Figure 33), the average time of high-level athletes to complete standard supported high-five push-ups (feet 25 cm above the ground) is 1.21s, and the standard deviation is 0.06s. The total time of the four athletes participating in the test to complete the standard support high-five push-up (feet 25cm above the ground) is very similar, and the total time of athlete A2 to complete the standard support push-up (feet 25cm above the ground) is 1.14s, which is the shortest among the four athletes. The total time of athlete D to complete the standard support high-five push-up (feet 25 cm above the ground) is 1.27s, which is the longest time of the four athletes.



Figure 34 Standard support high-five push-ups schematic (30 cm)

From the total time of standard supported high-five push-ups (feet 30 cm above the ground) (table 6 and Figure 34), the average time of high-level athletes to complete standard supported high-five push-ups (feet 30 cm above the ground) is 1.15s, and the standard deviation is 0.08s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 30cm above the ground) is very similar, and the total time of athlete A2 to complete the standard support push-ups (feet 30cm above the ground) is 1.06s, which is the shortest among the four athletes. Athlete C's total time to complete the standard high-five push-up (feet 30 cm above the ground) was 1.25s, the longest time of the four athletes.

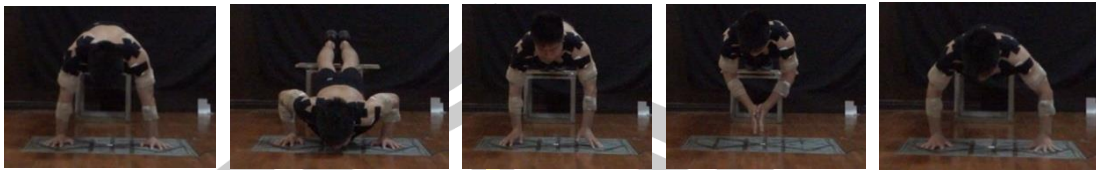


Figure 35 Standard support high-five push-ups schematic (40 cm)

Judging from the total time of standard supported high-five push-ups (feet 40 cm above the ground) (table 6 and Figure 35), the average time of high-level athletes to complete standard supported high-five push-ups (feet 40 cm above the ground) is 1.18s, and the standard deviation is 0.08s. The total time of the four athletes participating in the test to complete the standard supported high-five push up (feet 40cm above the ground) is very similar, and the total time of athlete D to complete the standard supported high-five push up (feet 40cm above the ground) is 1.08s, which is the shortest among the four athletes. Athletes A2 and C took 1.24 seconds to complete the standard high-five push-up (feet 40 cm above the ground), the longest time of the four athletes.

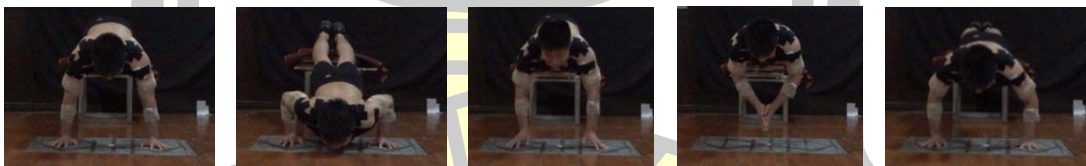


Figure 36 Standard support high-five push-ups schematic (50 cm)

From the total time of standard supported high-five push-ups (feet 50 cm above the ground) (table 6 and Figure 36), the average time of high-level athletes to complete standard supported high-five push-ups (feet 50 cm above the ground) is 1.33s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the standard support push up (feet 50cm above the ground) is very similar, and the total time of athlete C to complete the standard support high-five push up (feet 50cm above the ground) is 1.31s, which is the shortest among the four athletes.

Athletes A2 and D took 1.35s to complete the standard high-five push-up (feet 50 cm above the ground), which was the longest time of the four athletes.

(4) The total time of wide support for different loads of high-five push-ups

Table 7 Total time required to complete wide support high-five push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	1.29	1.29	1.23	1.28	1.39
A2	1.38	1.3	1.28	1.46	1.36
A3	1.32	1.2	1.19	1.2	1.38
A4	1.28	1.28	1.23	1.18	1.36
$\bar{X} \pm S$	1.32 $\pm$ 0.05	1.27 $\pm$ 0.06	1.23 $\pm$ 0.04	1.28 $\pm$ 0.13	1.37 $\pm$ 0.02



Figure 37 Wide support high-five push-ups schematic (0 cm)

In terms of the total time of wide-supported high-five push-ups (both feet on the ground) (table 7 and Figure 37), the average time for high-level athletes to complete wide-supported high-five push-ups is 1.32s, and the standard deviation is 0.05s. The total time of the four athletes participating in the test to complete the wide-supported high-five push up (flat ground) is very close, and the total time of athlete D to complete the wide-supported high-five push up (feet on the ground) is 1.28s, which is the shortest among the four athletes. The total time of athlete A2 to complete the wide support push-up (feet on the ground) is 1.38s, which is the longest time of the four athletes.

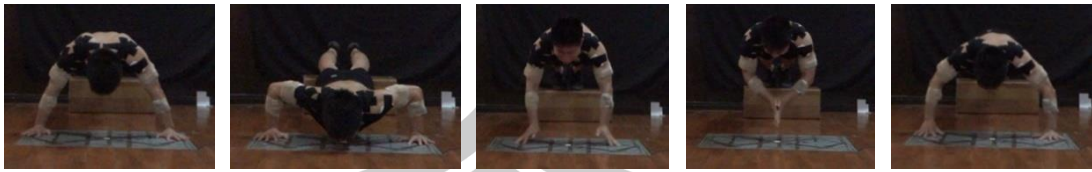


Figure 38 Wide support high-five push-ups schematic (25cm)

In terms of the total time required for wide-supported high-five push-ups (feet 25 cm above the ground) (table 7 and Figure 38), the average time for high-level athletes to complete wide-supported high-five push-ups (feet 25 cm above the ground) is 1.27s with a standard deviation of 0.06s. The total time of the four athletes participating in the test to complete the wide-supported high-five push-up (feet 25 cm above the ground) is very similar, and the total time of athlete C to complete the wide-supported push-up (feet 25 cm above the ground) is 1.2s, which is the shortest among the four athletes. Athlete A2 took 1.3s to complete the wide-supported high-five push-up (feet 25 cm above the ground), which was the longest time among the four athletes.

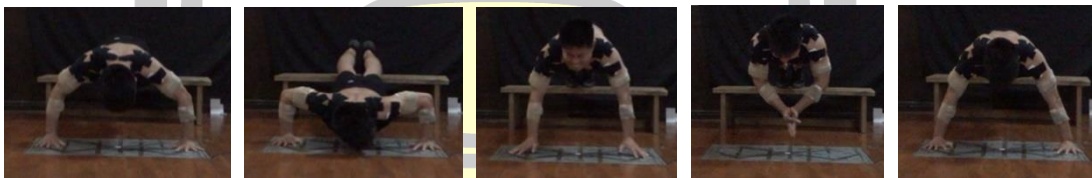


Figure 39 Wide support high-five push-ups schematic (30 cm)

In terms of the total time of wide-supported push-ups (feet 30 cm above the ground) (table 7 and Figure 39), the average time of high-level athletes to complete wide-supported push-ups (feet 30 cm above the ground) is 1.23s, and the standard deviation is 0.04s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 30cm above the ground) is very similar, and the total time of athlete C to complete the wide support push-up (feet 30cm above the ground) is 1.19s, which is the shortest among the four athletes. Athlete A2 took 1.28s to complete the wide-supported high-five push-up (feet 30 cm above the ground), which was the longest time among the four athletes.



Figure 40 Wide support high-five push-ups schematic (40 cm)

In terms of the total time of wide-supported push-ups (feet 40 cm above the ground) (table 7 and Figure 40), the average time of high-level athletes to complete wide-supported push-ups (feet 40 cm above the ground) is 1.28s, and the standard deviation is 0.13s. The total time of the four athletes participating in the test to complete the wide-supported high-five push up (feet 40cm above the ground) is very similar, and the total time of athlete D to complete the wide-supported high-five push up (feet 40cm above the ground) is 1.18s, which is the shortest among the four athletes. Athlete A2 took 1.46s to complete the wide-supported high-five push-up (feet 40 cm above the ground), which was the longest time among the four athletes.



Figure 41 Wide support high-five push-ups schematic (50 cm)

In terms of the total time of wide-supported push-ups (feet 50 cm above the ground) (table 7 and Figure 41), the average time for high-level athletes to complete wide-supported push-ups (feet 50 cm above the ground) is 1.37s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the wide support push up (feet 50cm above the ground) is very similar, among which the total time of athletes A2 and D to complete the wide support high-five push up (feet 50cm above the ground) is 1.36s, which is the shortest among the four athletes. Athlete A1 took 1.39s to complete the wide-supported high-five push-up (feet 50 cm above the ground), which was the longest time among the four athletes.

2.1.1.2 Time characteristics of the bending arm stage in the downward flexion

(1) The time used for standard push-ups with different loads to support the bending arm

Table 8 Time required to complete standard support push-ups and bend arms (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.46	0.47	0.45	0.49	0.52
A2	0.45	0.44	0.45	0.48	0.51
A3	0.43	0.43	0.47	0.52	0.46
A4	0.46	0.42	0.44	0.51	0.52
$\bar{X} \pm S$	0.45±0.1	0.44±0.02	0.45±0.01	0.5±0.02	0.50±0.03



Figure 42 Standard support push-up down flexion phase diagram (0 cm)

In terms of the time taken to complete the standard support push-up with the lower arm flexure (both feet on the ground) (table 8 and Figure 42), the average time taken by high-level athletes to complete the standard support push-up with the lower arm flexure is 0.45s, and the standard deviation is 0.10s. The time of the four athletes participating in the test to complete the standard support push-up down flexion arm (feet on the ground) is very similar, and the time of athlete C to complete the standard support push-up down flexion arm (feet on the ground) is 0.43s, which is the shortest among the four athletes. Athletes A1 and D took 0.46s to complete the standard

support push-up with their arms bent down (feet 25 cm above the ground), the longest time of the four athletes.

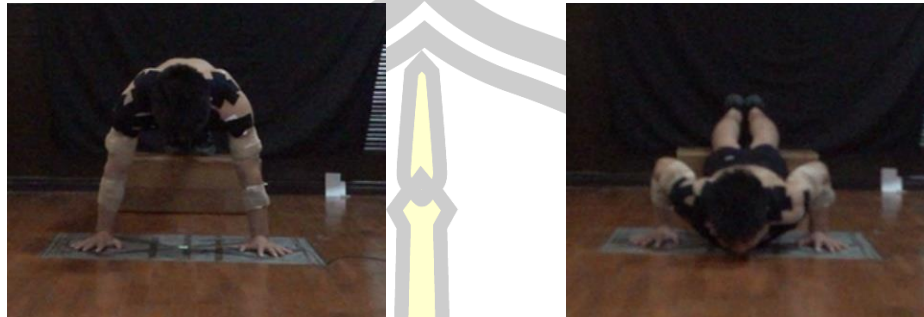


Figure 43 Standard support push-up down flexion phase diagram (25 cm)

In terms of the time, it takes for a standard support push-up to bend the arms down (feet 25 cm above the ground) (table 8 and Figure 43), the average time for a high-level athlete to complete a standard support push-up to bend the arms down (feet 25 cm above the ground) is 0.44s, and the standard deviation is 0.02s. The four athletes who participated in the test took very similar time to complete the standard support push-up down flexion arm (feet 25cm above the ground), and the time for athlete D to complete the standard support push-up down flexion arm (feet 25cm above the ground) was 0.42s, which was the shortest among the four athletes. Athlete A1 took 0.47s to complete the standard support push-up with his arms bent down (feet 25 cm above the ground), which was the longest time among the four athletes.

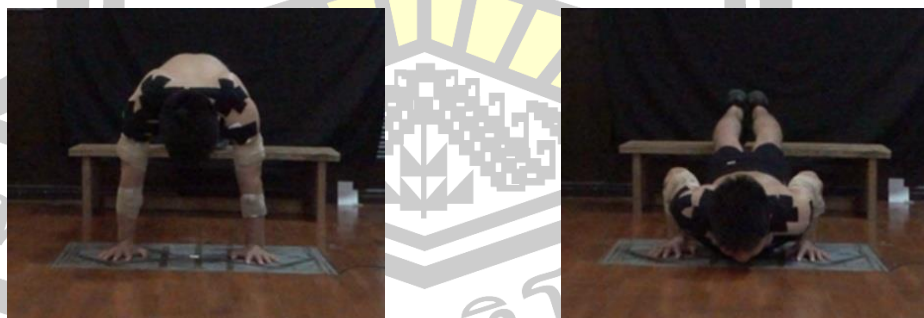


Figure 44 Standard support push-up down flexion phase diagram (30 cm)

In terms of the time, it takes for a standard support push-up to bend the arms down (feet 30cm above the ground) (table 8 and Figure 44), the average time for a high-level athlete to complete a standard support push-up to bend the arms down (feet 30cm above the ground) is 0.45s, and the standard deviation is 0.01s. The four athletes

who participated in the test took very similar time to complete the standard support push up and bend down the arms (feet 30cm above the ground). Among them, athlete D took 0.44s to complete the standard support push up and bend down the arms (feet 30cm above the ground), which was the shortest time among the four athletes. Athlete C took 0.47s to complete the standard support push-up with his arms bent down (feet 30 cm above the ground), which was the longest time among the four athletes.

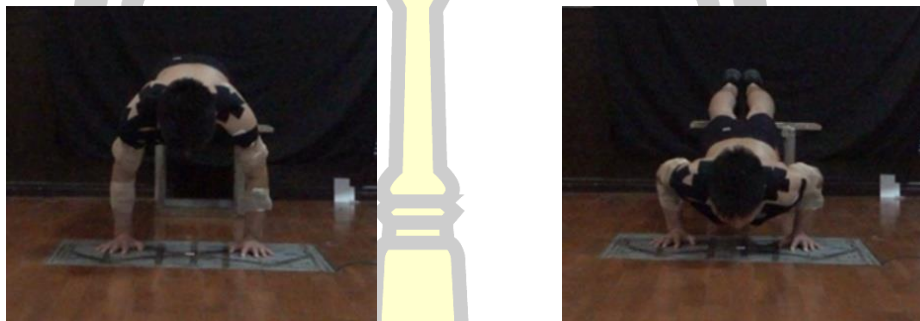


Figure 45 Standard support push-up down flexion phase diagram (40 cm)

In terms of the time, it takes for a standard support push-up to bend the arms down (feet 40 cm above the ground) (table 8 and Figure 45), the average time for a high-level athlete to complete a standard support push-up to bend the arms down (feet 40 cm above the ground) is 0.5s, and the standard deviation is 0.02s. The four athletes who participated in the test took very similar time to complete the standard support push-up and bend the arms down (feet 40cm above the ground). Among them, athlete A2 took 0.48s to complete the standard support push-up and bend the arms down (feet 40cm above the ground), which was the shortest time among the four athletes. Athlete C took 0.52 seconds to complete the standard push-up with his arms bent down (feet 40 cm above the ground), the longest time among the four athletes.



Figure 46 Standard support push-up down flexion phase diagram (50 cm)

In terms of the time, it takes for a standard support push-up to bend the arms down (feet 50 cm above the ground) (table 8 and Figure 46), the average time for a high-level athlete to complete a standard support push-up to bend the arms down (feet 50 cm above the ground) is 0.50s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support push-up down flexural arm (feet 50cm above the ground) is very similar, and the time of athlete C to complete the standard support push-up down flexural arm (feet 50cm above the ground) is 0.46s, which is the shortest among the four athletes. Athletes A1 and D took 0.52 seconds to complete the standard push-up with their arms bent down (feet 50 cm above the ground), the longest time of the four athletes.

(2) The time for wide support of different load push-ups to support the bending arm

Table 9 Time required to complete a wide support push-up and bend arms (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.47	0.42	0.46	0.53	0.61
A2	0.45	0.44	0.46	0.52	0.62
A3	0.49	0.43	0.45	0.56	0.64
A4	0.46	0.42	0.43	0.57	0.6
$\bar{X} \pm S$	0.47±0.02	0.43±0.01	0.45±0.01	0.55±0.02	0.62±0.02

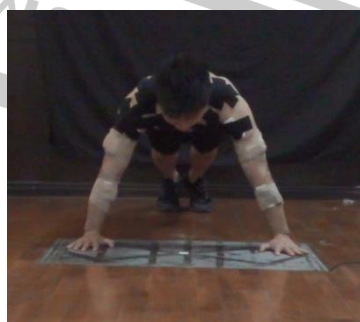


Figure 47 Wide support push-up down flexion phase diagram (0 cm)

In terms of the time, it took for the wide support push-up to bend the arms down (with both feet on the ground) (table 9 and Figure 47), the average time for the high-level athletes to complete the wide support push-up to bend the arms down is 0.47s, and the standard deviation is 0.02s. The time of the four athletes who participated in the test to complete the wide support push-up down flexion arm (feet on the ground) is very similar, and the time of athlete A2 to complete the wide support push-up down flexion arm (feet on the ground) is 0.45s, which is the shortest among the four athletes. Athlete C took 0.49s to complete the broad support push up and down with bent arms (feet on the ground), which was the longest time among the four athletes.

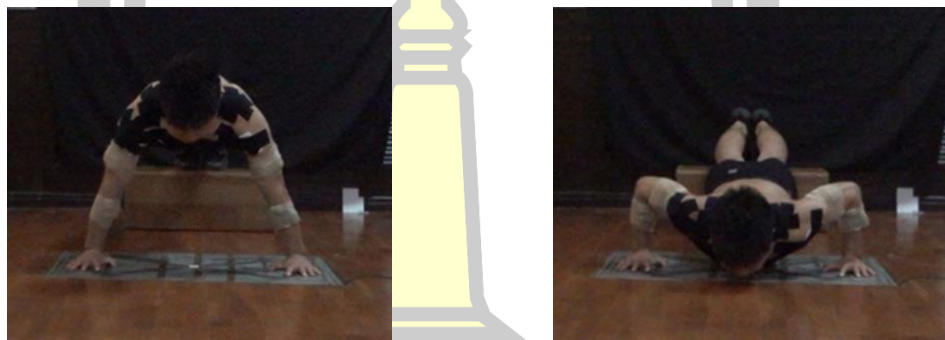


Figure 48 Wide support push-up down flexion phase diagram (25 cm)

In terms of the time, it took for the wide support push up to hold the arms down (feet 25 cm above the ground) (table 9 and Figure 48), the average time for the high-level athletes to complete the wide support push up to hold the arms down (feet 25 cm above the ground) was 0.43s, and the standard deviation was 0.01s. The time of the four athletes participating in the test to complete the wide support push-up down flexion arm (feet 25cm above the ground) is very similar, and the time of athletes A1 and D to complete the wide support push-up down flexion arm (feet 25cm above the ground) is 0.4s, which is the shortest among the four athletes. Athlete A2 took 0.44s to complete the wide support push up and down with his arms bent (feet 25 cm above the ground), which was the longest time among the four athletes.

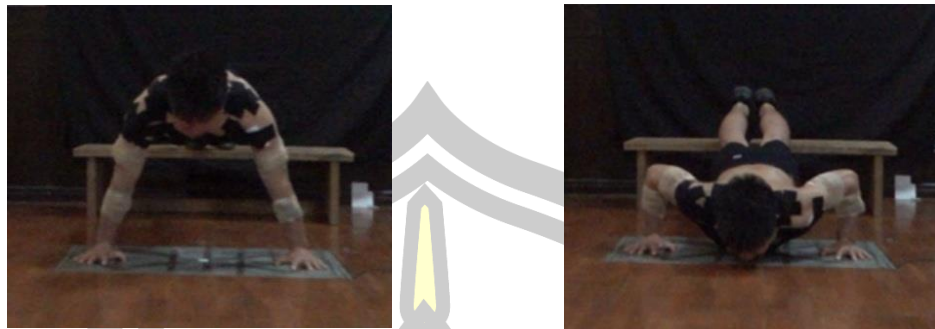


Figure 49 Wide support push-up down flexion phase diagram (30 cm)

In terms of the time, it took for the wide support push up to hold the arms down (feet 30 cm above the ground) (table 9 and Figure 49), the average time for the high-level athletes to complete the wide support push up to hold the arms down (feet 30 cm above the ground) was 0.45s, and the standard deviation was 0.01s. The four athletes who participated in the test took very similar time to complete the wide support push up and bend down the arms (feet 30cm above the ground). Among them, athlete D took 0.43s to complete the wide support push up and bend down the arms (feet 30cm above the ground), which was the shortest time among the four athletes. Athletes A1 and A2 took 0.46s to complete the wide support push up and down with their arms bent (feet 30 cm above the ground), which was the longest time of the four athletes.

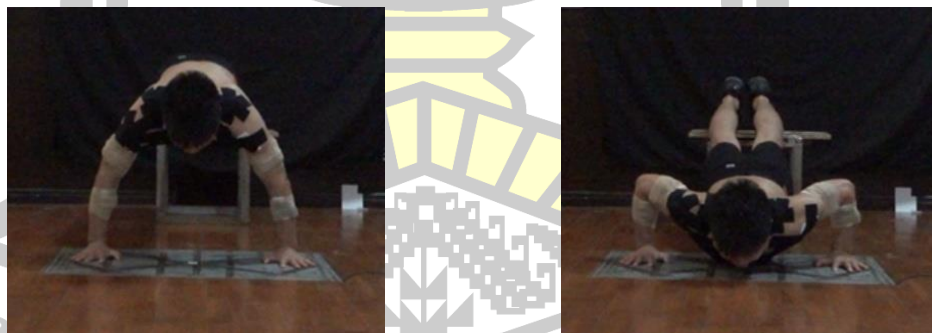


Figure 50 Wide support push-up down flexion phase diagram (40 cm)

In terms of the time, it took for the wide support push-up to hold the arms down (feet 40 cm above the ground) (table 9 and Figure 50), the average time for the high-level athletes to complete the wide support push-up to hold the arms down (feet 40 cm above the ground) was 0.55s, and the standard deviation was 0.02s. The four

athletes who participated in the test took very similar time to complete the wide support push up and bend down the arms (feet 40cm above the ground). Among them, athlete A2 took 0.52s to complete the wide support push up and bend down the arms (feet 40cm above the ground), which was the shortest time among the four athletes. Athlete D took 0.57s to complete the wide support push up and down with his arms bent (feet 40 cm above the ground), which was the longest time among the four athletes.

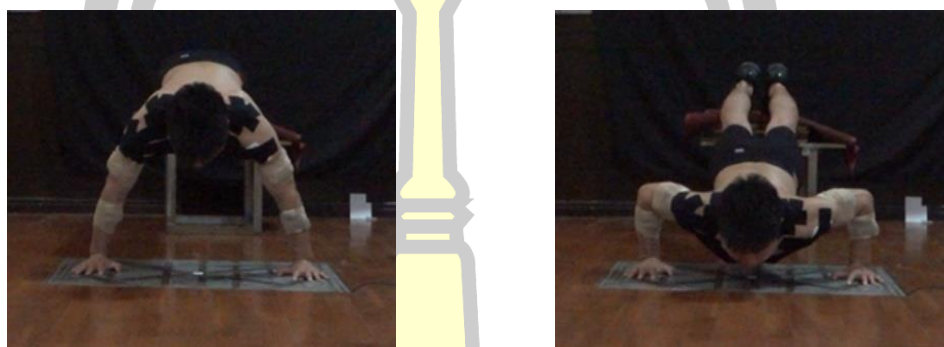


Figure 51 Wide support push-up down flexion phase diagram (50 cm)

In terms of the time, it took for the wide support push up to hold the arms down (feet 50 cm above the ground) (table 9 and Figure 51), the average time for the high-level athletes to complete the wide support push up to hold the arms down (feet 50 cm above the ground) was 0.62s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the wide support push-up down flexion arm (feet 50cm above the ground) is very similar, and the time of athlete D to complete the wide support push-up down flexion arm (feet 50cm above the ground) is 0.60s, which is the shortest among the four athletes. Athlete C took 0.64s to complete the wide support push up and down with his arms bent (feet 50 cm above the ground), which was the longest time among the four athletes.

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(3) The time for standard support of different loads of high-five push-ups to support the bending arm

Table 10 Standard support High-five push-ups Down flexion arms time table (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.48	0.45	0.32	0.46	0.54
A2	0.31	0.37	0.29	0.35	0.48
A3	0.53	0.49	0.5	0.43	0.53
A4	0.41	0.42	0.45	0.37	0.55
$\bar{X} \pm S$	0.43±0.10	0.43±0.05	0.39±0.1	0.4±0.05	0.53±0.03

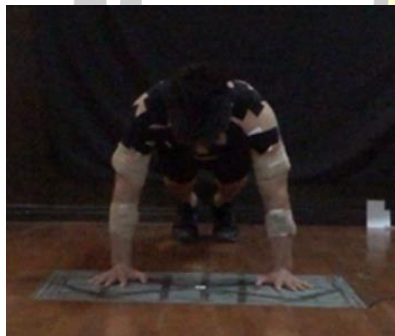


Figure 52 Standard support High-five push-ups Down flexion phase diagram (0 cm)

In terms of the time, it took for the standard supported high-five push-up to bend the arms down (with both feet on the ground) (table 10 and Figure 52), the average time for high-level athletes to complete the standard supported high-five push-up to bend the arms down is 0.43s, and the standard deviation is 0.10s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet on the ground) is very similar, and the time of athlete A2 to complete the standard supported high-five push-up down flexion arms (feet on the ground) is 0.31s, which is the shortest among the four athletes. Athlete C took 0.53s to complete the standard support high-five push-up and bend the arms (feet on the ground), which was the longest time among the 4 athletes.



Figure 53 Standard support High-five push-ups Down flexion phase diagram (25 cm)

From the perspective of the time, it took for the standard supported high-five push-up to bend the arms down (feet 25 cm above the ground) (table 10 and Figure 36), the average time for high-level athletes to complete the standard supported high-five push-up to bend the arms down (feet 25 cm above the ground) was 0.43s, and the standard deviation was 0.05s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet 25cm above the ground) is very similar, and the time of athlete A2 to complete the standard supported high-five push-up down flexion arms (feet 25cm above the ground) is 0.37s, which is the shortest among the four athletes. Athlete C took 0.49s to complete the standard support high-five push-up and bend the arms down (feet 25 cm above the ground), which was the longest time among the four athletes.

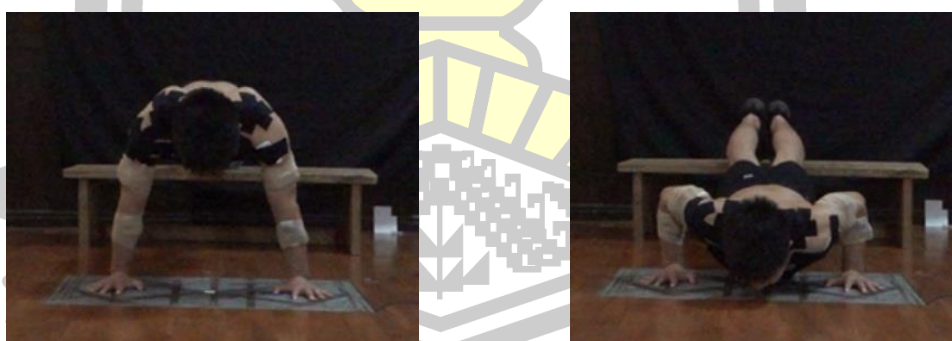


Figure 54 Standard support High-five push-ups Down flexion phase diagram (30 cm)

In terms of the time, it took for the standard supported high-five push-up to bend the arms down (feet 30cm above the ground) (table 10 and Figure 54), the average time for high-level athletes to complete the standard supported high-five push-up to bend the arms down (feet 30cm above the ground) was 0.39s, and the standard

deviation was 0.1s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet 30cm above the ground) is very similar, and the time of athlete A2 to complete the standard supported high-five push-up down flexion arms (feet 30cm above the ground) is 0.29s, which is the shortest among the four athletes. Athlete D took 0.5s to complete the standard support high-five push-up and bend the arms (feet are 30 cm above the ground), which was the longest time of the four athletes.

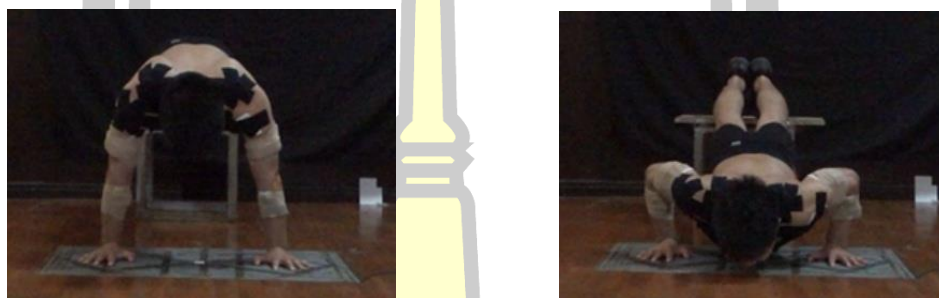


Figure 55 Standard support High-five push-ups Down flexion phase diagram (40 cm)

In terms of the time, it took for the standard supported high-five push-up to bend the arms down (feet 40cm above the ground) (table 10 and Figure 55), the average time for high-level athletes to complete the standard supported high-five push-up to bend the arms down (feet 40cm above the ground) was 0.4s, and the standard deviation was 0.05s. The four athletes who participated in the test took very similar time to complete the standard supported high-five push-up and bend the arms down (feet 40cm higher than the ground). Among them, athlete A2 took 0.35s to complete the standard supported high-five push-up and bend the arms down (feet 40cm higher than the ground), which was the shortest time among the four athletes. Athlete A1 took 0.46s to complete the standard support high-five push-up and bend the arms (feet are 40 cm above the ground), which was the longest time among the four athletes.

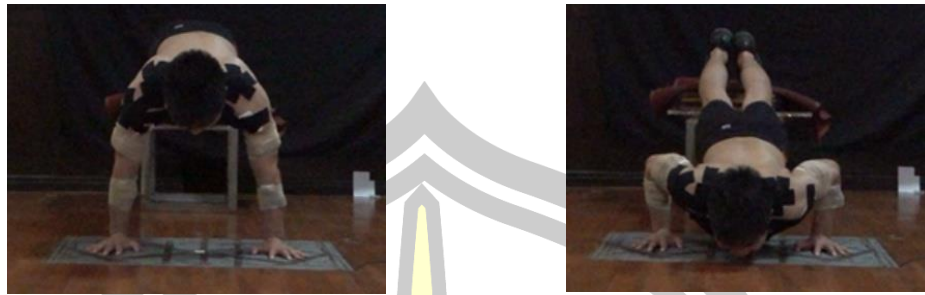


Figure 56 Standard support High-five push-ups Down flexion phase diagram (50 cm)

In terms of the time, it took for the standard supported high-five push-up to bend the arms down (feet 50 cm above the ground) (table 10 and Figure 56), the average time for the high-level athletes to complete the standard supported high-five push-up to bend the arms down (feet 50 cm above the ground) was 0.53s, and the standard deviation was 0.03s. The four athletes who participated in the test took very similar time to complete the standard supported high-five push up and bend down the arms (feet 50cm above the ground). Among them, athlete A2 took 0.48s to complete the standard supported high-five push up and bend down the arms (feet 50cm above the ground), which was the shortest time among the four athletes. Athlete D took 0.55s to complete the standard support high-five push-up and bend the arms (feet 50 cm above the ground), which was the longest time among the four athletes.

(4) The time for wide support of different loads of high-five push-ups to support the bending arm down

Table 11 Wide support High-five push-ups Down flexion arms time table (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.43	0.4	0.42	0.48	0.55
A2	0.43	0.52	0.46	0.68	0.53
A3	0.42	0.42	0.42	0.46	0.54
A4	0.45	0.48	0.48	0.44	0.52
$\bar{X} \pm S$	0.43±0.01	0.46±0.06	0.45±0.03	0.52±0.11	0.54±0.01

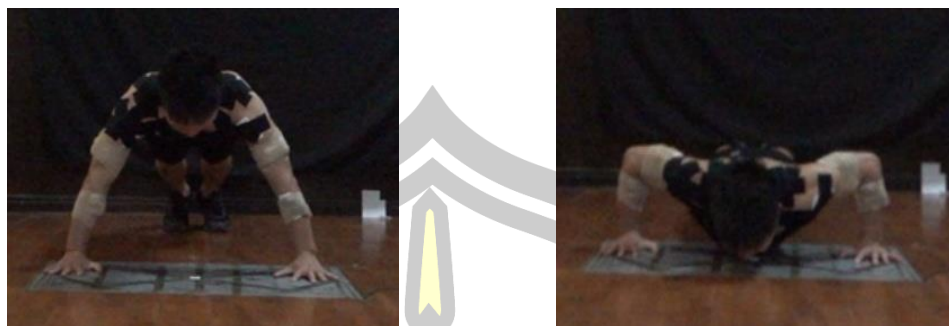


Figure 57 Wide support High five push-ups Down flexion phase diagram (0 cm)

In terms of the time, it took for the wide supported high-five push-up to bend the arms down (with both feet on the ground) (Table 11 and Figure 57), the average time for the high-level athletes to complete the wide supported high-five push-up to bend the arms down is 0.43s, and the standard deviation is 0.01s. The time of the four athletes who participated in the test to complete the wide-supported high-five push-up down flexion arms (feet on the ground) was very similar, and the time of athlete C to complete the wide-supported high-five push-up down flexion arms (feet on the ground) was 0.42s, which was the shortest among the four athletes. It took athlete D 0.45s to complete the broad support high-five push-up and bend the arms (feet on the ground), which was the longest time among the four athletes.

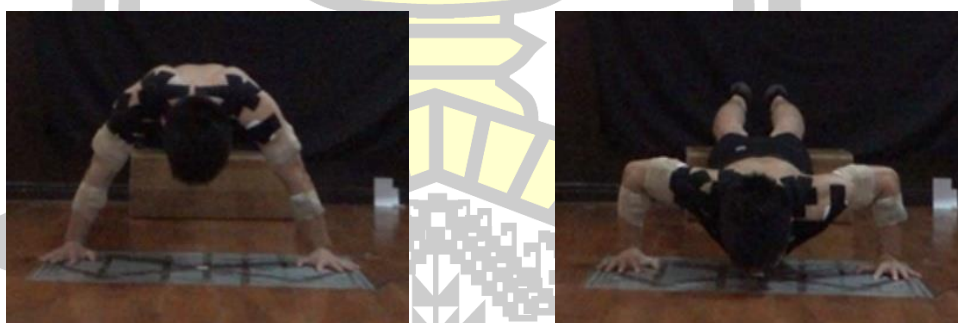


Figure 58 Wide support High five push-ups Down flexion phase diagram (25 cm)

In terms of the time, it took for the wide supported push-up to bend the arms down (feet 25 cm above the ground) (table 11 and Figure 58), the average time for the high-level athletes to complete the wide supported push-up to bend the arms down (feet 25 cm above the ground) was 0.46s, and the standard deviation was 0.06s. The time of the four athletes participating in the test to complete the wide-supported

high-five push-up down flexion arms (feet 25cm above the ground) is very similar, and the time of athlete A1 to complete the wide-supported high-five push-up down flexion arms (feet 25cm above the ground) is 0.4s, which is the shortest among the four athletes. Athlete A2 took 0.52 seconds to complete the broad support high-five push up and down with his arms bent (feet 25 cm above the ground), which was the longest time among the four athletes.



Figure 59 Wide support High five push-ups Down flexion phase diagram (30 cm)

In terms of the time, it took for the wide supported push-up to bend the arms down (feet 30 cm above the ground) (table 11 and Figure 59), the average time for the high-level athletes to complete the wide supported push-up to bend the arms down (feet 30 cm above the ground) was 0.45s, and the standard deviation was 0.03s. The time of the four athletes participating in the test to complete the wide supported high-five push-up down flexion arms (feet 30cm above the ground) is very similar, and the time of athletes A1 and C to complete the wide supported high-five push-up down flexion arms (feet 30cm above the ground) is 0.42s, which is the shortest among the four athletes. Athlete D took 0.48s to complete the broad support high-five push up and bend the arms (feet are 30 cm above the ground), which was the longest time among the four athletes.

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Figure 60 Wide support High five push-ups Down flexion phase diagram (40 cm)

In terms of the time, it took for the wide supported push-up to bend the arms down (feet 40 cm above the ground) (table 11 and Figure 60), the average time for the high-level athletes to complete the wide supported push-up to bend the arms down (feet 40 cm above the ground) was 0.52s, and the standard deviation was 0.11s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 40cm higher than the ground) is very similar, and the time of athlete D to complete the wide-supported high-five push-up down flexion arms (feet 40cm higher than the ground) is 0.44s, which is the shortest among the four athletes. Athlete A2 took 0.68s to complete the broad support high-five push up and bend the arms (feet are 40 cm above the ground), which was the longest time among the four athletes.

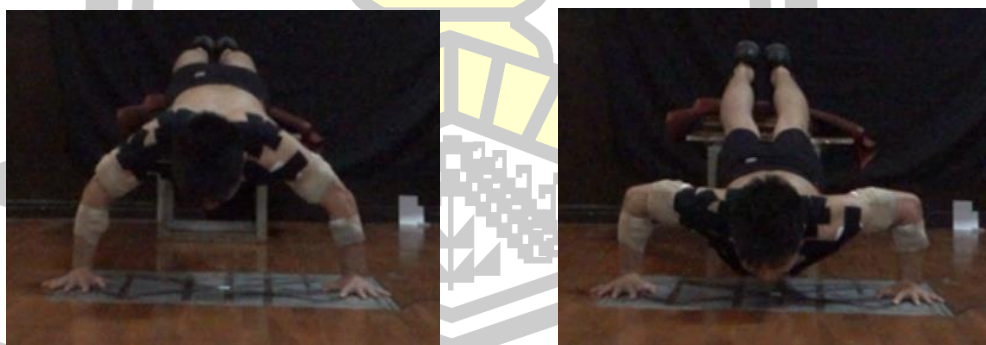


Figure 61 Wide support High five push-ups Down flexion phase diagram (50 cm)

In terms of the time, it took for the wide supported push-up to bend the arms down (feet 50 cm above the ground) (table 11 and Figure 61), the average time for the high-level athletes to complete the wide supported push-up to bend the arms down (feet 50 cm above the ground) was 0.54s, and the standard deviation was 0.01s.

The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 50cm above the ground) is very similar, and the time of athlete D to complete the wide-supported high-five push-up down flexion arms (feet 50cm above the ground) is 0.52s, which is the shortest among the four athletes. Athlete A1 took 0.55s to complete the broad support high-five push-up and bend the arms down (feet 50 cm above the ground), which was the longest time among the four athletes.

2.1.1.3 Time Characteristics of the up-push phase

(1) The time used to push up push-ups with different loads of standard support

Table 12 Statistical table when standard support push-ups are completed (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.5	0.48	0.51	0.61	0.61
A2	0.5	0.5	0.49	0.64	0.68
A3	0.52	0.53	0.48	0.63	0.66
A4	0.51	0.51	0.52	0.62	0.68
$\bar{X} \pm S$	0.51±0.01	0.51±0.02	0.5±0.02	0.63±0.01	0.66±0.03



Figure 62 Standard support push-up up stage movement diagram (0 cm)

In terms of the time taken to push up (with both feet on the ground) with standard support push-ups (table 12 and Figure 62), the average time and standard deviation for high-level athletes to complete the push-up with standard support push-ups is 0.51s, and the standard deviation is 0.01s. The time of the four athletes

participating in the test to complete the standard support push up (feet on the ground) is very close, and the time of athletes A1 and A2 to complete the standard support push up (feet on the ground) is 0.5s, which is the shortest among the four athletes. Athlete C took 0.52 seconds to complete the standard support push up (feet on the ground), which was the longest time among the four athletes.

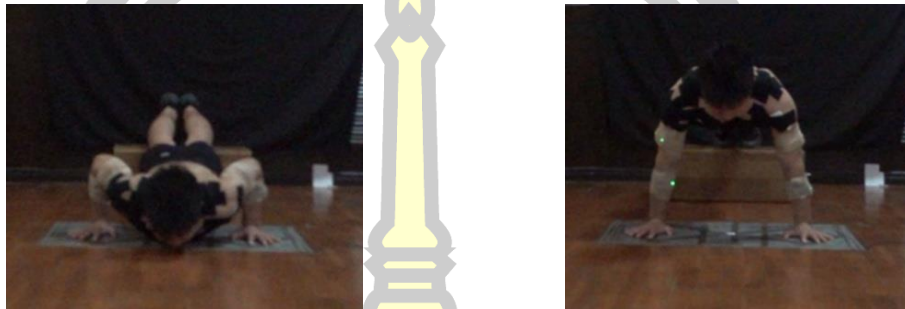


Figure 63 Standard support push-up up stage movement diagram (25cm)

In terms of the time taken to push up from the standard support push-up (with feet 25 cm above the ground) (table 12 and Figure 63), the average time for the advanced athletes to complete the standard support push-up (with feet 25 cm above the ground) was 0.51s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the standard support push up (feet 25cm above the ground) is very similar, and the time of athlete A1 to complete the standard support push up (feet 25cm above the ground) is 0.48s, which is the shortest among the four athletes. Athlete C took 0.53s to complete the standard support push up (feet 25 cm above the ground) movement, which was the longest time of the four athletes.



Figure 64 Standard support push-up up stage movement diagram (30 cm)

In terms of the time taken to push up with standard support push-up (feet 30 cm above the ground) (table 12 and Figure 64), the average time taken by high-level athletes to push up with standard support push-up (feet 30 cm above the ground) is 0.5s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support push up (feet 30cm higher than the ground) is very similar, and the time of athlete C to complete the standard support push up (feet 30cm higher than the ground) is 0.48s, which is the shortest among the four athletes. Athlete D took 0.52 seconds to complete the standard support push up (feet 30 cm above the ground), which was the longest time of the four athletes.



Figure 65 Standard support push-up up stage movement diagram (40 cm)

In terms of the time taken to push up with standard support push-up (with feet 40 cm above the ground) (table 12 and Figure 65), the average time taken by high-level athletes to push up with standard support push-up (with feet 40 cm above the ground) is 0.63s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support push up (feet 40cm higher than the ground) is very similar, and the time of athlete A1 to complete the standard support push up (feet 40cm higher than the ground) is 0.61s, which is the shortest among the four athletes. Athlete A2 took 0.64s to complete the standard support push up (feet 40 cm above the ground), which was the longest time of the four athletes.



Figure 66 Standard support push-up up stage movement diagram (50 cm)

In terms of the time taken to push up with standard support push-up (feet 50 cm above the ground) (table 12 and Figure 66), the average time taken by high-level athletes to push up with standard support push-up (feet 50 cm above the ground) is 0.66s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support push up (feet 50cm above the ground) is very similar, and the time of athlete A1 to complete the standard support push up (feet 50cm above the ground) is 0.61s, which is the shortest among the four athletes. Athletes A2 and D took 0.68s to complete the standard support push up (feet 50 cm above the ground), which was the longest time of the four athletes.

(2) The time when the wide support push-ups with different loads are pushed up

Table 13 Statistical table for Wide support push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.51	0.51	0.49	0.55	0.67
A2	0.53	0.5	0.48	0.54	0.64
A3	0.48	0.52	0.48	0.56	0.66
A4	0.47	0.51	0.52	0.54	0.72
$\bar{X} \pm S$	0.50±0.03	0.51±0.01	0.49±0.02	0.55±0.01	0.67±0.03

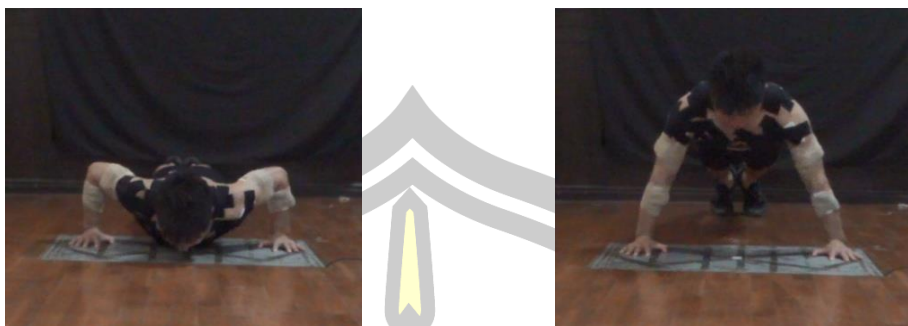


Figure 67 Movement diagram of wide support push up stage (0 cm)

In terms of the time taken to push up with wide support push-ups (both feet on the ground) (table 13 and Figure 67), the average time taken by high-level athletes to complete the push up with wide support push-ups is 0.50s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support push up (feet on the ground) is very close, and the time of athlete D to complete the wide support push up (feet on the ground) is 0.47s, which is the shortest among the four athletes. Athlete A2 took 0.53s to complete the wide support push up movement (feet on the ground), which was the longest time among the four athletes.

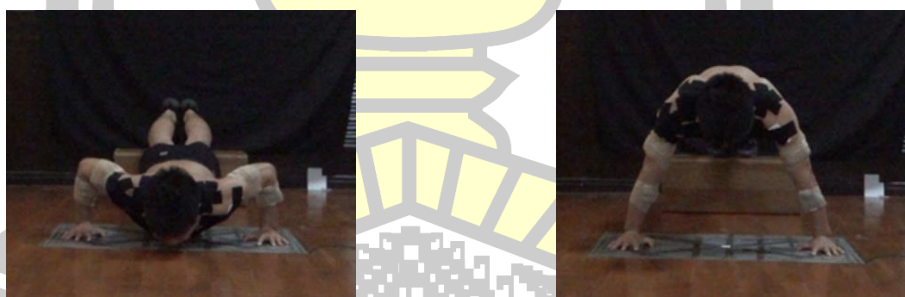


Figure 68 Movement diagram of wide support push up stage (25 cm)

In terms of the time taken to push up with wide support push-ups (feet 25 cm above the ground) (table 13 and Figure 68), the average time taken by high-level athletes to complete the push up with wide support push-ups (feet 25 cm above the ground) is 0.51s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the wide support push up (feet 25cm above the ground) is very similar, and the time of athlete A2 to complete the wide support push

up (feet 25cm above the ground) is 0.5s, which is the shortest among the four athletes. Athlete C took 0.52 seconds to complete the wide support push up (feet 25 cm above the ground), which was the longest time of the four athletes.

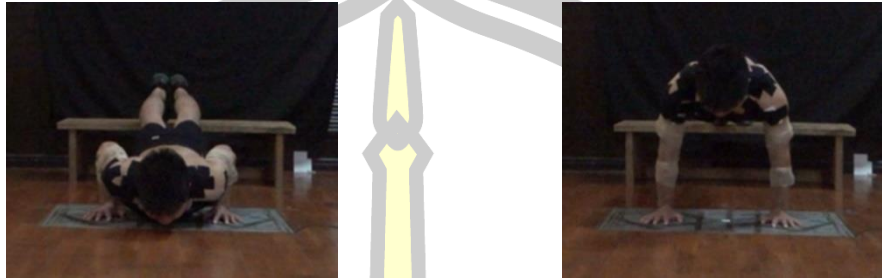


Figure 69 Movement diagram of wide support push up stage (30 cm)

In terms of the time taken to push up with wide support push-ups (feet 30 cm above the ground) (table 13 and Figure 69), the average time taken by high-level athletes to complete the push up with wide support push-ups (feet 30 cm above the ground) is 0.49s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the wide support push up (feet 30cm higher than the ground) is very similar, and the time of athletes A2 and C to complete the wide support push up (feet 30cm higher than the ground) is 0.48s, which is the shortest among the four athletes. Athlete D took 0.52 seconds to complete the wide support push up movement (feet are 30 cm above the ground), which was the longest time among the four athletes.



Figure 70 Movement diagram of wide support push up stage (40 cm)

In terms of the time taken to push up with wide support push-ups (feet 40 cm above the ground) (table 13 and Figure 70), the average time taken by high-level athletes to complete the push up with wide support push-ups (feet 40 cm above the

ground) is 0.55s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the wide support push up (feet 40cm higher than the ground) is very similar, and the time of athletes A2 and D to complete the wide support push up (feet 40cm higher than the ground) is 0.54s, which is the shortest among the four athletes. Athlete C took 0.56s to complete the wide support push up (feet 40 cm above the ground) movement, which was the longest time among the four athletes.

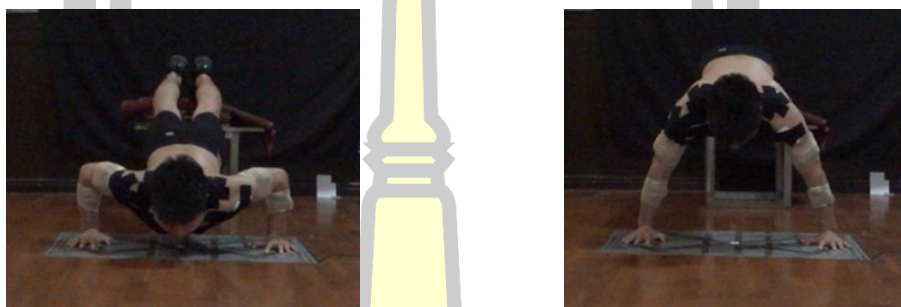


Figure 71 Movement diagram of wide support push up stage (50 cm)

In terms of the time taken to push up with wide support push-ups (feet 50 cm above the ground) (table 13 and Figure 54), the average time taken by high-level athletes to complete the push up with wide support push-ups (feet 50 cm above the ground) is 0.67s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support push up (feet 50cm above the ground) is very similar, and the time of athlete A2 to complete the wide support push up (feet 50cm above the ground) is 0.64s, which is the shortest among the four athletes. Athlete D took 0.72s to complete the broad support push up (feet 50 cm above the ground) movement, which was the longest time among the four athletes.

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(3) Standard support for different loads of high-five push-ups pushed up

Table 14 Complete standard support High-five push-ups when pushing up (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.43	0.42	0.5	0.46	0.44
A2	0.45	0.41	0.45	0.55	0.56
A3	0.42	0.37	0.4	0.45	0.42
A4	0.47	0.43	0.38	0.39	0.47
$\bar{X} \pm S$	0.44±0.02	0.41±0.03	0.43±0.05	0.46±0.07	0.47±0.06

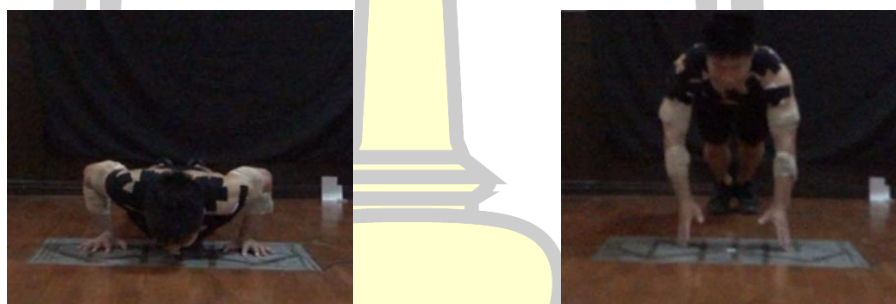


Figure 72 Standard support high-five push up phase movement diagram (0 cm)

In terms of the time taken to push up (with both feet on the ground) with standard support high-five push-ups (table 14 and Figure 72), the average time and standard deviation for high-level athletes to complete the push-up with standard support high-five push-ups is 0.44s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet on the ground) is very close, and the time of athlete C to complete the standard support high-five push up (feet on the ground) is 0.42s, which is the shortest among the four athletes. Athlete D took 0.47s to complete the standard support high-five push up movement (feet on the ground), which was the longest time among the four athletes.

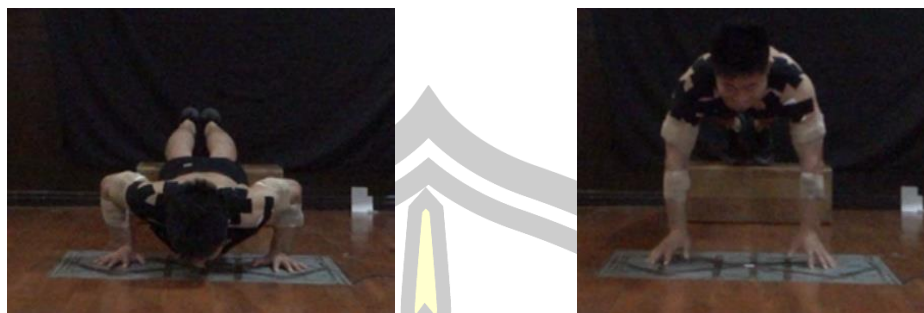


Figure 73 Standard support high-five push up phase movement diagram (25cm)

In terms of the time it took to push up (feet 25 cm above the ground) in the standard supported high-five push up (feet 25 cm above the ground) (table 14 and Figure 73), the average time for high-level athletes to push up (feet 25 cm above the ground) in the standard supported high-five push up (feet 25 cm above the ground) was 0.41s, and the standard deviation was 0.03s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 25cm above the ground) is very similar, and the time of athlete C to complete the standard support high-five push up (feet 25cm above the ground) is 0.37s, which is the shortest among the four athletes. Athlete D took 0.43s to complete the standard support high-five push up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

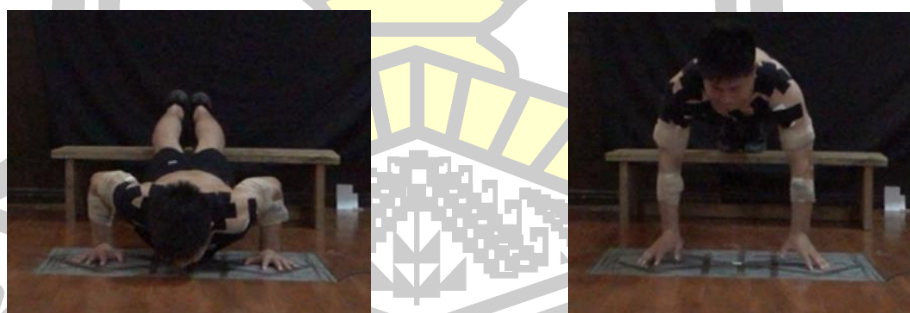


Figure 74 Standard support high-five push up phase movement diagram (30 cm)

According to the time taken to push up (feet 30 cm above the ground) in the standard supported high-five push up (feet 30 cm above the ground) (table 14 and Figure 74), the average time taken by high-level athletes to push up (feet 30 cm above the ground) in the standard supported high-five push up is 0.43s, and the standard

deviation is 0.05s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 30cm higher than the ground) is very similar, and the time of athlete D to complete the standard support high-five push up (feet 30cm higher than the ground) is 0.38s, which is the shortest among the four athletes. Athlete A1 took 0.5s to complete the standard support high-five push up (feet 30 cm above the ground) movement, which was the longest time of the four athletes.

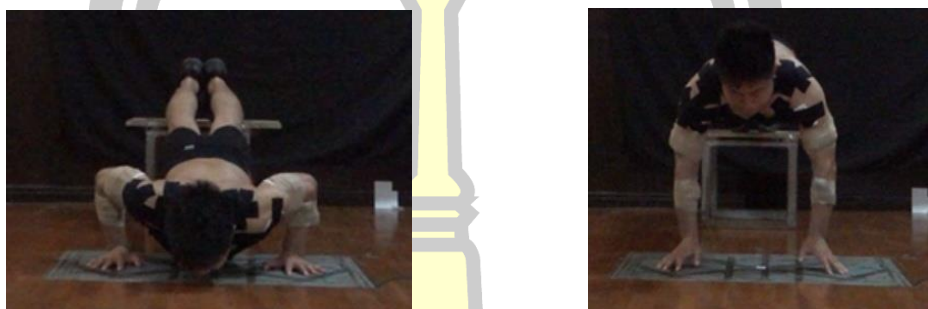


Figure 75 Standard support high-five push up phase movement diagram (40 cm)

In terms of the time taken to push up (feet 40 cm above the ground) in the standard supported high-five push up (feet 40 cm above the ground) (table 14 and Figure 75), the average time taken by high-level athletes to push up (feet 40 cm above the ground) in the standard supported high-five push up (feet 40 cm above the ground) is 0.46s, and the standard deviation is 0.07s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 40cm higher than the ground) is very similar, and the time of athlete D to complete the standard support high-five push up (feet 40cm higher than the ground) is 0.39s, which is the shortest among the four athletes. Athlete A2 took 0.55s to complete the standard support high-five push up (feet 40 cm above the ground) movement, which was the longest time among the four athletes.



Figure 76 Standard support high-five push up phase movement diagram (50 cm)

Judging from the time taken to push up (feet 50 cm above the ground) in the standard supported high-five push up (feet 50 cm above the ground) (table 14 and Figure 76), the average time taken by high-level athletes to complete the standard supported high-five push up (feet 50 cm above the ground) is 0.47s, and the standard deviation is 0.06s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 50cm above the ground) is very similar, and the time of athlete C to complete the standard support high-five push up (feet 50cm above the ground) is 0.42s, which is the shortest among the four athletes. Athlete A2 took 0.56s to complete the standard support high-five push up movement (feet 50 cm above the ground), which was the longest time among the four athletes.

(4) Wide support for different loads of high-five push-ups pushed up

Table 15 Statistical table when complete Wide Support high-five push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.46	0.52	0.43	0.5	0.51
A2	0.56	0.43	0.5	0.52	0.51
A3	0.45	0.39	0.45	0.48	0.52
A4	0.42	0.46	0.41	0.42	0.49
$\bar{X} \pm S$	0.47 $\pm$ 0.06	0.45 $\pm$ 0.5	0.45 $\pm$ 0.04	0.48 $\pm$ 0.04	0.51 $\pm$ 0.01

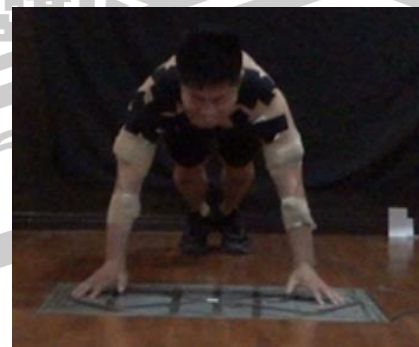


Figure 77 Broad support high-five push up phase movement diagram (0 cm)

In terms of the time it takes to push up with both feet on the ground (table 15 and Figure 77), the average time and standard deviation of the high level athletes to complete the push up with wide support is 0.47s, and the standard deviation is 0.06s. The time of the four athletes who participated in the test to complete the wide support high-five push up (feet on the ground) is very close, and the time of athlete D to complete the wide support high-five push up (feet on the ground) is 0.42s, which is the shortest among the four athletes. Athlete A2 took 0.56s to complete the broad support high-five push up (feet on the ground) movement, which was the longest time among the four athletes.

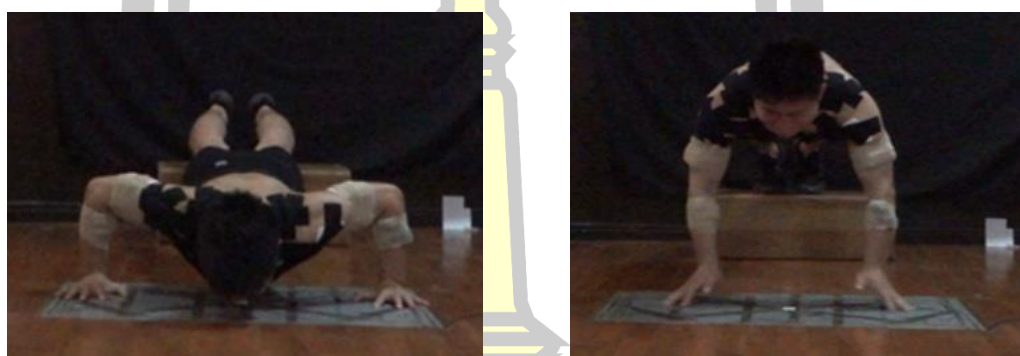


Figure 78 Broad support high-five push up phase movement diagram (25cm)

In terms of the time, it took to push up with wide support high-five push-ups (feet 25 cm above the ground) (table 15 and Figure 78), the average time and standard deviation of high-level athletes to push up with wide support high-five push-ups (feet 25 cm above the ground) was 0.45s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 25cm above the ground) is very similar, and the time of athlete C to complete the wide support high-five push up (feet 25cm above the ground) is 0.39s, which is the shortest among the four athletes. Athlete A1 took 0.52 seconds to complete the broad support high-five push up (feet 25 cm above the ground), which was the longest time among the four athletes.

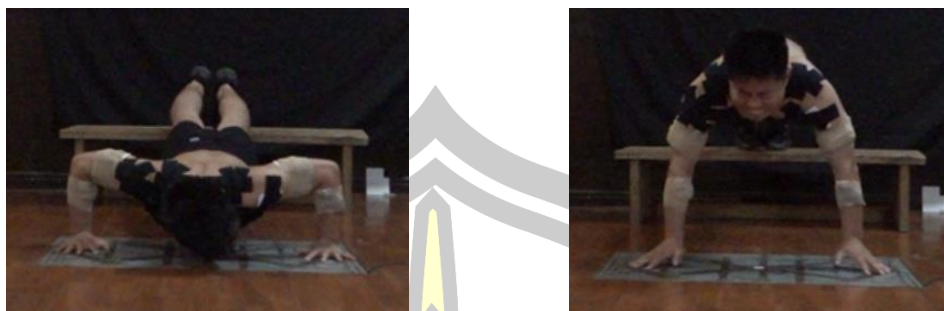


Figure 79 Broad support high-five push up phase movement diagram (30 cm)

In terms of the time taken to push up (feet 30 cm above the ground) with wide support push-ups (table 15 and Figure 79), the average time taken by high-level athletes to complete the push up (feet 30 cm above the ground) with wide support push-ups is 0.45s, and the standard deviation is 0.04s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 30cm higher than the ground) is very similar, and the time of athlete D to complete the wide support high-five push up (feet 30cm higher than the ground) is 0.41s, which is the shortest among the four athletes. Athlete A2 took 0.5s to complete the broad support high-five push up (feet 30 cm above the ground) movement, which was the longest time of the four athletes.

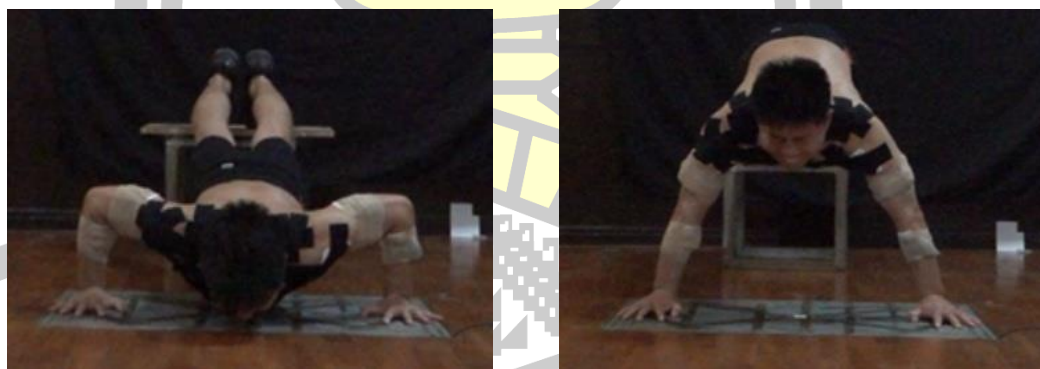


Figure 80 Broad support high-five push up phase movement diagram (40 cm)

In terms of the time, it took to push up with wide support high-five push-ups (feet 40 cm above the ground) (table 15 and Figure 80), the average time for high-level athletes to push up with wide support high-five push-ups (feet 40 cm above the ground) was 0.48s, and the standard deviation was 0.04s. The time of the four athletes

participating in the test to complete the wide support high-five push up (feet 40cm higher than the ground) is very similar, and the time of athlete D to complete the wide support high-five push up (feet 40cm higher than the ground) is 0.42s, which is the shortest among the four athletes. Athlete A2 took 0.52 seconds to complete the broad support high-five push up (feet 40 cm above the ground), which was the longest time among the four athletes.

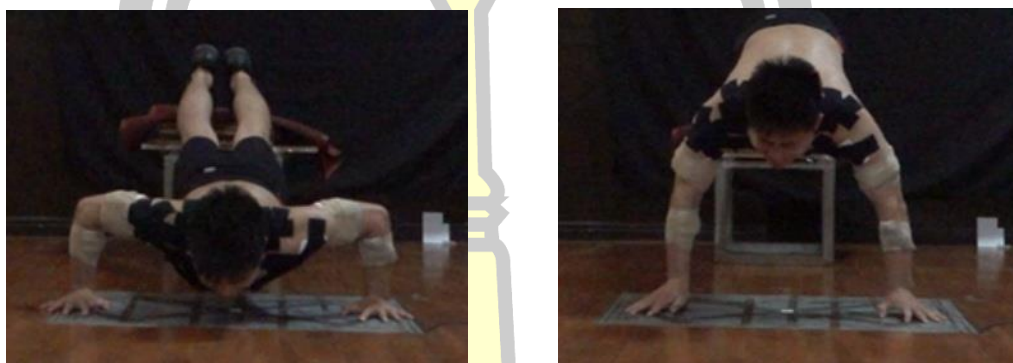


Figure 81 Broad support high-five push up phase movement diagram (50 cm)

In terms of the time taken to push up (feet 50 cm above the ground) with wide support push-ups (table 15 and Figure 81), the average time taken by high-level athletes to push up (feet 50 cm above the ground) with wide support push-ups was 0.51s, and the standard deviation was 0.01s. The four athletes who participated in the test took very similar time to complete the wide support high-five push up (feet 50cm above the ground), and the time for athlete D to complete the wide support high-five push up (feet 50cm above the ground) was 0.49s, which was the shortest among the four athletes. Athlete C took 0.52 seconds to complete the broad support high-five push up (feet 50 cm above the ground) movement, which was the longest time of the four athletes.

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2.1.1.4 Time characteristics of high-five push-ups in the air phase

(1) Standard support for different loads of high-five push-ups in the air stage

Table 16 Complete standard support high-five push-up time statistics table (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.4	0.31	0.32	0.25	0.34
A2	0.39	0.36	0.32	0.34	0.31
A3	0.45	0.38	0.35	0.36	0.36
A4	0.41	0.42	0.3	0.32	0.33
$\bar{X} \pm S$	0.41±0.03	0.37±0.05	0.32±0.02	0.32±0.05	0.34±0.02

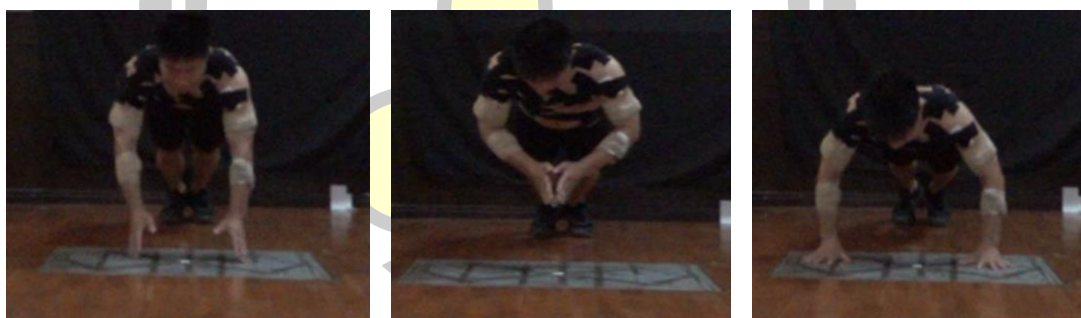


Figure 82 Schematic diagram of high-five push-ups with standard support (0cm)

According to the time taken to complete the air lift (with both feet on the ground) of the standard supported high-five push-up (table 16 and Figure 82), the average time taken by high-level athletes to complete the air lift of the standard supported high-five push-up is 0.41s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet on the ground) is very close, and the time of athlete A2 to complete the standard support high-five push-up movement (feet on the ground) is 0.39s, which is the shortest among the four athletes. Athlete C took 0.45s to complete

the standard support high-five push-up movement (feet on the ground), which was the longest time among the four athletes.



Figure 83 Schematic diagram of high-five push-ups with standard support (25cm)

According to the time taken to complete the air lift of the standard supported high-five push-up (both feet are 25 cm higher than the ground) (table 16 and Figure 83), the average time taken by high-level athletes to complete the air lift of the standard supported high-five push-up is 0.37s, and the standard deviation is 0.05s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 25cm above the ground) is very similar, and the time of athlete A1 to complete the standard support high-five push-up movement (feet 25cm above the ground) is 0.31s, which is the shortest among the four athletes. Athlete D took 0.42s to complete the standard support high-five push-up (feet 25 cm above the ground), which was the longest time among the four athletes.

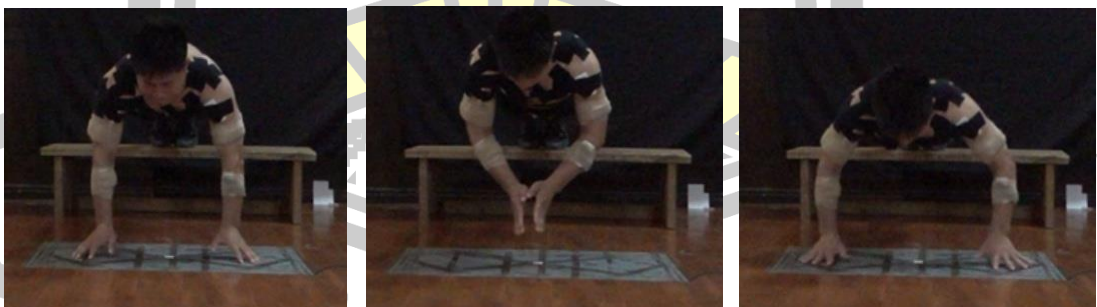


Figure 84 Schematic diagram of high-five push-ups with standard support (30cm)

According to the time taken to complete the air lift of the standard supported high-five push-up (feet 30 cm above the ground) (table 16 and Figure 84), the average time and standard deviation of the high-level athletes to complete the air

lift of the standard supported high-five push-up is 0.32s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 30cm higher than the ground) is very similar, and the time of athlete D to complete the standard support high-five push-up movement (feet 30cm higher than the ground) is 0.3s, which is the shortest among the four athletes. Athlete C took 0.35s to complete the standard support high-five push-up movement (feet 30 cm above the ground), which was the longest time among the four athletes.

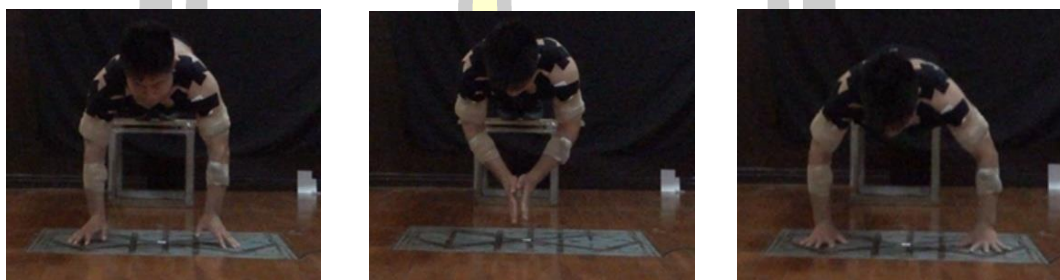


Figure 85 Schematic diagram of high-five push-ups with standard support (40cm)

According to the time taken to complete the air lift of the standard supported high-five push-up (both feet are 40 cm higher than the ground) (table 16 and Figure 85), the average time taken by high-level athletes to complete the air lift of the standard supported high-five push-up is 0.32s, and the standard deviation is 0.05s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 40cm higher than the ground) was very similar, and the time of athlete A1 to complete the standard support high-five push-up movement (feet 40cm higher than the ground) was 0.25s, which was the shortest among the four athletes. Athlete C took 0.36s to complete the standard support high-five push-up movement (feet 25 cm above the ground), which was the longest time among the four athletes.

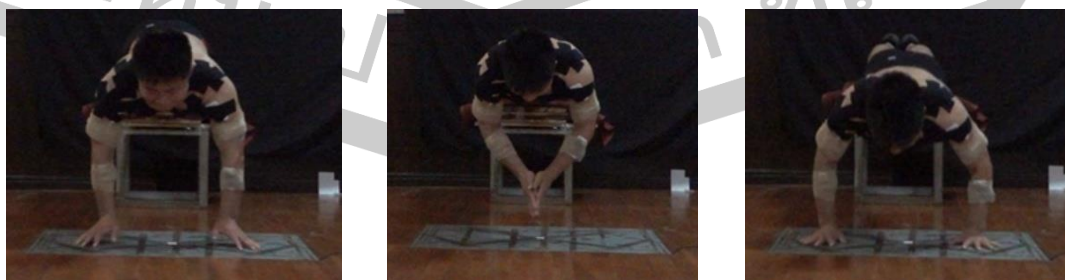


Figure 86 Schematic diagram of high-five push-ups with standard support (50cm)

In terms of the time, it takes to push up (feet 50 cm above the ground) from the standard supported push-up (table 16 and Figure 86), the average time and standard deviation of high-level athletes in the air to complete the standard supported push-up is 0.34s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 50cm above the ground) is very similar, and the time of athlete A2 to complete the standard support high-five push-up movement (feet 50cm above the ground) is 0.31s, which is the shortest among the four athletes. Athlete C took 0.36s to complete the standard support high-five push-up movement (feet 50 cm above the ground), which was the longest time among the four athletes.

(2) The use of wide support for different loads of high-five push-ups in the air stage

Table 17 Complete wide support high-five push-up time statistics table (s)

measure	0cm	25cm	30cm	40cm	50cm
A1	0.31	0.37	0.38	0.3	0.33
A2	0.36	0.35	0.32	0.26	0.32
A3	0.38	0.39	0.32	0.26	0.32
A4	0.42	0.34	0.34	0.32	0.35
$\bar{X} \pm S$	0.37±0.05	0.36±0.2	0.34±0.03	0.29±0.03	0.33±0.01



Figure 87 Schematic diagram of high-fiving push-ups with wide support (0cm)

In terms of the time taken to complete the wide supported push-up with both feet on the ground (table 17 and Figure 87), the average time taken by high-level athletes to complete the wide supported push-up with a standard deviation of 0.37s was 0.05s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet on the ground) was very similar, and the time of athlete A1 to complete the wide-supported high-five push-up movement (feet on the ground) was 0.31s, which was the shortest among the four athletes. Athlete D took 0.42s to complete the wide support high-five push-up (feet on the ground), which was the longest time among the four athletes.

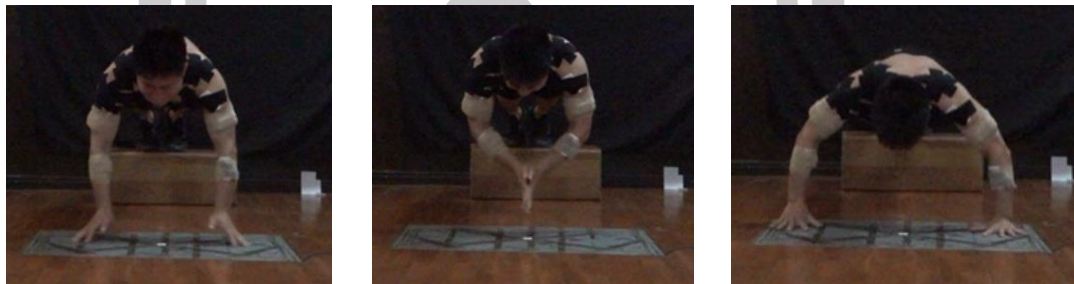


Figure 88 Schematic diagram of high-five push-ups with wide support (25cm)

In terms of the time, it takes to complete a wide-supported push-up (feet 25 cm above the ground) (table 17 and Figure 88), the average time for high-level athletes to complete a wide-supported push-up is 0.36s, and the standard deviation is 0.2s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 25cm higher than the ground) is very similar, and the time of athlete D to complete the wide-supported high-five push-up movement (feet 25cm higher than the ground) is 0.34s, which is the shortest among the four athletes. Athlete C took 0.39s to complete the wide support high-five push-up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

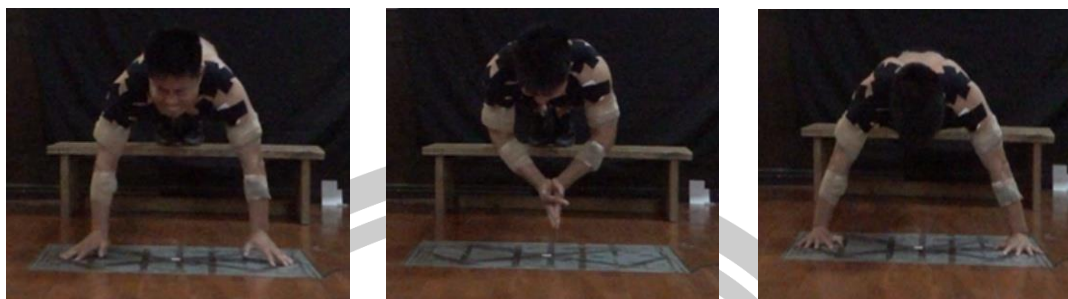


Figure 89 Schematic diagram of high-five push-ups with wide support (30cm)

In terms of the time, it takes to complete a wide-supported push-up (feet 30 cm above the ground) (table 17 and Figure 89), the average time for high-level athletes to complete a wide-supported push-up is 0.34s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 30cm higher than the ground) is very similar, and the time of athletes A2 and C to complete the wide-supported high-five push-up movement (feet 30cm higher than the ground) is 0.32s, which is the shortest among the four athletes. Athlete A1 took 0.38s to complete the wide support high-five push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

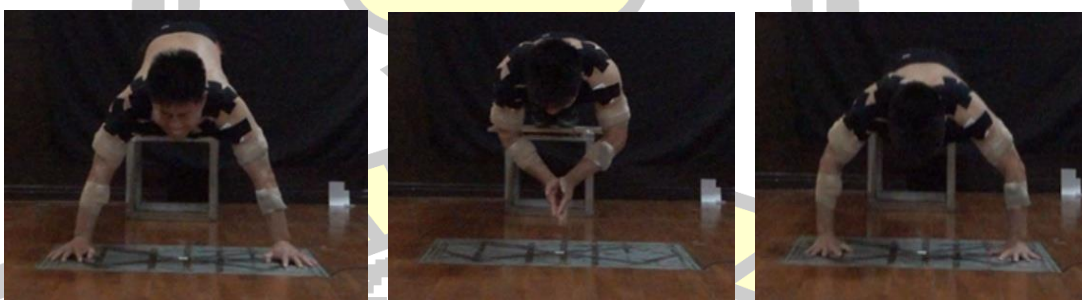


Figure 90 Schematic diagram of high-fiving push-ups with wide support (40cm)

In terms of the time, it takes to complete a wide-supported push-up (feet 40 cm above the ground) (table 17 and Figure 90), the average time for high-level athletes to complete a wide-supported push-up is 0.29s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 40cm higher than the ground) is very similar, and the time of athletes A2 and C to complete the wide-supported high-five

push-up movement (feet 40cm higher than the ground) is 0.26s, which is the shortest among the four athletes. Athlete D took 0.32s to complete the wide support high-five push-up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

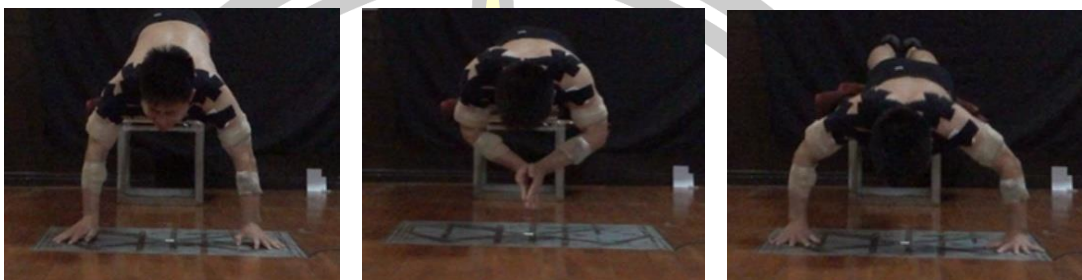


Figure 91 Schematic diagram of high-five push-ups with wide support (50cm)

In terms of the time taken to push up from the wide-supported push-up (feet 50 cm above the ground) (table 17 and Figure 91), the average time for the high-level athletes to complete the wide-supported push-up is 0.33s, and the standard deviation is 0.01s. The four athletes who participated in the test took very similar time to complete the wide-supported high-five push-up movement (feet 50cm above the ground), in which athletes A2 and C took 0.32s to complete the wide-supported high-five push-up movement (feet 50cm above the ground), which was the shortest time among the four athletes. Athlete D took 0.35s to complete the wide support high-five push-up (feet 50 cm above the ground) movement, which was the longest time among the four athletes.



2.1.2 Speed characteristics

2.1.2.1 Peak velocity characteristics of shoulder joint in the stage of downward flexion

Table 18 Peak shoulder joint speed in standard support push-up down flexion (m/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.894	0.706	0.721	0.874	0.799±0.099
	Right shoulder joint	0.797	0.663	0.688	0.757	0.726±0.062
25cm	Left shoulder joint	0.906	0.898	0.933	0.846	0.896±0.036
	Right shoulder joint	0.992	0.842	0.887	0.912	0.908±0.091
30cm	Left shoulder joint	0.970	1.016	1.071	0.870	0.982±0.085
	Right shoulder joint	0.959	0.891	0.956	0.879	0.921±0.042
40cm	Left shoulder joint	0.889	0.951	1.006	0.829	0.919±0.076
	Right shoulder joint	0.913	0.955	1.000	0.873	0.935±0.055
50cm	Left shoulder joint	0.917	1.235	1.270	0.897	1.080±0.200
	Right shoulder joint	1.059	1.222	1.247	1.049	1.144±0.105

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (0cm) and the stage of downward flexion (Table 18), the average speed and standard deviation of the left shoulder joint of high-level athletes in the stage of downward flexion with standard support push-up are 0.799m/s and 0.099m/s respectively. The mean velocity of the right shoulder joint was 0.726m/s, and the standard deviation was 0.062m/s. High-level athletes in the standard support push-up (feet height of 0 cm) in the stage of bending the arms of the downward flexion stage of the characteristics of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (25cm) and the stage of downward flexural arms flexural (Table 18), the average speed and standard deviation of the left shoulder

joint of high-level athletes in the stage of downward flexural arms flexural with standard support push-up are 0.896m/s and 0.036m/s. The mean velocity of the right shoulder joint was 0.908m/s, and the standard deviation was 0.091m/s. High-level athletes in the standard support push-up (feet height of 25 cm) down flexion phase of the characteristics of the characteristics of the left shoulder joint and the right shoulder joint speed there is a certain difference, the right shoulder joint speed is greater than the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (30cm) and the stage of downward flexion (Table 18), the average speed and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with standard support push-up are 0.982m/s and 0.085m/s. The mean velocity of the right shoulder joint was 0.921m/s, and the standard deviation was 0.042m/s. High-level athletes in the standard support push-ups (feet height of 30 cm) in the stage of downward flexion of the arms are characterized by a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of push-ups with standard support with feet on the ground (40cm) and the stage of bending arms with downward flexure (Table 18), the average speed and standard deviation of the left shoulder joint of high-level athletes in the stage of bending arms with downward flexure with standard support push-ups are 0.919m/s and 0.076m/s. The mean velocity of the right shoulder joint was 0.935m/s, and the standard deviation was 0.055m/s. High-level athletes in the standard support push-ups (feet height of 40 cm) in the stage of downward flexion of the arms are characterized by a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (50cm) and the stage of downward flexion (Table 18), the average speed and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with standard support push-up are 1.080m/s

and 0.200m/s, respectively. The mean velocity of the right shoulder joint was 1.144m/s, and the standard deviation was 0.105m/s. High-level athletes in the standard support push-ups (feet height of 50 cm) in the stage of downward flexion of the arms are characterized by a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

Table 19 The peak angular velocity of shoulder joint of high-level athletes in broad support push-up down flexion stage (m/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.954	0.826	0.939	0.815	0.883±0.073
	Right shoulder joint	1.023	0.816	1.008	0.805	0.913±0.118
25cm	Left shoulder joint	1.184	1.125	1.169	1.114	1.148±0.034
	Right shoulder joint	1.167	1.111	1.152	1.100	1.133±0.032
30cm	Left shoulder joint	1.071	1.170	1.056	1.159	1.114±0.059
	Right shoulder joint	1.107	1.192	1.092	1.181	1.143±0.051
40cm	Left shoulder joint	1.228	1.508	1.213	1.497	1.361±0.163
	Right shoulder joint	1.171	1.298	1.156	1.287	1.228±0.075
50cm	Left shoulder joint	1.159	1.200	1.144	1.189	1.173±0.026
	Right shoulder joint	1.123	1.178	1.108	1.167	1.144±0.034

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward flexion (Table 19), the average speed and standard deviation of the left shoulder joint of high-level athletes are 0.883m/s and 0.073m/s in the stage of downward flexion with wide-supported push-up. The mean velocity of the right shoulder joint was 0.0913/s, and the standard deviation was 0.118m/s. The characteristics of high-level athletes in the stage

of bending their arms in the downward push-up after completing the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

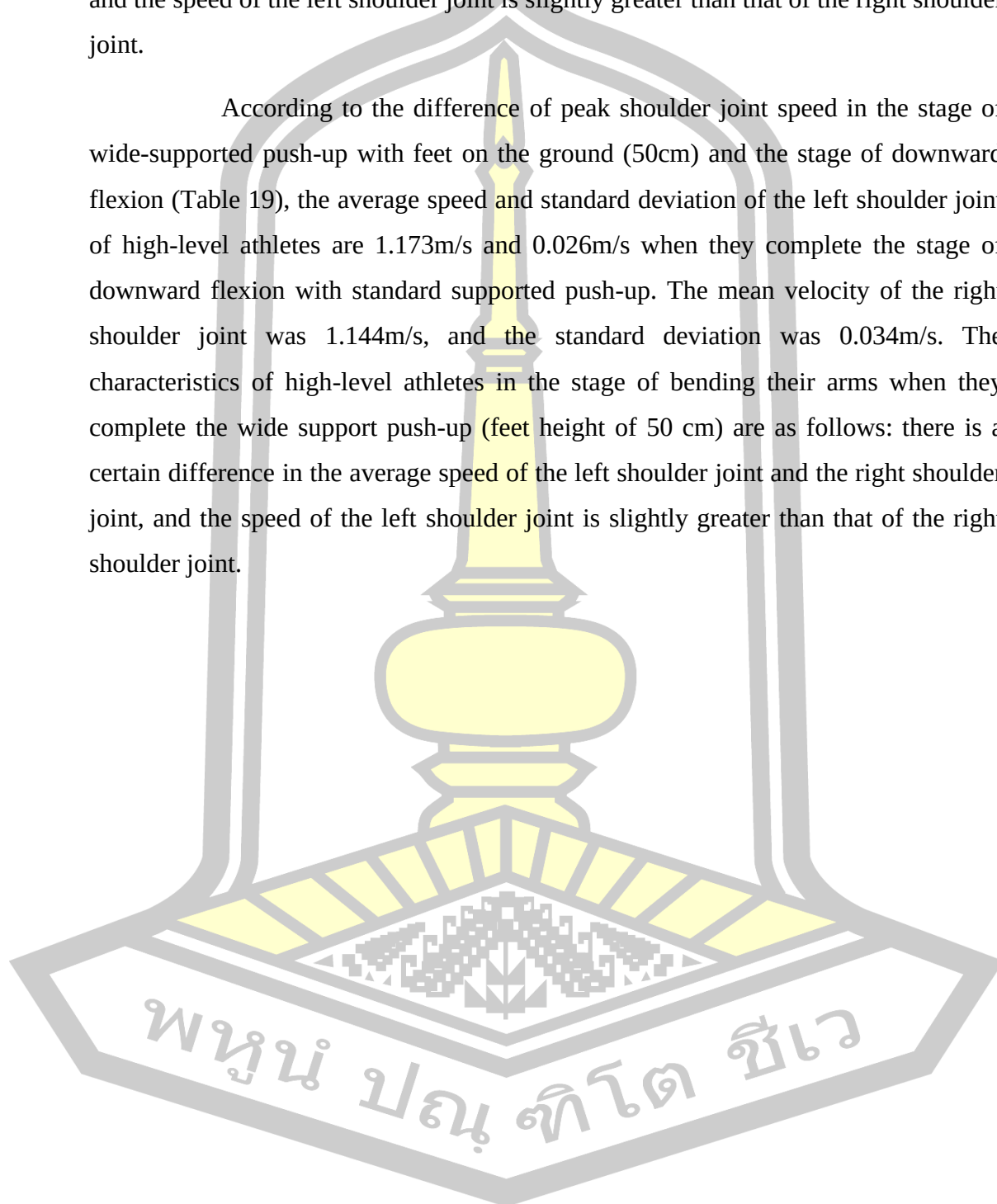
According to the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (25cm) and the stage of downward flexion (Table 19), the average speed and standard deviation of the left shoulder joint of high-level athletes in the stage of downward flexion with standard supported push-up are 1.148m/s and 0.034m/s. The mean velocity of the right shoulder joint was 1.133m/s, and the standard deviation was 0.032m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 25 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

According to the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (30cm) and the stage of downward flexion (Table 19), the average speed and standard deviation of the left shoulder joint of high-level athletes are 1.114m/s and 0.059m/s in the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.143m/s, and the standard deviation was 0.051m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 30 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (40cm) and the stage of downward flexion (Table 19), the average speed and standard deviation of the left shoulder joint of high-level athletes in the stage of downward flexion with standard supported push-up are 1.361m/s and 0.163m/s. The mean velocity of the right shoulder joint was 1.228m/s, and the standard deviation was 0.075m/s. The characteristics of high-level athletes in the stage of bending the arms in the downward push-up after completing the wide

support push-up (the height of the feet is 40 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

According to the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (50cm) and the stage of downward flexion (Table 19), the average speed and standard deviation of the left shoulder joint of high-level athletes are 1.173m/s and 0.026m/s when they complete the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.144m/s, and the standard deviation was 0.034m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.



2.1.2.2 Peak velocity characteristics of shoulder joint in the upward pushing stage

Table 20 The peak of shoulder joint speed during the push-up phase of standard support for high-level athletes (m/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.918	0.884	0.894	0.903	0.900±0.015
	Right shoulder joint	0.866	0.864	0.874	0.851	0.864±0.010
25cm	Left shoulder joint	0.915	1.041	1.051	0.900	0.977±0.081
	Right shoulder joint	0.852	0.990	1.000	0.837	0.920±0.087
30cm	Left shoulder joint	1.038	1.028	1.038	1.023	1.032±0.007
	Right shoulder joint	1.009	0.970	0.980	0.994	0.988±0.017
40cm	Left shoulder joint	1.027	1.107	1.117	1.012	1.066±0.054
	Right shoulder joint	0.975	0.975	0.985	0.960	0.974±0.010
50cm	Left shoulder joint	1.075	1.321	1.331	1.060	1.197±0.149
	Right shoulder joint	0.947	1.259	1.269	0.932	1.102±0.188

From the difference of shoulder joint speed peak value in push-ups with standard support height (0cm) on the ground and upward push stage (Table 20), the average speed and standard deviation of left shoulder joint of high-level athletes in push-ups with standard support are 0.900m/s and 0.015m/s respectively. The mean velocity of the right shoulder joint was 0.864m/s and the standard deviation was 0.010m/s. High-level athletes in the completion of the standard support push-up (feet height 0 cm) push up stage features: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the left shoulder joint is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with both feet on the ground (25cm) and in push-up stage (Table 20),

the average speed and standard deviation of left shoulder joint of high-level athletes in push-up stage with standard support are 0.977m/s and 0.081m/s respectively. The mean velocity of the right shoulder joint was 0.920m/s, and the standard deviation was 0.087m/s. High level athletes in the completion of the standard support push-up (feet height of 25 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (30cm) and upward push stage (Table 20), the average speed of left shoulder joint of high-level athletes in push-ups with standard support is 1.032m/s, and the standard deviation is 0.007m/s. The mean velocity of the right shoulder joint was 0.988m/s, and the standard deviation was 0.017m/s. High-level athletes in the completion of the standard support push up stage (feet height of 30 cm) the characteristics of the performance of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with both feet on the ground (40cm) and upward push stage (Table 20), the average speed and standard deviation of left shoulder joint of high-level athletes in push-ups with standard support are 1.066m/s and 0.054m/s respectively. The mean velocity of the right shoulder joint was 0.974m/s, and the standard deviation was 0.010m/s. High-level athletes in the completion of the standard support push-up (feet height of 40 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (50cm) and upward push stage (Table 20), the average speed and standard deviation of left shoulder joint of high-level athletes in push-ups with standard support are 1.197m/s and 0.149m/s, respectively. The mean velocity of the right shoulder joint was 1.102m/s, and the standard deviation was 0.188m/s. High-level athletes in the completion of the standard support push-up (feet

height of 50 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

Table 21 The peak of shoulder joint speed of high-level athletes in the push up stage of wide support push-up (m/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.899	0.977	0.884	0.966	0.931±0.047
	Right shoulder joint	0.826	1.066	0.811	1.055	0.940±0.140
25cm	Left shoulder joint	0.922	1.169	0.907	1.158	1.039±0.144
	Right shoulder joint	0.900	1.294	0.885	1.283	1.090±0.229
30cm	Left shoulder joint	0.886	1.346	0.871	1.335	1.110±0.267
	Right shoulder joint	0.947	1.243	0.932	1.232	1.088±0.173
40cm	Left shoulder joint	0.923	1.355	0.908	1.344	1.133±0.251
	Right shoulder joint	0.966	1.117	0.951	1.106	1.035±0.089
50cm	Left shoulder joint	0.870	1.232	0.855	1.221	1.044±0.210
	Right shoulder joint	0.890	1.110	0.875	1.099	0.993±0.128

From the difference of peak shoulder joint speed in the stage of broad support push-up with feet on the ground (0cm) and upward push (Table 21), the average speed of the left shoulder joint and standard deviation of the left shoulder joint are 0.931m/s and 0.047m/s, and the average speed of the right shoulder joint are 0.940m/s when high-level athletes complete the stage of broad support push-up and upward push. The standard deviation is 0.140m/s. The characteristics of high-level athletes in the stage of pushing up after completing the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (25cm) and upward push stage (Table 21), the average speed and standard deviation of left shoulder joint of high-level athletes are 1.039m/s and 0.144m/s when they complete the upward push stage of standard support push-ups. The mean velocity of the right shoulder joint was 1.090m/s, and the standard deviation was 0.229m/s. The characteristics of high-level athletes in the stage of pushing up after completing the wide support push-up (feet height of 25 cm) are: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (30cm) and upward push stage (Table 21), the average speed and standard deviation of left shoulder joint of high-level athletes are 1.110m/s and 0.267m/s when they complete the upward push stage of standard support push-ups. The mean velocity of the right shoulder joint was 1.088m/s, and the standard deviation was 0.173m/s. High-level athletes in the completion of the wide support push up stage (feet height of 30 cm) the characteristics of the performance of the left shoulder joint and the right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (40cm) and upward push stage (Table 21), the average speed and standard deviation of left shoulder joint of high-level athletes are 1.133m/s and 0.251m/s when they complete the upward push stage of standard support push-ups. The mean velocity of the right shoulder joint was 1.035m/s, and the standard deviation was 0.089m/s. High-level athletes in the completion of the wide support push-up (feet height of 40 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (50cm) and upward push stage (Table 21), the average speed and standard deviation of left shoulder joint of high-level athletes are

1.044m/s and 0.210m/s when they complete the upward push stage of standard support push-ups. The mean velocity of the right shoulder joint was 0.993m/s, and the standard deviation was 0.128m/s. High-level athletes in the completion of the wide support push-up (feet height of 50 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

2.1.3 Features of elbow joint Angle and shoulder joint angular velocity

2.1.3.1 Angle characteristics of the lowest elbow joint in the lower flexion arm

(1) Standard support push-up downward flexion elbow Angle

Table 22 The standard support push-up for advanced athletes is the low elbow Angle of the lower bend arm (°)

Foot height	Articulatio cubiti	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	29.14	30.23	36.54	31.33	31.81±3.28
	Right elbow joint	31.85	32.18	37.12	32.35	33.38±2.51
25cm	Left elbow joint	29.55	30.82	37.07	32.15	32.40±3.29
	Right elbow joint	32.16	33.79	38.05	33.36	34.34±2.57
30cm	Left elbow joint	31.35	32.52	39.33	42.11	36.33±5.22
	Right elbow joint	33.36	36.39	41.05	43.26	38.52±4.47
40cm	Left elbow joint	31.35	32.52	39.33	42.17	36.34±5.24
	Right elbow joint	33.37	36.39	41.16	43.26	38.55±4.49
50cm	Left elbow joint	33.46	34.74	40.45	43.33	38±4.68
	Right elbow joint	35.57	36.17	43.26	44.15	39.79±4.54

From the perspective of the difference between the peak Angle of the elbow joint at the lowest point in the push-up stage with the feet on the ground (0cm) and the lower flexion stage with the lower flexion stage (Table 22), the average Angle and standard deviation of the left elbow joint of high-level athletes at the lowest point

in the lower flexion stage with the standard push-up are 31.81° and 3.28° . The mean Angle of the right elbow joint was 33.38° and the standard deviation was 2.51° . The lowest point of the lower arm flexion phase of the standard support push-up (feet height 0 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the difference of peak elbow Angle of the lowest point in push-ups with standard support with both feet 25 cm higher than the ground (Table 22), the average Angle and standard deviation of the left elbow joint of the highest-level athletes are 32.40° and 3.29° at the lowest point in the stage of push-ups with standard support and bending arms (Table 19). The mean Angle of the right elbow joint was 34.34° and the standard deviation was 2.57° . The lowest point of the lower arm flexion phase of the standard support push-up (feet height of 25 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 30cm higher than the ground (Table 22), the average Angle and standard deviation of the left elbow joint of high-level athletes are 36.33° and 5.22° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 19). The mean Angle of the right elbow joint was 38.52° and the standard deviation was 4.47° . The lowest point of the lower arm flexion phase of the standard support push-up (feet height of 30 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 40 cm higher than the ground (Table 22), the average Angle and standard deviation of the left elbow joint of high-level athletes are 36.34° and 5.24° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 19). The mean Angle of the right elbow joint was 38.55° and the standard deviation was 4.49° . The lowest point of the lower arm flexion phase of the standard support push-up (feet height of 40 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak Angle of elbow joint at the lowest point in push-ups with feet 50 cm higher than the ground and in the lower flexion stage (Table 22), the average Angle of left elbow joint is 38°, the standard deviation is 4.68° and the average Angle of right elbow joint is 39.79° for high-level athletes at the lowest point in the lower flexion stage after completing standard push-ups. The standard deviation is 4.54°. The lowest point of the lower arm flexion phase of the standard support push-up (feet height 50 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

(2) Wide support push up downward flexion arm elbow joint Angle

Table 23 High level athletes wide support push up lower bend arm low elbow joint Angle (°)

Foot height	Articulatio cubiti	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	28.02	29.01	35.21	29.99	30.56±3.2
	Right elbow joint	30.73	30.96	35.79	31.01	32.12±2.45
25cm	Left elbow joint	28.43	29.6	35.74	30.81	31.15±3.21
	Right elbow joint	31.04	32.57	36.72	32.02	33.09±2.5
30cm	Left elbow joint	30.23	31.3	38.1	40.77	35.1±5.14
	Right elbow joint	32.24	35.17	39.72	41.92	37.26±4.37
40cm	Left elbow joint	30.23	31.3	38.03	40.83	35.1±5.15
	Right elbow joint	32.24	35.17	39.72	41.92	37.26±4.37
50cm	Left elbow joint	32.34	33.52	39.12	41.99	36.74±4.58
	Right elbow joint	34.45	34.95	41.93	42.81	39.79±4.54

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported push-up with both feet on the ground (0cm) and the stage of downward flexion (Table 23), the average Angle of the left elbow joint is 30.56°, the standard deviation is 3.2°, and the average Angle of the right elbow

joint is 32.12° . The standard deviation is 2.45° . The lowest point of a high-level athlete completing a wide support push-up (feet 0 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in push-ups with wide support height 25cm higher than the ground and the lower bend arm stage (Table 23), the average Angle and standard deviation of the left elbow joint of high-level athletes at the lowest point in the lower bend arm stage after completing wide push-ups are 31.15° and 3.21° respectively. The mean Angle of the right elbow joint was 33.09° and the standard deviation was 2.5° . The lowest point of the lower arm flexion phase of a high-level athlete completing a wide support push-up (feet height 25 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide support push-up with feet 30 cm higher than the ground and the stage of downward flexion (Table 23), the average Angle of the left elbow joint and the standard deviation of the right elbow joint are 35.1° and 5.14° respectively, and the average Angle of the right elbow joint is 37.26° . The standard deviation is 4.37° . The lowest point of the lower arm flexion phase of a high-level athlete completing a wide support push-up (feet height of 30 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in the peak Angle of the lowest elbow joint in the stage of wide support push-up with feet 40 cm higher than the ground (Table 23), the average Angle of the left elbow joint is 35.1° , the standard deviation is 5.15° , and the average Angle of the right elbow joint is 37.26° . The standard deviation is 4.37° . The lowest point of the lower arm flexion phase of a high-level athlete completing a wide support push-up (feet height 40 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide-supported push-ups with feet 50 cm higher than the ground (Table 23), the average Angle and standard deviation of the left elbow joint of high-

level athletes are 36.74° and 4.58° respectively at the lowest point in the stage of wide-supported push-ups and downward flexion. The mean Angle of the right elbow joint was 39.79° and the standard deviation was 4.54° . The lowest point of the lower arm flexion phase of a high-level athlete completing a wide support push-up (feet height 50 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

(3) Standard support high-five push-ups downward flexion arm elbow Angle

Table 24 High level athlete standard support High five push-up down bend arm low elbow joint Angle ($^\circ$)

Foot height	Articulatio cubiti	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	31.25	32.45	38.87	33.77	34.09 $\pm$ 3.35
	Right elbow joint	33.96	34.4	39.45	34.79	35.65 $\pm$ 2.56
25cm	Left elbow joint	31.66	33.04	39.4	34.59	34.67 $\pm$ 3.37
	Right elbow joint	34.27	36.01	40.38	35.8	36.62 $\pm$ 2.63
30cm	Left elbow joint	33.46	34.74	41.66	44.55	38.60 $\pm$ 5.36
	Right elbow joint	35.47	38.61	43.38	45.7	40.79 $\pm$ 4.61
40cm	Left elbow joint	33.46	34.64	41.66	44.61	38.59 $\pm$ 5.4
	Right elbow joint	35.47	38.61	43.38	45.7	40.79 $\pm$ 4.61
50cm	Left elbow joint	35.57	36.96	42.78	45.77	40.27 $\pm$ 4.82
	Right elbow joint	37.68	38.39	45.59	46.59	42.06 $\pm$ 4.68

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of standard high-five push-ups with feet on the ground (0cm) and the stage of downward flexion (Table 24), the average Angle of the left elbow joint and the standard deviation of the left elbow joint are 34.09° and 3.35° respectively. The mean Angle of the right elbow joint was 35.65° and the standard deviation was

2.56°. The lowest point of a high-level athlete in a standard high-five push-up (feet 0 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of high-fiving push-ups with feet 25 cm higher than the ground and the stage of downward flexion (Table 24), the average Angle of the left elbow joint of high-level athletes is 34.67° and the standard deviation is 3.37° at the lowest point in the stage of downward flexion when they complete the standard high-fiving push-ups. The mean Angle of the right elbow joint was 36.62° and the standard deviation was 2.63°. The lowest point of a high-performing athlete in a standard high-five push-up (feet 25 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of high-fiving push-ups with feet 30 cm higher than the ground and in the stage of downward flexion (Table 24), the average Angle of the left elbow joint of high-level athletes is 38.6° and the standard deviation is 5.36° at the lowest point in the stage of completing the standard high-fiving push-ups and downward flexion. The mean Angle of the right elbow joint was 40.79° and the standard deviation was 4.61°. The lowest point of a high-performing athlete in a standard high-five push-up (feet height 30 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference between the peak Angle of the elbow joint at the lowest point in the stage of push-ups with standard support with feet 40 cm higher than the ground (Table 24), the average Angle of the left elbow joint is 38.59° and the standard deviation is 5.4° for high-level athletes at the lowest point in the stage of push-ups with standard support with feet 40 cm higher than the ground. The mean Angle of the right elbow joint was 40.79° and the standard deviation was 4.61°. The lowest point of a high-performing athlete in a standard high-five push-up (with feet 40 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of push-ups with standard support with feet 50 cm higher than the ground (Table 24), the average Angle and standard deviation of the left elbow joint of high-level athletes are 40.27° and 4.82° at the lowest point in the stage of push-ups with standard support with feet 50 cm higher than the ground. The mean Angle of the right elbow joint was 42.06° and the standard deviation was 4.68°. The lowest point of a high-performing athlete in a standard high-five push-up (feet 50 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

(4) Wide support high-five push-ups down flexion arm lowest elbow joint Angle

Table 25 High level athlete wide brace high five push up lower bend arm low elbow joint Angle (°)

Foot height	Articulatio cubiti	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	30.2	31.38	37.78	32.66	33.01±3.34
	Right elbow joint	32.91	33.33	38.39	33.68	34.58±2.56
25cm	Left elbow joint	30.61	31.97	38.31	33.48	33.59±3.36
	Right elbow joint	33.22	34.94	42.99	34.69	36.46±4.42
30cm	Left elbow joint	32.41	33.67	40.57	43.44	37.52±5.33
	Right elbow joint	34.42	37.54	42.39	44.59	39.74±4.61
40cm	Left elbow joint	32.41	33.57	40.57	43.5	37.51±5.38
	Right elbow joint	34.42	37.54	42.29	44.59	39.71±4.59
50cm	Left elbow joint	34.52	35.89	41.69	44.66	39.19±4.79
	Right elbow joint	36.63	37.32	44.5	45.48	40.98±4.65

From the perspective of the difference in the Angle value of the lowest elbow joint in the stage of wide-supported high-five push-ups with their feet on the ground (0cm) and in the stage of downward flexion, (Table 25), the average Angle of the left elbow joint is 33.01° and the standard deviation is 3.34° for high-level athletes in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 34.58° and the standard deviation was 2.56° . The lowest point of a high-level athlete completing a wide support high-five push-up (feet 0 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet 25 cm higher than the ground and the stage of downward flexion (Table 25), the average Angle and standard deviation of the left elbow joint of high-level athletes are 33.59° and 3.36° at the lowest point in the stage of downward flexion. The mean Angle of the right elbow joint was 36.46° and the standard deviation was 4.42° . The lowest point of a high-level athlete completing a wide support high-five push-up (feet height 25 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet 30 cm higher than the ground and the stage of downward flexion (Table 25), the average Angle and standard deviation of the left elbow joint of high-level athletes are 37.52° and 5.33° at the lowest point in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 39.74° and the standard deviation was 4.61° . The lowest point of a high-level athlete completing a wide support high-five push up (feet height 30 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported push-ups with feet 40 cm higher than the ground and the stage of downward flexion (Table 25), the average Angle of the left elbow joint of high-level athletes is 37.51° and the standard deviation is 5.38° when they complete the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 39.71° and the standard deviation was 4.59° . The

lowest point of a high-level athlete completing a wide support high-five push-up (feet height 40 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet 50 cm higher than the ground and the stage of downward flexion (Table 25), the average Angle and standard deviation of the left elbow joint of high-level athletes are 39.19° and 4.79° at the lowest point in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 40.98° and the standard deviation was 4.65° . The lowest point of a high-level athlete completing a wide support high-five push-up (feet height 40 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.



2.1.3.2 Peak angular velocity characteristics of shoulder joint in the stage of downward flexion

Table 26 Peak angular velocity of shoulder joint in standard support push-ups for high-level athletes ($^{\circ}/s$)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	440.77	431.64	428.52	426.44	431.84±6.32
	Right shoulder joint	462.08	452.65	449.63	446.65	452.75±6.68
25cm	Left shoulder joint	515.78	506.15	503.13	500.25	506.33±6.75
	Right shoulder joint	612.43	602.60	599.58	596.80	602.86±6.81
30cm	Left shoulder joint	662.28	652.25	649.23	646.55	652.58±6.87
	Right shoulder joint	611.84	601.61	598.59	596.01	602.01±6.94
40cm	Left shoulder joint	543.51	533.08	530.06	527.58	533.56±7.01
	Right shoulder joint	523.89	513.26	510.24	507.86	513.81±7.07
50cm	Left shoulder joint	588.32	577.49	574.47	572.19	578.11±7.14
	Right shoulder joint	579.38	568.35	565.33	563.15	569.06±7.21

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support (0cm) on the ground and in the stage of bending arms with down support (Table 26), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of bending arms with down support are 431.84m/s and 6.32m/s respectively. The mean angular velocity of the right shoulder joint was 452.75/s and the standard deviation was 6.68m/s. The characteristics of high-level athletes in the stage of bending their arms when completing the standard support push-up (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of standard support push-up with feet on the ground (25cm) and in the stage of downward flexion (Table 26), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with standard support push-up are 506.33m/s and 6.75m/s respectively. The mean angular velocity of the right shoulder joint was 602.86m/s and the standard deviation was 6.81m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the standard support push-up (the height of their feet is 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (30cm) and in the stage of bending arms with downward support (Table 26), the average angular velocity of left shoulder joint of high-level athletes in the stage of bending arms with downward support is 652.58m/s, and the standard deviation is 6.87m/s. The mean angular velocity of the right shoulder joint was 602.01m/s and the standard deviation was 6.94m/s. High-level athletes in the standard support push-ups (feet height of 30 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (40cm) and in the stage of bending arms with downward support (Table 26), the average angular velocity of left shoulder joint of high-level athletes in the stage of bending arms with downward support is 533.56m/s, and the standard deviation is 7.01m/s. The mean angular velocity of the right shoulder joint was 513.81m/s, and the standard deviation was 7.07m/s. High-level athletes in the standard support push-ups (feet height of 40 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (50cm) and the stage of bending arms with downward support (Table 26), the average angular velocity of left shoulder joint of high-level athletes in the stage of bending arms with downward support is 578.11m/s, and the standard deviation is 7.14m/s. The mean angular velocity of the right shoulder joint was 569.06m/s and the standard deviation was 7.21m/s. High-level athletes in the standard support push-ups (feet height of 50 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

Table 27 The peak angular velocity of shoulder joint of high-level athletes in broad support push-up down flexion stage (°/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	690.61	675.49	673.38	669.20	677.17±9.33
	Right shoulder joint	520.84	503.92	503.31	499.33	506.85±9.55
25cm	Left shoulder joint	607.71	590.99	589.98	586.10	593.70±9.58
	Right shoulder joint	587.47	570.95	569.54	565.76	573.43±9.61
30cm	Left shoulder joint	736.96	720.64	718.83	715.15	722.89±9.65
	Right shoulder joint	740.36	724.24	722.03	718.45	726.27±9.69
40cm	Left shoulder joint	801.38	785.46	782.85	779.37	787.26±9.74
	Right shoulder joint	804.29	788.77	785.56	782.18	790.20±9.77
50cm	Left shoulder joint	833.04	817.72	814.11	810.83	818.92±9.82
	Right shoulder joint	831.00	814.88	812.07	808.59	816.63±9.92

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward flexion (Table 27), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with wide-supported push-up are 677.17m/s and 9.33m/s respectively. The mean angular velocity of the right shoulder joint was 506.85/s and the standard deviation was 9.55m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (25cm) and the stage of downward flexion (Table 27), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with standard supported push-up are 593.70m/s and 9.58m/s respectively. The mean angular velocity of the right shoulder joint was 573.43m/s and the standard deviation was 9.61m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (30cm) and the stage of downward flexion (Table 27), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with standard supported push-up are 722.89m/s and 9.65m/s respectively. The mean angular velocity of the right shoulder joint was 726.27m/s and the standard deviation was 9.69m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 30 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and

the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (40cm) and the stage of downward flexural arm flexural (Table 27), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexural arm flexural after completing standard supported push-up are 787.26m/s and 9.74m/s respectively. The mean angular velocity of the right shoulder joint was 790.20m/s, and the standard deviation was 9.77m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 40 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (50cm) and the stage of downward flexion (Table 27), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of downward flexion with standard supported push-up are 818.92m/s and 9.82m/s respectively. The mean angular velocity of the right shoulder joint was 816.63m/s, and the standard deviation was 9.92m/s. The characteristics of high-level athletes in the stage of bending their arms when they complete the wide support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

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2.1.3.3 Peak angular velocity characteristics of shoulder joint during upward thrust

Table 28 Peak angular velocity of shoulder joint during the push-up phase of standard support for high-level athletes (°/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	463.09	451.91	449.93	447.88	453.2±6.79
	Right shoulder joint	627.55	616.07	614.19	612.24	617.51±6.87
25cm	Left shoulder joint	427.71	416.03	414.15	412.30	417.54±6.94
	Right shoulder joint	387.60	375.72	373.84	372.09	377.31±7.02
30cm	Left shoulder joint	724.26	712.18	710.30	708.65	713.85±7.09
	Right shoulder joint	888.11	875.83	873.95	872.40	877.58±7.16
40cm	Left shoulder joint	712.12	699.64	697.76	696.31	701.46±7.24
	Right shoulder joint	683.34	672.16	668.78	667.43	672.93±7.22
50cm	Left shoulder joint	555.32	542.64	540.56	539.31	544.46±7.37
	Right shoulder joint	676.31	663.43	661.35	660.20	665.33±7.45

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet at 0cm on the ground (Table 28), the average angular velocity and standard deviation of left shoulder joint of high-level athletes during the push-up stage with standard support push-ups are 453.2m/s and 6.79m/s respectively. The mean angular velocity of the right shoulder joint was 617.51/s and the standard deviation was 6.87m/s. The characteristics of high-level athletes in the push-up stage of standard support push-ups (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet on the ground (25cm) and the

upward push stage (Table 28), the average angular velocity and standard deviation of left shoulder joint of high-level athletes during the push-up stage with standard support push-ups are 417.54m/s and 6.94m/s respectively. The mean angular velocity of the right shoulder joint was 377.31m/s, and the standard deviation was 7.02m/s. The characteristics of high-level athletes in the push-up stage after completing the standard support push-up (feet height of 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet on the ground (30cm) and the upward push stage (Table 28), the average angular velocity and standard deviation of the left shoulder joint of high-level athletes during the push-up stage with standard support push-ups are 713.85m/s and 7.09m/s respectively. The mean angular velocity of the right shoulder joint was 877.58m/s and the standard deviation was 7.16m/s. The characteristics of high-level athletes in the push-up stage after completing the standard support push-up (feet height of 30 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with both feet on the ground (40cm) and the upward push stage (Table 28), the average angular velocity of left shoulder joint of high-level athletes during the push-up stage with standard support push-ups is 701.46m/s, and the standard deviation is 7.24m/s. The mean angular velocity of the right shoulder joint was 672.93m/s and the standard deviation was 7.22m/s. The characteristics of high-level athletes in the push-up stage after completing the standard support push-up (feet height of 40 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet at 50cm on the ground (Table 28), the average angular velocity and standard deviation of left shoulder joint of high-

level athletes during the push-up stage with standard support push-ups are 544.46m/s and 7.37m/s respectively. The mean angular velocity of the right shoulder joint was 665.33m/s and the standard deviation was 7.45m/s. The characteristics of high-level athletes in the push-up stage after completing the standard support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

Table 29 The peak angular velocity of shoulder joint of high-level athletes in broad support push up stage (°/s)

Foot height	Shoulder joint	A1	A2	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	533.74	520.37	517.96	516.49	522.14±7.90
	Right shoulder joint	477.83	462.36	460.85	459.28	465.08±8.59
25cm	Left shoulder joint	516.18	500.61	499.00	497.43	503.31±8.68
	Right shoulder joint	542.68	527.01	525.30	523.73	529.68±8.77
30cm	Left shoulder joint	619.39	603.62	601.81	600.24	606.26±8.86
	Right shoulder joint	817.69	801.92	781.91	798.34	799.97±14.68
40cm	Left shoulder joint	477.06	461.19	459.08	457.51	463.71±9.03
	Right shoulder joint	680.60	664.63	664.58	660.85	667.67±8.80
50cm	Left shoulder joint	475.35	459.28	459.31	455.40	462.33±8.87
	Right shoulder joint	614.14	597.97	598.08	593.99	601.05±8.93

From the difference of peak angular velocity of shoulder joint in the stage of broad support push-up with feet on the ground (0cm) and upward push (Table 29), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of broad support push-up are 522.14m/s and 7.90m/s respectively. The mean angular velocity of the right shoulder joint was 465.08/s and the standard deviation was 8.59m/s. The characteristics of high-level athletes in the stage of pushing

up after completing the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

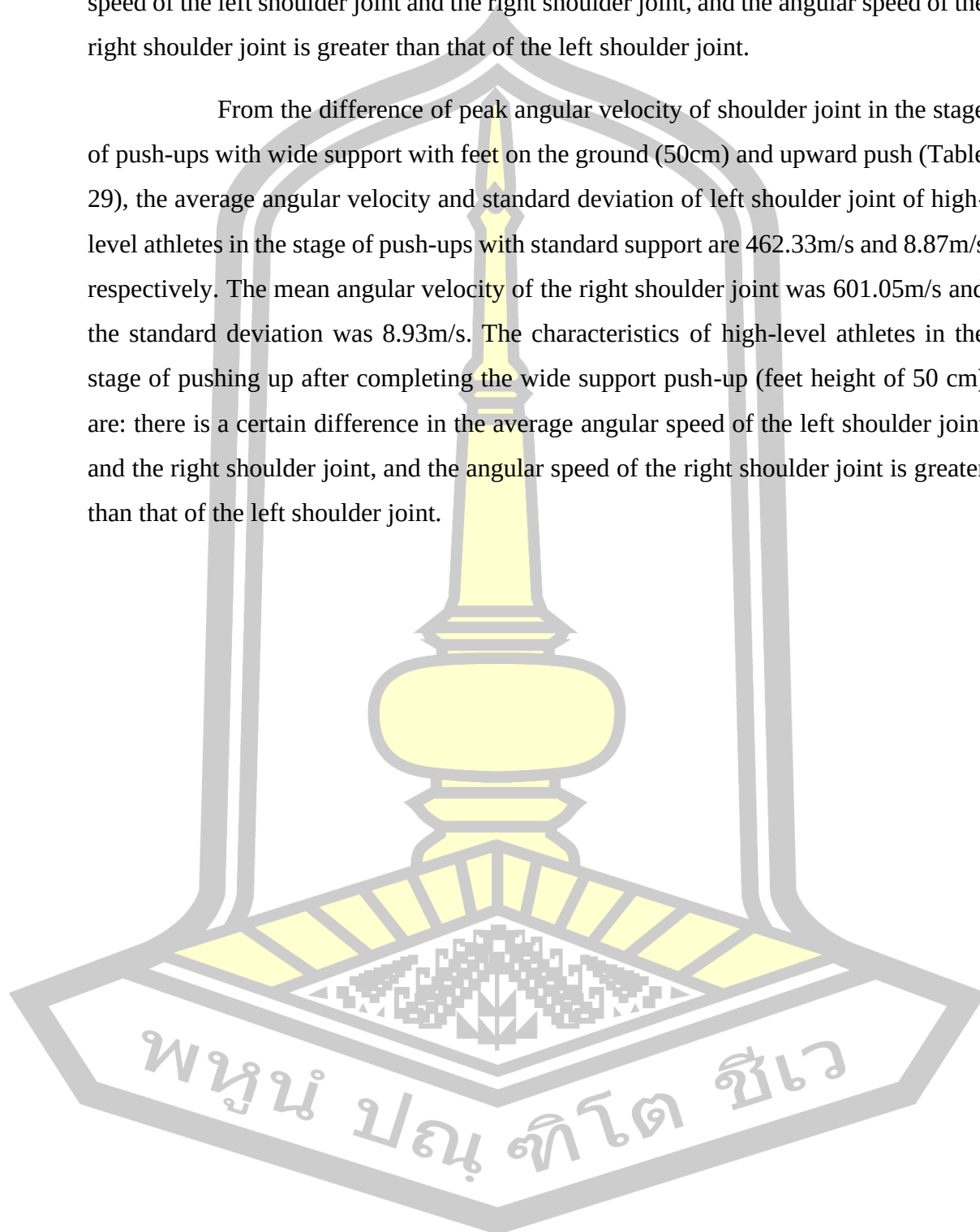
From the difference of peak angular velocity of shoulder joint in the stage of broad support push-up with feet on the ground (25cm) and upward push (Table 29), the average angular velocity and standard deviation of left shoulder joint of high-level athletes are 503.31m/s and 8.68m/s when they complete the stage of broad support push-up. The mean angular velocity of the right shoulder joint was 529.68m/s, and the standard deviation was 8.77m/s. The characteristics of high-level athletes in the stage of pushing up after completing the wide support push-up (the height of the feet is 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with feet on the ground (30cm) and upward push (Table 29), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of push-ups with standard support are 606.26m/s and 8.86m/s respectively. The mean angular velocity of the right shoulder joint was 799.97m/s and the standard deviation was 14.68m/s. The characteristics of high-level athletes in the stage of pushing up after completing the wide support push-up (feet height of 30 cm) are: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with both feet on the ground (40cm) and upward push (Table 29), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of push-ups with standard support are 463.71m/s and 9.03m/s respectively. The mean angular velocity of the right shoulder joint was 667.67m/s and the standard deviation was 8.80m/s. The characteristics of high-level athletes in the stage of pushing up after completing the wide support push up (the height

of the feet is 40 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with feet on the ground (50cm) and upward push (Table 29), the average angular velocity and standard deviation of left shoulder joint of high-level athletes in the stage of push-ups with standard support are 462.33m/s and 8.87m/s respectively. The mean angular velocity of the right shoulder joint was 601.05m/s and the standard deviation was 8.93m/s. The characteristics of high-level athletes in the stage of pushing up after completing the wide support push-up (feet height of 50 cm) are: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.



2.1.4 Mechanical characteristics

2.1.4.1 Peak characteristics of ground vertical reaction force during the depression stage under standard support push-ups

Table 30 The peak value of ground reaction force in the down flexion phase of standard support push-up for high-level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A1	312.58	280.08	346.73	338.6	531.54
A2	474.44	425.18	300.9	496.32	501.48
C	316.41	283.91	350.56	417.46	516.51
D	481.16	431.9	307.62	513.04	507.32
$\bar{X} \pm S$	396.15±94.34	355.27±84.67	326.45±25.82	441.36±80.19	514.21±13.1

From the difference between the peak value of ground vertical reaction force in the stage of push-ups with standard support (0cm) and the stage of bending arms with downward support (Table 30), the average value and standard deviation of ground vertical reaction force of high-level athletes in the stage of bending arms with downward support push-ups are 396.15N and 94.34N respectively.

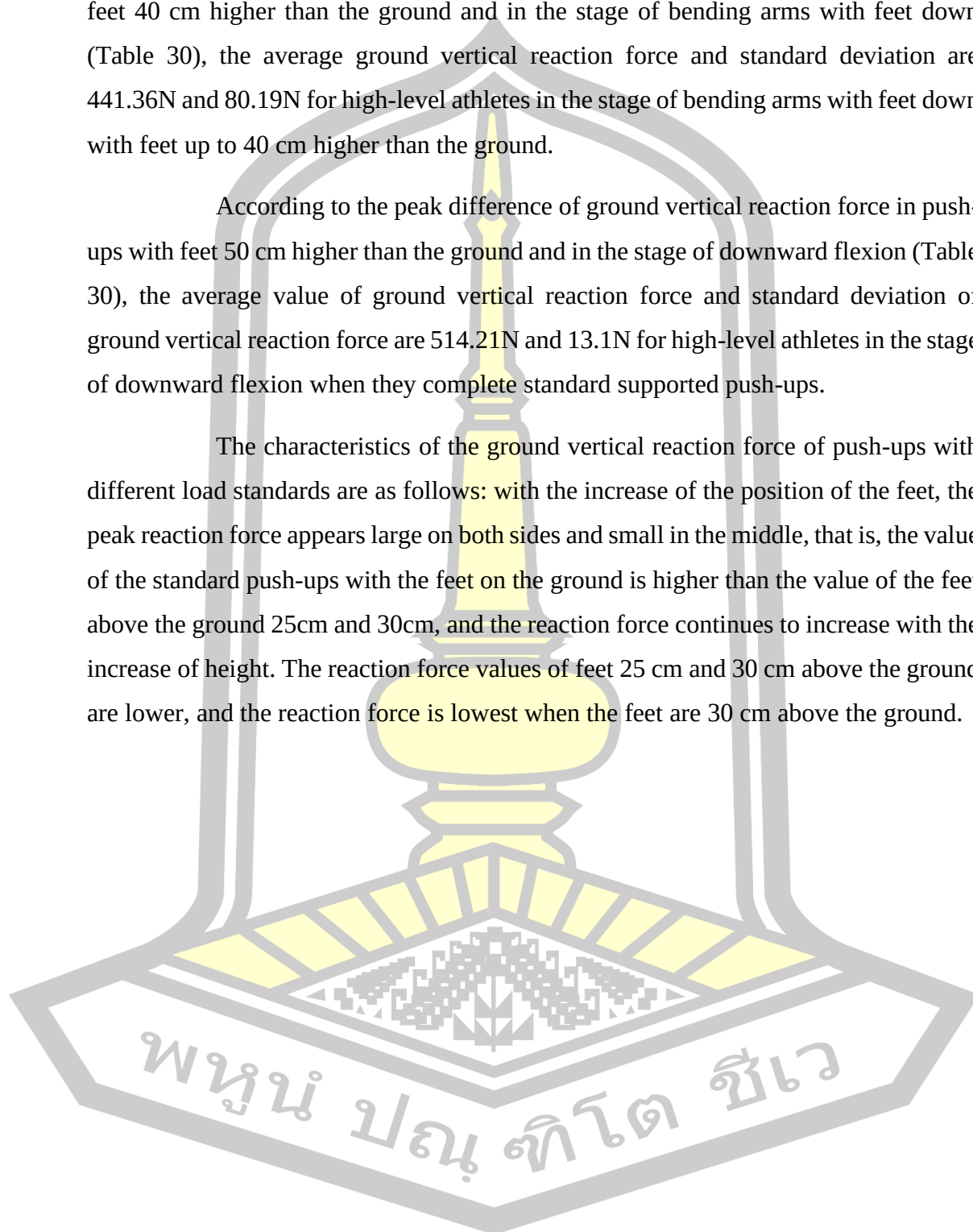
From the difference of peak ground vertical reaction force in push-ups with standard support with feet 25 cm higher than the ground and in the stage of bending arms with downward flexion (Table 30), the mean value of ground vertical reaction force and standard deviation of ground vertical reaction force are 355.27N and 84.67N for high-level athletes in the stage of bending arms with downward flexion after completing standard support push-ups.

From the difference of peak ground vertical reaction force in push-ups with feet 30cm higher than the ground and in the stage of bending arms with feet down (Table 30), the mean value of ground vertical reaction force and standard deviation of ground vertical reaction force in the stage of bending arms with feet down with feet up to 30cm higher than the ground are 326.45N and 25.82N respectively.

From the difference of peak ground vertical reaction force in push-ups with feet 40 cm higher than the ground and in the stage of bending arms with feet down (Table 30), the average ground vertical reaction force and standard deviation are 441.36N and 80.19N for high-level athletes in the stage of bending arms with feet down with feet up to 40 cm higher than the ground.

According to the peak difference of ground vertical reaction force in push-ups with feet 50 cm higher than the ground and in the stage of downward flexion (Table 30), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 514.21N and 13.1N for high-level athletes in the stage of downward flexion when they complete standard supported push-ups.

The characteristics of the ground vertical reaction force of push-ups with different load standards are as follows: with the increase of the position of the feet, the peak reaction force appears large on both sides and small in the middle, that is, the value of the standard push-ups with the feet on the ground is higher than the value of the feet above the ground 25cm and 30cm, and the reaction force continues to increase with the increase of height. The reaction force values of feet 25 cm and 30 cm above the ground are lower, and the reaction force is lowest when the feet are 30 cm above the ground.



2.1.4.2 Peak characteristics of ground vertical reaction force under broad support push-ups

Table 31 The peak value of ground reaction force in the lower flexion stage of broad support push-up for high-level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A1	479.17	422.42	405.04	501.24	505.62
A2	483.7	425.57	414.96	504.79	508.37
C	473.02	462.02	465.08	478.09	465.43
D	428.11	425.33	424.37	465.28	488.34
$\bar{X} \pm S$	466.01±25.64	433.84±18.84	427.36±26.35	487.35±18.88	491.94±19.77

From the difference between the peak value of ground vertical reaction force in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward bending arms flexion (Table 31), the average value and standard deviation of ground vertical reaction force of high-level athletes in the stage of downward bending arms flexion after completing wide-supported push-up are 466.01N and 25.64N respectively.

According to the difference of peak ground vertical reaction force in the stage of wide-supported push-ups with feet 25 cm higher than the ground and the stage of downward flexion (Table 31), the mean value of ground vertical reaction force and standard deviation of ground vertical reaction force are 433.84N and 18.84N for high-level athletes in the stage of downward flexion when they complete wide-supported push-ups.

According to the peak difference of ground vertical reaction force (Table 31), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 427.36N and 26.35N for high-level athletes when they complete wide-supported push-ups with their feet 30 cm higher than the ground.

According to the difference of peak ground vertical reaction force in the stage of wide-supported push-ups with feet 40 cm higher than the ground and the stage

of downward flexion (Table 31), the mean value of ground vertical reaction force and standard deviation of ground vertical reaction force are 487.35N and 18.88N for advanced athletes in the stage of downward flexion when they complete wide-supported push-ups.

According to the difference of peak ground vertical reaction force in push-ups with wide support height 50 cm higher than the ground and in the stage of downward flexion (Table 31), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 491.94N and 19.77N for high-level athletes in the stage of downward flexion when they complete standard push-ups.

The characteristics of the ground vertical reaction force of push-ups with different load widths in the downward flexion stage are as follows: with the increase of the position of the feet, the peak of the reaction force appears to be large on both sides and small in the middle, that is, the value of the wide-supported push-ups with the feet on the ground is higher than the value of the feet above the ground 25cm and 30cm, and the reaction force continues to increase with the increase of height. The reaction force values of feet 25 cm and 30 cm above the ground are lower, and the reaction force is lowest when the feet are 30 cm above the ground. The above features are consistent with those of standard support push-ups.

2.1.4.3 Peak characteristics of ground vertical reaction force during the push-up phase of standard support push-ups

Table 32 The peak of ground reaction force in the push-up stage of standard support for high-level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A1	527.04	650.62	661.12	658.17	755.99
A2	561.93	562.9	667.27	655.73	784.43
C	538.89	633.13	669.03	688.13	778.34
D	558.25	587.81	636.58	693.06	791.13
$\bar{X} \pm S$	546.53±16.46	608.62±40.37	658.5±15	673.77±19.55	777.47±15.24

From the difference of peak value of ground vertical reaction force in push-ups with standard support height (0cm) on the ground and push up stage (Table 32), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of high-level athletes in push-up stage with standard support push-up are 546.53N and 16.46N.

According to the difference of peak value of ground vertical reaction force in push-ups with standard support with feet 25 cm higher than the ground (Table 32), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in push-ups with standard support are 608.62N and 40.37N for high-level athletes in push-ups with standard support.

According to the difference in the peak value of ground vertical reaction force during the push-up stage with standard support push-ups with feet 30 cm higher than the ground (Table 32), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force during the push-up stage with standard support push-ups are 658.5N and 15N for high-level athletes.

According to the difference in the peak value of ground vertical reaction force in push-ups with standard support with feet 40 cm higher than the ground (Table 32), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in push-ups with standard support are 673.77N and 19.55N respectively for high-level athletes in push-ups with standard support.

From the difference of peak ground vertical reaction force in the push-up stage with standard support push-ups with feet 50 cm higher than the ground (Table 32), the average ground vertical reaction force and standard deviation are 777.47N and 15.24N for high-level athletes in the push-up stage with standard push-ups.

The characteristics of the ground vertical reaction force in the push-up stage of different load standard support push-ups are as follows: with the increase of the position of the feet, the peak value of the reaction force gradually increases, that is, the value of the push-up with the feet on the ground is the lowest, and the value of the standard support push-up with the feet 50 cm above the ground is the highest.

2.1.4.3 Peak characteristics of ground vertical reaction force during the upward push up stage of wide-supported push-ups

Table 33 The peak of ground reaction force in the push up stage of wide-supported push-ups for high-level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A1	673.33	775.61	812.96	913.16	915.38
A2	583.43	824.11	789.79	908.91	892.22
C	679.01	779.21	855.39	866.37	913.14
D	598.33	838.07	833.13	862.13	873.89
$\bar{X} \pm S$	633.53±49.67	804.25±31.55	822.82±28.02	887.64±27.12	898.66±19.53

From the difference of the peak value of the ground vertical reaction force in the stage of the wide-supported push-up with the feet on the ground (0cm) and the stage of the upward push (Table 33), the average value and standard deviation of the ground vertical reaction force of the high-level athletes in the stage of the upward push of the wide-supported push-up are 633.53N and 49.67N.

From the difference of peak value of ground vertical reaction force in the push-up stage with wide support push-ups with feet 25 cm higher than the ground (Table 33), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 804.25N and 31.55N for high-level athletes in the push-up stage with wide support push-ups.

From the difference of peak value of ground vertical reaction force in the push-up stage with wide support push-ups with feet 30 cm higher than the ground (Table 33), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 822.82N and 28.02N for high-level athletes in the push-up stage with wide support push-ups.

From the difference of peak ground vertical reaction force in the push-up stage with wide support push-ups with feet 40 cm higher than the ground (Table 33), the mean value of ground vertical reaction force and standard deviation of ground vertical reaction force in the push-up stage with wide support push-ups are 887.64N and 27.12N respectively.

Judging from the difference in the peak value of ground vertical reaction force in push-ups with wide support height 50 cm higher than the ground (Table 33), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force for high-level athletes in the push-up stage after completing standard push-ups are 898.66N and 19.53N respectively.

The characteristics of the ground vertical reaction force of push-ups with different load widths are as follows: with the increase of the position of the feet, the peak value of the reaction force gradually increases, that is, the value of the standard support push-ups with the feet on the ground is the lowest, and the value of the standard support push-ups with the feet 50 cm above the ground is the highest. The above features are consistent with those of standard support push-ups.

2.1.5 Surface EMG characteristics

2.1.5.1 Sequence (activation time) characteristics of muscle activation in the lower flexion stage

Table 34 A table of muscle activation sequence for high-level athletes completing standard support push-ups in the down flexion phase

Muscle	unactivated 1	Activate 1	unactivated 2	Activate 2	unactivated 3	Activate 3
Left biceps brachii	28.48	23.62	13.8	33.95	0	0
Right biceps brachii	27.97	23.26	15.69	33.11	0	0
Left triceps brachii	27.05	4.79	31.44	28.75	9.79	0
Right triceps brachii	15.57	21.45	7.48	39.55	15.95	0
Left deltoid anterior fasciculus	38.03	13.88	9.61	12.13	6.98	19.27
Anterior bundle of right deltoid	39.03	12.18	9.51	12.73	6.78	19.37
Left pectoralis major	23.02	24.94	12.04	11.13	6.78	21.37
Right pectoralis major	20.05	25.4	12.55	11.73	6.58	24.37

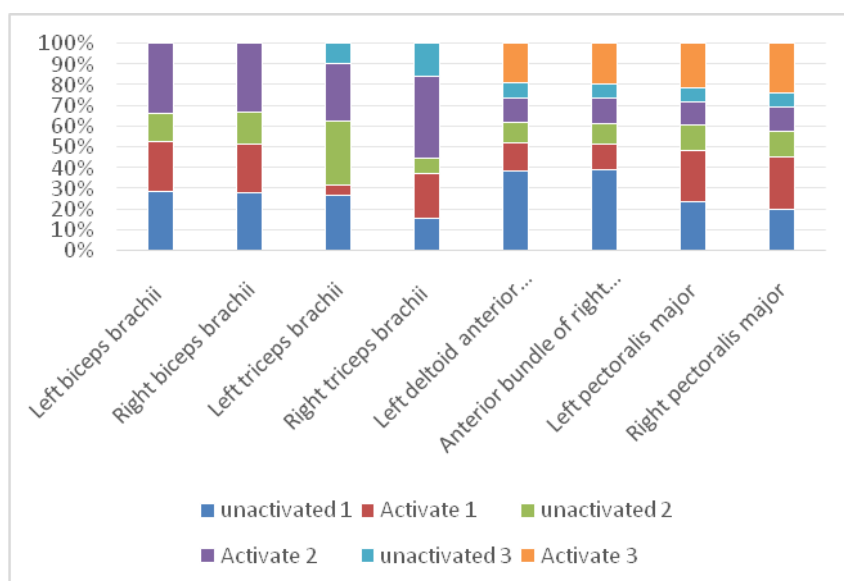
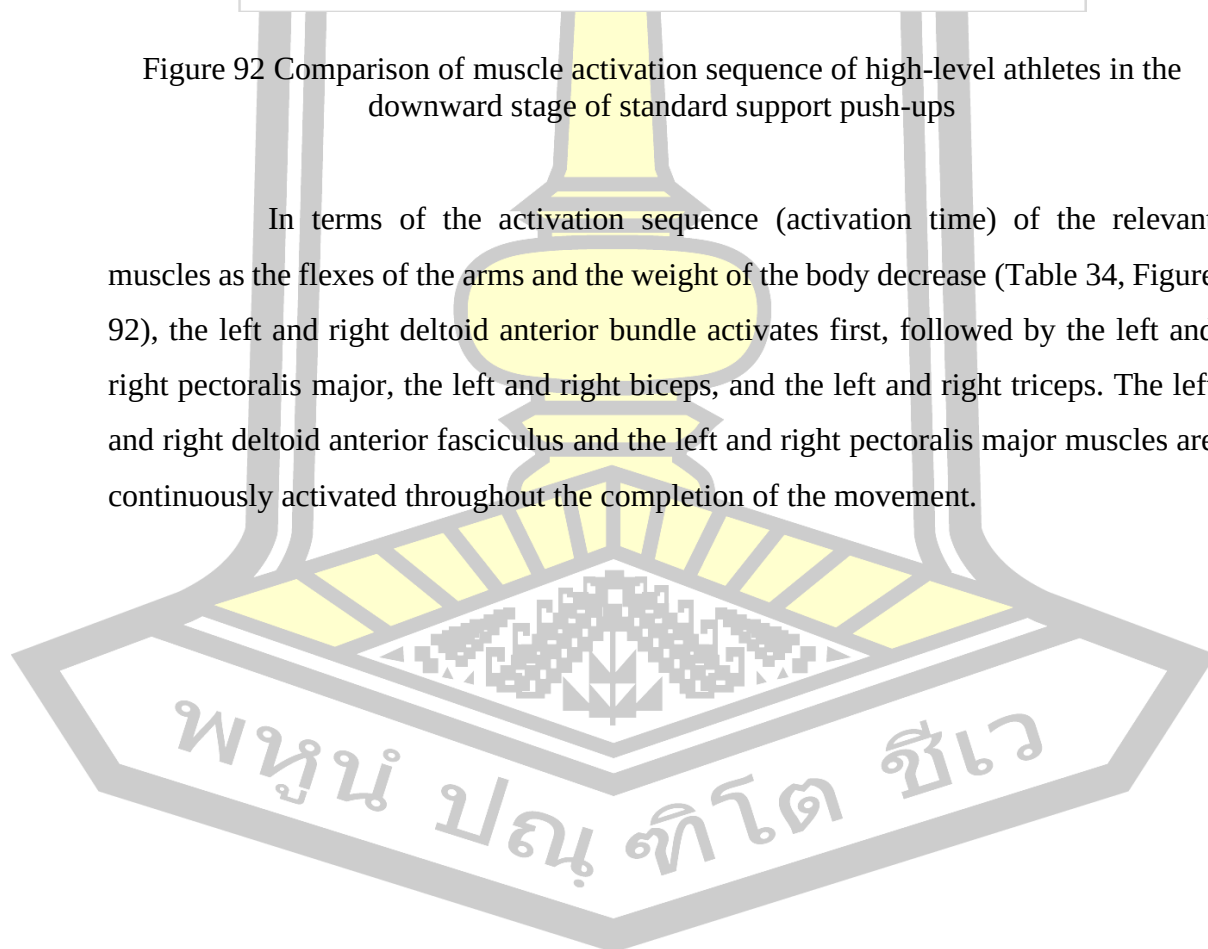


Figure 92 Comparison of muscle activation sequence of high-level athletes in the downward stage of standard support push-ups

In terms of the activation sequence (activation time) of the relevant muscles as the flexes of the arms and the weight of the body decrease (Table 34, Figure 92), the left and right deltoid anterior bundle activates first, followed by the left and right pectoralis major, the left and right biceps, and the left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the completion of the movement.



2.1.5.2 Characteristics of integrated EMG values of muscles related to the lower flexion stage

Table 35 The muscle integral myoelectric value of the high-level athletes completing the standard support push-up down flexion arm stage (μVs)

measure	A1	A2	C	D	$\bar{X} \pm S$
Left biceps brachii	120.2	119.05	121.35	118.03	119.66 $\pm$ 1.43
Right biceps brachii	120.8	119.07	122.31	118.07	120.06 $\pm$ 1.88
Left triceps brachii	494.7	492.68	497.58	492.53	494.37 $\pm$ 2.36
Right triceps brachii	490.3	489.15	493.92	487.03	490.10 $\pm$ 2.88
Left deltoid anterior fasciculus	134.8	131.55	138.15	132.63	134.28 $\pm$ 2.91
Anterior bundle of right deltoid	133.9	131.6	135.05	131.73	133.07 $\pm$ 1.69
Left pectoralis major	266.12	264.97	267.27	262.85	265.30 $\pm$ 1.89
Right pectoralis major	263.34	262.19	264.49	260.32	262.59 $\pm$ 1.78

From the point of view of the integrated EMG value of the relevant muscles of high-level athletes in the stage of completing the standard support push-up and bending arms (table 35), the average value of the integrated EMG value of the left biceps of high-level athletes is 119.66 μVs , and the standard deviation is 1.43 μVs . The mean value and standard deviation of the right biceps were 120.06 μVs and 1.88 μVs . The mean and standard deviation of the integrated EMG values of left triceps were 494.37 μVs and 2.36 μVs . The mean value and standard deviation of the right triceps were 490.10 μVs and 2.88 μVs . The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were 134.28 μVs and 2.91 μVs . The mean and standard deviation of the integrated EMG values of the right deltoid anterior bundle were 133.07 μVs and 1.69 μVs . The mean and standard deviation of the integrated EMG value of the left pectoral major were 265.30 μVs and 1.89 μVs . The mean and standard deviation of the integrated EMG values of the right pectoralis major were 262.59 μVs and 1.78 μVs . There are some differences in the integrated EMG values of the left and right muscles of the high level athletes in the stage of completing the standard support push-up, but the difference is not large.

2.1.5.3 Sequential (activation time) characteristics of muscle activation related to the push up stage

Table 36 Order table of muscle activation during the push-up phase of standard support push-ups for high-level athletes

Muscle	unactivated 1	Activate 1	unactivated 2	Activate 2	unactivated 3	Activate 3
Left biceps brachii	28.48	24.62	13.8	32.95	0	0
Right biceps brachii	27.97	24.26	15.69	32.11	0	0
Left triceps brachii	27.05	4.79	30.44	28.75	9.79	0
Right triceps brachii	26.57	5.45	29.48	29.55	8.95	0
Left deltoid anterior fasciculus	37.03	13.88	10.61	12.13	6.98	19.27
Anterior bundle of right deltoid	37.03	12.18	10.51	13.73	6.78	19.37
Left pectoralis major	23.02	23.94	12.04	12.33	6.78	21.57
Right pectoralis major	20.05	23.4	12.55	12.83	6.58	24.37

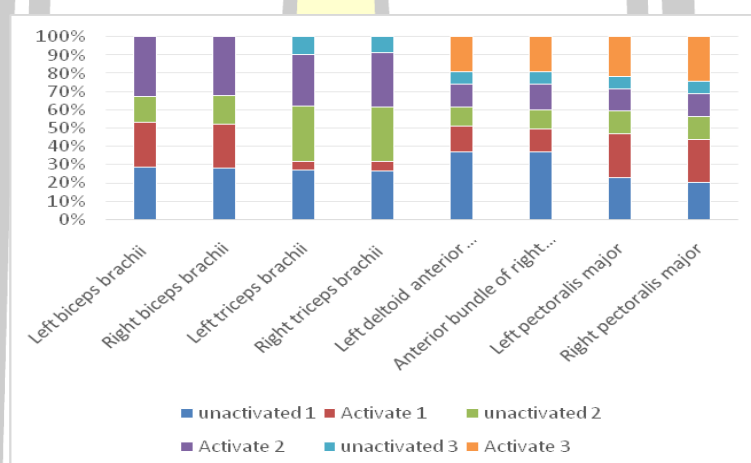


Figure 93 Comparison of muscle activation sequence in the uppush phase of standard support push-ups in high-level athletes

As the arms straighten and the weight of the body gradually rise, the relevant muscle activation sequence (activation time) of the advanced athletes during the push-up phase of the standard support push-up (Table 36, Figure 93) shows that the left and right deltoid anterior fasciculus activate first, followed by the left and right pectoralis major, the left and right triceps, and the left and right biceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the completion of the movement.

2.1.5.4 Integrated EMG characteristics of muscles associated with the uppush stage

Table 37 The integrated myoelectric value of muscle during the push-up phase of standard support push-ups for high-level athletes (μVs)

measure	A1	A2	C	D	$\bar{X} \pm S$
Left biceps brachii	115.05	111.77	116.2	112.88	113.98 $\pm$ 2.01
Right biceps brachii	115.65	110.76	117.16	112.92	114.12 $\pm$ 2.85
Left triceps brachii	499.85	505.03	502.73	497.68	501.32 $\pm$ 3.22
Right triceps brachii	495.45	500.6	499.07	492.18	496.83 $\pm$ 3.78
Left deltoid anterior fasciculus	139.95	145.46	143.3	145.12	143.46 $\pm$ 2.52
Anterior bundle of right deltoid	139.05	144.2	140.2	144.22	141.92 $\pm$ 2.69
Left pectoralis major	271.27	276.42	272.42	276.46	274.14 $\pm$ 2.69
Right pectoralis major	268.49	273.64	269.64	274.34	271.53 $\pm$ 2.90

From the point of view of the integrated EMG value of the relevant muscles of high-level athletes during the push-up stage of standard support push-ups (table 37), the average value of the integrated EMG value of the left biceps of high-level athletes was 113.98 μVs , and the standard deviation was 2.01 μVs . The mean value and standard deviation of the right biceps were 114.12 μVs and 2.85 μVs . The mean and standard deviation of the integrated EMG values of left triceps were 501.32 μVs and 3.22 μVs . The mean value and standard deviation of the right triceps were 496.83 μVs and 3.78 μVs . The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were 143.46 μVs and 2.52 μVs . The mean and standard deviation of the integrated EMG values of the right deltoid anterior bundle were 141.92 μVs and 2.69 μVs . The mean and standard deviation of the integrated EMG values of the left pectoral major were 274.14 μVs and 2.69 μVs . The mean and standard deviation of the integrated EMG values of the right pectoralis major were 271.53 μVs and 2.90 μVs . There are some differences in the integrated EMG values of the left and right muscles of the high-level athletes in the stage of completing the standard support push-up, but the difference is not large.

2.2 Biomechanical characteristics of push-ups performed by intermediate level athletes

2.2.1 Time characteristics

2.2.1.1 Complete action time characteristics

(1) The total time of standard push-ups supporting different loads

Table 38 Statistical table of total time for Intermediate level athletes to complete standard support push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.34	1.23	1.3	1.33	1.34
B	1.21	1.18	1.23	1.32	1.38
C	1.27	1.27	1.19	1.29	1.37
D	1.29	1.16	1.23	1.3	1.48
$\bar{X} \pm S$	1.28±0.05	1.21±0.05	1.24±0.05	1.31±0.02	1.39±0.06

Judging from the total time of standard support push-ups (with both feet on the ground) (table 38), the average time for intermediate level athletes to complete standard support push-ups is 1.28s, and the standard deviation is 0.05s. The total time of the four athletes who participated in the test to complete the standard support push-ups (flat ground) was very close, and the total time of athletes B to complete the standard support push-ups (feet on the ground) was 1.21s, which was the shortest among the four athletes. The total time of athlete A to complete the standard support push-up (feet on the ground) is 1.34s, which is the longest time of the four athletes.

Judging from the total time of standard support push-ups (feet 25 cm above the ground) (table 38), the average time of intermediate level athletes to complete standard support push-ups (feet 25 cm above the ground) is 1.21s, and the standard deviation is 0.05s. The total time of the four athletes participating in the test to complete the standard support push-up (feet 25cm above the ground) is very similar, and the total time of athlete D to complete the standard support push-up (feet 25cm above the

ground) is 1.16s, which is the shortest among the four athletes. Athlete C's total time to complete the standard support push-up (feet 25 cm above the ground) is 1.27s, which is the longest time of the four athletes.

Judging from the total time of standard support push-ups (feet 30cm above the ground) (table 38), the average time of intermediate level athletes to complete standard support push-ups (feet 30cm above the ground) is 1.24s, and the standard deviation is 0.05s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 30cm above the ground) is very similar, and the total time of athlete C to complete the standard support push-ups (feet 30cm above the ground) is 1.19s, which is the shortest among the four athletes. Athlete A took 1.3s to complete the standard support push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

Judging from the total time of standard support push-ups (feet 40 cm above the ground) (table 38), the average time for intermediate level athletes to complete standard support push-ups (feet 40 cm above the ground) is 1.31s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 40cm above the ground) is very similar, and the total time of athlete C to complete the standard support push-ups (feet 40cm above the ground) is 1.29s, which is the shortest among the four athletes. The total time of athlete A to complete the standard support push-up (feet 40 cm above the ground) is 1.33s, which is the longest time of the four athletes.

Judging from the total time of standard support push-ups (feet 50 cm above the ground) (table 38), the average time for intermediate level athletes to complete standard support push-ups (feet 50 cm above the ground) is 1.39s, and the standard deviation is 0.06s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 50cm above the ground) is very similar, and the total time of athlete A to complete the standard support push-ups (feet 50cm above the ground) is 1.34s, which is the shortest among the four athletes. The total time of athlete D to complete the standard support push-up (feet 50 cm above the ground) is 1.48s, which is the longest time of the four athletes.

(2) The total time of push-ups with different loads of wide support

Table 39 Statistical table of the total time for intermediate level athletes to complete wide support push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.21	1.21	1.18	1.41	1.47
B	1.2	1.2	1.22	1.38	1.5
C	1.19	1.19	1.19	1.36	1.51
D	1.19	1.19	1.26	1.41	1.48
$\bar{X} \pm S$	1.20±0.01	1.20±0.01	1.21±0.04	1.39±0.02	1.49±0.02

In terms of the total time of wide-supported push-ups (both feet on the ground) (table 39), the average time of intermediate level athletes to complete wide-supported push-ups is 1.20s, and the standard deviation is 0.01s. The total time of the four athletes participating in the test to complete the wide support push-up (flat ground) is very close, and the total time of athlete C and D to complete the wide support push-up (feet on the ground) is 1.19s, which is the shortest among the four athletes. The total time of athletes A to complete the wide support push-up (feet on the ground) was 1.21s, which was the longest time of the four athletes.

In terms of the total time for wide-supported push-ups (feet 25 cm above the ground) (table 39), the average time for intermediate level athletes to complete wide-supported push-ups (feet 25 cm above the ground) is 1.20s, with a standard deviation of 0.01s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 25 cm above the ground) is very similar, and the total time of athletes C and D to complete the wide support push-up (feet 25 cm above the ground) is 1.19s, which is the shortest among the four athletes. Athlete A's total time to complete the standard support push-up (feet 25 cm above the ground) was 1.21s, which was the longest time of the four athletes.

In terms of the total time for wide-supported push-ups (feet 30 cm above the ground) (table 39), the average time for intermediate level athletes to complete wide-supported push-ups (feet 30 cm above the ground) is 1.21s, and the standard deviation is 0.04s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 30cm above the ground) is very similar, and the total time of athlete C to complete the wide support push-up (feet 30cm above the ground) is 1.19s, which is the shortest among the four athletes. The total time of athletes D to complete the wide support push-up (feet 30 cm above the ground) was 1.26s, which was the longest time of the four athletes.

In terms of the total time for wide-supported push-ups (feet 40 cm above the ground) (table 39), the average time for intermediate level athletes to complete wide-supported push-ups (feet 40 cm above the ground) is 1.39s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 40cm above the ground) is very similar, and the total time of athlete C to complete the wide support push-up (feet 40cm above the ground) is 1.36s, which is the shortest among the four athletes. The total time of Athlete A and D to complete the wide support push-up (feet 40 cm above the ground) is 1.41s, which is the longest time of the four athletes.

In terms of the total time for wide-supported push-ups (feet 50 cm above the ground) (table 39), the average time for intermediate level athletes to complete wide-supported push-ups (feet 50 cm above the ground) is 1.49s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 50cm above the ground) is very close, and the total time of athlete A to complete the wide support push-up (feet 50cm above the ground) is 1.47s, which is the shortest among the four athletes. The total time of athlete C to complete the wide support push-up (feet 50 cm above the ground) is 1.51 seconds, which is the longest time of the four athletes.

(3) The total time used for standard high-five push-ups with different loads

Table 40 Statistical table of total time for intermediate level athletes to complete standard support high-five push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.42	1.2	1.36	1.41	1.52
B	1.46	1.45	1.38	1.55	1.56
C	1.43	1.24	1.33	1.44	1.53
D	1.39	1.48	1.36	1.53	1.5
$\bar{X} \pm S$	1.43±0.03	1.34±0.14	1.36±0.02	1.48±0.07	1.53±0.02

Judging from the total time of standard supported high-five push-ups (both feet on the ground) (table 40), the average time of intermediate level athletes to complete standard supported high-five push-ups is 1.43s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the standard supported high-five push-ups (flat ground) is very close, and the total time of athlete D to complete the standard supported high-five push-ups (feet on the ground) is 1.39s, which is the shortest among the four athletes. The total time of athlete B to complete the standard support push-up (feet on the ground) is 1.46s, which is the longest time of the four athletes.

Judging from the total time of standard supported high-five push-ups (feet 25 cm above the ground) (table 40), the average time of intermediate level athletes to complete standard supported high-five push-ups (feet 25 cm above the ground) is 1.34s, and the standard deviation is 0.14s. The total time of the four athletes participating in the test to complete the standard support high-five push-up (feet 25cm above the ground) is very similar, and the total time of athlete A to complete the standard support push-up (feet 25cm above the ground) is 1.20s, which is the shortest among the four athletes. The total time of athlete D to complete the standard support high-five push-up (feet 25 cm above the ground) is 1.48s, which is the longest time of the four athletes.

Judging from the total time of standard supported high-five push-ups (feet 30cm above the ground) (table 40), the average time of intermediate level athletes to complete standard supported high-five push-ups (feet 30cm above the ground) is 1.36s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 30cm above the ground) is very similar, and the total time of athlete C to complete the standard support push-ups (feet 30cm above the ground) is 1.33s, which is the shortest among the four athletes. Athlete B's total time to complete the standard high-five push-up (feet 30 cm above the ground) was 1.38s, the longest time of the four athletes.

Judging from the total time of standard supported high-five push-ups (feet 40 cm above the ground) (table 40), the average time of intermediate level athletes to complete standard supported high-five push-ups (feet 40 cm above the ground) is 1.48s, and the standard deviation is 0.07s. The total time of the four athletes participating in the test to complete the standard supported high-five push up (feet 40cm above the ground) is very similar, and the total time of athlete A to complete the standard supported high-five push up (feet 40cm above the ground) is 1.41s, which is the shortest among the four athletes. Athletes B took 1.55 seconds to complete the standard high-five push-up (feet 40 cm above the ground), the longest time of the four athletes.

Judging from the total time of standard supported high-five push-ups (feet 50 cm above the ground) (table 40), the average time of intermediate level athletes to complete standard supported high-five push-ups (feet 50 cm above the ground) is 1.53s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard support push up (feet 50cm above the ground) is very similar, and the total time of athlete D to complete the standard support high-five push up (feet 50cm above the ground) is 1.50s, which is the shortest among the four athletes. Athletes B took 1.56s to complete the standard high-five push-up (feet 50 cm above the ground), which was the longest time of the four athletes.

(4) The total time of wide support for different loads of high-five push-ups

Table 41 Statistical table of the total time for intermediate level athletes to complete wide support high-five push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.46	1.26	1.31	1.58	1.55
B	1.59	1.58	1.41	1.41	1.55
C	1.62	1.38	1.4	1.58	1.57
D	1.64	1.67	1.53	1.56	1.52
$\bar{X} \pm S$	1.58±0.08	1.47±0.19	1.41±0.09	1.53±0.08	1.55±0.02

In terms of the total time of wide-supported high-five push-ups (both feet on the ground) (table 41), the average time of intermediate level athletes to complete wide-supported high-five push-ups is 1.58s, and the standard deviation is 0.08s. The total time of the four athletes participating in the test to complete the wide-supported high-five push up (flat ground) is very close, and the total time of athlete A to complete the wide-supported high-five push up (feet on the ground) is 1.46s, which is the shortest among the four athletes. The total time of athlete D to complete the wide support push-up (feet on the ground) is 1.64s, which is the longest time of the four athletes.

In terms of the total time of wide-supported push-ups (feet 25 cm above the ground) (table 41), the average time for intermediate level athletes to complete wide-supported push-ups (feet 25 cm above the ground) is 1.47s, and the standard deviation is 0.19s. The total time of the four athletes participating in the test to complete the wide-supported high-five push-up (feet 25 cm above the ground) is very similar, and the total time of athlete A to complete the wide-supported push-up (feet 25 cm above the ground) is 1.26s, which is the shortest among the four athletes. Athlete D took 1.67s to complete the wide-supported high-five push-up (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 30 cm above the ground) (table 41), the average time of intermediate athletes to complete

wide-supported high-five push-ups (feet 30 cm above the ground) is 1.41s, and the standard deviation is 0.09s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 30cm above the ground) is very similar, and the total time of athlete A to complete the wide support push-up (feet 30cm above the ground) is 1.31s, which is the shortest among the four athletes. Athlete D took 1.53s to complete the wide-supported high-five push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 40 cm above the ground) (table 41), the average time of intermediate level athletes to complete wide-supported high-five push-ups (feet 40 cm above the ground) is 1.53s, and the standard deviation is 0.08s. The total time of the four athletes participating in the test to complete the wide-supported high-five push up (feet 40cm above the ground) is very similar, and the total time of athlete B to complete the wide-supported high-five push up (feet 40cm above the ground) is 1.41s, which is the shortest among the four athletes. Athlete A and C took 1.58s to complete the wide-supported high-five push-up (feet 40 cm above the ground), which was the longest time among the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 50 cm above the ground) (table 41), the average time of intermediate athletes to complete wide-supported high-five push-ups (feet 50 cm above the ground) is 1.55s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the wide support push up (feet 50cm above the ground) is very similar, among which the total time of athletes D to complete the wide support high-five push up (feet 50cm above the ground) is 1.52s, which is the shortest among the four athletes. Athlete C took 1.57s to complete the wide-supported high-five push-up (feet 50 cm above the ground), which was the longest time among the four athletes.

2.2.1.2 Time characteristics of the flexion stage of the downward flexion

(1) The time used for standard push-ups with different loads to support the bending arm

Table 42 Statistics of the time taken by intermediate level athletes to complete standard support push-ups and bend arms (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.66	0.55	0.56	0.65	0.62
B	0.57	0.56	0.58	0.63	0.66
C	0.59	0.57	0.54	0.62	0.61
D	0.56	0.53	0.56	0.62	0.65
$\bar{X} \pm S$	0.60±0.05	0.55±0.02	0.56±0.02	0.63±0.01	0.64±0.02

In terms of the time, it took for standard support push-up to bend the arms down (with both feet on the ground) (table 42), the average time for intermediate level athletes to complete the standard support push-up to bend the arms down is 0.60s, and the standard deviation is 0.05s. The time of the four athletes participating in the test to complete the standard support push-up down flexion arm (feet on the ground) is very similar, and the time of athlete D to complete the standard support push-up down flexion arm (feet on the ground) is 0.56s, which is the shortest among the four athletes. Athletes A took 0.66s to complete the standard support push-up with their arms bent down (feet on the ground), the longest time of the four athletes.

In terms of the time, it took for standard support push-up to bend the arms down (feet 25 cm above the ground) (table 42), the average time for intermediate level athletes to complete standard support push-up to bend the arms down (feet 25 cm above the ground) was 0.55s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the standard support push-up down flexion arm (feet 25cm above the ground), and the time for athlete D to complete the standard support push-up down flexion arm (feet 25cm above the ground) was 0.53s, which was the shortest among the four athletes. Athlete C took 0.57s to complete

the standard support push-up with his arms bent down (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for standard support push-up to bend the arms down (feet 30cm above the ground) (table 42), the average time for intermediate level athletes to complete standard support push-up to bend the arms down (feet 30cm above the ground) was 0.56s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the standard support push up and bend down the arms (feet 30cm above the ground). Among them, athlete C took 0.54s to complete the standard support push up and bend down the arms (feet 30cm above the ground), which was the shortest time among the four athletes. Athlete B took 0.58s to complete the standard support push-up with his arms bent down (feet 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it takes for standard support push-up to bend the arms down (feet 40 cm above the ground) (table 42), the average time for intermediate level athletes to complete standard support push-up to bend the arms down (feet 40 cm above the ground) is 0.63s, and the standard deviation is 0.01s. The four athletes who participated in the test took very similar time to complete the standard support push-up and bend the arms down (feet 40cm above the ground). Among them, athlete C and D took 0.62s to complete the standard support push-up and bend the arms down (feet 40cm above the ground), which was the shortest time among the four athletes. Athlete A took 0.65 seconds to complete the standard push-up with his arms bent down (feet 40 cm above the ground), the longest time among the four athletes.

In terms of the time, it takes for standard support push-up to bend the arms down (feet 50 cm above the ground) (table 42), the average time for intermediate level athletes to complete standard support push-up to bend the arms down (feet 50 cm above the ground) is 0.64s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support push-up down flexural arm (feet 50cm above the ground) is very similar, and the time of athlete C to complete the standard support push-up down flexural arm (feet 50cm above the ground) is 0.61s, which is the shortest among the four athletes. Athletes B took 0.66 seconds to complete

the standard push-up with their arms bent down (feet 50 cm above the ground), the longest time of the four athletes.

(2) The time for wide support of different load push-ups to support the bending arm

Table 43 Statistics of the time taken by intermediate level athletes to complete wide support push-ups and bend arms (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.63	0.59	0.56	0.67	0.71
B	0.57	0.57	0.58	0.66	0.73
C	0.62	0.55	0.54	0.63	0.76
D	0.63	0.54	0.58	0.65	0.72
$\bar{X} \pm S$	0.61±0.03	0.56±0.02	0.57±0.02	0.65±0.02	0.73±0.02

In terms of the time, it took for wide-supported push-ups to bend the arms down (with both feet on the ground) (table 43), the average time for intermediate level athletes to complete wide-supported push-ups to bend the arms down is 0.61s, and the standard deviation is 0.03s. The time of the four athletes who participated in the test to complete the wide support push-up down flexion arm (feet on the ground) is very similar, and the time of athlete B to complete the wide support push-up down flexion arm (feet on the ground) is 0.57s, which is the shortest among the four athletes. Athlete A and D took 0.63s to complete the broad support push up and down with bent arms (feet on the ground), which was the longest time among the four athletes.

In terms of the time, it took for the wide support push up to bend the arms down (feet 25 cm above the ground) (table 43), the average time for intermediate level athletes to complete the wide support push up to bend the arms down (feet 25 cm above the ground) was 0.56s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the wide support push-up down flexion arm (feet 25cm above the ground) is very similar, and the time of athletes D to complete the

wide support push-up down flexion arm (feet 25cm above the ground) is 0.54s, which is the shortest among the four athletes. Athlete A took 0.59s to complete the wide support push up and down with his arms bent (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for wide-supported push-ups to bend the arms down (feet 30cm above the ground) (table 43), the average time for intermediate level athletes to complete wide-supported push-ups to bend the arms down (feet 30cm above the ground) was 0.57s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the wide support push up and bend down the arms (feet 30cm above the ground). Among them, athlete C took 0.54s to complete the wide support push up and bend down the arms (feet 30cm above the ground), which was the shortest time among the four athletes. Athletes B and D took 0.58s to complete the wide support push up and down with their arms bent (feet 30 cm above the ground), which was the longest time of the four athletes.

In terms of the time, it took for the wide support push up to bend the arms down (feet 40 cm above the ground) (table 43), the average time for the intermediate level athletes to complete the wide support push up to bend the arms down (feet 40 cm above the ground) was 0.65s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the wide support push up and bend down the arms (feet 40cm above the ground). Among them, athlete C took 0.63s to complete the wide support push up and bend down the arms (feet 40cm above the ground), which was the shortest time among the four athletes. Athlete A took 0.67s to complete the wide support push up and down with his arms bent (feet 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for the wide support push up to bend the arms down (feet 50 cm above the ground) (table 43), the average time for the intermediate level athletes to complete the wide support push up to bend the arms down (feet 50 cm above the ground) was 0.73s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the wide support push-up down flexion arm (feet 50cm above the ground) is very similar, and the time of athlete A to complete the wide support push-up down flexion arm (feet 50cm above the ground) is 0.71s, which

is the shortest among the four athletes. Athlete C took 0.76s to complete the wide support push up and down with his arms bent (feet 50 cm above the ground), which was the longest time among the four athletes.

(3) The time for standard support of different loads of high-five push-ups to support the bending arm

Table 44 Intermediate level athletes standard support High-five push-ups down flexion arms time table (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.63	0.51	0.55	0.61	0.65
B	0.68	0.57	0.53	0.63	0.69
C	0.62	0.55	0.47	0.61	0.68
D	0.64	0.59	0.51	0.65	0.64
$\bar{X} \pm S$	0.64±0.03	0.56±0.03	0.52±0.03	0.63±0.02	0.67±0.02

In terms of the time, it took for standard supported high-five push-up to bend the arms down (with both feet on the ground) (table 44), the average time for intermediate level athletes to complete the standard supported high-five push-up to bend the arms down is 0.64s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet on the ground) is very similar, and the time of athlete C to complete the standard supported high-five push-up down flexion arms (feet on the ground) is 0.62s, which is the shortest among the four athletes. Athlete B took 0.68s to complete the standard support high-five push-up and bend the arms (feet on the ground), which was the longest time among the 4 athletes.

From the perspective of the time, it took for standard supported high-five push-up to bend the arms down (feet 25cm above the ground) (table 44 and Figure 36), the average time for intermediate level athletes to complete standard supported high-five push-up to bend the arms down (feet 25cm above the ground) was 0.56s, and the

standard deviation was 0.03s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet 25cm above the ground) is very similar, and the time of athlete A to complete the standard supported high-five push-up down flexion arms (feet 25cm above the ground) is 0.51s, which is the shortest among the four athletes. Athlete D took 0.59s to complete the standard support high-five push-up and bend the arms down (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for standard supported high-five push-ups to bend the arms down (feet 30cm above the ground) (table 44), the average time for intermediate level athletes to complete standard supported high-five push-ups to bend the arms down (feet 30cm above the ground) was 0.52s, and the standard deviation was 0.03s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet 30cm above the ground) is very similar, and the time of athlete C to complete the standard supported high-five push-up down flexion arms (feet 30cm above the ground) is 0.47s, which is the shortest among the four athletes. Athlete A took 0.55s to complete the standard support high-five push-up and bend the arms (feet are 30 cm above the ground), which was the longest time of the four athletes.

In terms of the time, it took for standard supported high-five push-up to bend the arms down (feet 40cm above the ground) (table 44), the average time for intermediate level athletes to complete the standard supported high-five push-up to bend the arms down (feet 40cm above the ground) was 0.63s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the standard supported high-five push-up and bend the arms down (feet 40cm higher than the ground). Among them, athlete A and C took 0.61s to complete the standard supported high-five push-up and bend the arms down (feet 40cm higher than the ground), which was the shortest time among the four athletes. Athlete D took 0.65s to complete the standard support high-five push-up and bend the arms (feet are 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for standard supported high-five push-up to bend the arms down (feet 50 cm above the ground) (table 44), the average time for

intermediate level athletes to complete the standard supported high-five push-up to bend the arms down (feet 50 cm above the ground) was 0.67s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the standard supported high-five push up and bend down the arms (feet 50cm above the ground). Among them, athlete D took 0.64s to complete the standard supported high-five push up and bend down the arms (feet 50cm above the ground), which was the shortest time among the four athletes. Athlete B took 0.69s to complete the standard support high-five push-up and bend the arms (feet 50 cm above the ground), which was the longest time among the four athletes.

(4) The time for wide support of different loads of high-five push-ups to support the bending arm down

Table 45 Intermediate level athletes wide support high-five push-ups down flexion arms time table (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.54	0.51	0.53	0.69	0.63
B	0.55	0.55	0.53	0.66	0.65
C	0.58	0.54	0.57	0.65	0.63
D	0.6	0.59	0.59	0.66	0.61
$\bar{X} \pm S$	0.57±0.03	0.55±0.03	0.56±0.03	0.67±0.02	0.63±0.02

In terms of the time, it took for wide-supported high-five push-ups to bend the arms down (with both feet on the ground) (table 45), the average time for intermediate level athletes to complete wide-supported high-five push-ups to bend the arms down is 0.57s, and the standard deviation is 0.03s. The time of the four athletes who participated in the test to complete the wide-supported high-five push-up down flexion arms (feet on the ground) was very similar, and the time of athlete A to complete the wide-supported high-five push-up down flexion arms (feet on the ground) was 0.54s, which was the shortest among the four athletes. It took athlete D 0.60s to

complete the broad support high-five push-up and bend the arms (feet on the ground), which was the longest time among the four athletes.

In terms of the time, it took for wide-supported push-ups to bend the arms down (feet 25 cm above the ground) (table 45), the average time for intermediate level athletes to complete wide-supported push-ups to bend the arms down (feet 25 cm above the ground) was 0.55s, and the standard deviation was 0.03s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 25cm above the ground) is very similar, and the time of athlete A to complete the wide-supported high-five push-up down flexion arms (feet 25cm above the ground) is 0.51s, which is the shortest among the four athletes. Athlete D took 0.59 seconds to complete the broad support high-five push up and down with his arms bent (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for wide-supported push-ups to bend the arms down (feet 30cm above the ground) (table 45), the average time for intermediate level athletes to complete wide-supported push-ups to bend the arms down (feet 30cm above the ground) was 0.56s, and the standard deviation was 0.03s. The time of the four athletes participating in the test to complete the wide supported high-five push-up down flexion arms (feet 30cm above the ground) is very similar, and the time of athletes A and B to complete the wide supported high-five push-up down flexion arms (feet 30cm above the ground) is 0.53s, which is the shortest among the four athletes. Athlete D took 0.59s to complete the broad support high-five push up and bend the arms (feet are 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for wide-supported push-ups to bend the arms down (feet 40 cm above the ground) (table 45), the average time for intermediate level athletes to complete wide-supported push-ups to bend the arms down (feet 40 cm above the ground) was 0.67s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 40cm higher than the ground) is very similar, and the time of athlete C to complete the wide-supported high-five push-up down flexion arms (feet 40cm higher than the ground) is 0.65s, which is the shortest among the four athletes. Athlete

A took 0.69s to complete the broad support high-five push up and bend the arms (feet are 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time, it took for wide-supported push-ups to bend the arms down (feet 50 cm above the ground) (table 45), the average time for intermediate level athletes to complete wide-supported push-ups to bend the arms down (feet 50 cm above the ground) was 0.63s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 50cm above the ground) is very similar, and the time of athlete D to complete the wide-supported high-five push-up down flexion arms (feet 50cm above the ground) is 0.61s, which is the shortest among the four athletes. Athlete B took 0.65s to complete the broad support high-five push-up and bend the arms down (feet 50 cm above the ground), which was the longest time among the four athletes.

2.2.1.3 Time characteristics of the push up phase

(1) The time used to push up push-ups with different loads of standard support

Table 46 Statistical table for intermediate level athletes when they complete push-ups with different loads of standard support (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.68	0.68	0.74	0.68	0.72
B	0.65	0.62	0.65	0.69	0.72
C	0.68	0.7	0.65	0.67	0.76
D	0.65	0.63	0.67	0.68	0.83
$\bar{X} \pm S$	0.67 ± 0.02	0.66 ± 0.04	0.68 ± 0.04	0.68 ± 0.01	0.76 ± 0.05

In terms of the time taken to push up from the standard support push-up (with both feet on the ground) (table 46), the average time for intermediate level athletes to complete the standard support push-up is 0.67s, and the standard deviation is 0.02s.

The time of the four athletes participating in the test to complete the standard support push up (feet on the ground) is very close, and the time of athletes B and D to complete the standard support push up (feet on the ground) is 0.65s, which is the shortest among the four athletes. Athlete A and C took 0.68 seconds to complete the standard support push up (feet on the ground), which was the longest time among the four athletes.

In terms of the time it took to push up from the standard support push-up (with feet 25 cm above the ground) (table 46), the average time for intermediate level athletes to complete the standard support push-up (with feet 25 cm above the ground) was 0.66s, and the standard deviation was 0.04s. The time of the four athletes participating in the test to complete the standard support push up (feet 25cm above the ground) is very similar, and the time of athlete B to complete the standard support push up (feet 25cm above the ground) is 0.62s, which is the shortest among the four athletes. Athlete C took 0.70s to complete the standard support push up (feet 25 cm above the ground) movement, which was the longest time of the four athletes.

In terms of the time it takes to push up from the standard support push-up (feet 30 cm above the ground) (table 46), the average time for intermediate level athletes to complete the standard support push-up (feet 30 cm above the ground) is 0.68s, and the standard deviation is 0.04s. The time of the four athletes participating in the test to complete the standard support push up (feet 30cm higher than the ground) is very similar, and the time of athlete B and C to complete the standard support push up (feet 30cm higher than the ground) is 0.65s, which is the shortest among the four athletes. Athlete A took 0.74 seconds to complete the standard support push up (feet 30 cm above the ground), which was the longest time of the four athletes.

In terms of the time taken to push up from the standard support push-up (feet 40 cm above the ground) (table 46), the average time for intermediate level athletes to push up from the standard support push-up (feet 40 cm above the ground) is 0.68s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support push up (feet 40cm higher than the ground) is very similar, and the time of athlete C to complete the standard support push up (feet 40cm higher than the ground) is 0.67s, which is the shortest among the four athletes. Athlete

B took 0.69s to complete the standard support push up (feet 40 cm above the ground), which was the longest time of the four athletes.

In terms of the time taken to push up from the standard support push-up (feet 50 cm above the ground) (table 46), the average time for intermediate level athletes to complete the standard support push-up (feet 50 cm above the ground) is 0.76s, and the standard deviation is 0.05s. The time of the four athletes participating in the test to complete the standard support push up (feet 50cm above the ground) is very similar, and the time of athlete A and B to complete the standard support push up (feet 50cm above the ground) is 0.72s, which is the shortest among the four athletes. Athletes D took 0.83s to complete the standard support push up (feet 50 cm above the ground), which was the longest time of the four athletes.

(2) The time when the wide support push-ups with different loads are pushed up

Table 47 Statistics Table for intermediate level athletes when they complete the Wide Support push up push (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.71	0.62	0.62	0.74	0.76
B	0.64	0.63	0.64	0.72	0.77
C	0.65	0.64	0.65	0.73	0.75
D	0.66	0.65	0.68	0.76	0.76
$\bar{X} \pm S$	0.67±0.03	0.64±0.01	0.65±0.03	0.74±0.02	0.76±0.01

In terms of the time taken to push up with wide support push-ups (both feet on the ground) (table 47), the average time for intermediate level athletes to complete the push up with wide support push-ups is 0.67s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support push up (feet on the ground) is very close, and the time of athlete B to complete the wide support push up (feet on the ground) is 0.64s, which is the shortest among the four

athletes. Athlete A took 0.71s to complete the wide support push up movement (feet on the ground), which was the longest time among the four athletes.

In terms of the time taken to push up with wide support push-ups (feet 25 cm above the ground) (table 47), the average time for intermediate level athletes to complete the push up with wide support push-ups (feet 25 cm above the ground) is 0.64s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the wide support push up (feet 25cm above the ground) is very similar, and the time of athlete A to complete the wide support push up (feet 25cm above the ground) is 0.62s, which is the shortest among the four athletes. Athlete D took 0.65 seconds to complete the wide support push up (feet 25 cm above the ground), which was the longest time of the four athletes.

In terms of the time it takes to push up with wide support push-ups (feet 30 cm above the ground) (table 47), the average time for intermediate level athletes to push up with wide support push-ups (feet 30 cm above the ground) is 0.65s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support push up (feet 30cm higher than the ground) is very similar, and the time of athletes A to complete the wide support push up (feet 30cm higher than the ground) is 0.62s, which is the shortest among the four athletes. Athlete D took 0.68 seconds to complete the wide support push up movement (feet are 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took to push up with wide support push-ups (feet 40 cm above the ground) (table 47), the average time for intermediate level athletes to push up with wide support push-ups (feet 40 cm above the ground) was 0.74s, and the standard deviation was 0.02s. The time of the four athletes participating in the test to complete the wide support push up (feet 40cm higher than the ground) is very similar, and the time of athletes B to complete the wide support push up (feet 40cm higher than the ground) is 0.72s, which is the shortest among the four athletes. Athlete D took 0.76s to complete the wide support push up (feet 40 cm above the ground) movement, which was the longest time among the four athletes.

In terms of the time taken to push up with wide support push-ups (feet 50 cm above the ground) (table 47), the average time for intermediate level athletes to complete the wide support push-ups (feet 50 cm above the ground) was 0.76s, and the standard deviation was 0.01s. The time of the four athletes participating in the test to complete the wide support push up (feet 50cm above the ground) is very similar, and the time of athlete C to complete the wide support push up (feet 50cm above the ground) is 0.75s, which is the shortest among the four athletes. Athlete B took 0.77s to complete the broad support push up (feet 50 cm above the ground) movement, which was the longest time among the four athletes.

(3) Standard support for different loads of high-five push-ups pushed up

Table 48 Statistics Table for intermediate level athletes when they complete Standard support high-five push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.41	0.43	0.51	0.57	0.58
B	0.45	0.47	0.53	0.58	0.57
C	0.44	0.42	0.55	0.6	0.54
D	0.43	0.49	0.52	0.53	0.58
$\bar{X} \pm S$	0.43±0.02	0.45±0.03	0.53±0.02	0.57±0.03	0.57±0.02

Judging from the time taken to push up (with both feet on the ground) in the standard supported high-five push-up (table 48), the average time for intermediate athletes to push up in the standard supported high-five push-up is 0.43s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet on the ground) is very close, and the time of athlete A to complete the standard support high-five push up (feet on the ground) is 0.41s, which is the shortest among the four athletes. Athlete B took 0.45s to complete the standard support high-five push up movement (feet on the ground), which was the longest time among the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 25 cm above the ground) (table 48), the average time for intermediate level athletes to push up from the standard supported high-five push up (feet 25 cm above the ground) is 0.45s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 25cm above the ground) is very similar, and the time of athlete C to complete the standard support high-five push up (feet 25cm above the ground) is 0.42s, which is the shortest among the four athletes. Athlete D took 0.49s to complete the standard support high-five push up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 30 cm above the ground) (table 48), the average time for intermediate level athletes to push up from the standard supported high-five push up (feet 30 cm above the ground) is 0.53s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 30cm higher than the ground) is very similar, and the time of athlete A to complete the standard support high-five push up (feet 30cm higher than the ground) is 0.51s, which is the shortest among the four athletes. Athlete C took 0.55s to complete the standard support high-five push up (feet 30 cm above the ground) movement, which was the longest time of the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 40 cm above the ground) (table 48), the average time for intermediate level athletes to push up from the standard supported high-five push up (feet 40 cm above the ground) is 0.57s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 40cm higher than the ground) is very similar, and the time of athlete D to complete the standard support high-five push up (feet 40cm higher than the ground) is 0.53s, which is the shortest among the four athletes. Athlete C took 0.60s to complete the standard support high-five push up (feet 40 cm above the ground) movement, which was the longest time among the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 50 cm above the ground) (table 48), the average time for intermediate level athletes to push up from the standard supported high-five push up (feet 50 cm above the ground) is 0.57s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 50cm above the ground) is very similar, and the time of athlete C to complete the standard support high-five push up (feet 50cm above the ground) is 0.54s, which is the shortest among the four athletes. Athlete A and D took 0.58s to complete the standard support high-five push up movement (feet 50 cm above the ground), which was the longest time among the four athletes.

(4) Wide support for different loads of high-five push-ups pushed up

Table 49 Statistics Table for intermediate level athletes when they complete Wide Support high-five push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.57	0.53	0.5	0.61	0.62
B	0.63	0.62	0.58	0.51	0.63
C	0.65	0.62	0.54	0.65	0.63
D	0.61	0.66	0.63	0.65	0.61
$\bar{X} \pm S$	0.62±0.03	0.61±0.06	0.56±0.06	0.61±0.07	0.62±0.01

In terms of the time it took to push up with both feet on the ground (table 49), the average time for intermediate level athletes to complete the push up with wide support is 0.62s, and the standard deviation is 0.03s. The time of the four athletes who participated in the test to complete the wide support high-five push up (feet on the ground) is very close, and the time of athlete A to complete the wide support high-five push up (feet on the ground) is 0.57s, which is the shortest among the four athletes. Athlete C took 0.65s to complete the broad support high-five push up (feet on the ground) movement, which was the longest time among the four athletes.

In terms of the time it took to push up with wide support high-five push-ups (feet 25 cm above the ground) (table 49), the average time for intermediate level athletes to push up with wide support high-five push-ups (feet 25 cm above the ground) was 0.61s, and the standard deviation was 0.06s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 25cm above the ground) is very similar, and the time of athlete A to complete the wide support high-five push up (feet 25cm above the ground) is 0.53s, which is the shortest among the four athletes. Athlete D took 0.66 seconds to complete the broad support high-five push up (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time taken to push up from the wide-supported high-five push up (feet 30 cm above the ground) (table 49), the average time for intermediate level athletes to complete the wide-supported high-five push up (feet 30 cm above the ground) is 0.56s, and the standard deviation is 0.06s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 30cm higher than the ground) is very similar, and the time of athlete A to complete the wide support high-five push up (feet 30cm higher than the ground) is 0.50s, which is the shortest among the four athletes. Athlete D took 0.63s to complete the broad support high-five push up (feet 30 cm above the ground) movement, which was the longest time of the four athletes.

In terms of the time it took to push up with wide support high-five push-ups (feet 40 cm above the ground) (table 49), the average time for intermediate level athletes to push up with wide support high-five push-ups (feet 40 cm above the ground) was 0.61s, and the standard deviation was 0.07s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 40cm higher than the ground) is very similar, and the time of athlete B to complete the wide support high-five push up (feet 40cm higher than the ground) is 0.51s, which is the shortest among the four athletes. Athlete C and D took 0.65 seconds to complete the broad support high-five push up (feet 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took to push up with wide support high-five push-ups (feet 50 cm above the ground) (table 49), the average time for intermediate level athletes to push up with wide support high-five push-ups (feet 50 cm above the ground) was 0.62s, and the standard deviation was 0.01s. The four athletes who participated in the test took very similar time to complete the wide support high-five push up (feet 50cm above the ground), and the time for athlete D to complete the wide support high-five push up (feet 50cm above the ground) was 0.61s, which was the shortest among the four athletes. Athlete B and C took 0.63 seconds to complete the broad support high-five push up (feet 50 cm above the ground) movement, which was the longest time of the four athletes.

2.2.1.4 Time characteristics of high-five push-ups in the air stage

(1) Standard support for different loads of high-five push-ups in the air stage

Table 50 Statistical table of the time taken by intermediate level athletes to complete Standard support high-five push-ups in the air (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.42	0.26	0.3	0.23	0.29
B	0.46	0.41	0.32	0.34	0.3
C	0.43	0.27	0.31	0.23	0.31
D	0.39	0.4	0.33	0.35	0.28
$\bar{X} \pm S$	0.43±0.03	0.34±0.08	0.32±0.01	0.29±0.07	0.30±0.01

According to the time taken to complete the air lift of the standard supported high-five push-up (with both feet on the ground) (table 50), the average time for intermediate level athletes to complete the air lift of the standard supported high-five push-up is 0.43s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet on the ground) is very close, and the time of athlete D to complete the standard

support high-five push-up movement (feet on the ground) is 0.39s, which is the shortest among the four athletes. Athlete B took 0.46s to complete the standard support high-five push-up movement (feet on the ground), which was the longest time among the four athletes.

Judging from the time taken to complete the air lift of the standard supported high-five push-up (both feet are 25 cm above the ground) (table 50), the average time for intermediate level athletes to complete the air lift of the standard supported high-five push-up is 0.34s, and the standard deviation is 0.08s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 25cm above the ground) is very similar, and the time of athlete A to complete the standard support high-five push-up movement (feet 25cm above the ground) is 0.26s, which is the shortest among the four athletes. Athlete B took 0.41s to complete the standard support high-five push-up (feet 25 cm above the ground), which was the longest time among the four athletes.

From the perspective of the time taken to complete the air lift of the standard supported high-five push-up (both feet are 30 cm above the ground) (table 50), the average time for intermediate level athletes to complete the air lift of the standard supported high-five push-up is 0.32s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 30cm higher than the ground) is very similar, and the time of athlete A to complete the standard support high-five push-up movement (feet 30cm higher than the ground) is 0.3s, which is the shortest among the four athletes. Athlete D took 0.33s to complete the standard support high-five push-up movement (feet 30 cm above the ground), which was the longest time among the four athletes.

From the perspective of the time taken to complete the air lift of the standard supported high-five push-up (both feet are 40 cm higher than the ground) (table 50), the average time for intermediate level athletes to complete the air lift of the standard supported high-five push-up is 0.29s, and the standard deviation is 0.07s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 40cm higher than the ground) was very similar, and the time of athlete A and C to complete the standard support high-five push-up movement

(feet 40cm higher than the ground) was 0.23s, which was the shortest among the four athletes. Athlete D took 0.35s to complete the standard support high-five push-up movement (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time it takes to push up from the standard supported high-five push up (feet 50 cm above the ground) (see 50), the average time for intermediate athletes to complete the standard supported high-five push up is 0.30s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 50cm above the ground) is very similar, and the time of athlete A to complete the standard support high-five push-up movement (feet 50cm above the ground) is 0.29s, which is the shortest among the four athletes. Athlete C took 0.31s to complete the standard support high-five push-up movement (feet 50 cm above the ground), which was the longest time among the four athletes.

(2) The use of wide support for different loads of high-five push-ups in the air stage

Table 51 Statistical table of the time taken by intermediate level athletes to complete the Wide support high-five push-up (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.46	0.22	0.28	0.28	0.3
B	0.59	0.41	0.3	0.24	0.27
C	0.62	0.22	0.29	0.28	0.31
D	0.64	0.42	0.31	0.25	0.3
$\bar{X} \pm S$	0.58±0.08	0.32±0.11	0.30±0.01	0.26±0.02	0.30±0.02

In terms of the time taken to complete the high-five push-up with wide support (both feet on the ground) (table 51), the average time taken for intermediate

athletes to complete the high-five push-up with wide support was 0.58s, and the standard deviation was 0.08s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet on the ground) was very similar, and the time of athlete A to complete the wide-supported high-five push-up movement (feet on the ground) was 0.46s, which was the shortest among the four athletes. Athlete D took 0.64s to complete the wide support high-five push-up (feet on the ground), which was the longest time among the four athletes.

In terms of the time taken to complete a wide-supported push-up (feet 25 cm above the ground) (table 51), the average time for intermediate level athletes to complete a wide-supported push-up is 0.32s, and the standard deviation is 0.11s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 25cm higher than the ground) is very similar, and the time of athlete A and D to complete the wide-supported high-five push-up movement (feet 25cm higher than the ground) is 0.22s, which is the shortest among the four athletes. Athlete D took 0.42s to complete the wide support high-five push-up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

In terms of the time taken to complete a wide-supported push-up (feet 30 cm above the ground) (table 51), the average time for intermediate level athletes to complete a wide-supported push-up is 0.30s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 30cm higher than the ground) is very similar, and the time of athletes A to complete the wide-supported high-five push-up movement (feet 30cm higher than the ground) is 0.28s, which is the shortest among the four athletes. Athlete D took 0.31s to complete the wide support high-five push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time taken to complete a wide-supported push-up (feet 40 cm above the ground) (table 51), the average time for intermediate level athletes to complete a wide-supported push-up is 0.26s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 40cm higher than the ground) is very similar, and the time of athletes B to complete the wide-supported high-five push-up movement (feet 40cm

higher than the ground) is 0.24s, which is the shortest among the four athletes. Athlete A and C took 0.28s to complete the wide support high-five push-up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

In terms of the time taken to push up from the wide-supported push-up (feet 50 cm above the ground) (table 51), the average time for intermediate level athletes to complete the wide-supported push-up is 0.30s, and the standard deviation is 0.02s. The four athletes who participated in the test took very similar time to complete the wide-supported high-five push-up movement (feet 50cm above the ground), in which athletes B took 0.27s to complete the wide-supported high-five push-up movement (feet 50cm above the ground), which was the shortest time among the four athletes. Athlete C took 0.31s to complete the wide support high-five push-up (feet 50 cm above the ground) movement, which was the longest time among the four athletes.

2.2.2 Speed characteristics

2.2.2.1 Peak velocity characteristics of shoulder joint in the stage of downward flexion

Table 52 The peak of shoulder joint speed in standard support push-up for intermediate level athletes (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.754	0.566	0.581	0.734	0.785±0.099
	Right shoulder joint	0.657	0.523	0.548	0.617	0.712±0.062
25cm	Left shoulder joint	0.786	0.778	0.921	0.726	0.884±0.036
	Right shoulder joint	0.872	0.722	0.767	0.792	0.896±0.063
30cm	Left shoulder joint	0.860	0.906	0.961	0.760	0.971±0.085
	Right shoulder joint	0.849	0.781	0.846	0.769	0.910±0.042
40cm	Left shoulder joint	0.759	0.821	0.876	0.699	0.906±0.076
	Right shoulder joint	0.783	0.825	0.870	0.743	0.922±0.055
50cm	Left shoulder joint	0.767	1.085	1.120	0.747	1.065±0.200
	Right shoulder joint	0.909	1.072	1.097	0.899	1.129±0.105

From the difference of peak shoulder joint speed in the stage of push-ups with standard support with feet on the ground (0cm) and the stage of bending arms with

downward flexion (Table 52), the average speed and standard deviation of the left shoulder joint of the intermediate level athletes are 0.785m/s and 0.099m/s when they complete the stage of bending arms with standard support push-ups. The mean velocity of the right shoulder joint was 0.712m/s, and the standard deviation was 0.062m/s. Intermediate level athletes in the completion of standard support push-ups (feet height 0 cm) in the stage of bending the arms of the downward flexion features: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (25cm) and the stage of downward flexural arms flexural (Table 52), the average speed and standard deviation of left shoulder joint of intermediate level athletes in the stage of downward flexural arms flexural with standard support push-up are 0.884m/s and 0.036m/s. The mean velocity of the right shoulder joint was 0.896m/s, and the standard deviation was 0.036m/s. Intermediate level athletes in the standard support push-ups (feet height of 25 cm) in the stage of bending the arms of the downward flexure features: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the right shoulder joint is greater than the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (30cm) and the stage of downward flexion, the average speed and standard deviation of the left shoulder joint of intermediate level athletes are 0.971m/s and 0.085m/s in the stage of downward flexion with standard support push-up (Table 52). The mean velocity of the right shoulder joint was 0.910m/s, and the standard deviation was 0.042m/s. Intermediate level athletes in the completion of standard support push-ups (feet height of 30 cm) in the stage of bending the arms of the downward flexion characteristics are: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in the stage of push-ups with standard support with both feet on the ground (40cm) and in the stage of

bending arms with down support (Table 52), the average speed and standard deviation of the left shoulder joint of intermediate level athletes in the stage of bending arms with down support are 0.906m/s and 0.076m/s. The mean velocity of the right shoulder joint was 0.922m/s, and the standard deviation was 0.055m/s. Intermediate level athletes in the completion of standard support push-ups (feet height of 40 cm) in the stage of downward flexion of the arms are characterized by a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (50cm) and the stage of downward flexion, the average speed and standard deviation of the left shoulder joint of the intermediate level athletes in the stage of downward flexion with standard support push-up are 1.065m/s and 0.200m/s, respectively (Table 52). The mean velocity of the right shoulder joint was 1.129m/s, and the standard deviation was 0.105m/s. Intermediate level athletes in the completion of standard support push-ups (feet height of 50 cm) in the stage of bending the arms of the downward flexion characteristics are: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

Table 53 The peak of shoulder joint speed of intermediate level athletes in broad support push-up down flexion stage (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.941	0.813	0.926	0.802	0.883±0.073
	Right shoulder joint	1.010	0.803	0.995	0.792	0.913±0.118
25cm	Left shoulder joint	1.172	1.113	1.157	1.102	1.148±0.034
	Right shoulder joint	1.155	1.099	1.140	1.088	1.133±0.032
30cm	Left shoulder joint	1.060	1.159	1.045	1.148	1.114±0.059
	Right shoulder joint	1.096	1.181	1.081	1.170	1.143±0.051
40cm	Left shoulder joint	1.216	1.496	1.201	1.485	1.361±0.163
	Right shoulder joint	1.159	1.286	1.144	1.275	1.228±0.075
50cm	Left shoulder joint	1.147	1.188	1.132	1.177	1.173±0.026
	Right shoulder joint	1.111	1.166	1.096	1.155	1.144±0.034

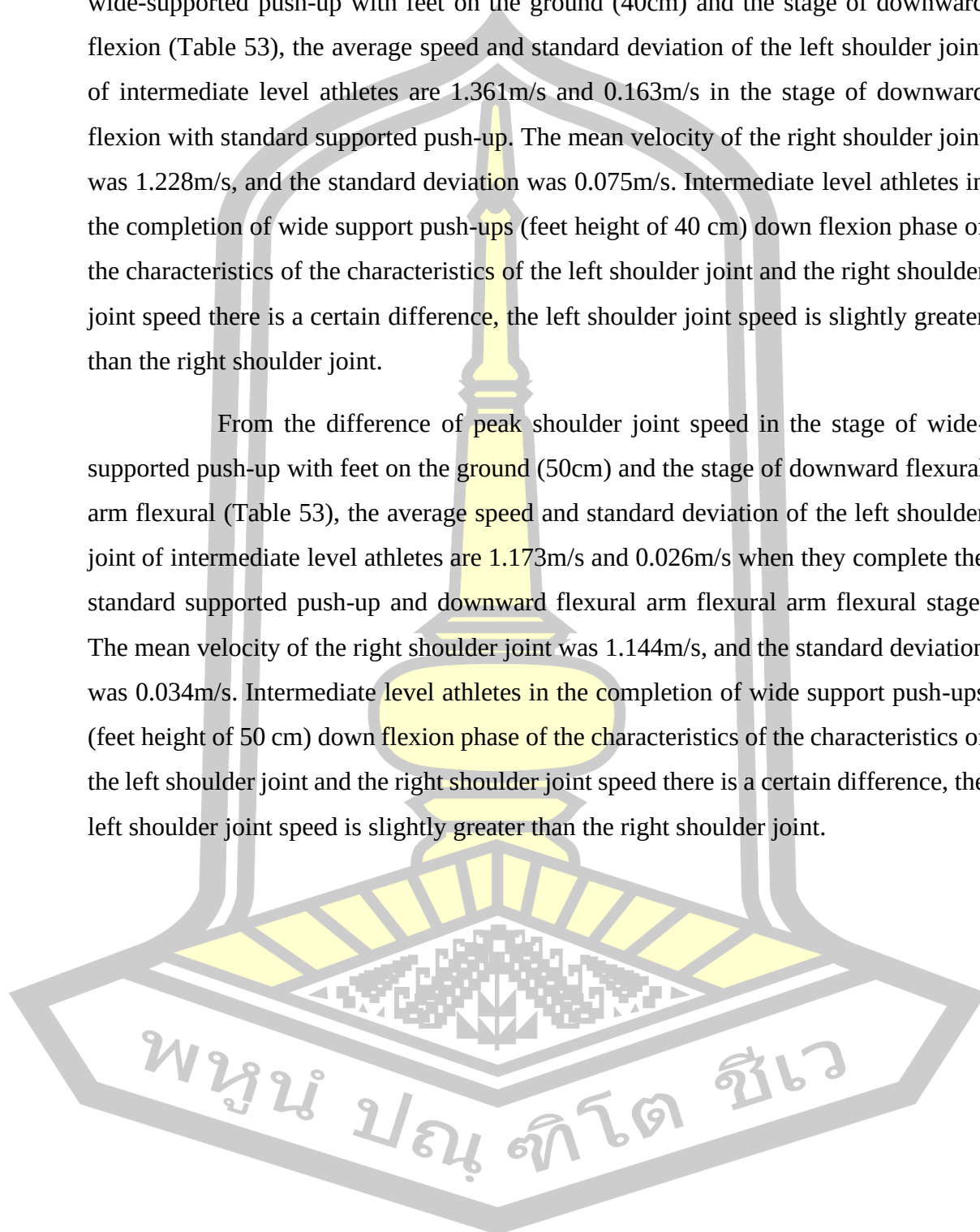
From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward flexion (Table 53), the average speed and standard deviation of the left shoulder joint of intermediate level athletes are 0.883m/s and 0.073m/s in the stage of downward flexion with wide-supported push-up. The mean velocity of the right shoulder joint was 0.0913/s, and the standard deviation was 0.118m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 0 cm) in the stage of bending the arms of the downward flexion characteristics of the left shoulder joint and the right shoulder joint speed there is a certain difference, the speed of the right shoulder joint is slightly greater than the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (25cm) and the stage of downward bending arms (Table 53), the average speed and standard deviation of the left shoulder joint of intermediate level athletes are 1.148m/s and 0.034m/s in the stage of downward bending arms of standard supported push-up. The mean velocity of the right shoulder joint was 1.133m/s, and the standard deviation was 0.032m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 25 cm) in the stage of bending the arms of the downward flexion characteristics are: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in the stage of wide-supported push-up with feet on the ground (30cm) and the stage of downward flexion (Table 53), the average speed and standard deviation of the left shoulder joint of intermediate level athletes are 1.114m/s and 0.059m/s in the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.143m/s, and the standard deviation was 0.051m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 30 cm) in the stage of bending the arms of the downward flexion characteristics are: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

According to the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (40cm) and the stage of downward flexion (Table 53), the average speed and standard deviation of the left shoulder joint of intermediate level athletes are 1.361m/s and 0.163m/s in the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.228m/s, and the standard deviation was 0.075m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 40 cm) down flexion phase of the characteristics of the characteristics of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (50cm) and the stage of downward flexural arm flexural (Table 53), the average speed and standard deviation of the left shoulder joint of intermediate level athletes are 1.173m/s and 0.026m/s when they complete the standard supported push-up and downward flexural arm flexural arm flexural stage. The mean velocity of the right shoulder joint was 1.144m/s, and the standard deviation was 0.034m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 50 cm) down flexion phase of the characteristics of the characteristics of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.



2.2.2.2 Peak velocity characteristics of shoulder joint in the upward pushing stage

Table 54 The peak of shoulder joint speed during the push-up phase of standard support for intermediate level athletes (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.903	0.869	0.879	0.888	0.885±0.015
	Right shoulder joint	0.851	0.849	0.859	0.836	0.849±0.010
25cm	Left shoulder joint	0.903	1.029	1.039	0.888	0.965±0.081
	Right shoulder joint	0.840	0.978	0.988	0.825	0.908±0.087
30cm	Left shoulder joint	1.027	1.017	1.027	1.012	1.021±0.007
	Right shoulder joint	0.998	0.959	0.969	0.983	0.977±0.017
40cm	Left shoulder joint	1.015	1.095	1.105	1.000	1.054±0.054
	Right shoulder joint	0.963	0.963	0.973	0.948	0.962±0.010
50cm	Left shoulder joint	1.062	1.308	1.318	1.047	1.184±0.149
	Right shoulder joint	0.934	1.246	1.256	0.919	1.089±0.188

From the difference of peak shoulder joint speed during the push-up stage with standard support push-ups with feet at 0cm on the ground (Table 54), the average speed and standard deviation of the left shoulder joint of the intermediate level athletes during the push-up stage with standard support push-ups are 0.885m/s and 0.015m/s respectively. The mean velocity of the right shoulder joint was 0.849m/s and the standard deviation was 0.010m/s. Intermediate level athletes in the completion of standard support push-ups (feet height of 0 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with both feet on the ground (25cm) and in push-up stage (Table 54), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-up stage with standard support are 0.965m/s and 0.081m/s. The mean velocity of the right shoulder joint was 0.908m/s, and the standard deviation was

0.087m/s. Intermediate level athletes in the completion of the standard support push up stage (feet height of 25 cm) the characteristics of the performance of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (30cm) and upward push stage (Table 54), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-ups with standard support are 1.021m/s and 0.007m/s respectively. The mean velocity of the right shoulder joint was 0.977m/s, and the standard deviation was 0.017m/s. Intermediate level athletes in the completion of the standard support push up stage (feet height of 30 cm) the characteristics of the performance of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with both feet on the ground (40cm) and in push-up stage (Table 54), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-up stage with standard support are 1.054m/s and 0.054m/s respectively. The mean velocity of the right shoulder joint was 0.962m/s, and the standard deviation was 0.010m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 40 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (50cm) and upward push stage (Table 54), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-ups with standard support are 1.184m/s and 0.149m/s, respectively. The mean velocity of the right shoulder joint was 1.089m/s, and the standard deviation was 0.188m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 50 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

Table 55 The peak of shoulder joint speed of intermediate level athletes in broad support push up stage (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.869	0.847	0.754	0.836	0.826±0.050
	Right shoulder joint	0.896	0.936	0.681	0.925	0.860±0.120
25cm	Left shoulder joint	0.802	1.049	0.787	1.038	0.919±0.144
	Right shoulder joint	0.780	1.174	0.765	1.163	0.970±0.229
30cm	Left shoulder joint	0.776	1.236	0.761	1.225	1.000±0.267
	Right shoulder joint	0.837	1.133	0.822	1.122	0.978±0.173
40cm	Left shoulder joint	0.883	1.235	0.788	1.224	1.013±0.231
	Right shoulder joint	0.865	0.997	0.831	0.986	0.920±0.084
50cm	Left shoulder joint	0.920	1.082	0.705	1.071	0.944±0.176
	Right shoulder joint	0.940	0.960	0.725	0.949	0.893±0.113

From the difference of peak shoulder joint speed in the stage of broad support push-up with feet on the ground (0cm) and upward push (Table 55), the average speed of the left shoulder joint and standard deviation of the left shoulder joint are 0.826m/s and 0.050m/s, and the average speed of the right shoulder joint are 0.860m/s for the intermediate level athletes in the stage of broad support push-up and upward push. The standard deviation is 0.120m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 0 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the speed of the right shoulder joint is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (25cm) and upward push stage (Table 52), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-ups with standard support are 0.919m/s and 0.144m/s respectively. The mean velocity of the right shoulder joint was 0.970m/s, and the standard deviation was 0.229m/s. Intermediate level athletes in the completion of wide support push-up (feet

height of 25 cm) push up stage features: left shoulder joint and right shoulder joint average speed there is a certain difference, the speed of the right shoulder joint is slightly greater than the left shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (30cm) and upward push stage (Table 52), the average speed and standard deviation of left shoulder joint of intermediate level athletes are 1.000m/s and 0.267m/s when they complete the upward push stage of standard support push-ups. The mean velocity of the right shoulder joint was 0.978m/s, and the standard deviation was 0.173m/s. Intermediate level athletes in the completion of the wide support push up stage (feet height of 30 cm) the characteristics of the performance of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (40cm) and upward push stage (Table 52), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-ups with standard support are 1.013m/s and 0.231m/s respectively. The mean velocity of the right shoulder joint was 0.920m/s, and the standard deviation was 0.084m/s. Intermediate level athletes in the completion of the wide support push up stage (feet height of 40 cm) the characteristics of the performance of the left shoulder joint and the right shoulder joint speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (50cm) and upward push stage (Table 52), the average speed and standard deviation of left shoulder joint of intermediate level athletes in push-ups with standard support are 0.944m/s and 0.176m/s respectively. The mean velocity of the right shoulder joint was 0.893m/s, and the standard deviation was 0.113m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 50 cm) push up stage features: the left shoulder joint and the right shoulder joint average speed there is a certain difference, the left shoulder joint speed is slightly greater than the right shoulder joint.

2.2.3 Elbow joint Angle and shoulder joint angular velocity characteristics

2.2.3.1 Angle characteristics of the lowest elbow joint of the lower flexion arm

(1) Standard support push-up downward flexion elbow Angle

Table 56 Intermediate level athletes standard support push-up down flexion arm lowest elbow Angle ($^{\circ}$)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	31.36	32.36	38.69	33.5	33.98 $\pm$ 3.26
	Right elbow joint	34.07	34.31	39.27	34.52	35.54 $\pm$ 2.49
25cm	Left elbow joint	31.67	33.05	39.21	34.43	34.59 $\pm$ 3.28
	Right elbow joint	34.28	36.02	40.19	35.64	36.53 $\pm$ 2.55
30cm	Left elbow joint	33.47	34.64	41.47	44.27	38.46 $\pm$ 5.24
	Right elbow joint	35.48	38.51	43.19	45.42	40.65 $\pm$ 4.49
40cm	Left elbow joint	33.58	34.76	41.47	44.33	38.54 $\pm$ 5.20
	Right elbow joint	35.6	38.63	43.30	45.42	40.74 $\pm$ 4.45
50cm	Left elbow joint	35.7	36.86	42.59	45.49	40.16 $\pm$ 4.66
	Right elbow joint	37.81	38.29	45.40	46.31	41.95 $\pm$ 4.53

From the difference of peak elbow Angle of the lowest point in push-ups with feet on the ground (0cm) and the lowest point in the downward flexion stage (Table 56), the average Angle of the left elbow joint of the intermediate level athletes is 33.98 $^{\circ}$ and the standard deviation is 3.26 $^{\circ}$ in the lowest point in the downward flexion stage after completing the standard push-ups. The mean Angle of the right elbow joint was 35.54 $^{\circ}$ and the standard deviation was 2.49 $^{\circ}$. Intermediate level athletes in the standard support push-up (feet height 0 cm) in the lower bend phase of the lowest characteristic is: the right elbow joint Angle is greater than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of push-up with standard support with both feet 25 cm higher than the ground (Table 56), the average Angle and standard deviation of the left elbow joint of

the intermediate level athletes are 34.59° and 3.28° respectively at the lowest point in the stage of push-up with standard support and bend arm flexion (Table 53). The mean Angle of the right elbow joint was 36.53° and the standard deviation was 2.55° . Intermediate level athletes in the standard support push-up (feet height of 25 cm) in the lower bend phase of the lowest characteristic is: the right elbow joint Angle is greater than the left elbow joint.

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 30cm higher than the ground (Table 56), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 38.46° and 5.24° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 53). The mean Angle of the right elbow joint was 40.65° and the standard deviation was 4.49° . Intermediate level athletes in the standard support push-up (feet height of 30 cm) in the lower bend phase of the lowest characteristic is: the right elbow joint Angle is greater than the left elbow joint.

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 40 cm higher than the ground (Table 56), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 38.54° and 5.20° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 53). The mean Angle of the right elbow joint was 40.74° and the standard deviation was 4.45° . Intermediate level athletes in the standard support push-up (feet height of 40 cm) in the lower bend phase of the lowest characteristic is: the right elbow joint Angle is greater than the left elbow joint.

According to the difference in peak elbow Angle of the lowest point in push-ups with feet 50 cm higher than the ground and the lowest point in the downward flexion stage (Table 56), the average Angle of the left elbow joint of the intermediate level athletes is 40.16° and the standard deviation is 4.66° at the lowest point in the downward flexion stage when they complete the standard push-ups. The mean Angle of the right elbow joint was 41.95° and the standard deviation was 4.53° . Intermediate level athletes in the standard support push-up (feet height of 50 cm) in the lower bend phase of the lowest characteristic is: the right elbow joint Angle is greater than the left elbow joint.

(2) Wide support push up downward flexion arm elbow joint Angle

Table 57 Intermediate level athletes wide support push up down flexion arm low elbow joint Angle ($^{\circ}$)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	30.27	31.15	37.37	32.17	32.74 $\pm$ 3.18
	Right elbow joint	32.98	33.1	37.95	33.19	34.31 $\pm$ 2.43
25cm	Left elbow joint	30.55	31.74	38.03	32.99	33.33 $\pm$ 3.29
	Right elbow joint	33.16	34.71	39.01	34.2	35.27 $\pm$ 2.58
30cm	Left elbow joint	32.35	33.44	40.26	43.08	37.28 $\pm$ 5.21
	Right elbow joint	34.36	37.31	41.88	44.23	39.45 $\pm$ 4.44
40cm	Left elbow joint	32.48	33.44	40.19	43.01	37.28 $\pm$ 5.13
	Right elbow joint	34.49	37.31	41.88	44.1	39.45 $\pm$ 4.35
50cm	Left elbow joint	34.46	35.66	41.28	44.17	38.89 $\pm$ 4.61
	Right elbow joint	36.57	37.09	44.09	44.99	40.69 $\pm$ 4.47

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported push-up with both feet on the ground (0cm) and the stage of downward flexion (Table 57), the average Angle of the left elbow joint is 32.74 $^{\circ}$, the standard deviation is 3.18 $^{\circ}$, and the average Angle of the right elbow joint is 34.31 $^{\circ}$. The standard deviation is 2.43 $^{\circ}$. The lowest point of the intermediate level athletes in the lower bend arm stage after completing a wide support push-up (feet height 0 cm) is characterized by the Angle of the right elbow joint being greater than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide support push-up with feet 25 cm higher than the ground (Table 57), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 33.33 $^{\circ}$ and 3.29 $^{\circ}$ respectively at the lowest point in the stage of wide push-up and downward flexion. The mean Angle of the right elbow joint was 35.27 $^{\circ}$ and the standard deviation was 2.58 $^{\circ}$. The lowest point of a mid-level athlete in a broad

support push-up (feet 25 cm high) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in push-ups with wide support height 30cm higher than the ground and the lower bend arm stage (Table 57), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 37.28° and 5.21° at the lowest point in the lower bend arm stage when they complete wide push-ups. The mean Angle of the right elbow joint was 39.45° and the standard deviation was 4.44° . The lowest point of a mid-level athlete in a broad support push-up (feet height 30 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in push-ups with wide support height 40cm higher than the ground and the lower bend arm stage (Table 57), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 37.28° and 5.13° respectively at the lowest point in the lower bend arm stage when they complete wide push-ups. The mean Angle of the right elbow joint was 39.45° and the standard deviation was 4.35° . The lowest point of a mid-level athlete in a wide-supported push-up (feet 40 cm high) is the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide-supported push-up with feet 50 cm higher than the ground (Table 57), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 38.89° and 4.61° respectively at the lowest point in the stage of wide-supported push-up and downward flexural arm flexural. The mean Angle of the right elbow joint was 40.69° and the standard deviation was 4.47° . The lowest point of a mid-level athlete in a broad support push-up (feet height 50 cm) is characterized by a greater Angle of the right elbow joint than the left elbow joint.

(3) Standard support high-five push-ups downward flexion arm elbow Angle

Table 58 Intermediate level athletes standard support high-five push-up down flexion arm low elbow joint Angle ($^{\circ}$)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	33.38	34.58	41.02	35.94	36.23 $\pm$ 3.36
	Right elbow joint	36.09	36.53	41.6	36.96	37.79 $\pm$ 2.56
25cm	Left elbow joint	33.77	35.19	41.55	36.76	36.82 $\pm$ 3.38
	Right elbow joint	36.38	38.16	42.53	37.97	38.76 $\pm$ 2.64
30cm	Left elbow joint	35.57	36.87	43.83	46.72	40.75 $\pm$ 5.39
	Right elbow joint	37.58	40.74	45.55	47.87	42.94 $\pm$ 4.64
40cm	Left elbow joint	35.59	36.77	43.83	46.78	40.74 $\pm$ 5.43
	Right elbow joint	37.60	40.74	45.55	47.87	42.94 $\pm$ 4.64
50cm	Left elbow joint	37.7	39.09	44.93	47.94	42.42 $\pm$ 4.84
	Right elbow joint	39.81	40.52	47.74	48.76	44.21 $\pm$ 4.70

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of standard high-five push-ups with feet on the ground (0cm) and the stage of downward flexion (Table 58), the average Angle of the left elbow joint is 36.23 $^{\circ}$ and the standard deviation is 3.36 $^{\circ}$ for intermediate level athletes in the stage of completing standard high-five push-ups and downward flexion. The mean Angle of the right elbow joint was 37.79 $^{\circ}$ and the standard deviation was 2.56 $^{\circ}$. Intermediate level athletes in the standard support high-five push-ups (feet height 0 cm) the lowest point of the downward flexion stage is characterized by: the Angle of the right elbow joint is greater than the left elbow joint.

According to the difference in peak elbow Angle of the lowest point in the stage of push-ups with standard support with feet 25 cm higher than the ground (Table 58), the average Angle of the left elbow joint and standard deviation of the left elbow

joint are 36.82° and 3.38° respectively for intermediate level athletes in the stage of push-ups with standard support with feet 25 cm higher than the ground. The mean Angle of the right elbow joint was 38.76° and the standard deviation was 2.64° . Intermediate level athletes in the standard support high-five push-ups (feet height of 25 cm) the lowest point of the downward flexion stage is characterized by the right elbow joint Angle is greater than the left elbow joint.

According to the difference in peak elbow Angle of the lowest point in the stage of push-ups with standard support with feet 30cm higher than the ground and the stage of bending arms with downward flexion (Table 58), the average Angle of the left elbow joint of the intermediate level athletes is 40.75° and the standard deviation is 5.39° at the lowest point in the stage of bending arms with downward flexion after completing standard push-ups with high five. The mean Angle of the right elbow joint was 42.94° and the standard deviation was 4.64° . Intermediate level athletes in the standard support high-five push-ups (feet height of 30 cm) the lowest point of the downward flexion stage is characterized by the right elbow joint Angle is greater than the left elbow joint.

From the difference of peak elbow Angle of the lowest point in the stage of push-ups with standard support with feet 40 cm higher than the ground (Table 58), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 40.74° and 5.43° respectively at the lowest point in the stage of push-ups with standard support with feet 40 cm higher than the ground. The mean Angle of the right elbow joint was 42.94° and the standard deviation was 4.64° . Intermediate level athletes in the standard support high-five push-ups (feet height of 40 cm) the lowest point of the downward flexion stage is characterized by the right elbow joint Angle is greater than the left elbow joint.

According to the difference in peak elbow Angle of the lowest point in the stage of push-ups with standard support with feet 50 cm higher than the ground (Table 58), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 42.42° and 4.84° respectively at the lowest point in the stage of push-ups with standard support with feet 50 cm higher than the ground. The mean Angle of the right elbow joint was 44.21° and the standard deviation was 4.70° . Intermediate

level athletes in the standard support high-five push up (feet height of 50 cm) in the lower bend phase of the lowest characteristic is: the Angle of the right elbow joint is greater than the left elbow joint.

(4) Wide support high-five push-ups down flexion arm lowest elbow joint Angle

Table 59 Intermediate level athletes wide support high five push up lower bend arm low elbow joint Angle (°)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	32.37	33.57	39.94	34.84	35.18±3.33
	Right elbow joint	35.08	35.52	40.55	35.86	36.75±2.55
25cm	Left elbow joint	32.73	34.16	40.52	35.66	35.77±3.39
	Right elbow joint	35.34	37.13	45.2	36.87	38.64±4.45
30cm	Left elbow joint	34.53	35.81	42.73	45.62	39.67±5.36
	Right elbow joint	36.54	39.68	44.55	46.77	41.89±4.63
40cm	Left elbow joint	34.58	35.71	42.73	45.73	39.69±5.41
	Right elbow joint	36.59	39.68	44.45	46.82	41.89±4.61
50cm	Left elbow joint	36.64	38.08	43.85	46.84	41.35±4.81
	Right elbow joint	38.75	39.51	46.66	47.66	43.15±4.66

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet on the ground (0cm) and the stage of downward flexion (Table 59), the average Angle of the left elbow joint is 35.18° and the standard deviation is 3.33° for intermediate level athletes in the stage of downward flexion when they complete wide-supported high-five push-ups. The mean Angle of the right elbow joint was 36.75° and the standard

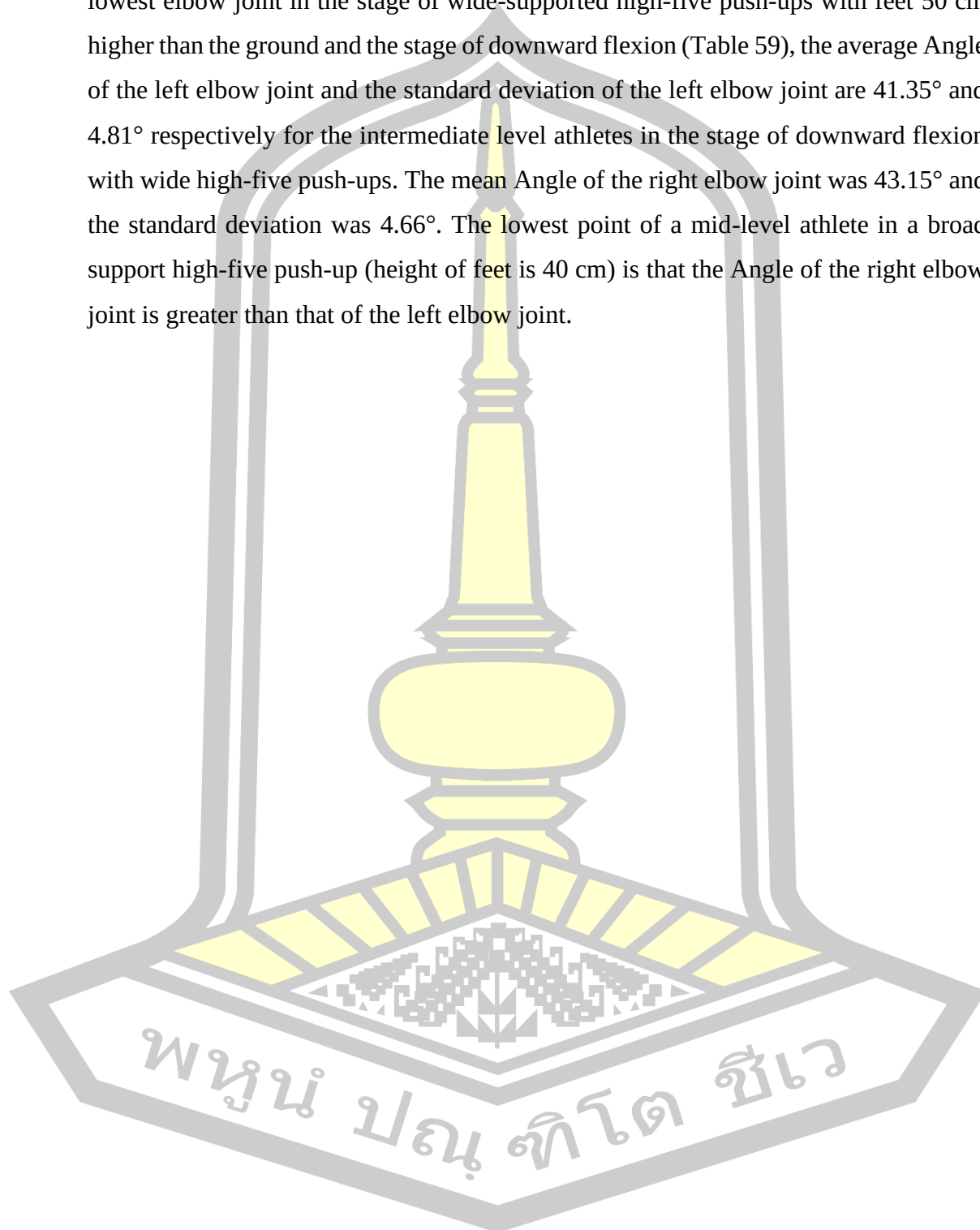
deviation was 2.55° . The lowest point of the intermediate level athletes who complete the wide-supported high-five push up (feet height 0 cm) is characterized by the right elbow joint Angle is greater than the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with both feet 25 cm higher than the ground and the stage of downward flexion (Table 59), the average Angle of the left elbow joint and the standard deviation of the left elbow joint are 35.77° and 3.39° respectively for the intermediate level athletes in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 38.64° and the standard deviation was 4.45° . The lowest point of a mid-level athlete in a broad support high-five push-up (with a height of 25 cm) is that the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet 30 cm higher than the ground and the stage of downward flexion (Table 59), the average Angle of the left elbow joint and the standard deviation of the left elbow joint are 39.67° and 5.36° respectively for the intermediate level athletes at the lowest point in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 41.89° and the standard deviation was 4.63° . The lowest point of the intermediate level athletes who complete the broad support high-five push up (feet height of 30 cm) is that the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported push-ups with feet 40 cm higher than the ground and the stage of downward flexion (Table 59), the average Angle and standard deviation of the left elbow joint of the intermediate level athletes are 39.69° and 5.41° respectively in the stage of completing wide-supported push-ups and downward flexion. The mean Angle of the right elbow joint was 41.89° and the standard deviation was 4.61° . The lowest point of a mid-level athlete in a broad support high-five push-up (height of feet is 40 cm) is that the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet 50 cm higher than the ground and the stage of downward flexion (Table 59), the average Angle of the left elbow joint and the standard deviation of the left elbow joint are 41.35° and 4.81° respectively for the intermediate level athletes in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 43.15° and the standard deviation was 4.66° . The lowest point of a mid-level athlete in a broad support high-five push-up (height of feet is 40 cm) is that the Angle of the right elbow joint is greater than that of the left elbow joint.



2.2.3.2 Peak angular velocity characteristics of shoulder joint in the stage of downward flexion

Table 60 The peak angular velocity of shoulder joint in the stage of standard support push-up for intermediate level athletes ($^{\circ}/s$)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	419.668	410.338	407.018	404.738	431.84 $\pm$ 6.32
	Right shoulder joint	440.979	431.349	428.129	424.949	452.75 $\pm$ 6.68
25cm	Left shoulder joint	493.179	484.849	480.529	478.549	506.33 $\pm$ 6.75
	Right shoulder joint	590.235	579.805	576.985	575.105	602.86 $\pm$ 6.81
30cm	Left shoulder joint	641.178	630.948	626.228	623.348	652.58 $\pm$ 6.87
	Right shoulder joint	590.741	580.311	577.091	574.311	602.01 $\pm$ 6.94
40cm	Left shoulder joint	522.411	511.781	507.461	505.881	533.56 $\pm$ 7.01
	Right shoulder joint	502.785	490.855	488.735	486.155	513.81 $\pm$ 7.07
50cm	Left shoulder joint	567.215	555.085	552.965	549.385	578.11 $\pm$ 7.14
	Right shoulder joint	558.285	545.955	543.835	540.355	569.06 $\pm$ 7.21

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support (0cm) on the ground and in the stage of bending arms with down support (Table 60), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of bending arms with down support push-ups are 431.84m/s and 6.32m/s respectively. The mean angular velocity of the right shoulder joint was 452.75/s and the standard deviation was 6.68m/s. Intermediate level athletes in the standard support push-ups (feet height of 0 cm) in the stage of bending the arms of the downward flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of standard support push-up with feet on the ground (25cm) and in the stage of downward flexion (Table 60), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes are 506.33m/s and 6.75m/s in the stage of downward flexion with standard support push-up. The mean angular velocity of the right shoulder joint was 602.86m/s and the standard deviation was 6.81m/s. Intermediate level athletes in the standard support push-ups (feet height of 25 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (30cm) and in the stage of bending arms with downward support (Table 60), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of bending arms with downward support push-ups are 652.58m/s and 6.87m/s respectively. The mean angular velocity of the right shoulder joint was 602.01m/s and the standard deviation was 6.94m/s. Intermediate level athletes in the standard support push-ups (feet height of 30 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (40cm) and in the stage of bending arms with downward support (Table 60), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of bending arms with downward support push-ups are 533.56m/s and 7.01m/s respectively. The mean angular velocity of the right shoulder joint was 513.81m/s, and the standard deviation was 7.07m/s. Intermediate level athletes in the standard support push-ups (feet height of 40 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (50cm) and in the stage of bending arms with down support (Table 60), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of bending arms with down support push-ups are 578.11m/s and 7.14m/s respectively. The mean angular velocity of the right shoulder joint was 569.06m/s and the standard deviation was 7.21m/s. Intermediate level athletes in the standard support push-ups (feet height of 50 cm) in the stage of bending the arms down flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

Table 61 The peak angular velocity of shoulder joint of intermediate level athletes in the stage of broad support push-up and bend arms ($^{\circ}/s$)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	670.81	658.09	655.88	651.60	677.17 $\pm$ 9.33
	Right shoulder joint	503.54	486.52	485.81	481.73	506.85 $\pm$ 9.55
25cm	Left shoulder joint	590.41	571.09	572.48	568.50	593.70 $\pm$ 9.58
	Right shoulder joint	570.17	551.05	552.04	548.16	573.43 $\pm$ 9.61
30cm	Left shoulder joint	719.66	703.24	698.83	697.55	722.89 $\pm$ 9.65
	Right shoulder joint	723.06	706.84	702.03	700.85	726.27 $\pm$ 9.69
40cm	Left shoulder joint	784.08	768.06	765.35	761.77	787.26 $\pm$ 9.74
	Right shoulder joint	786.99	771.37	768.06	764.58	790.20 $\pm$ 9.77
50cm	Left shoulder joint	813.24	797.82	796.61	793.23	818.92 $\pm$ 9.82
	Right shoulder joint	811.20	794.98	794.57	790.99	816.63 $\pm$ 9.92

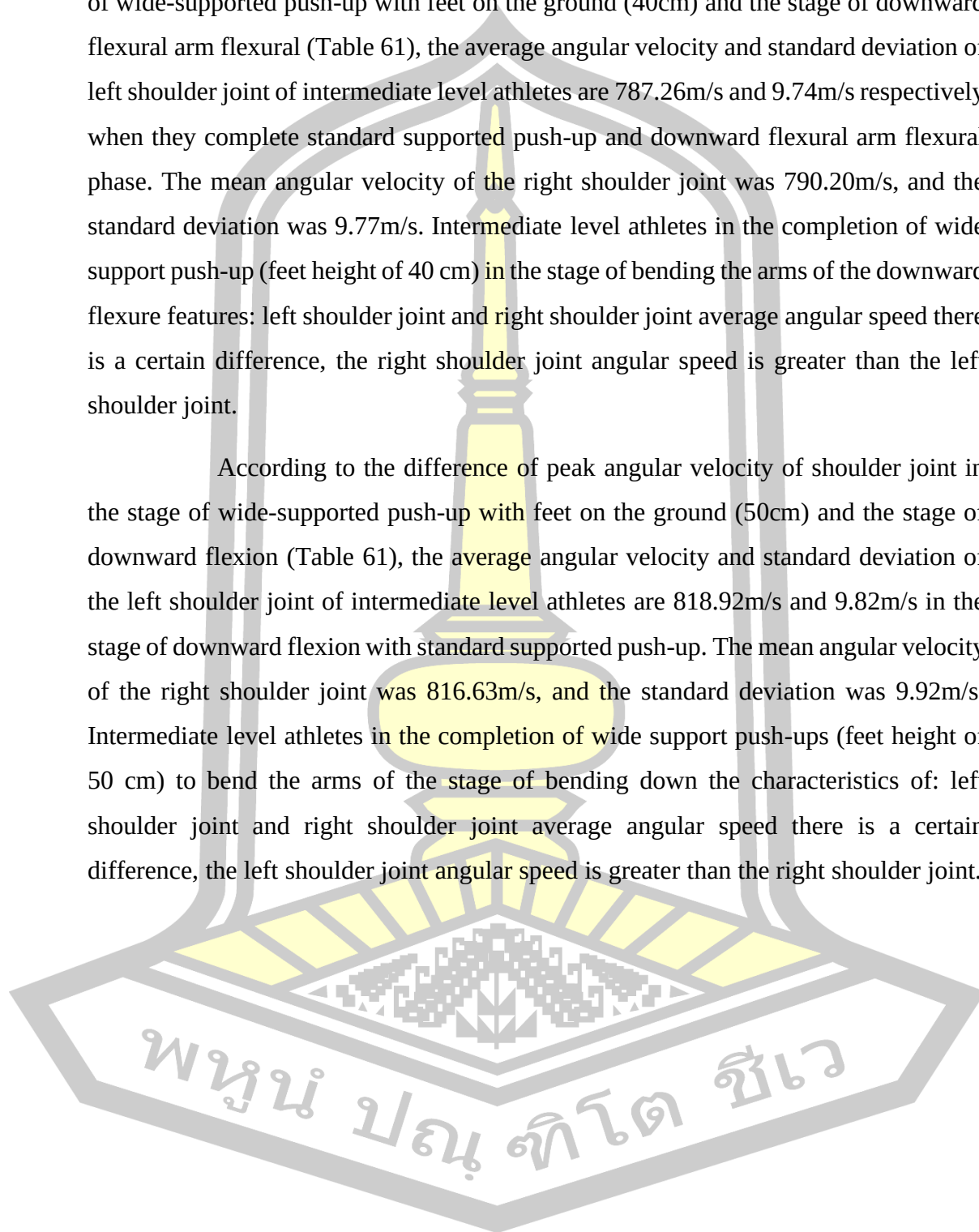
From the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward flexural arm flexural (Table 61), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes are 677.17m/s and 9.33m/s in the stage of downward flexural arm flexural with wide-supported push-up. The mean angular velocity of the right shoulder joint was 506.85/s and the standard deviation was 9.55m/s. Intermediate level athletes in the completion of wide support push-ups (feet height 0 cm) in the stage of bending the arms of the downward flexure features: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (25cm) and the stage of downward flexion (Table 61), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of downward flexion with standard supported push-up are 593.70m/s and 9.58m/s respectively. The mean angular velocity of the right shoulder joint was 573.43m/s and the standard deviation was 9.61m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 25 cm) to bend the arms of the stage of bending down the characteristics of: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (30cm) and the stage of downward flexion (Table 61), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of downward flexion with standard supported push-up are 722.89m/s and 9.65m/s respectively. The mean angular velocity of the right shoulder joint was 726.27m/s and the standard deviation was 9.69m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 30 cm) in the stage of bending the arms of the downward flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (40cm) and the stage of downward flexural arm flexural (Table 61), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes are 787.26m/s and 9.74m/s respectively when they complete standard supported push-up and downward flexural arm flexural phase. The mean angular velocity of the right shoulder joint was 790.20m/s, and the standard deviation was 9.77m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 40 cm) in the stage of bending the arms of the downward flexure features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (50cm) and the stage of downward flexion (Table 61), the average angular velocity and standard deviation of the left shoulder joint of intermediate level athletes are 818.92m/s and 9.82m/s in the stage of downward flexion with standard supported push-up. The mean angular velocity of the right shoulder joint was 816.63m/s, and the standard deviation was 9.92m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 50 cm) to bend the arms of the stage of bending down the characteristics of: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.



2.2.3.3 Peak angular velocity characteristics of shoulder joint in the upward pushing stage

Table 62 The peak angular velocity of shoulder joint in the push-up phase of standard support for intermediate level athletes ($^{\circ}/s$)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	444.991	432.311	431.431	429.181	453.2±6.79
	Right shoulder joint	609.445	596.465	595.685	593.535	617.51±6.87
25cm	Left shoulder joint	409.606	397.726	394.346	393.596	417.54±6.94
	Right shoulder joint	369.498	357.418	354.038	353.388	377.31±7.02
30cm	Left shoulder joint	704.861	693.881	691.801	689.951	713.85±7.09
	Right shoulder joint	868.713	857.533	855.453	853.703	877.58±7.16
40cm	Left shoulder joint	694.023	680.043	679.263	677.613	701.46±7.24
	Right shoulder joint	665.242	652.562	650.282	648.732	672.93±7.22
50cm	Left shoulder joint	537.222	524.342	520.762	520.612	544.46±7.37
	Right shoulder joint	658.215	645.135	641.555	641.505	665.33±7.45

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet at 0cm on the ground (Table 62), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes during the push-up stage with standard support push-ups are 453.2m/s and 6.79m/s respectively. The mean angular velocity of the right shoulder joint was 617.51/s and the standard deviation was 6.87m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 0 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet on the ground (25cm) and the upward push stage (Table 62), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes during the push-up stage with standard support push-ups are 417.54m/s and 6.94m/s respectively. The mean angular velocity of the right shoulder joint was 377.31m/s, and the standard deviation was 7.02m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 25 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with both feet on the ground (30cm) and the upward push stage (Table 62), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes during the push-up stage with standard support push-ups are 713.85m/s and 7.09m/s respectively. The mean angular velocity of the right shoulder joint was 877.58m/s and the standard deviation was 7.16m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 30 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with both feet on the ground (40cm) and the upward push stage (Table 62), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes during the push-up stage with standard support push-ups are 701.46m/s and 7.24m/s respectively. The mean angular velocity of the right shoulder joint was 672.93m/s and the standard deviation was 7.22m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 40 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet at 50cm on the ground (Table 62), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes during the push-up stage with standard support push-ups are 544.46m/s and 7.37m/s respectively. The mean angular velocity of the right shoulder joint was 665.33m/s and the standard deviation was 7.45m/s. Intermediate level athletes in the completion of the standard support push-up (feet height of 50 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

Table 63 The peak angular velocity of shoulder joint of intermediate level athletes in the stage of broad support push up (°/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	515.74	503.77	501.26	499.69	522.14±7.90
	Right shoulder joint	459.83	445.76	444.15	442.48	465.08±8.59
25cm	Left shoulder joint	499.68	484.01	482.30	479.13	503.31±8.68
	Right shoulder joint	526.18	510.41	508.60	505.43	529.68±8.77
30cm	Left shoulder joint	601.39	585.52	583.61	583.44	606.26±8.86
	Right shoulder joint	799.69	785.32	763.71	781.54	799.97±14.68
40cm	Left shoulder joint	460.56	443.09	442.38	440.71	463.71±9.03
	Right shoulder joint	664.10	646.53	647.88	644.05	667.67±8.80
50cm	Left shoulder joint	458.85	442.68	442.61	438.60	462.33±8.87
	Right shoulder joint	597.64	581.37	581.38	577.19	601.05±8.93

From the difference of peak angular velocity of shoulder joint in the stage of broad support push-up with feet on the ground (0cm) and upward push (Table 63),

the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of wide support push-up are 522.14m/s and 7.90m/s respectively. The mean angular velocity of the right shoulder joint was 465.08/s and the standard deviation was 8.59m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 0 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the left shoulder joint angular speed is greater than the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of broad support push-up with feet on the ground (25cm) and upward push (Table 63), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes are 503.31m/s and 8.68m/s when they complete the stage of broad support push-up. The mean angular velocity of the right shoulder joint was 529.68m/s, and the standard deviation was 8.77m/s. Intermediate level athletes in the completion of wide support push-up (feet height of 25 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with both feet on the ground (30cm) and upward push (Table 63), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of push-ups with standard support are 606.26m/s and 8.86m/s respectively. The mean angular velocity of the right shoulder joint was 799.97m/s and the standard deviation was 14.68m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 30 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with both feet on the ground (40cm) and upward push (Table 63), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of push-ups with standard support are 463.71m/s and 9.03m/s respectively. The mean angular velocity of the right shoulder joint was 667.67m/s and the standard deviation was 8.80m/s. Intermediate level athletes in the

completion of wide support push-ups (feet height of 40 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with feet on the ground (50cm) and upward push (Table 63), the average angular velocity and standard deviation of left shoulder joint of intermediate level athletes in the stage of push-ups with standard support are 462.33m/s and 8.87m/s respectively. The mean angular velocity of the right shoulder joint was 601.05m/s and the standard deviation was 8.93m/s. Intermediate level athletes in the completion of wide support push-ups (feet height of 50 cm) push up stage features: left shoulder joint and right shoulder joint average angular speed there is a certain difference, the right shoulder joint angular speed is greater than the left shoulder joint.

2.2.4 Mechanical characteristics

(1) Peak value of ground vertical reaction force in the depression stage under standard support push-ups

Table 64 The ground reaction force peak of the standard support push-up for intermediate level athletes in the down flexion phases (N)

measure	0cm	25cm	30cm	40cm	50cm
A	301.43	268.83	335.38	327.15	519.99
B	462.19	412.83	288.45	483.77	488.83
C	304.06	271.46	339.21	406.01	504.96
D	468.71	419.35	294.97	500.29	494.47
$\bar{X} \pm S$	384.10±93.98	343.12±84.31	314.50±26.50	429.31±79.55	502.06±13.69

From the difference between the peak value of ground vertical reaction force in the stage of push-ups with standard support (0cm) and the stage of bending

arms with downward support (Table 64), the average value of ground vertical reaction force and the standard deviation of ground vertical reaction force for intermediate level athletes in the stage of bending arms with downward support push-ups are 384.10N and 93.98N respectively.

According to the difference in the peak value of ground vertical reaction force in push-ups with feet 25 cm higher than the ground and in the stage of downward bending arms (Table 64), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of intermediate level athletes in the stage of downward bending arms with standard supporting push-ups are 343.12N and 84.31N respectively.

According to the peak difference of ground vertical reaction force in push-ups with standard support with feet 30 cm higher than the ground and in the stage of downward flexion (Table 64), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in the stage of downward flexion with standard support push-ups are 314.50N and 26.50N respectively for intermediate level athletes.

From the difference of peak ground vertical reaction force in push-ups with feet 40 cm higher than the ground and in the stage of bending arms with feet down (Table 64), the average ground vertical reaction force and standard deviation are 429.31N and 79.55N for intermediate level athletes in the stage of bending arms with feet down with feet up to 40 cm higher than the ground.

According to the peak difference of ground vertical reaction force in push-ups with feet 50 cm higher than the ground and in the stage of downward flexion (Table 64), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 502.06N and 13.69N for intermediate level athletes in the stage of downward flexion when they complete standard supported push-ups.

The characteristics of the ground vertical reaction force of push-ups with different load standards are as follows: with the increase of the position of the feet, the peak reaction force appears large on both sides and small in the middle, that is, the value of the standard push-ups with the feet on the ground is higher than the value of the feet

above the ground 25cm and 30cm, and the reaction force continues to increase with the increase of height. The reaction force values of feet 25 cm and 30 cm above the ground are lower, and the reaction force is lowest when the feet are 30 cm above the ground.

(2) The peak of vertical ground reaction force in the depression stage of wide-supported push-ups

Table 65 The peak of the ground reaction force of the intermediate level athletes in the stage of broad support push-up and bending arms (N)

measure	0cm	25cm	30cm	40cm	50cm
A	468.02	411.17	393.69	489.79	494.07
B	471.44	413.21	402.5	492.23	495.71
C	460.74	449.64	452.6	465.51	452.75
D	415.82	412.94	411.88	452.69	475.65
$\bar{X} \pm S$	454.01±25.84	421.74±18.62	415.17±26.04	475.06±19.18	479.55±20.05

From the difference between the peak value of ground vertical reaction force in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward bending arms flexion (Table 65), the average value of ground vertical reaction force and the standard deviation of ground vertical reaction force of intermediate level athletes in the stage of downward bending arms flexion with wide-supported push-up are 454.01N and 25.84N respectively.

According to the peak difference of ground vertical reaction force in the stage of wide-supported push-up with feet 25 cm higher than the ground and the stage of downward flexion (Table 65), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of intermediate level athletes in the stage of downward flexion with wide supported push-up are 421.74N and 18.62N respectively.

According to the peak difference of ground vertical reaction force in the stage of wide-supported push-up with feet 30 cm higher than the ground and the stage of downward flexion (Table 65), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of intermediate level athletes in the stage of downward flexion with wide supported push-up are 415.17N and 26.04N respectively.

From the difference in the peak value of ground vertical reaction force in the stage of wide-supported push-ups with feet 40 cm higher than the ground and the stage of downward flexion (Table 65), the average value of ground vertical reaction force and the standard deviation of ground vertical reaction force are 475.06N and 19.18N for intermediate level athletes in the stage of downward flexion when they complete wide-supported push-ups.

According to the difference of peak ground vertical reaction force in push-ups with wide support height 50 cm higher than the ground and in the stage of downward flexion (Table 65), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force for intermediate level athletes in the stage of downward flexion after completing standard push-ups are 479.55N and 20.05N respectively.

The characteristics of the ground vertical reaction force of push-ups with different load widths in the downward flexion stage are as follows: with the increase of the position of the feet, the peak of the reaction force appears to be large on both sides and small in the middle, that is, the value of the wide-supported push-ups with the feet on the ground is higher than the value of the feet above the ground 25cm and 30cm, and the reaction force continues to increase with the increase of height. The reaction force values of feet 25 cm and 30 cm above the ground are lower, and the reaction force is lowest when the feet are 30 cm above the ground. The above features are consistent with those of standard support push-ups.

(3) The peak of the ground vertical reaction force in the upward push up stage of the standard support push-up

Table 66 The peak of ground reaction force in the push-up stage of standard support for intermediate level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A	645.89	639.37	649.77	646.72	744.44
B	649.68	550.55	654.82	643.18	771.78
C	656.54	620.68	656.48	675.48	765.59
D	655.8	575.26	623.93	680.31	778.28
$\bar{X} \pm S$	651.98±5.09	596.47±40.76	646.25±15.15	661.42±19.18	765.02±14.67

From the difference of peak ground vertical reaction force in push-ups with standard support height (0cm) on the ground and upward push stage (Table 66), the average ground vertical reaction force and standard deviation of the intermediate level athletes in push-ups with standard support are 651.98N and 5.09N respectively.

From the difference of peak value of ground vertical reaction force in push-ups with standard support with feet 25 cm higher than the ground (Table 66), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in push-ups with standard support are 596.47N and 40.76N for intermediate level athletes in push-ups with standard support.

From the difference of peak ground vertical reaction force in push-ups with standard support with feet 30 cm higher than the ground (Table 66), the average ground vertical reaction force and standard deviation of 15N for intermediate level athletes in push-ups with standard support were 646.25N and 15.15N respectively.

According to the peak difference of ground vertical reaction force in push-ups with standard support with feet 40 cm higher than the ground (Table 66), the average value of ground vertical reaction force and standard deviation of ground

vertical reaction force for intermediate level athletes in push-ups with standard support were 661.42N and 19.18N respectively.

Judging from the difference in the peak value of ground vertical reaction force in the push-up stage when the feet are 50 cm higher than the ground in standard support push-ups (Table 66), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 765.02N and 14.67N for intermediate level athletes in the push-up stage when they complete standard push-ups.

The characteristics of the ground vertical reaction force in the push-up stage of different load standard support push-ups are as follows: with the increase of the position of the feet, the peak value of the reaction force gradually increases, that is, the value of the push-up with the feet on the ground is the lowest, and the value of the standard support push-up with the feet 50 cm above the ground is the highest.

(4) The peak of the ground vertical reaction force in the push up stage of wide support push-ups

Table 67 The peak of ground reaction force in the push up stage of wide support push-ups for intermediate level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A	884.48	764.36	801.61	901.71	903.83
B	893.48	811.76	777.34	896.36	879.57
C	888.96	766.76	842.84	853.72	900.39
D	878.18	825.52	820.48	849.38	861.04
$\bar{X} \pm S$	886.28±6.53	792.10±31.17	810.57±27.83	875.29±27.56	886.21±19.91

From the difference of peak value of ground vertical reaction force in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of upward push (Table 67), the average value of ground vertical reaction force and standard

deviation of ground vertical reaction force of intermediate level athletes in the stage of upward push of wide-supported push-up are 886.28N and 6.53N.

From the difference of the peak value of the ground vertical reaction force in the push up stage of wide-supported push-ups with feet 25 cm higher than the ground (Table 67), the average value of the ground vertical reaction force and the standard deviation of the ground vertical reaction force are 792.10N and 31.17N for intermediate level athletes in the push up stage of wide-supported push-ups.

From the difference of the peak value of the ground vertical reaction force in the push up stage when the feet are 30 cm higher than the ground in the wide support push up stage (Table 67), the average value of the ground vertical reaction force is 810.57N and the standard deviation is 27.83N for the intermediate level athletes in the push up stage when they complete the wide support push up stage.

From the difference of the peak value of the ground vertical reaction force in the push-up stage when the feet are 40 cm higher than the ground (Table 67), the average value of the ground vertical reaction force and the standard deviation of the ground vertical reaction force are 875.29N and 27.56N for the intermediate level athletes in the push-up stage when they complete the wide-supported push-up.

Judging from the difference in the peak value of ground vertical reaction force in push-ups with wide support height 50 cm higher than the ground (Table 67), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force for intermediate level athletes in the push-up stage after completing standard push-ups are 886.21N and 19.91N respectively.

The characteristics of the ground vertical reaction force of push-ups with different load widths are as follows: with the increase of the position of the feet, the peak value of the reaction force gradually increases, that is, the value of the standard support push-ups with the feet on the ground is the lowest, and the value of the standard support push-ups with the feet 50 cm above the ground is the highest. The above features are consistent with those of standard support push-ups.

2.2.5 Surface EMG characteristics

2.2.5.1 The sequence (activation time) characteristics of activation of relevant muscles in the lower flexion stage

Table 68 Intermediate level athletes to complete the standard support push-up down flexion arm activation sequence table

Muscle	unactivated 1	Activate 1	unactivated 2	Activate 2	unactivated 3	Activate 3
Left biceps brachii	27.48	23.62	14.88	33.95	0	0
Right biceps brachii	26.97	23.26	15.69	33.11	0	0
Left triceps brachii	26.05	4.19	31.24	28.75	9.79	0
Right triceps brachii	25.57	5.45	29.48	29.55	9.95	0
Left deltoid anterior fasciculus	37.03	13.88	10.61	12.13	6.98	19.27
Anterior bundle of right deltoid	38.03	12.18	10.51	12.73	6.78	19.37
Left pectoralis major	22.02	24.94	12.04	12.43	6.78	21.37
Right pectoralis major	20.05	25.4	12.55	11.73	6.58	24.37

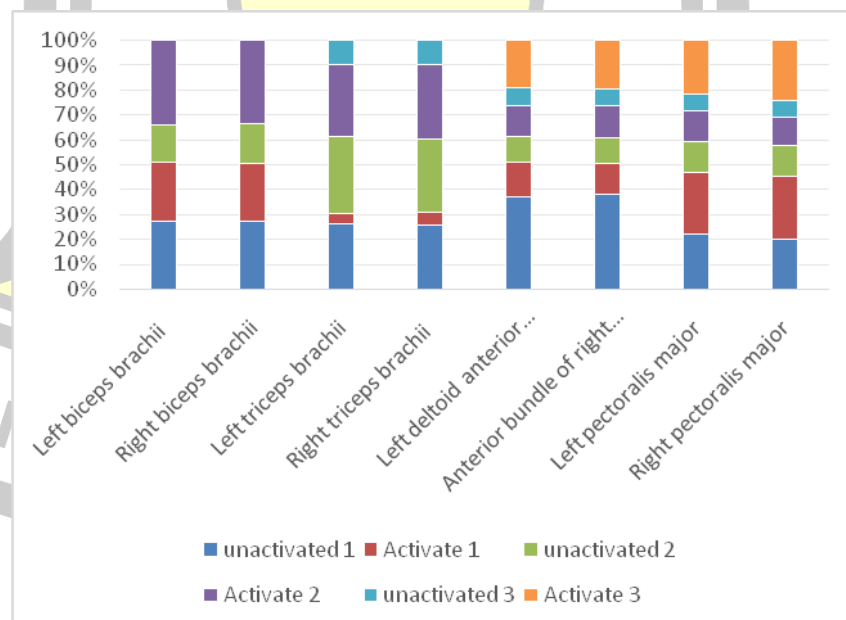


Figure 94 Comparison of muscle activation sequence of intermediate level athletes in the downward phase of standard support push-ups

From the order of activation (activation time) of relevant muscles (Table 68, Figure 94) as the bent arms and body center of gravity decrease during the lower flexion phase of the standard support push-up, the left and right deltoid anterior fasciculus activate first, followed by the left and right pectoralis major, left and right biceps, and left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the completion of the movement. The activation sequence of this muscle is consistent with the activation sequence of high-level athletes.

2.2.5.2 Characteristics of integrated EMG values of relevant muscles in the stage of downward flexion

Table 69 Intermediate level athletes complete the standard support push-up down stage muscle integral myoelectric value (μ Vs)

measure	A	B	C	D	$\bar{X} \pm S$
Left biceps brachii	116.89	115.25	117.71	114.5	116.09 $\pm$ 1.47
Right biceps brachii	117.49	115.27	118.67	114.54	116.49 $\pm$ 1.92
Left triceps brachii	491.39	488.88	493.94	489	490.80 $\pm$ 2.39
Right triceps brachii	486.99	485.35	490.28	483.5	486.53 $\pm$ 2.88
Left deltoid anterior fasciculus	131.49	127.75	134.51	129.1	130.71 $\pm$ 2.97
Anterior bundle of right deltoid	130.59	127.8	131.41	128.2	129.50 $\pm$ 1.77
Left pectoralis major	262.81	261.17	263.63	259.32	261.73 $\pm$ 1.91
Right pectoralis major	260.03	258.39	260.85	256.79	259.02 $\pm$ 1.80

From the point of view of the integrated EMG values of the relevant muscles of the intermediate level athletes during the push-up stage of standard support push-ups (table 69), the average value and standard deviation of the integrated EMG values of the left biceps of the intermediate level athletes were 116.09 μ Vs and 1.47 μ Vs. The mean value and standard deviation of the right biceps were 116.49 μ Vs and 1.92 μ Vs. The mean and standard deviation of the integrated EMG values of the left triceps were 490.80 μ Vs and 2.39 μ Vs. The mean value and standard deviation of the

right triceps were 486.53 μ Vs and 2.88 μ Vs. The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were 130.71 μ Vs and 2.97 μ Vs. The mean and standard deviation of the integrated EMG values of the right deltoid anterior bundle were 129.50 μ Vs and 1.77 μ Vs. The mean and standard deviation of the integrated EMG values of the left pectoralis major were 261.73 μ Vs and 1.91 μ Vs. The mean and standard deviation of the integrated EMG values of the right pectoralis major were 259.02 μ Vs and 1.80 μ Vs. There are some differences in the integrated EMG values of the left and right muscles of the high-level athletes in the stage of completing the standard support push-up, but the difference is not large.

2.2.5.3 Sequence (activation time) characteristics of muscle activation in the push up stage

Table 70 Intermediate level athletes to complete the standard support push up stage muscle activation sequence table

Muscle	unactivated 1	Activate 1	unactivated 2	Activate 2	unactivated 3	Activate 3
Left biceps brachii	27.18	24.82	14.98	32.95	0	0
Right biceps brachii	26.77	24.26	15.89	32.91	0	0
Left triceps brachii	27.05	4.79	31.44	28.75	9.79	0
Right triceps brachii	25.57	5.45	30.48	29.55	8.95	0
Left deltoid anterior fasciculus	36.13	12.88	11.61	13.13	6.98	19.27
Anterior bundle of right deltoid	36.83	12.18	11.51	13.63	6.28	19.57
Left pectoralis major	23.02	23.94	12.44	12.33	6.78	21.57
Right pectoralis major	22.65	23.34	12.15	12.83	6.58	22.37

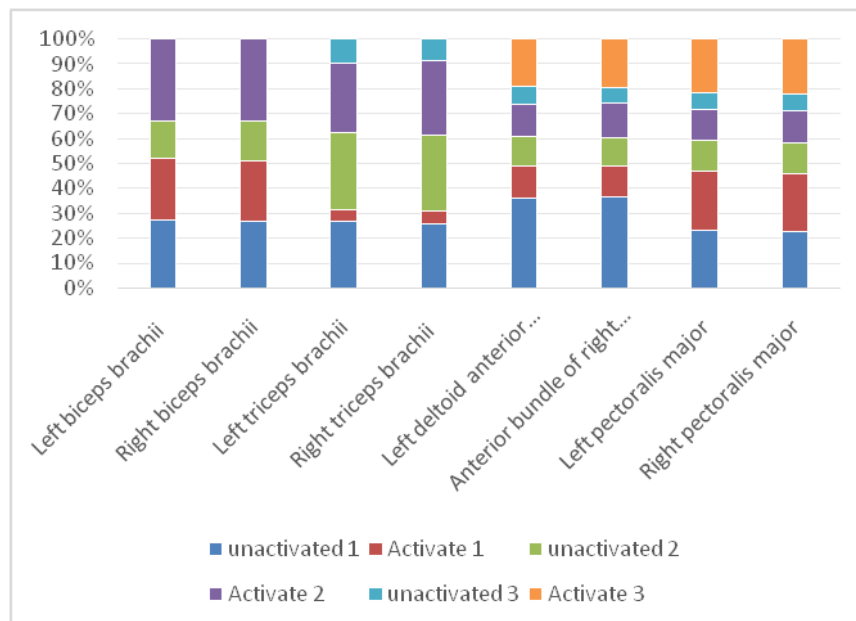


Figure 95 Comparison of muscle activation sequence of intermediate level athletes in the upward phase of standard support push-ups

From the point of view of the integrated EMG values of the relevant muscles of the intermediate level athletes during the push-up stage of standard support push-ups (table 70, Figure 95), the average value and standard deviation of the integrated EMG values of the left biceps of the intermediate level athletes were $113.79\mu\text{Vs}$ and $2.06\mu\text{Vs}$. The mean value and standard deviation of the right biceps were $113.94\mu\text{Vs}$ and $2.89\mu\text{Vs}$. The mean and standard deviation of the integrated EMG values of left triceps were $501.14\mu\text{Vs}$ and $3.20\mu\text{Vs}$. The mean value and standard deviation of the right triceps were $496.64\mu\text{Vs}$ and $3.76\mu\text{Vs}$. The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were $143.27\mu\text{Vs}$ and $2.41\mu\text{Vs}$. The mean and standard deviation of the integrated EMG values of the right deltoid anterior bundle were $141.73\mu\text{Vs}$ and $2.60\mu\text{Vs}$. The mean and standard deviation of the integrated EMG value of the left pectoralis major were $273.96\mu\text{Vs}$ and $2.61\mu\text{Vs}$. The mean and standard deviation of the integrated EMG values of the right pectoralis major were $271.34\mu\text{Vs}$ and $2.81\mu\text{Vs}$. There are some differences in the integrated EMG values of the left and right muscles of the intermediate level athletes in the stage of completing the standard support push-up, but the difference is not large.

2.2.5.4 Analysis of integrated EMG value of muscles related to the upward push stage

Table 71 Muscle integral electromyography value of intermediate level athletes when they complete standard support push-ups(μ Vs)

measure	A	B	C	D	$\bar{X} \pm S$
Left biceps brachii	115.05	111.54	115.95	112.61	113.79 $\pm$ 2.06
Right biceps brachii	115.65	110.53	116.91	112.65	113.94 $\pm$ 2.89
Left triceps brachii	499.85	504.8	502.48	497.41	501.14 $\pm$ 3.20
Right triceps brachii	495.45	500.37	498.82	491.91	496.64 $\pm$ 3.76
Left deltoid anterior fasciculus	139.95	145.23	143.05	144.85	143.27 $\pm$ 2.41
Anterior bundle of right deltoid	139.05	143.97	139.95	143.95	141.73 $\pm$ 2.60
Left pectoralis major	271.27	276.19	272.17	276.19	273.96 $\pm$ 2.61
Right pectoralis major	268.49	273.41	269.39	274.07	271.34 $\pm$ 2.81

From the point of view of the integrated EMG values of the relevant muscles of the intermediate level athletes during the push-up stage of standard support push-ups (see Table 71), the average value and standard deviation of the integrated EMG values of the left biceps of the intermediate level athletes were 113.79 μ Vs and 2.06 μ Vs. The mean value and standard deviation of the right biceps were 113.94 μ Vs and 2.89 μ Vs. The mean and standard deviation of the integrated EMG values of left triceps were 501.14 μ Vs and 3.20 μ Vs. The mean value and standard deviation of the right triceps were 496.64 μ Vs and 3.76 μ Vs. The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were 143.27 μ Vs and 2.41 μ Vs. The mean and standard deviation of the integrated EMG values of the right deltoid anterior bundle were 141.73 μ Vs and 2.60 μ Vs. The mean and standard deviation of the integrated EMG value of the left pectoralis major were 273.96 μ Vs and 2.61 μ Vs. The mean and standard deviation of the integrated EMG values of the right pectoralis major were 271.34 μ Vs and 2.81 μ Vs. There are some differences in the integrated EMG values of the left and right muscles of the intermediate level athletes in the stage of completing the standard support push-up, but the difference is not large.

2.3 Biomechanical characteristics of push-ups performed by ordinary athletes

2.3.1 Time characteristics

2.3.1.1 Complete action time characteristics

(1) The total time of standard push-ups supporting different loads

Table 72 Statistical table of total time required by average athletes to complete standard support push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.29	1.27	1.25	1.37	1.41
B	1.36	1.3	1.22	1.38	1.47
C	1.38	1.25	1.26	1.36	1.41
D	1.29	1.27	1.28	1.38	1.41
$\bar{x} \pm s$	1.33±0.05	1.27±0.02	1.25±0.03	1.37±0.01	1.43±0.03

From the total time of standard support push-ups (with both feet on the ground) (table 72), the average time of average athletes to complete standard support push-ups is 1.33s, and the standard deviation is 0.05s. The total time of the four athletes who participated in the test to complete the standard support push-ups (flat ground) was very close, and the total time of athletes A and D to complete the standard support push-ups (feet on the ground) was 1.29s, which was the shortest among the four athletes. The total time of athlete C to complete the standard support push-up (feet on the ground) is 1.38s, which is the longest time of the four athletes.

From the total time of standard support push-ups (feet 25 cm above the ground) (table 72), the average time of average athletes to complete standard support push-ups (feet 25 cm above the ground) is 1.27s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard support push-up (feet 25cm above the ground) is very similar, and the total time of athlete C to complete the standard support push-up (feet 25cm above the ground) is 1.25s, which is the shortest among the four athletes. Athlete B's total time to complete

the standard support push-up (feet 25 cm above the ground) is 1.30s, which is the longest time of the four athletes.

From the total time of standard support push-ups (feet 30cm above the ground) (table 72), the average time of average athletes to complete standard support push-ups (feet 30cm above the ground) is 1.25s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 30cm above the ground) is very similar, and the total time of athlete B to complete the standard support push-ups (feet 30cm above the ground) is 1.22s, which is the shortest among the four athletes. Athlete D took 1.28s to complete the standard support push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

From the total time of standard support push-ups (feet 40 cm above the ground) (table 72), the average time of average athletes to complete standard support push-ups (feet 40 cm above the ground) is 1.37s, and the standard deviation is 0.01s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 40cm above the ground) is very similar, and the total time of athlete C to complete the standard support push-ups (feet 40cm above the ground) is 1.36s, which is the shortest among the four athletes. The total time of athlete B and D to complete the standard support push-up (feet 40 cm above the ground) is 1.38s, which is the longest time of the four athletes.

From the total time of standard support push-ups (feet 50 cm above the ground) (table 72), the average time of average athletes to complete standard support push-ups (feet 50 cm above the ground) is 1.43s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 50cm above the ground) is very similar, and the total time of athlete A, C and D to complete the standard support push-ups (feet 50cm above the ground) is 1.41s, which is the shortest among the four athletes. The total time of athlete D to complete the standard support push-up (feet 50 cm above the ground) is 1.48s, which is the longest time of the four athletes.

(2) The total time of push-ups with different loads of wide support

Table 73 Statistical table of the total time taken by ordinary athletes to complete wide support push-ups (s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.41	1.24	1.21	1.46	1.42
B	1.27	1.31	1.26	1.3	1.45
C	1.33	1.3	1.22	1.4	1.47
D	1.35	1.26	1.28	1.4	1.41
$\bar{X} \pm S$	1.34±0.06	1.28±0.03	1.24±0.03	1.39±0.07	1.44±0.03

In terms of the total time of wide-supported push-ups (both feet on the ground) (table 73), the average time of the average athlete to complete the wide-supported push-ups is 1.34s, and the standard deviation is 0.06s. The total time of the four athletes participating in the test to complete the wide support push-up (flat ground) is very close, and the total time of athlete B to complete the wide support push-up (feet on the ground) is 1.27s, which is the shortest among the four athletes. The total time of athletes A to complete the wide support push-up (feet on the ground) was 1.41s, which was the longest time of the four athletes.

In terms of the total time of a wide-supported push-up (feet 25 cm above the ground) (see 73), the average time for an average athlete to complete a wide-supported push-up (feet 25 cm above the ground) is 1.28s, with a standard deviation of 0.03s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 25 cm above the ground) is very similar, and the total time of athletes A to complete the wide support push-up (feet 25 cm above the ground) is 1.24s, which is the shortest among the four athletes. Athlete B's total time to complete the standard support push-up (feet 25 cm above the ground) was 1.31s, which was the longest time of the four athletes.

In terms of the total time of wide-supported push-ups (feet 30 cm above the ground) (table 73), the average time of completing wide-supported push-ups (feet 30 cm above the ground) for ordinary athletes is 1.24s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 30cm above the ground) is very similar, and the total time of athlete A to complete the wide support push-up (feet 30cm above the ground) is 1.21s, which is the shortest among the four athletes. The total time of athletes D to complete the wide support push-up (feet 30 cm above the ground) was 1.28s, which was the longest time of the four athletes.

In terms of the total time of wide-supported push-ups (feet 40 cm above the ground) (table 73), the average time of the average athlete to complete wide-supported push-ups (feet 40 cm above the ground) is 1.39s, and the standard deviation is 0.07s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 40cm above the ground) is very similar, and the total time of athlete B to complete the wide support push-up (feet 40cm above the ground) is 1.30s, which is the shortest among the four athletes. The total time of Athlete A to complete the wide support push-up (feet 40 cm above the ground) is 1.46s, which is the longest time of the four athletes.

In terms of the total time of wide-supported push-ups (feet 50 cm above the ground) (table 73), the average time of the average athlete to complete wide-supported push-ups (feet 50 cm above the ground) is 1.44s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 50cm above the ground) is very close, and the total time of athlete D to complete the wide support push-up (feet 50cm above the ground) is 1.41s, which is the shortest among the four athletes. The total time of athlete C to complete the wide support push-up (feet 50 cm above the ground) is 1.47 seconds, which is the longest time of the four athletes.

(3) The total time used for standard high-five push-ups with different loads

Table 74 Statistical table of the total time taken by ordinary athletes to complete standard support high-five push-ups(s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.44	1.41	1.38	1.47	1.52
B	1.48	1.41	1.39	1.49	1.51
C	1.43	1.42	1.34	1.48	1.51
D	1.46	1.41	1.46	1.51	1.54
$\bar{X} \pm S$	1.45±0.02	1.41±0.01	1.39±0.05	1.49±0.02	1.52±0.01

Judging from the total time of standard supported high-five push-ups (both feet on the ground) (table 74), the average time of average athletes to complete standard supported high-five push-ups is 1.45s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard supported high-five push-ups (flat ground) is very close, and the total time of athlete C to complete the standard supported high-five push-ups (feet on the ground) is 1.43s, which is the shortest among the four athletes. The total time of athlete B to complete the standard support push-up (feet on the ground) is 1.48s, which is the longest time of the four athletes.

In terms of the total time of the standard supported high-five push up (feet 25 cm above the ground) (see 74), the average time of the average athlete to complete the standard supported high-five push up (feet 25 cm above the ground) is 1.41s, and the standard deviation is 0.01s. The total time of the four athletes participating in the test to complete the standard support high-five push-up (feet 25cm above the ground) is very similar, and the total time of athlete A,B and D to complete the standard support push-up (feet 25cm above the ground) is 1.41s, which is the shortest among the four athletes. The total time of athlete C to complete the standard support high-five push-up (feet 25 cm above the ground) is 1.42s, which is the longest time of the four athletes.

From the total time of standard supported high-five push-ups (feet 30cm above the ground) (table 74), the average time of average athletes to complete standard supported high-five push-ups (feet 30cm above the ground) is 1.39s, and the standard deviation is 0.05s. The total time of the four athletes participating in the test to complete the standard support push-ups (feet 30cm above the ground) is very similar, and the total time of athlete C to complete the standard support push-ups (feet 30cm above the ground) is 1.34s, which is the shortest among the four athletes. Athlete D's total time to complete the standard high-five push-up (feet 30 cm above the ground) was 1.46s, the longest time of the four athletes.

Judging from the total time of standard supported high-five push-ups (feet 40cm above the ground) (table 74), the average time of average athletes to complete standard supported high-five push-ups (feet 40cm above the ground) is 1.49s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the standard supported high-five push up (feet 40cm above the ground) is very similar, and the total time of athlete A to complete the standard supported high-five push up (feet 40cm above the ground) is 1.47s, which is the shortest among the four athletes. Athletes B and D took 1.51 seconds to complete the standard high-five push-up (feet 40 cm above the ground), the longest time of the four athletes.

From the total time of standard supported high-five push-ups (feet 50 cm above the ground) (table 74), the average time of average athletes to complete standard supported high-five push-ups (feet 50 cm above the ground) is 1.52s, and the standard deviation is 0.01s. The total time of the four athletes participating in the test to complete the standard support push up (feet 50cm above the ground) is very similar, and the total time of athlete B and C to complete the standard support high-five push up (feet 50cm above the ground) is 1.51s, which is the shortest among the four athletes. Athletes D took 1.54s to complete the standard high-five push-up (feet 50 cm above the ground), which was the longest time of the four athletes.

(4) The total time of wide support for different loads of high-five push-ups

Table 75 Statistical table of the total time used by ordinary athletes to complete wide-supported high-five push-ups(s)

measure	0cm	25cm	30cm	40cm	50cm
A	1.58	1.5	1.42	1.53	1.58
B	1.63	1.47	1.45	1.44	1.54
C	1.57	1.52	1.52	1.5	1.57
D	1.65	1.55	1.47	1.55	1.56
$\bar{X} \pm S$	1.61±0.04	1.51±0.03	1.47±0.04	1.51±0.05	1.56±0.02

In terms of the total time of wide-supported high-five push-ups (both feet on the ground) (table 75), the average time of completing wide-supported high-five push-ups for ordinary athletes is 1.61s, and the standard deviation is 0.04s. The total time of the four athletes participating in the test to complete the wide-supported high-five push up (flat ground) is very close, and the total time of athlete C to complete the wide-supported high-five push up (feet on the ground) is 1.57s, which is the shortest among the four athletes. The total time of athlete D to complete the wide support push-up (feet on the ground) is 1.65s, which is the longest time of the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 25 cm above the ground) (table 75), the average time of completing wide-supported high-five push-ups (feet 25 cm above the ground) for ordinary athletes is 1.51s, and the standard deviation is 0.03s. The total time of the four athletes participating in the test to complete the wide-supported high-five push-up (feet 25 cm above the ground) is very similar, and the total time of athlete B to complete the wide-supported push-up (feet 25 cm above the ground) is 1.47s, which is the shortest among the four athletes. Athlete D took 1.55s to complete the wide-supported high-five push-up (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 30cm above the ground) (table 75), the average time of completing wide-supported high-five

push-ups (feet 30cm above the ground) for ordinary athletes is 1.47s, and the standard deviation is 0.04s. The total time of the four athletes participating in the test to complete the wide support push-up (feet 30cm above the ground) is very similar, and the total time of athlete A to complete the wide support push-up (feet 30cm above the ground) is 1.42s, which is the shortest among the four athletes. Athlete C took 1.52s to complete the wide-supported high-five push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 40cm above the ground) (table 75), the average time of completing wide-supported high-five push-ups (feet 40cm above the ground) for ordinary athletes is 1.51s, and the standard deviation is 0.05s. The total time of the four athletes participating in the test to complete the wide-supported high-five push up (feet 40cm above the ground) is very similar, and the total time of athlete B to complete the wide-supported high-five push up (feet 40cm above the ground) is 1.44s, which is the shortest among the four athletes. Athlete D took 1.55s to complete the wide-supported high-five push-up (feet 40 cm above the ground), which was the longest time among the four athletes.

In terms of the total time of wide-supported high-five push-ups (feet 50 cm above the ground) (table 75), the average time of completing wide-supported high-five push-ups (feet 50 cm above the ground) for ordinary athletes is 1.56s, and the standard deviation is 0.02s. The total time of the four athletes participating in the test to complete the wide support push up (feet 50cm above the ground) is very similar, among which the total time of athletes B to complete the wide support high-five push up (feet 50cm above the ground) is 1.54s, which is the shortest among the four athletes. Athlete A took 1.58s to complete the wide-supported high-five push-up (feet 50 cm above the ground), which was the longest time among the four athletes.

2.3.1.2 Time characteristics of the bending arm stage in the lower flexion

(1) The time used for standard push-ups with different loads to support the bending arm

Table 76 Statistical table of the time taken by the average level athletes to complete the standard support push-up and bend the arms (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.66	0.61	0.62	0.66	0.68
B	0.68	0.63	0.59	0.63	0.71
C	0.69	0.61	0.61	0.64	0.67
D	0.67	0.62	0.63	0.65	0.69
$\bar{x} \pm s$	0.68±0.01	0.62±0.01	0.61±0.02	0.65±0.01	0.69±0.02

In terms of the time it took for standard support push-up to bend the arms down (with both feet on the ground) (table 76), the average time for average athletes to complete standard support push-up to bend the arms down is 0.68s, and the standard deviation is 0.10s. The time of the four athletes participating in the test to complete the standard support push-up down flexion arm (feet on the ground) is very similar, and the time of athlete A to complete the standard support push-up down flexion arm (feet on the ground) is 0.66s, which is the shortest among the four athletes. Athletes C took 0.69s to complete the standard support push-up with their arms bent down (feet 25 cm above the ground), the longest time of the four athletes.

In terms of the time it took for standard support push-up to bend the arms down (feet 25 cm above the ground) (table 76), the average time for ordinary athletes to complete standard support push-up to bend the arms down (feet 25 cm above the ground) was 0.62s, and the standard deviation was 0.01s. The four athletes who participated in the test took very similar time to complete the standard support push-up down flexion arm (feet 25cm above the ground), and the time for athlete A and D to complete the standard support push-up down flexion arm (feet 25cm above the ground) was 0.61s, which was the shortest among the four athletes. Athlete B took 0.63s to

complete the standard support push-up with his arms bent down (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time it takes for standard support push-up to bend the arms down (feet 30cm above the ground) (table 76), the average time for ordinary athletes to complete standard support push-up to bend the arms down (feet 30cm above the ground) is 0.61s, and the standard deviation is 0.02s. The four athletes who participated in the test took very similar time to complete the standard support push up and bend down the arms (feet 30cm above the ground). Among them, athlete B took 0.59s to complete the standard support push up and bend down the arms (feet 30cm above the ground), which was the shortest time among the four athletes. Athlete D took 0.63s to complete the standard support push-up with his arms bent down (feet 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time it takes for standard support push-up to bend the arms down (feet 40cm above the ground) (table 76), the average time for ordinary athletes to complete standard support push-up to bend the arms down (feet 40cm above the ground) is 0.65s, and the standard deviation is 0.01s. The four athletes who participated in the test took very similar time to complete the standard support push-up and bend the arms down (feet 40cm above the ground). Among them, athlete B took 0.63s to complete the standard support push-up and bend the arms down (feet 40cm above the ground), which was the shortest time among the four athletes. Athlete A took 0.66 seconds to complete the standard push-up with his arms bent down (feet 40 cm above the ground), the longest time among the four athletes.

From the perspective of the time it took for standard support push-up to bend the arms down (feet 50 cm above the ground) (table 76), the average time for ordinary athletes to complete standard support push-up to bend the arms down (feet 50 cm above the ground) is 0.69s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support push-up down flexural arm (feet 50cm above the ground) is very similar, and the time of athlete C to complete the standard support push-up down flexural arm (feet 50cm above the ground) is 0.67s, which is the shortest among the four athletes. Athletes B took 0.71 seconds to complete

the standard push-up with their arms bent down (feet 50 cm above the ground), the longest time of the four athletes.

(2) The time for wide support of different load push-ups to support the bending arm

Table 77 Statistical table of the time taken by the average level athletes to complete the wide support push up and bend the arms (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.67	0.58	0.58	0.67	0.69
B	0.6	0.63	0.62	0.59	0.67
C	0.65	0.61	0.61	0.63	0.68
D	0.66	0.55	0.59	0.61	0.66
$\bar{x} \pm s$	0.65±0.03	0.59±0.04	0.60±0.02	0.63±0.03	0.68±0.01

In terms of the time it took for wide-supported push-up to bend the arms down (with both feet on the ground) (table 77), the average time for the average athlete to complete the wide-supported push-up to bend the arms down is 0.65s, and the standard deviation is 0.03s. The time of the four athletes who participated in the test to complete the wide support push-up down flexion arm (feet on the ground) is very similar, and the time of athlete B to complete the wide support push-up down flexion arm (feet on the ground) is 0.60s, which is the shortest among the four athletes. Athlete A took 0.67s to complete the broad support push up and down with bent arms (feet on the ground), which was the longest time among the four athletes.

In terms of the time it took for the wide support push-up to bend the arms down (feet 25 cm above the ground) (table 77), the average time for the ordinary level athletes to complete the wide support push-up to bend the arms down (feet 25 cm above the ground) was 0.59s, and the standard deviation was 0.04s. The time of the four athletes participating in the test to complete the wide support push-up down flexion arm

(feet 25cm above the ground) is very similar, and the time of athletes D to complete the wide support push-up down flexion arm (feet 25cm above the ground) is 0.55s, which is the shortest among the four athletes. Athlete B took 0.63s to complete the wide support push up and down with his arms bent (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took for the wide support push-up to bend the arms down (feet 30cm above the ground) (table 77), the average time for the ordinary level athletes to complete the wide support push-up to bend the arms down (feet 30cm above the ground) was 0.60s, and the standard deviation was 0.02s. The four athletes who participated in the test took very similar time to complete the wide support push up and bend down the arms (feet 30cm above the ground). Among them, athlete A took 0.58s to complete the wide support push up and bend down the arms (feet 30cm above the ground), which was the shortest time among the four athletes. Athletes B took 0.62s to complete the wide support push up and down with their arms bent (feet 30 cm above the ground), which was the longest time of the four athletes.

In terms of the time it takes for the wide support push-up to bend the arms down (feet 40 cm above the ground) (table 77), the average time for the average level athlete to complete the wide support push-up to bend the arms down (feet 40 cm above the ground) is 0.63s, and the standard deviation is 0.03s. The four athletes who participated in the test took very similar time to complete the wide support push up and bend down the arms (feet 40cm above the ground). Among them, athlete B took 0.59s to complete the wide support push up and bend down the arms (feet 40cm above the ground), which was the shortest time among the four athletes. Athlete A took 0.67s to complete the wide support push up and down with his arms bent (feet 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time it takes for the wide support push-up to bend the arms down (feet 50 cm above the ground) (table 77), the average time for the average level athlete to complete the wide support push-up to bend the arms down (feet 50 cm above the ground) is 0.68s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the wide support push-up down flexion arm (feet 50cm above the ground) is very similar, and the time of athlete D to complete the wide

support push-up down flexion arm (feet 50cm above the ground) is 0.66s, which is the shortest among the four athletes. Athlete A took 0.69s to complete the wide support push up and down with his arms bent (feet 50 cm above the ground), which was the longest time among the four athletes.

(3) The time for standard support of different loads of high-five push-ups to support the bending arm

Table 78 Average level athletes standard support high-five push-ups down flexion arms use statistics (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.65	0.62	0.58	0.68	0.68
B	0.63	0.61	0.59	0.69	0.69
C	0.69	0.61	0.55	0.68	0.67
D	0.67	0.62	0.63	0.66	0.68
$\bar{x} \pm s$	0.66±0.03	0.62±0.01	0.59±0.03	0.68±0.01	0.68±0.01

In terms of the time it took for standard supported high-five push-ups to bend the arms down (with both feet on the ground) (table 78), the average time for ordinary athletes to complete standard supported high-five push-ups to bend the arms down is 0.66s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet on the ground) is very similar, and the time of athlete B to complete the standard supported high-five push-up down flexion arms (feet on the ground) is 0.63s, which is the shortest among the four athletes. Athlete C took 0.69s to complete the standard support high-five push-up and bend the arms (feet on the ground), which was the longest time among the 4 athletes.

In terms of the time it took for standard supported high-five push-up to bend the arms down (feet 25cm above the ground) (table 78), the average time for

ordinary athletes to complete standard supported high-five push-up to bend the arms down (feet 25cm above the ground) was 0.62s, and the standard deviation was 0.01s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet 25cm above the ground) is very similar, and the time of athlete B and C to complete the standard supported high-five push-up down flexion arms (feet 25cm above the ground) is 0.61s, which is the shortest among the four athletes. Athlete A and D took 0.62s to complete the standard support high-five push-up and bend the arms down (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time it takes for standard supported high-five push-ups to bend the arms down (feet 30cm above the ground) (table 78), the average time for ordinary athletes to complete standard supported high-five push-ups to bend the arms down (feet 30cm above the ground) is 0.59s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard supported high-five push-up down flexion arms (feet 30cm above the ground) is very similar, and the time of athlete C to complete the standard supported high-five push-up down flexion arms (feet 30cm above the ground) is 0.55s, which is the shortest among the four athletes. Athlete D took 0.63s to complete the standard support high-five push-up and bend the arms (feet are 30 cm above the ground), which was the longest time of the four athletes.

In terms of the time it takes for standard supported high-five push-up to bend the arms down (feet 40cm above the ground) (table 78), the average time for ordinary athletes to complete standard supported high-five push-up to bend the arms down (feet 40cm above the ground) is 0.68s, and the standard deviation is 0.01s. The four athletes who participated in the test took very similar time to complete the standard supported high-five push-up and bend the arms down (feet 40cm higher than the ground). Among them, athlete D took 0.66s to complete the standard supported high-five push-up and bend the arms down (feet 40cm higher than the ground), which was the shortest time among the four athletes. Athlete B took 0.69s to complete the standard support high-five push-up and bend the arms (feet are 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took for standard supported high-five push-ups to bend the arms down (feet 50cm above the ground) (table 78), the average time for ordinary athletes to complete standard supported high-five push-ups to bend the arms down (feet 50cm above the ground) was 0.68s, and the standard deviation was 0.01s. The four athletes who participated in the test took very similar time to complete the standard supported high-five push up and bend down the arms (feet 50cm above the ground). Among them, athlete C took 0.67s to complete the standard supported high-five push up and bend down the arms (feet 50cm above the ground), which was the shortest time among the four athletes. Athlete B took 0.69s to complete the standard support high-five push-up and bend the arms (feet 50 cm above the ground), which was the longest time among the four athletes.

(4) The time for wide support of different loads of high-five push-ups to support the bending arm down

Table 79 General level athletes wide support high-five push-ups down flexion arms use statistics (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.69	0.64	0.58	0.67	0.67
B	0.68	0.62	0.59	0.66	0.66
C	0.65	0.68	0.57	0.68	0.69
D	0.69	0.66	0.56	0.69	0.68
$\bar{X} \pm S$	0.68±0.02	0.65±0.03	0.58±0.01	0.68±0.01	0.68±0.01

In terms of the time it took for wide-supported high-five push-ups to bend the arms down (with both feet on the ground) (table 79), the average time it took for ordinary athletes to complete wide-supported high-five push-ups to bend the arms down is 0.68s, and the standard deviation is 0.02s. The time of the four athletes who participated in the test to complete the wide-supported high-five push-up down flexion arms (feet on the ground) was very similar, and the time of athlete C to complete the

wide-supported high-five push-up down flexion arms (feet on the ground) was 0.65s, which was the shortest among the four athletes. It took athlete A and D 0.69s to complete the broad support high-five push-up and bend the arms (feet on the ground), which was the longest time among the four athletes.

In terms of the time it took for wide-supported high-five push-up to bend the arms down (feet 25 cm above the ground) (table 79), the average time for the average level athletes to complete the wide-supported high-five push-up to bend the arms down (feet 25 cm above the ground) was 0.65s, and the standard deviation was 0.03s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 25cm above the ground) is very similar, and the time of athlete B to complete the wide-supported high-five push-up down flexion arms (feet 25cm above the ground) is 0.62s, which is the shortest among the four athletes. Athlete C took 0.68 seconds to complete the broad support high-five push up and down with his arms bent (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took for wide-supported high-five push-ups to bend the arms down (feet 30cm above the ground) (table 79), the average time for ordinary athletes to complete wide-supported high-five push-ups to bend the arms down (feet 30cm above the ground) was 0.58s, and the standard deviation was 0.01s. The time of the four athletes participating in the test to complete the wide supported high-five push-up down flexion arms (feet 30cm above the ground) is very similar, and the time of athletes D to complete the wide supported high-five push-up down flexion arms (feet 30cm above the ground) is 0.56s, which is the shortest among the four athletes. Athlete B took 0.59s to complete the broad support high-five push up and bend the arms (feet are 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took for wide-supported high-five push-ups to bend the arms down (feet 40 cm above the ground) (table 79), the average time for the average level athletes to complete the wide-supported high-five push-ups to bend the arms down (feet 40 cm above the ground) was 0.68s, and the standard deviation was 0.01s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 40cm higher than the ground) is

very similar, and the time of athlete B to complete the wide-supported high-five push-up down flexion arms (feet 40cm higher than the ground) is 0.66s, which is the shortest among the four athletes. Athlete D took 0.69s to complete the broad support high-five push up and bend the arms (feet are 40 cm above the ground), which was the longest time among the four athletes.

In terms of the time it took for wide-supported high-five push-ups to bend the arms down (feet 50 cm above the ground) (table 79), the average time for ordinary athletes to complete wide-supported high-five push-ups to bend the arms down (feet 50 cm above the ground) was 0.68s, and the standard deviation was 0.01s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up down flexion arms (feet 50cm above the ground) is very similar, and the time of athlete B to complete the wide-supported high-five push-up down flexion arms (feet 50cm above the ground) is 0.66s, which is the shortest among the four athletes. Athlete C took 0.69s to complete the broad support high-five push-up and bend the arms down (feet 50 cm above the ground), which was the longest time among the four athletes.

2.3.1.3 Time Feature of the push up phase

(1) The time used to push up push-ups with different loads of standard support

Table 80 Statistical table when the average level athlete completes the standard support push-up push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.63	0.66	0.63	0.71	0.73
B	0.68	0.67	0.63	0.75	0.76
C	0.69	0.64	0.65	0.72	0.74
D	0.62	0.65	0.65	0.73	0.72
$\bar{x} \pm s$	0.66±0.04	0.66±0.01	0.64±0.01	0.73±0.02	0.74±0.02

From the time taken to push up from the standard support push-up (with both feet on the ground) (table 80), the average time for the average athlete to complete the standard support push-up is 0.66s, and the standard deviation is 0.04s. The time of the four athletes participating in the test to complete the standard support push up (feet on the ground) is very close, and the time of athletes D to complete the standard support push up (feet on the ground) is 0.62s, which is the shortest among the four athletes. Athlete C took 0.69 seconds to complete the standard support push up (feet on the ground), which was the longest time among the four athletes.

From the time taken to push up from the standard support push up (feet 25 cm above the ground) (table 80), the average time for the average athlete to complete the standard support push up (feet 25 cm above the ground) is 0.66s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support push up (feet 25cm above the ground) is very similar, and the time of athlete C to complete the standard support push up (feet 25cm above the ground) is 0.64s, which is the shortest among the four athletes. Athlete B took 0.67s to complete the standard support push up (feet 25 cm above the ground) movement, which was the longest time of the four athletes.

From the time taken to push up from the standard support push-up (feet 30 cm above the ground) (table 80), the average time taken by the average athlete to push up from the standard support push-up (feet 30 cm above the ground) is 0.64s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support push up (feet 30cm higher than the ground) is very similar, and the time of athlete A and B to complete the standard support push up (feet 30cm higher than the ground) is 0.63s, which is the shortest among the four athletes. Athlete C and D took 0.65 seconds to complete the standard support push up (feet 30 cm above the ground), which was the longest time of the four athletes.

From the time taken to push up from the standard support push-up (feet 40 cm above the ground) (table 80), the average time for the average athlete to push up from the standard support push-up (feet 40 cm above the ground) is 0.73s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support push up (feet 40cm higher than the ground) is very

similar, and the time of athlete A to complete the standard support push up (feet 40cm higher than the ground) is 0.71s, which is the shortest among the four athletes. Athlete B took 0.75s to complete the standard support push up (feet 40 cm above the ground), which was the longest time of the four athletes.

From the time taken to push up from the standard support push-up (feet 50 cm above the ground) (table 80), the average time taken by the average athlete to complete the standard support push-up (feet 50 cm above the ground) is 0.74s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support push up (feet 50cm above the ground) is very similar, and the time of athlete D to complete the standard support push up (feet 50cm above the ground) is 0.72s, which is the shortest among the four athletes. Athletes B took 0.76s to complete the standard support push up (feet 50 cm above the ground), which was the longest time of the four athletes.

(2) The time when the wide support push-ups with different loads are pushed up

Table 81 Statistical table when the general level athletes complete the wide support push up push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.74	0.66	0.63	0.79	0.73
B	0.67	0.68	0.64	0.71	0.78
C	0.68	0.69	0.61	0.77	0.79
D	0.69	0.71	0.69	0.79	0.75
$\bar{x} \pm s$	0.70±0.03	0.69±0.02	0.64±0.03	0.77±0.04	0.76±0.03

In terms of the time taken to push up with wide support push-up (both feet on the ground) (table 81), the average time taken by ordinary athletes to complete the push up with wide support push-up is 0.70s, and the standard deviation is 0.03s. The

time of the four athletes participating in the test to complete the wide support push up (feet on the ground) is very close, and the time of athlete B to complete the wide support push up (feet on the ground) is 0.67s, which is the shortest among the four athletes. Athlete A took 0.74s to complete the wide support push up movement (feet on the ground), which was the longest time among the four athletes.

In terms of the time taken to push up with wide support push-up (feet 25 cm above the ground) (table 81), the average time taken by ordinary athletes to push up with wide support push-up (feet 25 cm above the ground) is 0.69s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the wide support push up (feet 25cm above the ground) is very similar, and the time of athlete A to complete the wide support push up (feet 25cm above the ground) is 0.66s, which is the shortest among the four athletes. Athlete D took 0.71 seconds to complete the wide support push up (feet 25 cm above the ground), which was the longest time of the four athletes.

In terms of the time taken to push up with wide support push-ups (feet 30 cm above the ground) (table 81), the average time taken by ordinary athletes to push up with wide support push-ups (feet 30 cm above the ground) is 0.64s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support push up (feet 30cm higher than the ground) is very similar, and the time of athletes C to complete the wide support push up (feet 30cm higher than the ground) is 0.61s, which is the shortest among the four athletes. Athlete D took 0.69 seconds to complete the wide support push up movement (feet are 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time taken to push up with wide support push-up (feet 40cm above the ground) (table 81), the average time taken by ordinary athletes to push up with wide support push-up (feet 40cm above the ground) is 0.77s, and the standard deviation is 0.04s. The time of the four athletes participating in the test to complete the wide support push up (feet 40cm higher than the ground) is very similar, and the time of athletes B to complete the wide support push up (feet 40cm higher than the ground) is 0.71s, which is the shortest among the four athletes. Athlete A and D took 0.79s to

complete the wide support push up (feet 40 cm above the ground) movement, which was the longest time among the four athletes.

In terms of the time taken to push up with wide support push-up (feet 50 cm above the ground) (table 81), the average time taken by ordinary athletes to push up with wide support push-up (feet 50 cm above the ground) is 0.76s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support push up (feet 50cm above the ground) is very similar, and the time of athlete A to complete the wide support push up (feet 50cm above the ground) is 0.73s, which is the shortest among the four athletes. Athlete C took 0.79s to complete the broad support push up (feet 50 cm above the ground) movement, which was the longest time among the four athletes.

(3) Standard support for different loads of high-five push-ups pushed up

Table 82 Statistical table when the average level athletes complete the standard support high-five push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.52	0.48	0.51	0.57	0.63
B	0.57	0.51	0.52	0.55	0.61
C	0.51	0.49	0.51	0.57	0.62
D	0.52	0.51	0.54	0.59	0.63
$\bar{X} \pm S$	0.53±0.03	0.50±0.02	0.52±0.01	0.57±0.02	0.62±0.01

Judging from the time taken to push up (with both feet on the ground) in standard supported high-five push-ups (table 82), the average time taken by ordinary athletes to push up in standard supported high-five push-ups is 0.53s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet on the ground) is very close, and the time of athlete C to complete the standard support high-five push up (feet on the ground) is 0.51s, which is the shortest among the four athletes. Athlete B took 0.57s to complete

the standard support high-five push up movement (feet on the ground), which was the longest time among the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 25 cm above the ground) (table 82), the average time taken by the ordinary athletes to push up from the standard supported high-five push up (feet 25 cm above the ground) is 0.50s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 25cm above the ground) is very similar, and the time of athlete A to complete the standard support high-five push up (feet 25cm above the ground) is 0.48s, which is the shortest among the four athletes. Athlete B and D took 0.51s to complete the standard support high-five push up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 30cm above the ground) (table 82), the average time taken by the ordinary athletes to push up from the standard supported high-five push up (feet 30cm above the ground) is 0.52s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 30cm higher than the ground) is very similar, and the time of athlete A and C to complete the standard support high-five push up (feet 30cm higher than the ground) is 0.51s, which is the shortest among the four athletes. Athlete D took 0.54s to complete the standard support high-five push up (feet 30 cm above the ground) movement, which was the longest time of the four athletes.

Judging from the time taken to push up (feet 40 cm above the ground) in the standard supported high-five push up (feet 40 cm above the ground) (table 82), the average time taken by ordinary athletes to push up (feet 40 cm above the ground) in the standard supported high-five push up is 0.57s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 40cm higher than the ground) is very similar, and the time of athlete B to complete the standard support high-five push up (feet 40cm higher than the ground) is 0.55s, which is the shortest among the four athletes. Athlete D took 0.59s to

complete the standard support high-five push up (feet 40 cm above the ground) movement, which was the longest time among the four athletes.

Judging from the time taken to push up from the standard supported high-five push up (feet 50 cm above the ground) (table 82), the average time taken by the ordinary athletes to push up from the standard supported high-five push up (feet 50 cm above the ground) is 0.62s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push up (feet 50cm above the ground) is very similar, and the time of athlete B to complete the standard support high-five push up (feet 50cm above the ground) is 0.61s, which is the shortest among the four athletes. Athlete A and D took 0.63s to complete the standard support high-five push up movement (feet 50 cm above the ground), which was the longest time among the four athletes.

(4) Wide support for different loads of high-five push-ups pushed up

Table 83 Statistical table when the general level athletes complete the wide support high-five push up (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.65	0.55	0.62	0.61	0.69
B	0.68	0.56	0.55	0.55	0.65
C	0.67	0.52	0.66	0.58	0.67
D	0.69	0.57	0.59	0.57	0.64
$\bar{x} \pm s$	0.67±0.02	0.55±0.02	0.61±0.05	0.58±0.03	0.66±0.02

In terms of the time taken to push up (with both feet on the ground) in the wide-supported push-up (table 83), the average time for the average athlete to complete the wide-supported push-up is 0.67s, and the standard deviation is 0.02s. The time of the four athletes who participated in the test to complete the wide support high-five push up (feet on the ground) is very close, and the time of athlete A to complete the wide support high-five push up (feet on the ground) is 0.65s, which is the shortest among the four athletes. Athlete D took 0.69s to complete the broad support high-five

push up (feet on the ground) movement, which was the longest time among the four athletes.

From the point of view of the time taken to push up with wide support high-five push-ups (feet 25 cm above the ground) (table 83), the average time taken by ordinary athletes to push up with wide support high-five push-ups (feet 25 cm above the ground) is 0.55s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 25cm above the ground) is very similar, and the time of athlete C to complete the wide support high-five push up (feet 25cm above the ground) is 0.52s, which is the shortest among the four athletes. Athlete D took 0.57 seconds to complete the broad support high-five push up (feet 25 cm above the ground), which was the longest time among the four athletes.

In terms of the time taken to push up with wide support high-five push-ups (feet 30cm above the ground) (table 83), the average time taken by ordinary athletes to push up with wide support high-five push-ups (feet 30cm above the ground) is 0.61s, and the standard deviation is 0.05s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 30cm higher than the ground) is very similar, and the time of athlete B to complete the wide support high-five push up (feet 30cm higher than the ground) is 0.55s, which is the shortest among the four athletes. Athlete C took 0.66s to complete the broad support high-five push up (feet 30 cm above the ground) movement, which was the longest time of the four athletes.

From the point of view of the time taken to push up with wide support high-five push up (feet 40 cm above the ground) (table 83), the average time taken by ordinary athletes to push up with wide support high-five push up (feet 40 cm above the ground) is 0.58s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide support high-five push up (feet 40cm higher than the ground) is very similar, and the time of athlete B to complete the wide support high-five push up (feet 40cm higher than the ground) is 0.55s, which is the shortest among the four athletes. Athlete A took 0.61 seconds to complete the broad support high-five push up (feet 40 cm above the ground), which was the longest time among the four athletes.

From the point of view of the time taken to push up with wide support high-five push-ups (feet 50 cm above the ground) (table 83), the average time taken by ordinary athletes to push up with wide support high-five push-ups (feet 50 cm above the ground) is 0.66s, and the standard deviation is 0.02s. The four athletes who participated in the test took very similar time to complete the wide support high-five push up (feet 50cm above the ground), and the time for athlete D to complete the wide support high-five push up (feet 50cm above the ground) was 0.64s, which was the shortest among the four athletes. Athlete A took 0.69 seconds to complete the broad support high-five push up (feet 50 cm above the ground) movement, which was the longest time of the four athletes.

2.3.1.4 Time characteristics of high-five push-ups in the air phase

(1) Standard support for different loads of high-five push-ups in the air stage

Table 84 Statistical table of the time taken by ordinary athletes to complete standard support high-five push-ups in the air (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.27	0.31	0.29	0.22	0.21
B	0.28	0.29	0.28	0.25	0.21
C	0.23	0.32	0.28	0.23	0.22
D	0.27	0.28	0.29	0.26	0.23
$\bar{x} \pm s$	0.26±0.02	0.31±0.01	0.29±0.01	0.24±0.02	0.22±0.01

From the perspective of the time taken to complete the air lift of the standard supported high-five push up (with both feet on the ground) (table 84), the average time taken by the ordinary athletes to complete the air lift of the standard supported high-five push up is 0.26s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet on the ground) is very close, and the time of athlete C to complete the standard support high-five push-up movement (feet on the ground) is

0.23s, which is the shortest among the four athletes. Athlete B took 0.28s to complete the standard support high-five push-up movement (feet on the ground), which was the longest time among the four athletes.

Judging from the time taken to complete the air lift of the standard supported high-five push-up (both feet are 25 cm above the ground) (table 84), the average time taken by the ordinary athletes to complete the air lift of the standard supported high-five push-up is 0.31s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 25cm above the ground) is very similar, and the time of athlete D to complete the standard support high-five push-up movement (feet 25cm above the ground) is 0.28s, which is the shortest among the four athletes. Athlete C took 0.32s to complete the standard support high-five push-up (feet 25 cm above the ground), which was the longest time among the four athletes.

Judging from the time taken to complete the air lift of standard supported high-five push-ups (feet are 30 cm above the ground) (table 84), the average time taken by ordinary athletes to complete the air lift of standard supported high-five push-ups is 0.29s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 30cm higher than the ground) is very similar, and the time of athlete B and C to complete the standard support high-five push-up movement (feet 30cm higher than the ground) is 0.28s, which is the shortest among the four athletes. Athlete A and D took 0.29s to complete the standard support high-five push-up movement (feet 30 cm above the ground), which was the longest time among the four athletes.

Judging from the time taken to complete the air lift of the standard supported high-five push-up (both feet are 40 cm higher than the ground) (table 84), the average time taken by the ordinary athletes to complete the air lift of the standard supported high-five push-up is 0.24s, and the standard deviation is 0.02s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 40cm higher than the ground) was very similar, and the time of athlete A to complete the standard support high-five push-up movement (feet 40cm higher than the ground) was 0.22s, which was the shortest among the four athletes.

Athlete D took 0.26s to complete the standard support high-five push-up movement (feet 25 cm above the ground), which was the longest time among the four athletes.

Judging from the time taken to push up (feet 50 cm above the ground) in the standard supported high-five push up (table 84), the average time for the average athlete to complete the standard supported high-five push up in the air is 0.22s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the standard support high-five push-up movement (feet 50cm above the ground) is very similar, and the time of athlete A and B to complete the standard support high-five push-up movement (feet 50cm above the ground) is 0.21s, which is the shortest among the four athletes. Athlete D took 0.23s to complete the standard support high-five push-up movement (feet 50 cm above the ground), which was the longest time among the four athletes.

(2) The use of wide support for different loads of high-five push-ups in the air stage

Table 85 Statistical table of the time taken by ordinary athletes to complete the wide support high-five push-up in the air (s)

measure	0cm	25cm	30cm	40cm	50cm
A	0.24	0.31	0.22	0.25	0.22
B	0.27	0.29	0.31	0.23	0.23
C	0.25	0.32	0.29	0.24	0.21
D	0.27	0.32	0.32	0.29	0.24
$\bar{x} \pm s$	0.26±0.02	0.29±0.01	0.29±0.05	0.25±0.03	0.23±0.01

In terms of the time taken to complete the high-five push-up with wide support (with both feet on the ground), it can be seen (table 85) that the average time taken by ordinary athletes to complete the high-five push-up with wide support is 0.26s, and the standard deviation is 0.02s. The time of the four athletes participating in the test

to complete the wide-supported high-five push-up movement (feet on the ground) was very similar, and the time of athlete A to complete the wide-supported high-five push-up movement (feet on the ground) was 0.24s, which was the shortest among the four athletes. Athlete B and D took 0.27s to complete the wide support high-five push-up (feet on the ground), which was the longest time among the four athletes.

In terms of the time taken to complete a wide-supported high-five push-up (both feet are 25 cm above the ground) (table 85), the average time taken by ordinary athletes to complete a wide-supported high-five push-up is 0.29s, and the standard deviation is 0.01s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 25cm higher than the ground) is very similar, and the time of athlete B to complete the wide-supported high-five push-up movement (feet 25cm higher than the ground) is 0.29s, which is the shortest among the four athletes. Athlete C and D took 0.32s to complete the wide support high-five push-up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

In terms of the time taken to complete the wide support high-five push up air (feet are 30 cm above the ground) (table 85), the average time taken by ordinary athletes to complete the wide support high-five push up air is 0.29s, and the standard deviation is 0.05s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 30cm higher than the ground) is very similar, and the time of athletes A to complete the wide-supported high-five push-up movement (feet 30cm higher than the ground) is 0.22s, which is the shortest among the four athletes. Athlete D took 0.32s to complete the wide support high-five push-up (feet 30 cm above the ground), which was the longest time among the four athletes.

In terms of the time taken to complete a wide-supported push-up with high five (both feet are 40 cm above the ground) (table 85), the average time taken by ordinary athletes to complete a wide-supported push-up with high five is 0.25s, and the standard deviation is 0.03s. The time of the four athletes participating in the test to complete the wide-supported high-five push-up movement (feet 40cm higher than the ground) is very similar, and the time of athletes B and C to complete the wide-supported high-five push-up movement (feet 40cm higher than the ground) is 0.23s, which is the

shortest among the four athletes. Athlete D took 0.29s to complete the wide support high-five push-up (feet 25 cm above the ground) movement, which was the longest time among the four athletes.

In terms of the time taken to push up from the wide-supported push-up (feet 50 cm above the ground) (table 85), the average time for the average athlete to complete the wide-supported push-up is 0.23s, and the standard deviation is 0.01s. The four athletes who participated in the test took very similar time to complete the wide-supported high-five push-up movement (feet 50cm above the ground), in which athletes C took 0.21s to complete the wide-supported high-five push-up movement (feet 50cm above the ground), which was the shortest time among the four athletes. Athlete D took 0.24s to complete the wide support high-five push-up (feet 50 cm above the ground) movement, which was the longest time among the four athletes.

2.3.2 Speed Characteristics

2.3.2.1 Peak velocity characteristics of shoulder joint in the lower flexion phase

Table 86 The shoulder joint speed peak value of the standard support push-up for ordinary level athletes (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.728	0.726	0.791	0.724	0.742±0.032
	Right shoulder joint	0.739	0.783	0.775	0.777	0.768±0.020
25cm	Left shoulder joint	0.873	0.878	0.868	0.875	0.873±0.004
	Right shoulder joint	0.871	0.865	0.822	0.841	0.850±0.023
30cm	Left shoulder joint	0.890	0.846	0.871	0.899	0.876±0.023
	Right shoulder joint	0.878	0.821	0.891	0.908	0.874±0.038
40cm	Left shoulder joint	0.809	0.781	0.841	0.858	0.822±0.034
	Right shoulder joint	0.833	0.785	0.835	0.878	0.832±0.038
50cm	Left shoulder joint	0.818	0.765	0.810	0.826	0.805±0.028
	Right shoulder joint	0.830	0.752	0.808	0.838	0.807±0.039

Athletes : A、B、C and D

From the difference of peak shoulder joint speed in the stage of push-ups with standard support (0cm) on the ground and the stage of bending arms with downward flexion (Table 86), the average speed and standard deviation of the left shoulder joint of ordinary athletes are 0.742m/s and 0.032m/s when they complete the stage of bending arms with downward support push-ups. The mean velocity of the right shoulder joint was 0.768m/s, and the standard deviation was 0.020m/s. The characteristics of the average level athletes in the standard support push-ups (feet height 0 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of push-ups with standard support with feet on the ground (25cm) and in the stage of bending arms with downward flexion (Table 86), the average speed and standard deviation of the left shoulder joint of ordinary athletes are 0.873m/s and 0.004m/s when they complete the stage of bending arms with downward flexion with standard support push-ups. The mean velocity of the right shoulder joint was 0.850m/s, and the standard deviation was 0.023m/s. The average speed of the right shoulder joint and the left shoulder joint is different, and the speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (30cm) and the stage of downward flexion (Table 86), the average speed and standard deviation of left shoulder joint of ordinary athletes in the stage of downward flexion with standard support push-up are 0.876m/s and 0.023m/s respectively. The mean velocity of the right shoulder joint was 0.874m/s, and the standard deviation was 0.038m/s. The characteristics of the average level athletes in the standard support push-ups (feet height of 30 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of push-ups with standard support with feet on the ground (40cm) and the stage of bending arms

with downward flexure (Table 86), the average speed and standard deviation of the left shoulder joint of ordinary athletes are 0.822m/s and 0.034m/s when they complete the stage of bending arms with downward flexure with standard support push-ups. The mean velocity of the right shoulder joint was 0.832m/s, and the standard deviation was 0.038m/s. The characteristics of the average level athletes in the standard support push-ups (feet height of 40 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of standard support push-up with feet on the ground (50cm) and the stage of downward flexion (Table 86), the average speed and standard deviation of left shoulder joint of ordinary athletes in the stage of downward flexion with standard support push-up are 0.805m/s and 0.028m/s respectively. The mean velocity of the right shoulder joint was 0.807m/s, and the standard deviation was 0.039m/s. The characteristics of the average level athletes in the standard support push-ups (feet height of 50 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

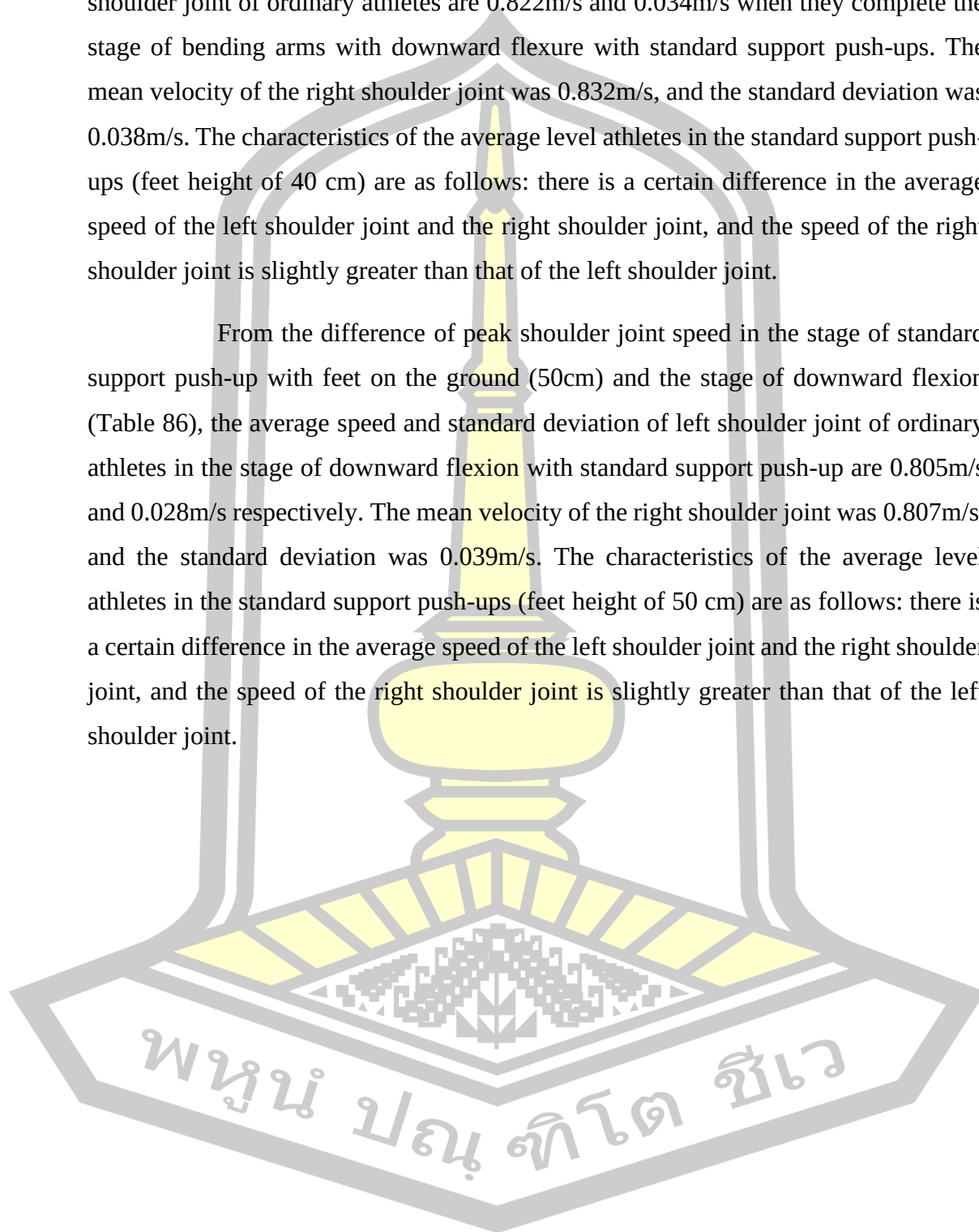


Table 87 The peak of shoulder joint speed of general level athletes in the stage of broad support push-up and bending arms (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.924	0.795	0.907	0.782	0.883±0.073
	Right shoulder joint	0.993	0.785	0.976	0.772	0.913±0.118
25cm	Left shoulder joint	1.154	1.094	1.137	1.081	1.148±0.034
	Right shoulder joint	1.137	1.080	1.120	1.067	1.133±0.032
30cm	Left shoulder joint	1.041	1.139	1.024	1.126	1.114±0.059
	Right shoulder joint	1.077	1.161	1.060	1.148	1.143±0.051
40cm	Left shoulder joint	1.198	1.477	1.181	1.464	1.361±0.163
	Right shoulder joint	1.141	1.267	1.124	1.254	1.228±0.075
50cm	Left shoulder joint	1.129	1.169	1.112	1.156	1.173±0.026
	Right shoulder joint	1.093	1.147	1.076	1.134	1.144±0.034

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward flexion (Table 87), the average speed and standard deviation of the left shoulder joint of ordinary level athletes are 0.883m/s and 0.073m/s when they complete wide-supported push-up and downward flexion. The mean velocity of the right shoulder joint was 0.0913/s, and the standard deviation was 0.118m/s. The characteristics of the general level athletes in the stage of bending the arms of the downward flexion after completing the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (25cm) and the stage of downward flexion (Table 87), the average speed and standard deviation of the left shoulder joint of ordinary athletes are 1.148m/s and 0.034m/s in the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.133m/s, and the standard deviation was 0.032m/s. The characteristics of the average

level athletes who complete the wide support push-up (the height of their feet is 25 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in the stage of wide-supported push-up with feet on the ground (30cm) and the stage of downward flexion (Table 87), the average speed and standard deviation of the left shoulder joint of ordinary athletes are 1.114m/s and 0.059m/s in the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.143m/s, and the standard deviation was 0.051m/s. The characteristics of the average level athletes who complete the wide support push-up (the height of their feet is 30 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (40cm) and the stage of downward flexion (Table 87), the average speed and standard deviation of the left shoulder joint of ordinary athletes are 1.361m/s and 0.163m/s in the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.228m/s, and the standard deviation was 0.075m/s. The characteristics of the average level athletes who complete the wide support push-up (the height of their feet is 40 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of peak shoulder joint speed in the stage of wide-supported push-up with feet on the ground (50cm) and the stage of downward flexion, Table 87 shows that the average speed and standard deviation of the left shoulder joint of ordinary athletes are 1.173m/s and 0.026m/s respectively when they complete the stage of downward flexion with standard supported push-up. The mean velocity of the right shoulder joint was 1.144m/s, and the standard deviation was 0.034m/s. The characteristics of the average level athletes who complete the wide support push-up

(feet height of 50 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

2.3.2.2 Peak velocity characteristics of shoulder joint in the stage of upward pushing

Table 88 The peak of shoulder joint speed in push-up stage of standard support for ordinary athletes (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.885	0.850	0.859	0.867	0.900±0.015
	Right shoulder joint	0.833	0.864	0.839	0.815	0.864±0.010
25cm	Left shoulder joint	0.882	1.041	1.016	0.864	0.977±0.081
	Right shoulder joint	0.819	0.990	0.965	0.801	0.920±0.087
30cm	Left shoulder joint	1.005	1.028	1.003	0.987	1.032±0.007
	Right shoulder joint	0.976	0.970	0.945	0.958	0.988±0.017
40cm	Left shoulder joint	0.994	1.107	1.082	0.976	1.066±0.054
	Right shoulder joint	0.942	0.975	0.950	0.924	0.974±0.010
50cm	Left shoulder joint	1.042	1.321	1.296	1.024	1.197±0.149
	Right shoulder joint	0.914	1.259	1.234	0.896	1.102±0.188

From the difference of shoulder joint speed peak value in push-ups with standard support height (0cm) on the ground and upward push stage (Table 88), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 0.900m/s and 0.015m/s respectively. The mean velocity of the right shoulder joint was 0.864m/s and the standard deviation was 0.010m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the

standard support push-up (feet height 0 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (25cm) and upward push stage (Table 88), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 0.977m/s and 0.081m/s respectively. The mean velocity of the right shoulder joint was 0.920m/s, and the standard deviation was 0.087m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the standard support push-up (the height of the feet is 25 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (30cm) and upward push stage (Table 88), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 1.032m/s and 0.007m/s respectively. The mean velocity of the right shoulder joint was 0.988m/s, and the standard deviation was 0.017m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the standard support push-up (feet height of 30 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with both feet on the ground (40cm) and upward push stage (Table 88), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 1.066m/s and 0.054m/s respectively. The mean velocity of the right shoulder joint was 0.974m/s, and the standard deviation was 0.010m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the standard support push-up (the height of the feet is 40 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right

shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with standard support with feet on the ground (50cm) and upward push stage (Table 88), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 1.197m/s and 0.149m/s, respectively. The mean velocity of the right shoulder joint was 1.102m/s, and the standard deviation was 0.188m/s. The characteristics of ordinary athletes in the stage of pushing up after completing the standard support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

Table 89 The peak of shoulder joint speed of general level athletes in the stage of broad support push up (m/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	0.569	0.637	0.534	0.606	0.931±0.047
	Right shoulder joint	0.496	0.726	0.461	0.695	0.940±0.140
25cm	Left shoulder joint	0.592	0.829	0.557	0.798	1.039±0.144
	Right shoulder joint	0.570	0.954	0.535	0.923	1.090±0.229
30cm	Left shoulder joint	0.556	1.006	0.521	0.975	1.110±0.267
	Right shoulder joint	0.617	0.903	0.582	0.872	1.088±0.173
40cm	Left shoulder joint	0.593	1.015	0.558	0.984	1.133±0.251
	Right shoulder joint	0.636	0.777	0.601	0.746	1.035±0.089
50cm	Left shoulder joint	0.540	0.892	0.505	0.861	1.044±0.210
	Right shoulder joint	0.560	0.770	0.525	0.739	0.993±0.128

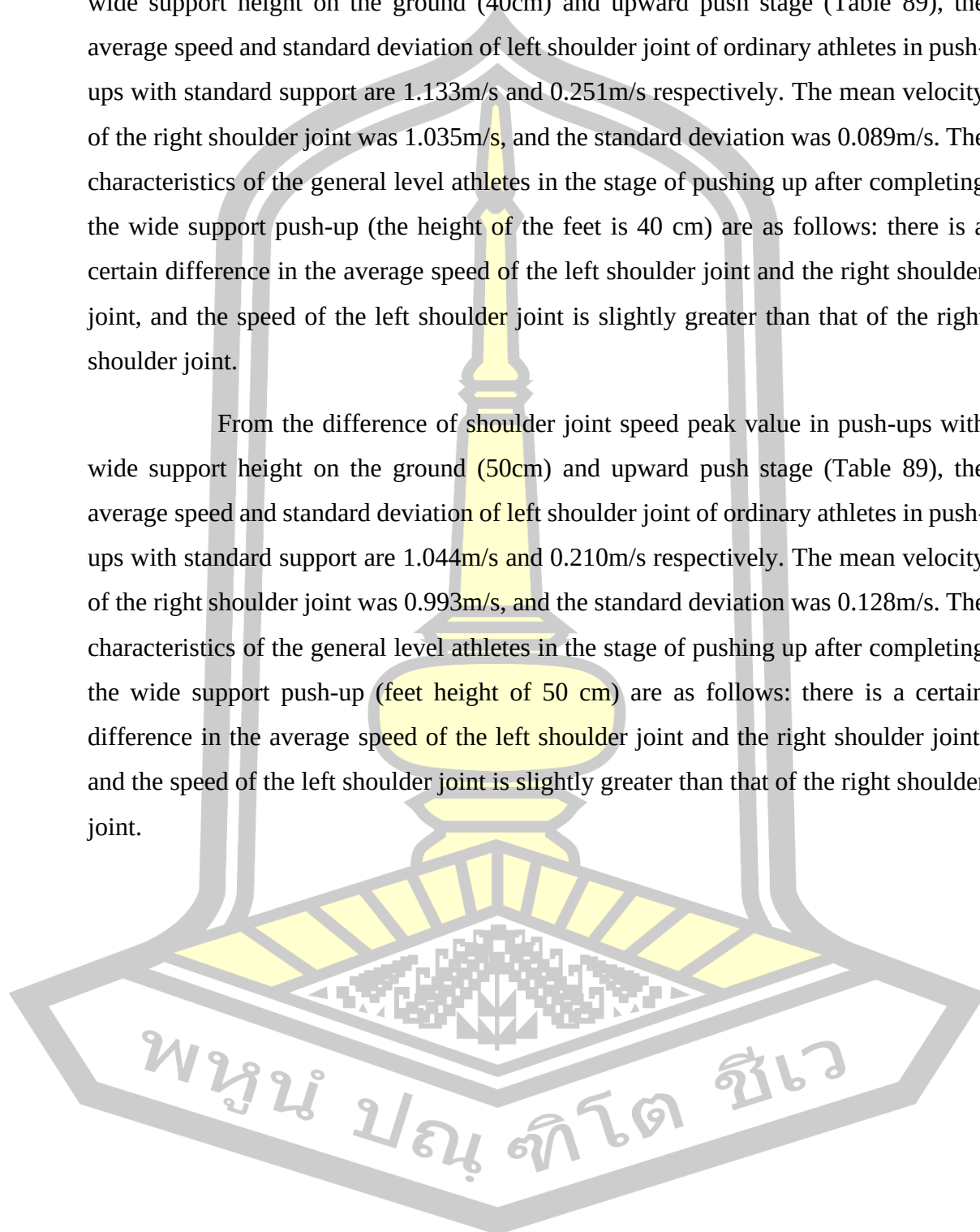
From the difference of peak shoulder joint speed in the stage of broad support push-up with feet on the ground (0cm) and upward push (Table 89), the average speed of the left shoulder joint and standard deviation of the right shoulder joint are 0.931m/s and 0.047m/s respectively for the average level athletes in the stage of broad support push-up and upward push. The mean velocity of the right shoulder joint was 0.940m/s, and the standard deviation was 0.140m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (25cm) and upward push stage (Table 89), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 1.039m/s and 0.144m/s respectively. The mean velocity of the right shoulder joint was 1.090m/s, and the standard deviation was 0.229m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push-up (the height of the feet is 25 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the right shoulder joint is slightly greater than that of the left shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (30cm) and upward push stage (Table 89), the average speed and standard deviation of left shoulder joint of ordinary athletes are 1.110m/s and 0.267m/s when they complete the upward push stage of standard support push-ups. The mean velocity of the right shoulder joint was 1.088m/s, and the standard deviation was 0.173m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push up (the height of the feet is 30 cm) are: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (40cm) and upward push stage (Table 89), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 1.133m/s and 0.251m/s respectively. The mean velocity of the right shoulder joint was 1.035m/s, and the standard deviation was 0.089m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push-up (the height of the feet is 40 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.

From the difference of shoulder joint speed peak value in push-ups with wide support height on the ground (50cm) and upward push stage (Table 89), the average speed and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 1.044m/s and 0.210m/s respectively. The mean velocity of the right shoulder joint was 0.993m/s, and the standard deviation was 0.128m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average speed of the left shoulder joint and the right shoulder joint, and the speed of the left shoulder joint is slightly greater than that of the right shoulder joint.



2.3.3 Features of elbow joint Angle and shoulder joint angular velocity

2.3.3.1 Angle characteristics of the lowest elbow joint in the lower flexion arm

(1) Standard support push-up downward flexion elbow Angle

Table 90 Average level athletes standard support push-up down flexion arm lowest elbow Angle ($^{\circ}$)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	32.6	33.59	39.94	34.77	35.23 $\pm$ 3.27
	Right elbow joint	35.31	35.54	40.52	35.79	36.79 $\pm$ 2.49
25cm	Left elbow joint	32.88	34.31	40.46	35.7	35.84 $\pm$ 3.29
	Right elbow joint	35.49	37.28	41.44	36.91	37.78 $\pm$ 2.56
30cm	Left elbow joint	34.68	35.87	42.75	45.54	39.71 $\pm$ 5.27
	Right elbow joint	36.69	39.74	44.47	46.69	41.90 $\pm$ 4.52
40cm	Left elbow joint	34.82	35.99	42.72	45.6	39.78 $\pm$ 5.21
	Right elbow joint	36.84	39.86	44.55	46.69	41.99 $\pm$ 4.46
50cm	Left elbow joint	36.91	38.12	43.84	46.79	41.42 $\pm$ 4.69
	Right elbow joint	39.02	39.55	46.65	47.61	43.21 $\pm$ 4.55

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height (0cm) on the ground and in the stage of downward flexion (Table 90), the average Angle and standard deviation of the left elbow joint of the average athlete in the stage of completing standard push-ups and downward flexion are 35.23 $^{\circ}$ and 3.27 $^{\circ}$ respectively. The mean Angle of the right elbow joint was 36.79 $^{\circ}$ and the standard deviation was 2.49 $^{\circ}$. The characteristics of the lowest point of the average level athlete when completing the standard support push-up (feet height 0 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 25 cm higher than the ground (Table 90), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 35.84° and 3.29° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 87). The mean Angle of the right elbow joint was 37.78° and the standard deviation was 2.56° . The lowest point of the average level athlete in the stage of the downward flexion is characterized by the Angle of the right elbow joint being greater than that of the left elbow joint when completing the standard support push-up (the height of the feet is 25 cm).

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 30cm higher than the ground (Table 90), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 39.71° and 5.27° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 87). The mean Angle of the right elbow joint was 41.90° and the standard deviation was 4.52° . The lowest point of the average level athlete in the stage of the downward flexion is characterized by the Angle of the right elbow joint being greater than that of the left elbow joint when completing the standard support push-up (the height of the feet is 30 cm).

From the difference of peak elbow Angle of the lowest point in push-ups with standard support height 40 cm higher than the ground (Table 90), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 39.78° and 5.21° respectively at the lowest point in the stage of push-ups with standard support and bending arms (Table 87). The mean Angle of the right elbow joint was 41.99° and the standard deviation was 4.46° . The lowest point of the average level athlete in the stage of the downward flexion is characterized by the Angle of the right elbow joint being greater than that of the left elbow joint when completing the standard support push-up (the height of the feet is 40 cm).

From the difference of peak elbow Angle of the lowest point in push-ups with feet 50 cm higher than the ground and the lowest point in the downward flexion stage (Table 90), the average Angle of the left elbow joint is 41.42° and the standard deviation is 4.69° in the lowest point in the downward flexion stage of the standard

push-ups for ordinary athletes. The mean Angle of the right elbow joint was 43.21° and the standard deviation was 4.55° . The lowest point of the average level athlete in the stage of the downward flexion is characterized by the Angle of the right elbow joint being greater than that of the left elbow joint when completing the standard support push-up (the height of the feet is 50 cm).

(2) Wide support push up downward flexion arm elbow joint Angle

Table 91 General level athletes wide support push up down flexion arm low elbow joint Angle

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	31.54	32.39	38.68	33.45	34.02 ± 3.21
	Right elbow joint	34.25	34.34	39.26	34.47	35.58 ± 2.45
25cm	Left elbow joint	31.77	33.03	39.29	34.27	34.59 ± 3.30
	Right elbow joint	34.38	36	40.27	35.48	36.53 ± 2.58
30cm	Left elbow joint	33.57	34.73	41.52	44.41	38.56 ± 5.25
	Right elbow joint	35.58	38.6	43.14	45.56	40.72 ± 4.48
40cm	Left elbow joint	33.75	34.68	41.45	44.29	38.54 ± 5.14
	Right elbow joint	35.76	38.55	43.14	45.38	40.71 ± 4.35
50cm	Left elbow joint	35.68	36.95	42.54	45.5	40.17 ± 4.64
	Right elbow joint	37.79	38.38	45.35	46.32	41.96 ± 4.50

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported push-up with both feet on the ground (0cm) and the stage of downward flexion (Table 91), the average Angle of the left elbow joint is 34.02° , the standard deviation is 3.21° , and the average Angle of the right elbow

joint is 35.58° . The standard deviation is 2.45° . The characteristics of the lowest point of the average level athlete when completing the wide support push up (the height of the feet is 0 cm) are: the Angle of the right elbow joint is greater than the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of push-ups with wide support with both feet 25 cm higher than the ground (Table 91), the average Angle of the left elbow joint and standard deviation of the left elbow joint are 34.59° and 3.30° respectively for the lowest point of the stage of push-ups with wide support and downward flexion (Table 88). The mean Angle of the right elbow joint was 36.53° and the standard deviation was 2.58° . The lowest point of the average level athlete in the stage of the downward flexion is characterized by the Angle of the right elbow joint being greater than that of the left elbow joint when completing the wide support push up (the height of the feet is 25 cm).

From the perspective of the difference in peak elbow Angle of the lowest point in push-ups with wide support height 30cm higher than the ground and the lower bend arm stage (Table 91), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 38.56° and 5.25° respectively at the lowest point in the lower bend arm stage after completing wide push-ups. The mean Angle of the right elbow joint was 40.72° and the standard deviation was 4.48° . The characteristics of the lowest point of the average level athlete when completing the wide support push up (the height of the feet is 30 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in push-ups with wide support height 40cm higher than the ground and the lower bend arm stage (Table 91), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 38.54° and 5.14° respectively at the lowest point in the lower bend arm stage after completing wide push-ups. The mean Angle of the right elbow joint was 40.71° and the standard deviation was 4.35° . The characteristics of the lowest point of the average level athlete when completing the wide support push up (the height of the feet is 40 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported push-up with feet 50 cm higher than the ground and the stage of downward flexural flexural (Table 91), the average Angle of the left elbow joint and the standard deviation of the left elbow joint are 40.17° and 4.64° respectively. The mean Angle of the right elbow joint was 41.96° and the standard deviation was 4.50°. The characteristics of the lowest point of the average level athlete when completing the wide support push up (the height of the feet is 50 cm) are: the Angle of the right elbow joint is greater than the left elbow joint.

(3) Standard support high-five push-ups downward flexion arm elbow Angle

Table 92 Average level athlete standard support high-five push up down flexion arm low elbow joint Angle (°)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	34.65	35.87	42.27	37.21	37.50±3.35
	Right elbow joint	37.36	37.82	42.85	38.23	39.06±2.55
25cm	Left elbow joint	34.98	36.48	42.8	38.03	38.07±3.39
	Right elbow joint	37.59	39.45	43.78	39.24	40.01±2.64
30cm	Left elbow joint	36.78	38.1	45.08	48.05	42.00±5.43
	Right elbow joint	38.79	41.97	46.8	49.2	44.19±4.69
40cm	Left elbow joint	36.86	38	45.14	48.05	42.01±5.44
	Right elbow joint	38.87	41.97	46.86	49.14	44.21±4.65
50cm	Left elbow joint	38.97	40.35	46.18	49.21	43.68±4.83
	Right elbow joint	41.08	41.78	48.99	50.03	45.47±4.69

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of standard high-five push-ups with both feet on the ground (0cm) and the stage of downward flexion (Table 92), the average Angle of the left elbow joint is 37.50° and the standard deviation is 3.35° in the stage of downward

flexion with standard high-five push-ups. The mean Angle of the right elbow joint was 39.06° and the standard deviation was 2.55° . The characteristics of the lowest point of the average level athlete in the stage of the downward flexion are: the Angle of the right elbow joint is greater than that of the left elbow joint.

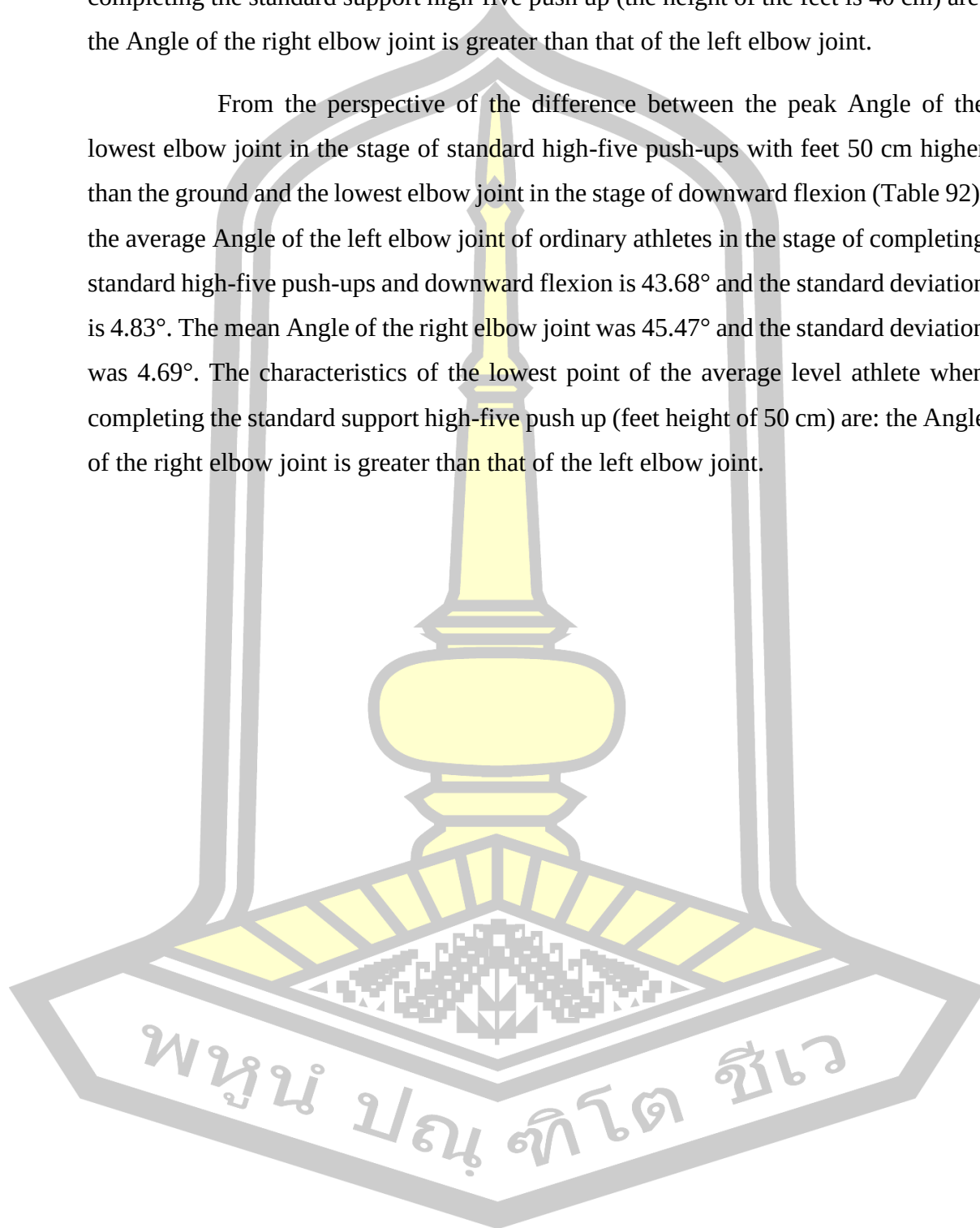
From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of standard support high-five push-ups with feet 25 cm higher than the ground and the stage of downward flexion (Table 92), the average Angle and standard deviation of the left elbow joint of ordinary athletes are 38.07° and 3.39° respectively at the lowest point in the stage of downward flexion when they complete standard high-five push-ups. The mean Angle of the right elbow joint was 40.01° and the standard deviation was 2.64° . The characteristics of the lowest point of the average level athlete when completing the standard support high-five push up (the height of the feet is 25 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of the standard support high-five push-ups with the height of both feet 30cm higher than the ground and the lowest elbow joint in the stage of the downward flexion (Table 92), the average Angle of the left elbow joint is 42.0° and the standard deviation is 5.43° for the average level athletes in the stage of the downward flexion when they complete the standard high-five push-ups. The mean Angle of the right elbow joint was 44.19° and the standard deviation was 4.69° . The characteristics of the lowest point of the average level athlete when completing the standard support high-five push up (the height of the feet is 30 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the elbow joint at the lowest point in the stage of the standard support high-five push-up with the height of both feet 40 cm higher than the ground (Table 92), the average Angle of the left elbow joint is 42.01° and the standard deviation is 5.44° in the stage of the lowest point in the stage of the downward flexion when the athletes complete the standard high-five push-up with the height of both feet being 40 cm higher than the ground. The mean Angle of the right elbow joint was 44.21° and the standard deviation

was 4.65° . The characteristics of the lowest point of the average level athlete when completing the standard support high-five push up (the height of the feet is 40 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of standard high-five push-ups with feet 50 cm higher than the ground and the lowest elbow joint in the stage of downward flexion (Table 92), the average Angle of the left elbow joint of ordinary athletes in the stage of completing standard high-five push-ups and downward flexion is 43.68° and the standard deviation is 4.83° . The mean Angle of the right elbow joint was 45.47° and the standard deviation was 4.69° . The characteristics of the lowest point of the average level athlete when completing the standard support high-five push up (feet height of 50 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.



(4) Wide support high-five push-ups down flexion arm lowest elbow joint

Angle

Table 93 General level athletes wide support high five push up down flexion arm lowest elbow joint Angle (°)

Foot height	Articulatio cubiti	A	B	C	D	$\bar{X} \pm S$
0cm	Left elbow joint	33.59	34.84	41.21	36.13	36.44±3.34
	Right elbow joint	36.3	36.79	41.82	37.15	38.02±2.56
25cm	Left elbow joint	33.95	35.43	41.79	36.98	37.04±3.40
	Right elbow joint	36.56	38.4	46.47	38.19	39.91±4.45
30cm	Left elbow joint	35.75	37.05	44.03	46.91	40.94±5.39
	Right elbow joint	37.76	40.92	45.82	48.06	43.14±4.66
40cm	Left elbow joint	35.83	36.95	44.03	47.02	40.96±5.43
	Right elbow joint	37.84	40.92	45.75	48.11	43.16±4.64
50cm	Left elbow joint	37.86	39.32	45.12	48.16	42.62±4.85
	Right elbow joint	39.97	40.75	47.93	48.98	44.41±4.70

From the perspective of the difference between the peak Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with feet on the ground (0cm) and the stage of downward flexion (Table 93), the average Angle of the left elbow joint is 36.44° and the standard deviation is 3.34° for the lowest point of the stage of downward flexion when the athletes complete the wide-supported high-five push-ups. The mean Angle of the right elbow joint was 38.02° and the standard deviation was 2.56°. The characteristics of the lowest point of the average level athlete in the stage of the downward flexion are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide-supported high-five push-ups with feet 25 cm higher than the ground and the stage of downward flexion (Table 93), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 37.04° and 3.40° respectively at the lowest point in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 39.91° and the standard deviation was 4.45° . The characteristics of the lowest point of the average level athlete when completing the wide-supported high-five push up (the height of the feet is 25 cm) are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide-supported high-fiving push-ups with feet 30 cm higher than the ground and the stage of downward flexion (Table 93), the average Angle of the left elbow joint is 40.94° and the standard deviation is 5.39° for the lowest point of the stage of downward flexion when the average athlete completed the wide-supported push-ups with feet 30 cm higher than the ground. The mean Angle of the right elbow joint was 43.14° and the standard deviation was 4.66° . The characteristics of the lowest point of the average level athlete in the stage of the downward flexion are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide-supported high-five push-ups with feet 40 cm higher than the ground and the stage of downward flexion (Table 93), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 40.96° and 5.43° respectively at the lowest point in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 43.16° and the standard deviation was 4.64° . The characteristics of the lowest point of the average level athlete in the stage of the downward flexion are: the Angle of the right elbow joint is greater than that of the left elbow joint.

From the perspective of the difference in peak elbow Angle of the lowest point in the stage of wide-supported high-five push-ups with feet 50 cm higher than the ground and the stage of downward flexion (Table 93), the average Angle and standard deviation of the left elbow joint of ordinary level athletes are 42.62° and 4.85° at the

lowest point in the stage of downward flexion with wide high-five push-ups. The mean Angle of the right elbow joint was 44.41° and the standard deviation was 4.70° . The characteristics of the lowest point of the average level athlete in the stage of the downward flexion are: the Angle of the right elbow joint is greater than that of the left elbow joint.

2.3.3.2 Peak angular velocity characteristics of shoulder joint in the stage of downward flexion

Table 94 The peak angular velocity of shoulder joint in the stage of standard support push-up for ordinary level athletes ($^\circ/\text{s}$)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	405.968	400.138	396.818	394.538	431.84 $\pm$ 6.32
	Right shoulder joint	427.279	421.149	417.929	414.749	452.75 $\pm$ 6.68
25cm	Left shoulder joint	484.479	474.649	471.429	464.849	506.33 $\pm$ 6.75
	Right shoulder joint	581.135	571.105	567.885	561.405	602.86 $\pm$ 6.81
30cm	Left shoulder joint	627.478	620.748	617.528	614.648	652.58 $\pm$ 6.87
	Right shoulder joint	577.041	570.111	566.891	564.111	602.01 $\pm$ 6.94
40cm	Left shoulder joint	512.211	501.581	494.861	495.681	533.56 $\pm$ 7.01
	Right shoulder joint	492.585	481.755	475.035	475.955	513.81 $\pm$ 7.07
50cm	Left shoulder joint	553.515	545.985	539.265	540.285	578.11 $\pm$ 7.14
	Right shoulder joint	544.585	536.855	530.135	531.255	569.06 $\pm$ 7.21

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support (0cm) on the ground and in the stage of bending arms with down support (Table 94), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of bending arms with down support

are 431.84m/s and 6.32m/s respectively. The mean angular velocity of the right shoulder joint was 452.75/s and the standard deviation was 6.68m/s. The characteristics of ordinary level athletes in the standard support push-up (feet height of 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (25cm) and in the stage of bending arms with down support (Table 94), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of bending arms with down support are 506.33m/s and 6.75m/s respectively. The mean angular velocity of the right shoulder joint was 602.86m/s and the standard deviation was 6.81m/s. The characteristics of the average level athletes in the standard support push-ups (the height of the feet is 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (30cm) and in the stage of bending arms with downward support (Table 94), the average angular velocity and standard deviation of the left shoulder joint of ordinary athletes in the stage of bending arms with downward support are 652.58m/s and 6.87m/s respectively. The mean angular velocity of the right shoulder joint was 602.01m/s and the standard deviation was 6.94m/s. The characteristics of the average level athletes in the standard support push-ups (feet height of 30 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (40cm) and in the stage of bending arms with down support (Table 94), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of bending arms with down support are 533.56m/s and 7.01m/s respectively. The mean angular velocity of

the right shoulder joint was 513.81m/s, and the standard deviation was 7.07m/s. The characteristics of the average level athletes in the standard support push-ups (feet height of 40 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with standard support with feet on the ground (50cm) and in the stage of bending arms with downward flexion (Table 94), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes are 578.11m/s and 7.14m/s when they complete the stage of bending arms with downward flexion with standard support push-ups. The mean angular velocity of the right shoulder joint was 569.06m/s and the standard deviation was 7.21m/s. The characteristics of the average level athletes in the standard support push-ups (feet height of 50 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

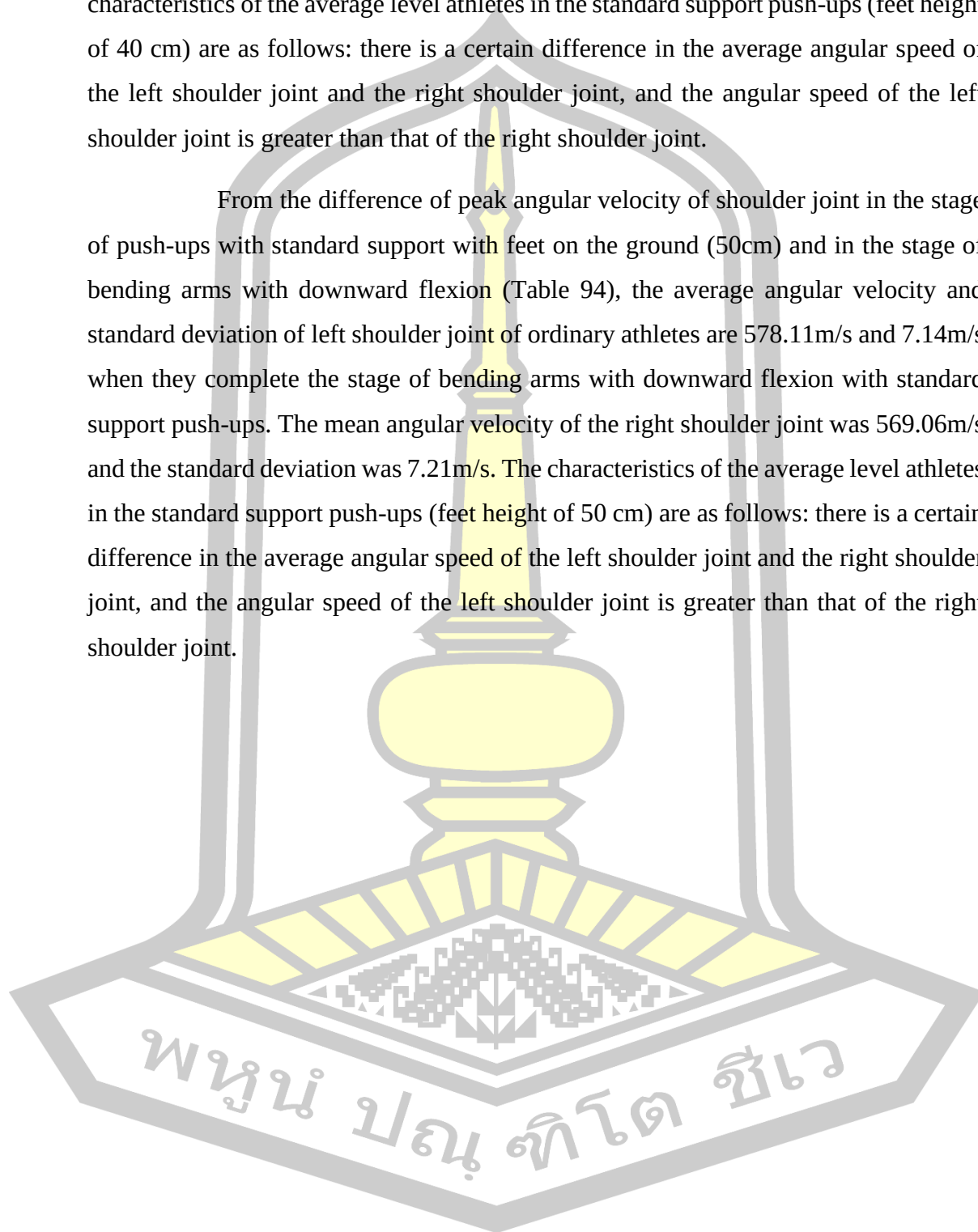


Table 95 The peak angular velocity of shoulder joint of general level athletes in the stage of broad support push-up and bending arms (°/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	658.315	642.995	640.685	636.305	677.17±9.33
	Right shoulder joint	488.536	471.416	470.606	466.426	506.85±9.55
25cm	Left shoulder joint	573.114	558.494	557.284	553.204	593.70±9.58
	Right shoulder joint	552.872	538.452	536.842	532.862	573.43±9.61
30cm	Left shoulder joint	702.356	688.136	683.826	682.246	722.89±9.65
	Right shoulder joint	705.757	691.737	687.027	685.547	726.27±9.69
40cm	Left shoulder joint	769.075	752.955	747.845	744.165	787.26±9.74
	Right shoulder joint	771.992	756.272	750.562	746.982	790.20±9.77
50cm	Left shoulder joint	798.438	785.218	781.408	777.928	818.92±9.82
	Right shoulder joint	796.398	782.378	779.368	775.688	816.63±9.92

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward flexion (Table 95), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of downward flexion with wide supported push-up are 677.17m/s and 9.33m/s respectively. The mean angular velocity of the right shoulder joint was 506.85/s and the standard deviation was 9.55m/s. The characteristics of the general level athletes in the stage of bending their arms when they complete the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (25cm) and the stage of

downward flexion (Table 95), the average angular velocity and standard deviation of the left shoulder joint of ordinary athletes are 593.70m/s and 9.58m/s in the stage of downward flexion with standard supported push-up. The mean angular velocity of the right shoulder joint was 573.43m/s and the standard deviation was 9.61m/s. The characteristics of the average level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (30cm) and the stage of downward flexion (Table 95), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of downward flexion with standard supported push-up are 722.89m/s and 9.65m/s respectively. The mean angular velocity of the right shoulder joint was 726.27m/s and the standard deviation was 9.69m/s. The characteristics of the general level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 30 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (40cm) and the stage of downward flexural arm flexural (Table 95), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of downward flexural arm flexural after completing standard supported push-up are 787.26m/s and 9.74m/s. The mean angular velocity of the right shoulder joint was 790.20m/s, and the standard deviation was 9.77m/s. The characteristics of the general level athletes in the stage of bending their arms when they complete the wide support push up (the height of their feet is 40 cm) are as follows: the average angular speed of the left shoulder joint and the right shoulder joint have a certain difference, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

According to the difference of peak angular velocity of shoulder joint in the stage of wide-supported push-up with feet on the ground (50cm) and the stage of downward flexion (Table 95), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of downward flexion with standard supported push-up are 818.92m/s and 9.82m/s respectively. The mean angular velocity of the right shoulder joint was 816.63m/s, and the standard deviation was 9.92m/s. The characteristics of ordinary level athletes in the stage of broad support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average angular speed of left shoulder joint and right shoulder joint, and the angular speed of left shoulder joint is greater than that of right shoulder joint.

2.3.3.3 Peak angular velocity characteristics of shoulder joint in the stage of upward pushing

Table 96 The peak angular velocity of shoulder joint in push-up stage of standard support for ordinary athletes (°/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	430.791	419.411	418.231	411.681	453.2±6.79
	Right shoulder joint	595.245	583.565	582.485	576.035	617.51±6.87
25cm	Left shoulder joint	395.406	383.526	382.446	380.396	417.54±6.94
	Right shoulder joint	355.298	343.218	342.138	340.188	377.31±7.02
30cm	Left shoulder joint	687.661	675.381	674.301	676.751	713.85±7.09
	Right shoulder joint	851.513	839.033	837.953	840.503	877.58±7.16
40cm	Left shoulder joint	679.823	662.843	666.063	660.113	701.46±7.24
	Right shoulder joint	651.042	635.362	637.082	631.232	672.93±7.22
50cm	Left shoulder joint	523.022	510.142	504.562	507.412	544.46±7.37
	Right shoulder joint	644.015	630.935	625.355	628.305	665.33±7.45

From the difference of peak angular velocity of shoulder joint in push-ups with standard support height (0cm) on the ground and upward push stage (Table 96), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 453.2m/s and 6.79m/s respectively. The mean angular velocity of the right shoulder joint was 617.51/s and the standard deviation was 6.87m/s. The characteristics of ordinary level athletes in the stage of push-up when completing the standard support push-up (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint during the push-up stage with standard support push-ups with feet on the ground (25cm) and the upward push stage (Table 96), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes during the push-up stage with standard support push-ups are 417.54m/s and 6.94m/s respectively. The mean angular velocity of the right shoulder joint was 377.31m/s, and the standard deviation was 7.02m/s. The characteristics of ordinary athletes in the stage of pushing up after completing the standard support push-up (the height of the feet is 25 cm) are as follows: the average angular speed of the left shoulder joint and the right shoulder joint have a certain difference, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in push-ups with standard support height (30cm) on the ground and upward push stage (Table 96), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 713.85m/s and 7.09m/s respectively. The mean angular velocity of the right shoulder joint was 877.58m/s and the standard deviation was 7.16m/s. The characteristics of ordinary athletes in the stage of pushing up after completing the standard support push-up (feet height of 30 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in push-ups with standard support height (40cm) on the ground and upward push stage (Table 96), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 701.46m/s and 7.24m/s respectively. The mean angular velocity of the right shoulder joint was 672.93m/s and the standard deviation was 7.22m/s. The characteristics of ordinary athletes in the stage of pushing up after completing the standard support push-up (the height of the feet is 40 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in push-ups with standard support height (50cm) on the ground and upward push stage (Table 96), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in push-ups with standard support are 544.46m/s and 7.37m/s respectively. The mean angular velocity of the right shoulder joint was 665.33m/s and the standard deviation was 7.45m/s. The characteristics of ordinary level athletes in the stage of push-up when completing the standard support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

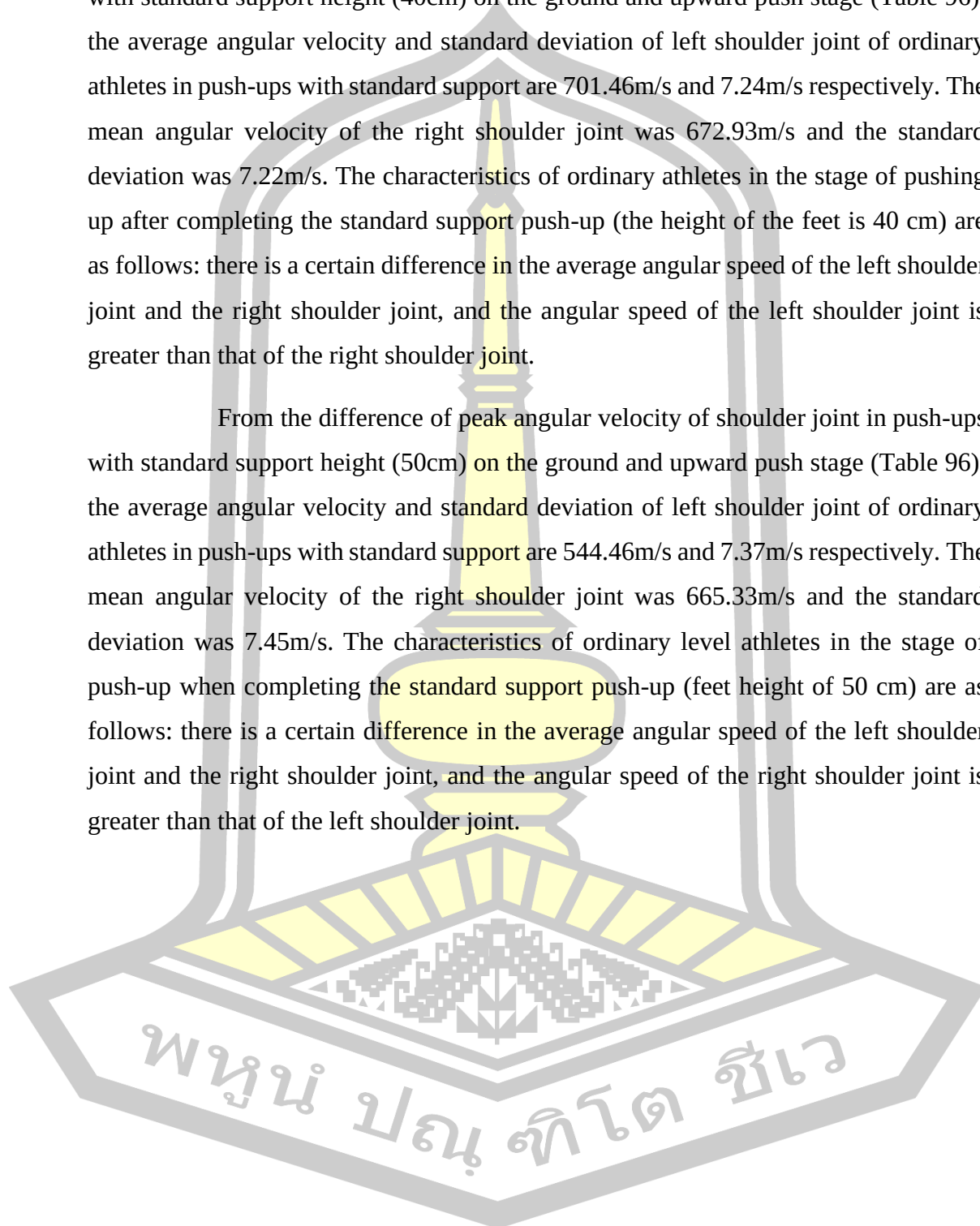


Table 97 The peak angular velocity of shoulder joint of ordinary horizontal athletes in the stage of broad support push up (°/s)

Foot height	Shoulder joint	A	B	C	D	$\bar{X} \pm S$
0cm	Left shoulder joint	497.742	486.872	484.262	482.692	487.89±6.79
	Right shoulder joint	441.827	428.857	427.147	425.477	430.83±7.46
25cm	Left shoulder joint	482.885	464.415	465.305	463.635	469.06±9.24
	Right shoulder joint	509.380	490.810	491.600	489.930	495.43±9.32
30cm	Left shoulder joint	583.390	570.120	568.110	566.440	572.01±7.73
	Right shoulder joint	781.691	768.421	748.211	764.541	765.72±13.79
40cm	Left shoulder joint	443.761	427.691	422.681	423.711	429.46±9.78
	Right shoulder joint	647.304	631.134	628.184	627.054	633.42±9.42
50cm	Left shoulder joint	442.046	425.776	425.606	418.896	428.08±9.85
	Right shoulder joint	580.842	564.472	564.382	557.492	566.80±9.92

From the difference of peak angular velocity of shoulder joint in the stage of broad support push-up with feet on the ground (0cm) and upward push (Table 97), the average angular velocity and standard deviation of left shoulder joint of ordinary level athletes in the stage of broad support push-up are 487.89m/s and 6.79m/s respectively. The mean angular velocity of the right shoulder joint was 430.83/s and the standard deviation was 7.46m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the wide support push-up (feet height 0 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the left shoulder joint is greater than that of the right shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of broad support push-up with feet on the ground (25cm) and upward push (Table 97), the average angular velocity and standard deviation of left shoulder joint of ordinary

level athletes are 469.06m/s and 9.24m/s when they complete the stage of broad support push-up. The mean angular velocity of the right shoulder joint was 495.43m/s, and the standard deviation was 9.32m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push-up (the height of the feet is 25 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with both feet on the ground (30cm) and upward push (Table 97), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of push-ups with standard support are 572.01m/s and 7.76m/s respectively. The mean angular velocity of the right shoulder joint was 765.72m/s and the standard deviation was 13.79m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push up (the height of the feet is 30 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support height (40cm) on the ground and upward push (Table 97), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of push-ups with standard support are 429.46m/s and 9.78m/s respectively. The mean angular velocity of the right shoulder joint was 633.42m/s and the standard deviation was 9.42m/s. The characteristics of the general level athletes in the stage of pushing up after completing the wide support push-up (the height of the feet is 40 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

From the difference of peak angular velocity of shoulder joint in the stage of push-ups with wide support with both feet on the ground (50cm) and upward push (Table 97), the average angular velocity and standard deviation of left shoulder joint of ordinary athletes in the stage of push-ups with standard support are 428.08m/s and

9.85m/s respectively. The mean angular velocity of the right shoulder joint was 566.80m/s and the standard deviation was 9.92m/s. The characteristics of ordinary level athletes in the stage of pushing up after completing the wide support push-up (feet height of 50 cm) are as follows: there is a certain difference in the average angular speed of the left shoulder joint and the right shoulder joint, and the angular speed of the right shoulder joint is greater than that of the left shoulder joint.

2.3.4 Mechanical characteristics

(1) Peak value of ground vertical reaction force in the depression stage under standard support push-ups

Table 98 The peak value of ground reaction force of standard support push-up for ordinary level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A	296.32	263.7	330.23	321.98	514.8
B	456.87	407.49	283.09	478.39	483.43
C	298.72	266.1	333.83	400.61	499.54
D	463.35	413.97	289.57	494.87	489.03
$\bar{X} \pm S$	378.82±93.91	337.82±84.24	309.18±26.56	423.96±79.45	496.70±13.79

From the difference between the peak value of ground vertical reaction force in the stage of push-ups with standard support (0cm) and the stage of bending arms with downward support (Table 98), the average value of ground vertical reaction force and the standard deviation of ground vertical reaction force are 378.82N and 93.91N for ordinary level athletes in the stage of bending arms with downward support push-ups.

From the difference in the peak value of ground vertical reaction force in push-ups with feet 25 cm higher than the ground and in the stage of bending arms with feet down (Table 98), the average value of ground vertical reaction force and standard

deviation of ground vertical reaction force are 337.82N and 84.24N for ordinary level athletes in the stage of bending arms with feet down with feet up to 25 cm higher than the ground.

From the difference in the peak value of ground vertical reaction force in push-ups with feet 30cm higher than the ground and in the stage of bending arms with feet down (Table 98), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in the stage of bending arms with feet down are 309.18N and 26.56N respectively for ordinary level athletes.

From the difference in the peak value of ground vertical reaction force in push-ups with feet 40 cm higher than the ground and in the stage of bending arms with feet down (Table 98), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 423.96N and 79.45N for ordinary level athletes in the stage of bending arms with feet down with feet up to 40 cm higher than the ground.

According to the peak difference of ground vertical reaction force in push-ups with feet 50 cm higher than the ground and in the stage of bending arms with feet down (Table 98), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in the stage of bending arms with feet down are 496.70N and 13.79N respectively for ordinary level athletes.

The characteristics of the ground vertical reaction force of push-ups with different load standards are as follows: with the increase of the position of the feet, the peak reaction force appears large on both sides and small in the middle, that is, the value of the standard push-ups with the feet on the ground is higher than the value of the feet above the ground 25cm and 30cm, and the reaction force continues to increase with the increase of height. The reaction force values of feet 25 cm and 30 cm above the ground are lower, and the reaction force is lowest when the feet are 30 cm above the ground.

(2) The peak of vertical ground reaction force in the depression stage of wide-supported push-ups

Table 99 Peak value of ground reaction force of general level athletes in the stage of broad support push-up and bending arms (N)

measure	0cm	25cm	30cm	40cm	50cm
A	462.91	406.04	388.54	484.62	488.88
B	466.12	407.87	397.14	486.85	490.31
C	455.4	444.28	447.22	460.11	447.33
D	410.46	407.56	406.48	447.27	470.21
$\bar{X} \pm S$	448.72±25.90	416.44±18.58	409.85±25.97	469.71±19.25	474.18±20.11

From the difference between the peak value of ground vertical reaction force in the stage of wide-supported push-up with feet on the ground (0cm) and the stage of downward bending arms flexion (Table 99), the average value of ground vertical reaction force and the standard deviation of ground vertical reaction force are 448.72N and 25.90N for ordinary horizontal athletes in the stage of downward bending arms flexion after completing wide-supported push-up.

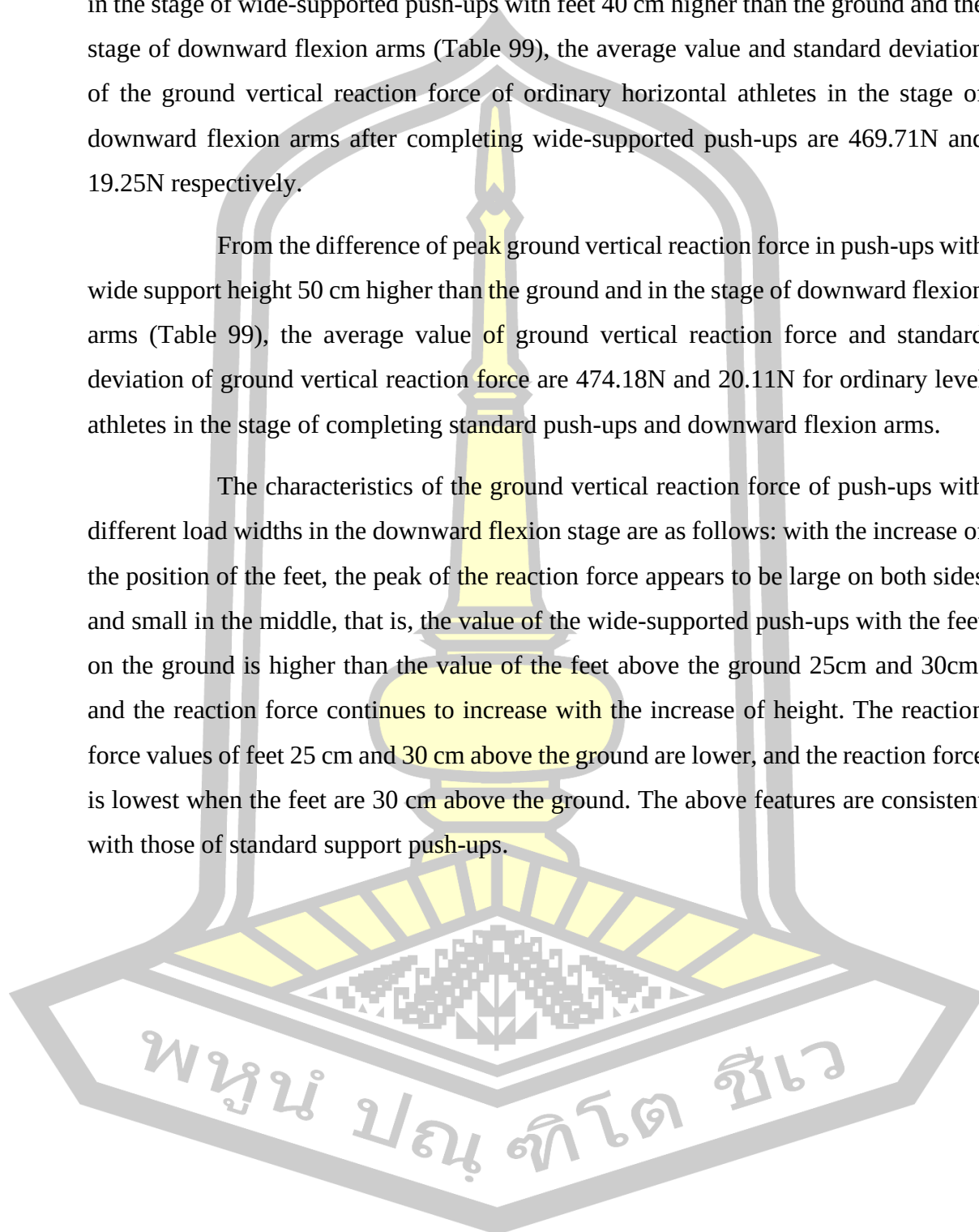
According to the peak difference of ground vertical reaction force in the stage of wide-supported push-up with feet 25 cm higher than the ground and the stage of downward flexion (Table 99), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of ordinary horizontal athletes in the stage of downward flexion with wide supported push-up are 416.44N and 18.58N respectively.

From the difference in the peak value of ground vertical reaction force in the stage of wide-supported push-ups with feet 30 cm higher than the ground and the stage of downward flexion arms (Table 99), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of ordinary horizontal athletes in the stage of downward flexion arms after completing wide-supported push-ups are 409.85N and 25.97N respectively.

From the difference in the peak value of the ground vertical reaction force in the stage of wide-supported push-ups with feet 40 cm higher than the ground and the stage of downward flexion arms (Table 99), the average value and standard deviation of the ground vertical reaction force of ordinary horizontal athletes in the stage of downward flexion arms after completing wide-supported push-ups are 469.71N and 19.25N respectively.

From the difference of peak ground vertical reaction force in push-ups with wide support height 50 cm higher than the ground and in the stage of downward flexion arms (Table 99), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 474.18N and 20.11N for ordinary level athletes in the stage of completing standard push-ups and downward flexion arms.

The characteristics of the ground vertical reaction force of push-ups with different load widths in the downward flexion stage are as follows: with the increase of the position of the feet, the peak of the reaction force appears to be large on both sides and small in the middle, that is, the value of the wide-supported push-ups with the feet on the ground is higher than the value of the feet above the ground 25cm and 30cm, and the reaction force continues to increase with the increase of height. The reaction force values of feet 25 cm and 30 cm above the ground are lower, and the reaction force is lowest when the feet are 30 cm above the ground. The above features are consistent with those of standard support push-ups.



(3) The peak of the ground vertical reaction force in the upward push up stage of the standard support push-up

Table 100 The peak of ground reaction force in push-up stage of standard support for ordinary level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A	640.78	634.24	644.62	641.55	739.25
B	644.44	545.29	649.54	637.88	766.46
C	651.28	615.4	651.18	670.16	760.25
D	650.52	569.96	618.61	674.97	772.92
$\bar{X} \pm S$	646.76 $\pm$ 5.02	591.22 $\pm$ 40.81	640.99 $\pm$ 15.18	656.14 $\pm$ 19.13	759.72 $\pm$ 14.59

From the difference of peak value of ground vertical reaction force in push-ups with standard support height (0cm) on the ground and push up stage (Table 100), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force of ordinary horizontal athletes are 646.76N and 5.02N when they complete push-up with standard support push-up stage.

From the difference of peak value of ground vertical reaction force in push-ups with standard support with feet 25 cm higher than the ground (Table 100), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in push-ups with standard support are 591.22N and 40.81N respectively for ordinary horizontal athletes in push-ups with standard support.

From the difference of peak value of ground vertical reaction force in push-ups with standard support with feet 30 cm higher than the ground (Table 100), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in push-ups with standard support are 640.99N and 15.18N respectively for ordinary athletes in push-ups with standard support.

From the difference of peak value of ground vertical reaction force in push-ups with standard support with feet 40 cm higher than the ground (Table 100), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force in push-ups with standard support are 656.14N and 19.13N respectively for ordinary horizontal athletes in push-ups with standard support.

From the difference of peak value of ground vertical reaction force in push-ups with standard support with feet 50 cm higher than the ground (Table 100), the average value of ground vertical reaction force and standard deviation are 759.72N and 14.59N for ordinary level athletes in push-ups with standard support with feet 50 cm higher than the ground.

The characteristics of the ground vertical reaction force in the push-up stage of different load standard support push-ups are as follows: with the increase of the position of the feet, the peak value of the reaction force gradually increases, that is, the value of the push-up with the feet on the ground is the lowest, and the value of the standard support push-up with the feet 50 cm above the ground is the highest.

(4) The peak of the ground vertical reaction force in the push up stage of wide support push-ups

Table 101 The peak of ground reaction force in the push up stage of broad support push-ups for ordinary level athletes (N)

measure	0cm	25cm	30cm	40cm	50cm
A	879.37	759.23	796.46	896.54	898.64
B	888.25	806.51	772.07	891.07	874.26
C	883.71	761.49	837.55	848.41	895.06
D	872.91	820.23	815.17	844.05	855.69
$\bar{X} \pm S$	881.06±6.53	786.87±31.13	805.31±27.81	870.02±27.62	880.91±19.96

From the difference of peak value of ground vertical reaction force in the stage of push-ups with wide support (0cm) and upward push with feet on the ground (Table 101), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 881.06N and 6.53N for ordinary horizontal athletes when they complete the stage of upward push with wide support push-ups.

From the difference in the peak value of the ground vertical reaction force in the push-up stage when the feet are 25cm higher than the ground in the wide-supported push-up stage (Table 101), the average value of the ground vertical reaction force is 786.87N and the standard deviation is 31.13N for ordinary horizontal athletes in the push-up stage when they complete the wide-supported push-up stage.

From the difference in the peak value of the ground vertical reaction force in the push-up stage with wide support push-ups with feet 30cm higher than the ground (Table 101), the average value of the ground vertical reaction force and the standard deviation of the ground vertical reaction force are 805.31N and 27.81N for ordinary horizontal athletes in the push-up stage with wide support push-ups.

From the difference in the peak value of ground vertical reaction force during the push-up stage with wide support push-ups with feet 40 cm higher than the ground (Table 101), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force during the push-up stage with wide support push-ups are 870.02N and 27.62N respectively for ordinary horizontal athletes.

From the difference of peak value of ground vertical reaction force in push-ups with wide support height 50 cm higher than the ground (Table 101), the average value of ground vertical reaction force and standard deviation of ground vertical reaction force are 880.91N and 19.96N for ordinary horizontal athletes in the push-up stage when they complete standard push-ups.

The characteristics of the ground vertical reaction force of push-ups with different load widths are as follows: with the increase of the position of the feet, the peak value of the reaction force gradually increases, that is, the value of the standard support push-ups with the feet on the ground is the lowest, and the value of the standard

support push-ups with the feet 50 cm above the ground is the highest. The above features are consistent with those of standard support push-ups.

2.3.5 Surface EMG characteristics

2.3.5.1 Sequence (activation time) characteristics of muscle activation in the lower flexion phase

Table 102 The order of muscle activation of normal athletes when they complete standard support push-ups and bend arms

Muscle	unactivated 1	Activate 1	unactivated 2	Activate 2	unactivated 3	Activate 3
Left biceps brachii	29.48	21.62	15.8	33.95	0	0
Right biceps brachii	28.97	21.26	15.69	33.11	0	0
Left triceps brachii	16.05	21.79	21.44	28.55	12.19	0
Right triceps brachii	15.57	21.45	22.48	28.55	11.95	0
Left deltoid anterior fasciculus	38.03	13.88	9.61	12.13	6.98	19.27
Anterior bundle of right deltoid	39.03	12.18	9.51	12.73	6.78	19.37
Left pectoralis major	21.02	24.94	13.04	11.13	6.78	23.37
Right pectoralis major	20.05	25.75	12.35	11.53	6.58	23.67

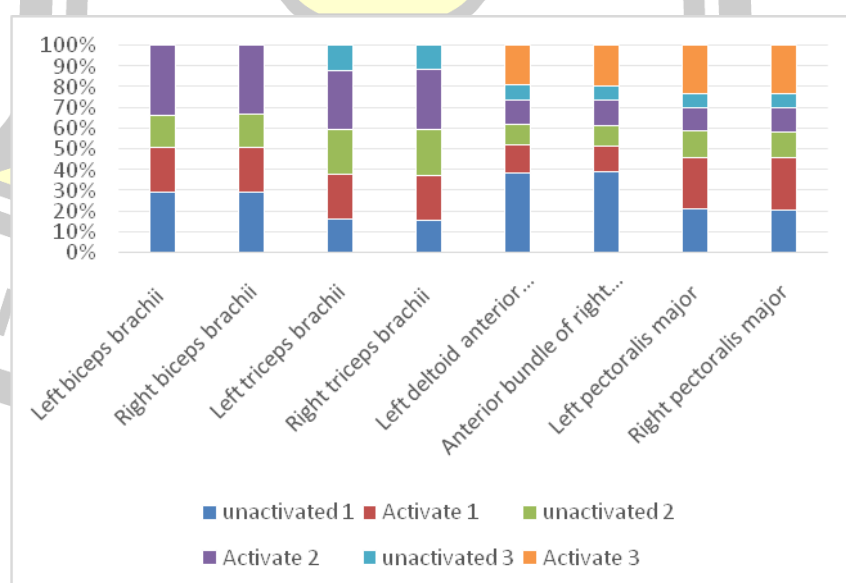


Figure 96 Comparison of muscle activation sequence in the downward phase of standard support push-ups in normal athletes

According to the activation sequence (activation time) of the relevant muscles as the flexes of the arms and the weight of the body decrease (Table 102, Figure 96), the left and right deltoid anterior bundle is activated first, followed by the left and right pectoralis major, the left and right biceps and the left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the completion of the movement. The sequence of activation of this muscle is consistent with the sequence of activation of standard support push-ups performed by advanced and intermediate level athletes.

2.3.5.2 Characteristics of integrated EMG values of related muscles in the lower flexion stage

Table 103 Average level athletes complete standard support push-ups down stage muscle integral myoelectric value (μVs)

measure	A	B	C	D	$\bar{X} \pm S$
Left biceps brachii	114.59	112.86	115.37	112.12	113.74 $\pm$ 1.50
Right biceps brachii	115.19	112.88	116.33	112.16	114.14 $\pm$ 1.95
Left triceps brachii	489.09	486.62	491.47	486.62	488.45 $\pm$ 2.33
Right triceps brachii	484.69	483.09	487.81	481.12	484.18 $\pm$ 2.83
Left deltoid anterior fasciculus	129.06	125.49	132.17	126.72	128.36 $\pm$ 2.94
Anterior bundle of right deltoid	128.16	125.54	129.07	125.82	127.15 $\pm$ 1.74
Left pectoralis major	260.51	258.91	261.16	256.94	259.38 $\pm$ 1.88
Right pectoralis major	257.73	256.13	258.38	254.41	256.66 $\pm$ 1.77

From the point of view of the integrated EMG value of the muscle related to the push-up stage of the standard support push-up of the ordinary athletes (table 103), the average value of the integrated EMG value of the left biceps of the ordinary athletes is 113.74 μVs , and the standard deviation is 1.50 μVs . The mean value and standard deviation of the right biceps were 114.14 μVs and 1.95 μVs . The mean and standard deviation of the integrated EMG values of left triceps were 488.45 μVs and 2.33 μVs . The mean value and standard deviation of the right triceps were 484.18 μVs and

2.83 μ Vs. The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were 128.36 μ Vs and 2.94 μ Vs. The mean and standard deviation of the integrated EMG value of the right deltoid anterior bundle were 127.15 μ Vs and 1.74 μ Vs. The mean and standard deviation of the integrated EMG value of the left pectoralis major were 259.38 μ Vs and 1.88 μ Vs. The mean and standard deviation of the integrated EMG value of the right pectoralis major were 256.66 μ Vs and 1.77V. There are some differences in the integrated EMG values of the left and right muscles of the normal athletes when they complete the push-ups with standard support, but the differences are not large.

2.3.5.3 Sequential (activation time) characteristics of muscle activation related to the push up phase

Table 104 Order table of muscle activation during the push-up phase of standard support push-ups for ordinary athletes

Muscle	unactivated 1	Activate 1	unactivated 2	Activate 2	unactivated 3	Activate 3
Left biceps brachii	28.48	24.62	13.8	32.95	0	0
Right biceps brachii	27.97	24.26	15.69	32.11	0	0
Left triceps brachii	26.05	4.79	22.44	28.75	18.19	0
Right triceps brachii	26.57	5.45	22.08	29.55	16.35	0
Left deltoid anterior fasciculus	37.03	13.88	10.61	12.13	6.98	19.27
Anterior bundle of right deltoid	37.03	12.18	10.51	13.73	6.78	19.37
Left pectoralis major	23.02	23.94	12.04	12.33	6.78	21.57
Right pectoralis major	20.05	23.4	12.55	12.83	6.58	24.37

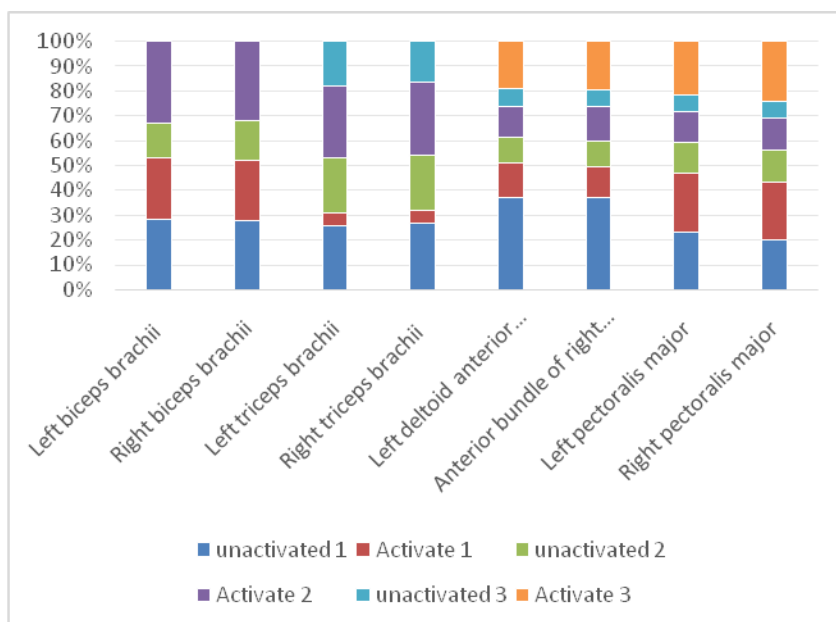


Figure 97 Comparison of muscle activation sequence of normal level athletes in the upward stage of standard support push-ups

According to the activation sequence (activation time) of relevant muscles (Table 104, Figure 97), the left and right deltoid anterior fasciculus are activated first, followed by left and right pectoralis major, left and right triceps, and left and right biceps in order of the normal level athletes in the push-up stage after completing the standard support push up movement (Table 101, Figure 79). The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the completion of the movement. The order of activation of this muscle is consistent with the order of activation of the movement performed by high-level and intermediate-level athletes.



2.3.5.4 Integrated EMG characteristics of related muscles in the uppush stage

Table 105 The average level athlete completes the standard support push up stage muscle integral myoelectric value (μ Vs)

measure	A	B	C	D	$\bar{X} \pm S$
Left biceps brachii	113.83	110.28	114.71	111.33	112.54 $\pm$ 2.08
Right biceps brachii	114.43	109.27	115.67	111.37	112.69 $\pm$ 2.91
Left triceps brachii	498.63	503.54	501.24	496.13	499.89 $\pm$ 3.21
Right triceps brachii	494.23	499.11	497.58	490.63	495.39 $\pm$ 3.77
Left deltoid anterior fasciculus	138.73	143.97	141.81	143.57	142.02 $\pm$ 2.39
Anterior bundle of right deltoid	137.83	142.71	138.71	142.67	140.48 $\pm$ 2.58
Left pectoralis major	270.05	274.93	270.93	274.91	272.71 $\pm$ 2.58
Right pectoralis major	267.27	272.15	268.15	272.79	270.09 $\pm$ 2.78

From the point of view of the integrated EMG value of the muscle related to the push-up stage of the standard support push-up of the ordinary athletes (table 105), the average value of the integrated EMG value of the left biceps of the ordinary athletes is 112.54 μ Vs, and the standard deviation is 2.08 μ Vs. The mean value and standard deviation of the right biceps were 112.69 μ Vs and 2.91 μ Vs. The mean and standard deviation of the integrated EMG values of left triceps were 499.89 μ Vs and 3.21 μ Vs. The mean value and standard deviation of the right triceps were 495.39 μ Vs and 3.77 μ Vs. The mean and standard deviation of the integrated EMG values of the left deltoid anterior bundle were 142.02 μ Vs and 2.39 μ Vs. The mean and standard deviation of the integrated EMG values of the right deltoid anterior bundle were 140.48 μ Vs and 2.58 μ Vs. The mean and standard deviation of the integrated EMG value of the left pectoralis major were 272.71 μ Vs and 2.58 μ Vs. The mean and standard deviation of the integrated EMG values of the right pectoralis major were 270.09 μ Vs and 2.78 μ Vs. There are some differences in the integrated EMG values of the left and right muscles of the normal athletes when they complete the push-ups with standard support, but the differences are not large.

2.4 Comparative analysis of biomechanical characteristics of push-ups performed by high-level athletes, intermediate athletes and ordinary athletes

2.4.1 Comparative analysis of time characteristics

2.4.1.1 Comparative analysis of complete movement time characteristics of athletes of the same level

Table 106 Comparison table of the complete time of push-ups supported by different load standards for high-level athletes

Foot height	$\bar{X} \pm S$	P
0cm	0.96±0.01	>0.05
25cm	0.95±0.01	
0cm	0.96±0.01	>0.05
30cm	0.95±0.01	
0cm	0.96±0.01	>0.05
40cm	1.13±0.02	
0cm	0.96±0.01	>0.05
50cm	1.16±0.04	

As can be seen from Table 106, when high-level athletes complete standard support push-ups, the average time to complete the complete movement also varies with the increasing position of their feet. There is no significant difference between the average time spent in push-ups with the feet on the ground and the feet 25 cm above the ground; There was also no significant difference between the average time spent in push-ups with feet on the ground and with feet 30 cm above the ground; There is a significant difference between the average time spent in push-ups with the feet on the ground and those with the feet 40 cm above the ground; There is also a very significant difference between the average time spent in push-ups with your feet on the ground and those with your feet 50 cm above the ground.

Table 107 Comparison table of the complete time of push-ups with different load width support for high-level athletes

Foot height	$\bar{X} \pm S$	P
0cm	0.97±0.02	>0.05
25cm	0.95±0.01	
0cm	0.97±0.02	>0.05
30cm	0.95±0.01	
0cm	0.97±0.02	<0.05
40cm	1.13±0.02	
0cm	0.97±0.02	<0.01
50cm	1.16±0.04	

As can be seen from Table 107, when the high-level athletes complete the wide support push-up, the average time to complete the complete movement also varies with the increasing position of the feet. There is no significant difference between the average time spent in push-ups with the feet on the ground and the feet 25 cm above the ground; There was also no significant difference between the average time spent in push-ups with feet on the ground and with feet 30 cm above the ground; There is a significant difference between the average time spent in push-ups with the feet on the ground and those with the feet 40 cm above the ground; There is also a very significant difference between the average time spent in push-ups with your feet on the ground and those with your feet 50 cm above the ground.

It can be seen that with the elevation of the position of the feet, the weight of the body borne by the hands gradually increases, and the total time to complete the movement also gradually increases. The total time from the time when the feet are placed on the ground to the time when the feet are 30 cm above the ground is not significantly increased, and the time when the feet are 40 cm above the ground is significantly increased. At the same time, it also reflects that there is no significant difference between the average total time spent when the feet are 25 cm to 30 cm above

the ground and the average total time spent when the feet are placed on the ground, regardless of the standard support or wide support state, but there is a significant difference and a very significant difference when the feet are 40 cm or more above the ground.

2.4.1.2 Comparative analysis of complete movement time characteristics of athletes at different levels

Table 108 Comparative analysis table of the total time used by athletes of different levels to complete standard support push-ups

Dependent variable	Athlete level	$\bar{X} \pm S$	Athlete level	$\bar{X} \pm S$	P
0cm	High-level	0.96±0.01	Intermediate level	1.28±0.05	<0.01
			Ordinary level	1.33±0.05	<0.01
	Intermediate level	1.28±0.05	Ordinary level	1.33±0.05	>0.05
25cm	High-level	0.95±0.01	Intermediate level	1.21±0.05	<0.01
			Ordinary level	1.27±0.02	<0.01
	Intermediate level	1.21±0.05	Ordinary level	1.27±0.02	<0.05
30cm	High-level	0.95±0.01	Intermediate level	1.24±0.05	<0.01
			Ordinary level	1.25±0.03	<0.01
	Intermediate level	1.24±0.05	Ordinary level	1.25±0.03	>0.05
40cm	High-level	1.13±0.02	Intermediate level	1.31±0.02	<0.01
			Ordinary level	1.37±0.01	<0.01
	Intermediate level	1.31±0.02	Ordinary level	1.37±0.01	<0.01
50cm	High-level	1.16±0.04	Intermediate level	1.39±0.06	<0.01
			Ordinary level	1.43±0.03	<0.01
	Intermediate level	1.39±0.06	Ordinary level	1.43±0.03	>0.05

As can be seen from Table 108, when athletes of different levels complete standard support push-ups, with the position of their feet increasing, the completion time of complete movements in the same position varies. In terms of the total time for completing push-ups with both feet on the ground (0cm), there is a significant difference between high-level athletes and intermediate level athletes, and there is also a significant difference between high-level athletes and average level athletes, while there is no significant difference between intermediate level athletes and average level athletes. There is a significant difference between high-level athletes and intermediate level athletes, between high-level athletes and average level athletes, and between intermediate level athletes and average level athletes in the total time of completing push-ups with feet 25cm higher than the ground. In terms of the total time for completing push-ups with feet 30cm higher than the ground, there is a significant difference between high-level athletes and intermediate athletes, and there is also a significant difference between high-level athletes and ordinary athletes, while there is no significant difference between intermediate athletes and ordinary athletes. In terms of the total time to complete push-ups with feet 40cm higher than the ground, there are significant differences between high-level athletes and intermediate athletes, between high-level athletes and ordinary athletes, and between intermediate athletes and ordinary athletes. In terms of the total time for completing push-ups with feet 50cm above the ground, there is a significant difference between high-level athletes and intermediate athletes, a significant difference between high-level athletes and ordinary athletes, and no significant difference between intermediate athletes and ordinary athletes.

This fully shows that there are significant and very significant differences between high-level athletes and intermediate level athletes in the total time of push-ups with different loads of standard support, and the total time of high-level athletes is less than that of other level athletes. The reason is that high-level athletes receive the same training for a longer time, the upper limb muscles and trunk muscles are more developed than other level athletes, the strength is relatively strong, and the completion of the movement is correspondingly easy. However, intermediate level and ordinary level athletes receive the same training for a short time, and the time is relatively close,

so there is no significance between each other when completing different load movements in most cases.

Table 109 Comparison table of the total time of high level and ordinary level athletes to complete wide support high-five push-ups

Exercise level	Foot height	$\bar{x} \pm s$	P
High level	0cm	1.32±0.05	<0.01
Ordinary level		1.61±0.04	
High level	25cm	1.27±0.06	<0.01
Ordinary level		1.51±0.03	
High level	30cm	1.23±0.04	<0.01
Ordinary level		1.47±0.04	
High level	40cm	1.28±0.13	<0.01
Ordinary level		1.51±0.05	
High level	50cm	1.37±0.02	<0.01
Ordinary level		1.56±0.02	

As can be seen from Table 109, when high-level and ordinary athletes complete wide-supported high-five push-ups, with the increasing position of their feet, there is a difference in the completion time of complete movements in the same position. When the feet are on the ground, the feet are 25 cm above the ground, the feet are 30 cm above the ground, the feet are 40 cm above the ground and the feet are 50 cm above the ground, there is a significant difference in the average total time between the high-level athletes and the average athletes to complete the standard support push-ups.

From this, it can be found that there is a significant difference between the average total time of completing the same push-up movement between high-level and intermediate level athletes, and between high-level and ordinary level athletes. The average time of high-level athletes is less than that of intermediate level athletes and less than that of ordinary level athletes. These results indicate that the athletic ability of

high-level athletes to complete standard support push-ups, wide support push-ups, standard support high-five push-ups and wide support high-five push-ups is higher than that of intermediate level athletes and ordinary level athletes. On the one hand, the training time of high-level athletes is relatively long, and the upper limb muscle development is better than that of intermediate level and ordinary level athletes; On the other hand, the accuracy and economy of the high-level athletes to complete the push-up movement are better than the other two different levels of athletes.



2.4.2 Comparative analysis of speed characteristics

2.4.2.1 Comparative analysis of peak velocity characteristics of shoulder joint in the stage of downward flexion

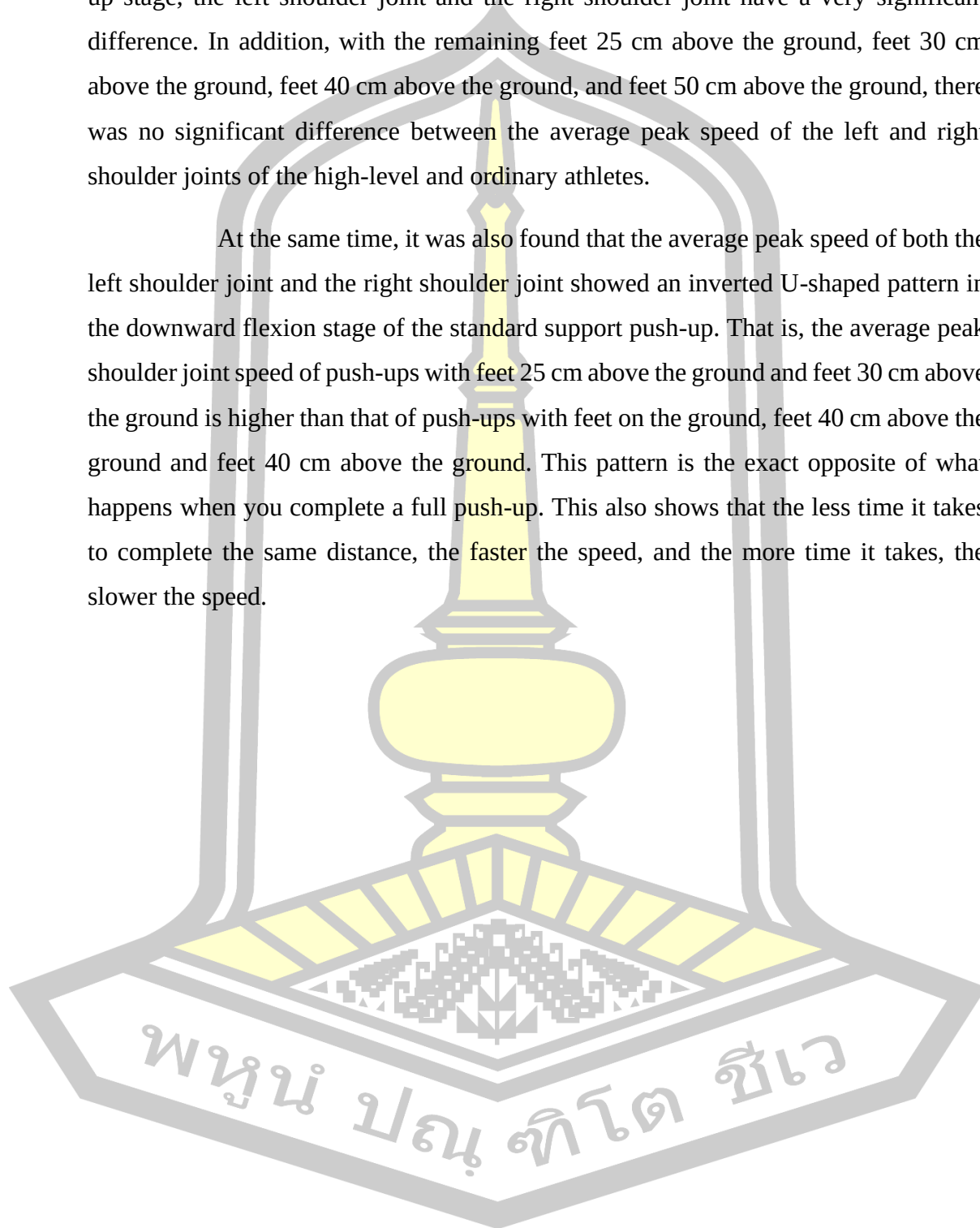
Table 110 Comparison of shoulder joint speed peak value between high level and ordinary athletes in the downward bend stage of standard support push-up (m/s)

Foot height	Shoulder joint	$\bar{X} \pm S$	P
0cm	Left shoulder joint	0.829±0.031	<0.05
		0.742±0.032	
	Right shoulder joint	0.961±0.027	<0.05
		0.768±0.020	
25cm	Left shoulder joint	0.905±0.020	>0.05
		0.873±0.004	
	Right shoulder joint	0.908±0.063	>0.05
		0.850±0.023	
30cm	Left shoulder joint	0.936±0.045	>0.05
		0.876±0.023	
	Right shoulder joint	0.921±0.042	>0.05
		0.874±0.038	
40cm	Left shoulder joint	0.862±0.027	>0.05
		0.822±0.034	
	Right shoulder joint	0.866±0.037	>0.05
		0.832±0.038	
50cm	Left shoulder joint	0.827±0.007	>0.05
		0.805±0.028	
	Right shoulder joint	0.834±0.013	>0.05
		0.807±0.039	

As can be seen from Table 110, the average peak speed of shoulder joints in standard push-ups with the same position is different from that of left shoulder joints and right shoulder joints as the position of the feet continues to increase in the stage of standard push-ups with the same position. The average peak value of shoulder joint

speed of high level and ordinary level athletes with their feet on the ground in the push-up stage, the left shoulder joint and the right shoulder joint have a very significant difference. In addition, with the remaining feet 25 cm above the ground, feet 30 cm above the ground, feet 40 cm above the ground, and feet 50 cm above the ground, there was no significant difference between the average peak speed of the left and right shoulder joints of the high-level and ordinary athletes.

At the same time, it was also found that the average peak speed of both the left shoulder joint and the right shoulder joint showed an inverted U-shaped pattern in the downward flexion stage of the standard support push-up. That is, the average peak shoulder joint speed of push-ups with feet 25 cm above the ground and feet 30 cm above the ground is higher than that of push-ups with feet on the ground, feet 40 cm above the ground and feet 40 cm above the ground. This pattern is the exact opposite of what happens when you complete a full push-up. This also shows that the less time it takes to complete the same distance, the faster the speed, and the more time it takes, the slower the speed.



2.4.2.2 Comparative analysis of shoulder joint speed peak characteristics in the upward pushing stage

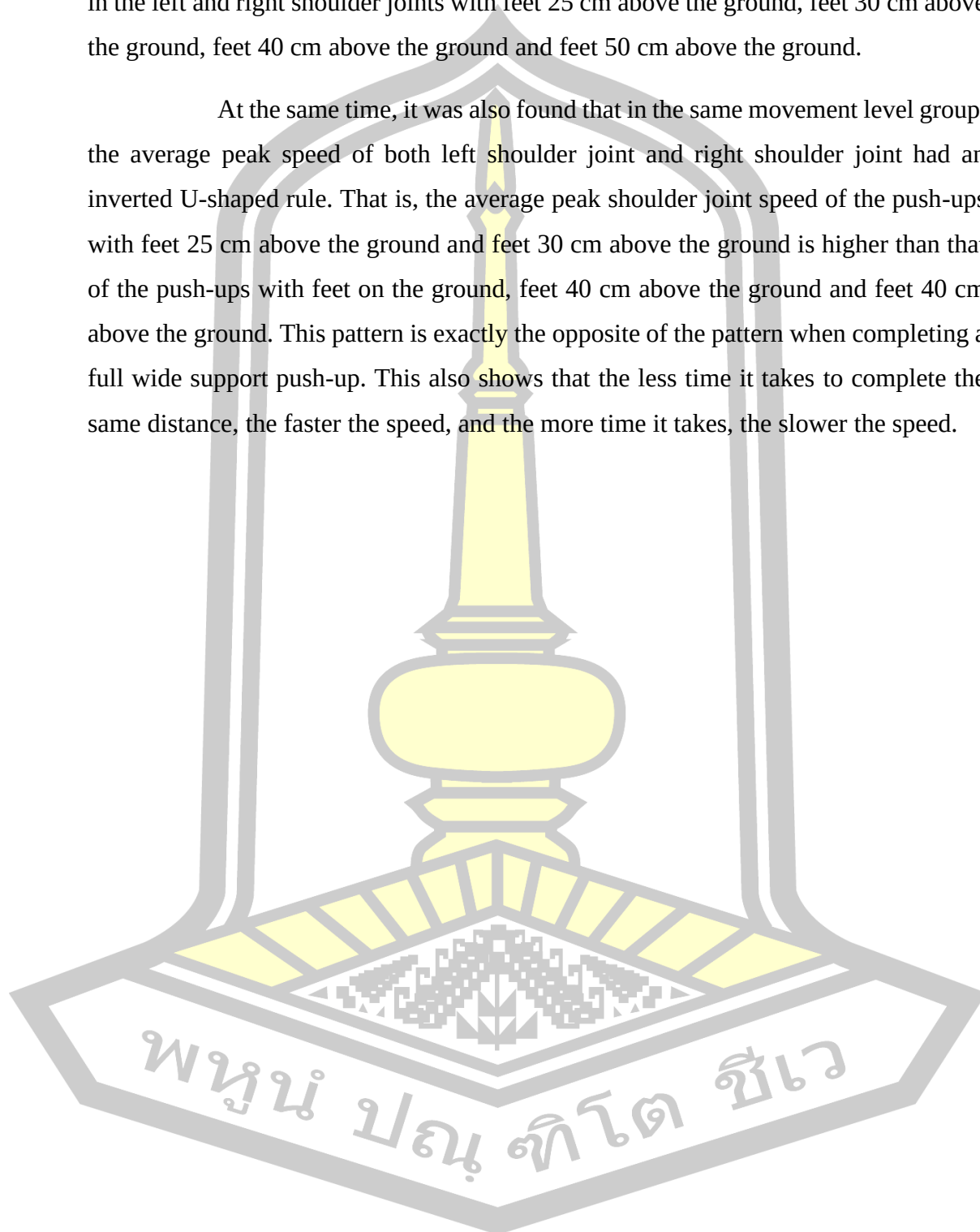
Table 111 Comparison of shoulder joint speed peak value between high-level and intermediate athletes in broad support push up stage (m/s)

Foot height	Shoulder joint	$\bar{X} \pm S$	P
0cm	Left shoulder joint	0.931±0.047	<0.05
		0.826±0.050	
	Right shoulder joint	0.940±0.140	>0.05
		0.860±0.120	
25cm	Left shoulder joint	1.039±0.144	<0.01
		0.919±0.144	
	Right shoulder joint	1.090±0.229	<0.01
		0.970±0.229	
30cm	Left shoulder joint	1.113±0.263	<0.01
		1.000±0.267	
	Right shoulder joint	1.093±0.168	<0.01
		0.978±0.173	
40cm	Left shoulder joint	1.133±0.251	<0.05
		1.013±0.231	
	Right shoulder joint	1.035±0.089	<0.01
		0.920±0.084	
50cm	Left shoulder joint	1.044±0.210	<0.05
		0.944±0.176	
	Right shoulder joint	0.993±0.128	<0.05
		0.893±0.113	

As can be seen from Table 111, the peak speed of shoulder joints in the push-up stage of the standard push-up with the same position is different between the left shoulder joints and the right shoulder joints as the position of the feet continues to increase. For high-level and intermediate level athletes, except that push-ups with feet on the ground pushed up the extreme shoulder joint speed peak, and there was no significant difference in the right shoulder joint, push-ups with feet on the ground

pushed up the extreme left shoulder joint speed peak. There were significant differences in the left and right shoulder joints with feet 25 cm above the ground, feet 30 cm above the ground, feet 40 cm above the ground and feet 50 cm above the ground.

At the same time, it was also found that in the same movement level group, the average peak speed of both left shoulder joint and right shoulder joint had an inverted U-shaped rule. That is, the average peak shoulder joint speed of the push-ups with feet 25 cm above the ground and feet 30 cm above the ground is higher than that of the push-ups with feet on the ground, feet 40 cm above the ground and feet 40 cm above the ground. This pattern is exactly the opposite of the pattern when completing a full wide support push-up. This also shows that the less time it takes to complete the same distance, the faster the speed, and the more time it takes, the slower the speed.



2.4.3 Comparative analysis of angular velocity characteristics of elbow joint and shoulder joint

2.4.3.1 Comparative analysis of Angle characteristics of the lowest elbow joint in the stage of downward flexion

Table 112 Comparison table of the Angle of the lowest elbow joint between high-level and ordinary athletes in the downward bend stage of standard support push-ups (°)

Foot height	Shoulder joint	$\bar{X} \pm S$	P
0cm	Left shoulder joint	31.81±3.28	<0.01
		35.23±3.27	
	Right shoulder joint	33.38±2.51	<0.05
		36.79±2.49	
25cm	Left shoulder joint	32.40±3.29	<0.01
		35.84±3.29	
	Right shoulder joint	34.34±2.57	<0.01
		37.78±2.56	
30cm	Left shoulder joint	36.33±5.22	<0.01
		39.71±5.27	
	Right shoulder joint	38.52±4.47	<0.01
		41.90±4.52	
40cm	Left shoulder joint	36.34±5.24	<0.01
		39.78±5.21	
	Right shoulder joint	38.55±4.49	<0.01
		41.99±4.46	
50cm	Left shoulder joint	38.00±4.68	<0.01
		41.42±4.69	
	Right shoulder joint	39.79±4.54	<0.01
		43.21±4.55	

As can be seen from Table 112, at the lowest position in the stage of completing the standard support push-up with the lower flexion arm, the average Angle of the lowest elbow joint in the stage of standard support push-up with the lower flexion

arm is significantly different between the left elbow joint and the right elbow joint in the same position as the position of the feet continues to increase. With the increasing of the position of the feet, the Angle of the elbow joint at the lowest position of the lower bend gradually increased.

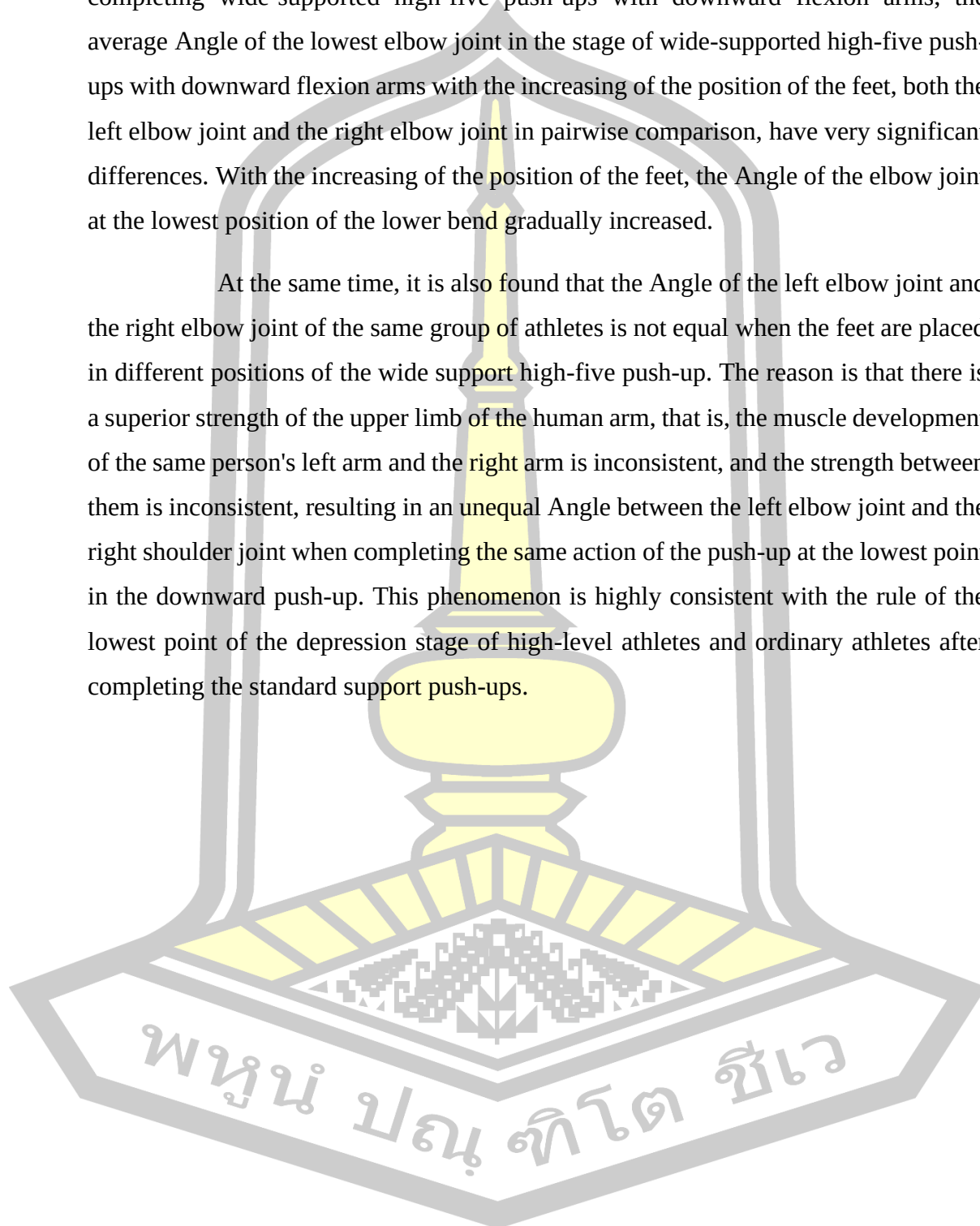
At the same time, it is also found that the Angle of the left elbow joint and the right elbow joint of the same group of athletes is not equal when the feet are placed in different positions of the standard support push-up. The reason is that there is a superior strength of the upper limb of the human arm, that is, the muscle development of the same person's left arm and the right arm is inconsistent, and the strength between them is inconsistent, resulting in the same action to complete the push-up at the lowest point of the left elbow joint and the right elbow joint Angle is not equal.

Table 113 Comparison table of the Angle of the lowest elbow joint between high level and intermediate athletes in the lower arm flexion stage of broad support high-five push-ups (°)

Foot height	Articulatio cubiti	$\bar{X} \pm S$	P
0cm	Left elbow joint	33.01±3.34	<0.01
		35.18±3.33	
	Right elbow joint	34.58±2.56	<0.01
		36.75±2.55	
25cm	Left elbow joint	33.59±3.36	<0.01
		35.77±3.39	
	Right elbow joint	36.46±4.42	<0.01
		38.64±4.45	
30cm	Left elbow joint	37.52±5.33	<0.01
		39.67±5.36	
	Right elbow joint	39.74±4.61	<0.01
		41.89±4.63	
40cm	Left elbow joint	37.51±5.38	<0.01
		39.69±5.41	
	Right elbow joint	39.71±4.59	<0.01
		41.89±4.61	
50cm	Left elbow joint	39.19±4.79	<0.01
		41.35±4.81	
	Right elbow joint	40.98±4.65	<0.01
		43.15±4.66	

As can be seen from Table 113, at the lowest position in the stage of completing wide-supported high-five push-ups with downward flexion arms, the average Angle of the lowest elbow joint in the stage of wide-supported high-five push-ups with downward flexion arms with the increasing of the position of the feet, both the left elbow joint and the right elbow joint in pairwise comparison, have very significant differences. With the increasing of the position of the feet, the Angle of the elbow joint at the lowest position of the lower bend gradually increased.

At the same time, it is also found that the Angle of the left elbow joint and the right elbow joint of the same group of athletes is not equal when the feet are placed in different positions of the wide support high-five push-up. The reason is that there is a superior strength of the upper limb of the human arm, that is, the muscle development of the same person's left arm and the right arm is inconsistent, and the strength between them is inconsistent, resulting in an unequal Angle between the left elbow joint and the right shoulder joint when completing the same action of the push-up at the lowest point in the downward push-up. This phenomenon is highly consistent with the rule of the lowest point of the depression stage of high-level athletes and ordinary athletes after completing the standard support push-ups.



2.4.3.2 Comparative analysis of peak angular velocity characteristics of shoulder joint in the stage of downward flexion

Table 114 Comparison of peak angular velocity of shoulder joint between high-level and intermediate-level athletes in the stage of standard support push-ups with downward flexion (°)

Foot height	Articulatio cubiti	$\bar{X} \pm S$	P
0cm	Left elbow joint	431.84±6.32	<0.01
		431.84±6.32	
	Right elbow joint	452.75±6.68	<0.01
		452.75±6.68	
25cm	Left elbow joint	506.33±6.75	<0.01
		506.33±6.75	
	Right elbow joint	602.86±6.81	<0.01
		602.86±6.81	
30cm	Left elbow joint	652.58±6.87	<0.01
		652.58±6.87	
	Right elbow joint	602.01±6.94	<0.01
		602.01±6.94	
40cm	Left elbow joint	533.56±7.01	<0.01
		533.56±7.01	
	Right elbow joint	513.81±7.07	<0.01
		513.81±7.07	
50cm	Left elbow joint	578.11±7.14	<0.01
		578.11±7.14	
	Right elbow joint	569.06±7.21	<0.01
		569.06±7.21	

As can be seen from Table 114, in the stage of completing standard support push-ups with downward flexural arms, the average angular speed of shoulder joints in the stage of standard support push-ups with downward flexural arms with the continuous increase of foot position of high-level and intermediate level athletes, no matter the left shoulder joint or the right shoulder joint pairwise comparison, there are very significant differences. The angular speed of shoulder joint of athletes of the same

level increased with the completion of the standard support push-up movement, and then decreased after increasing the position of the feet, and the peak appeared in the feet were 25 cm and 30 cm above the ground. There is an inverted U-shape, that is, the left shoulder joint and the right shoulder joint with the feet 25 cm and 30 cm above the ground are above the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is consistent with the total time taken to complete different actions and the test results of shoulder joint speed, the less time used, the faster the speed, the faster the angular speed, on the contrary, the more time, the slower the speed, the slower the angular speed.

2.4.3.3 Comparative analysis of peak angular velocity characteristics of shoulder joint in the stage of upward pushing

Table 115 Comparison of peak angular velocity of shoulder joint between high level and common athletes in broad support push up stage (°)

Foot height	Shoulder joint	$\bar{X} \pm S$	P
0cm	Left shoulder joint	522.14±7.90	<0.01
	Right shoulder joint	487.89±6.79	
25cm	Left shoulder joint	465.08±8.59	<0.01
	Right shoulder joint	430.83±7.46	
30cm	Left shoulder joint	503.31±8.68	<0.01
	Right shoulder joint	469.06±9.24	
40cm	Left shoulder joint	529.68±8.77	<0.01
	Right shoulder joint	495.43±9.32	
50cm	Left shoulder joint	606.26±8.86	<0.01
	Right shoulder joint	572.01±7.73	
	Left shoulder joint	799.97±14.68	<0.01
	Right shoulder joint	765.72±13.79	
	Left shoulder joint	463.71±9.03	<0.01
	Right shoulder joint	429.46±9.78	
	Left shoulder joint	667.67±8.80	<0.01
	Right shoulder joint	633.42±9.42	
	Left shoulder joint	462.33±8.87	<0.01
	Right shoulder joint	428.08±9.85	
	Left shoulder joint	601.05±8.93	<0.01
	Right shoulder joint	566.80±9.92	

As can be seen from Table 115, the average angular velocity of shoulder joints in the push-up stage of wide-supported push-ups is significantly different between the left shoulder joints and the right shoulder joints in the pairwise comparison with the increasing position of the feet of high-level and ordinary athletes in the push-up stage of wide-supported push-ups in the same position. The angular speed of the shoulder joint of the same level athletes increased with the completion of the wide support push-up movement, and then fell back with the increasing position of the feet, and the peak appeared in the feet above the ground 25cm and 30cm. There is an inverted U-shape, that is, the left shoulder joint and the right shoulder joint with the feet 25 cm and 30 cm above the ground are above the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is consistent with the total time taken to complete different actions and the test results of shoulder joint speed, the less time used, the faster the speed, the faster the angular speed, on the contrary, the more time, the slower the speed, the slower the angular speed.

2.4.4 Comparative analysis of mechanical characteristics

2.4.4.1 Comparative analysis of peak characteristics of ground vertical reaction force in the stage of downward flexion

Table 116 Comparison of the peak value of ground vertical reaction force between high and intermediate level athletes in broad support push-up down flexion stage (N)

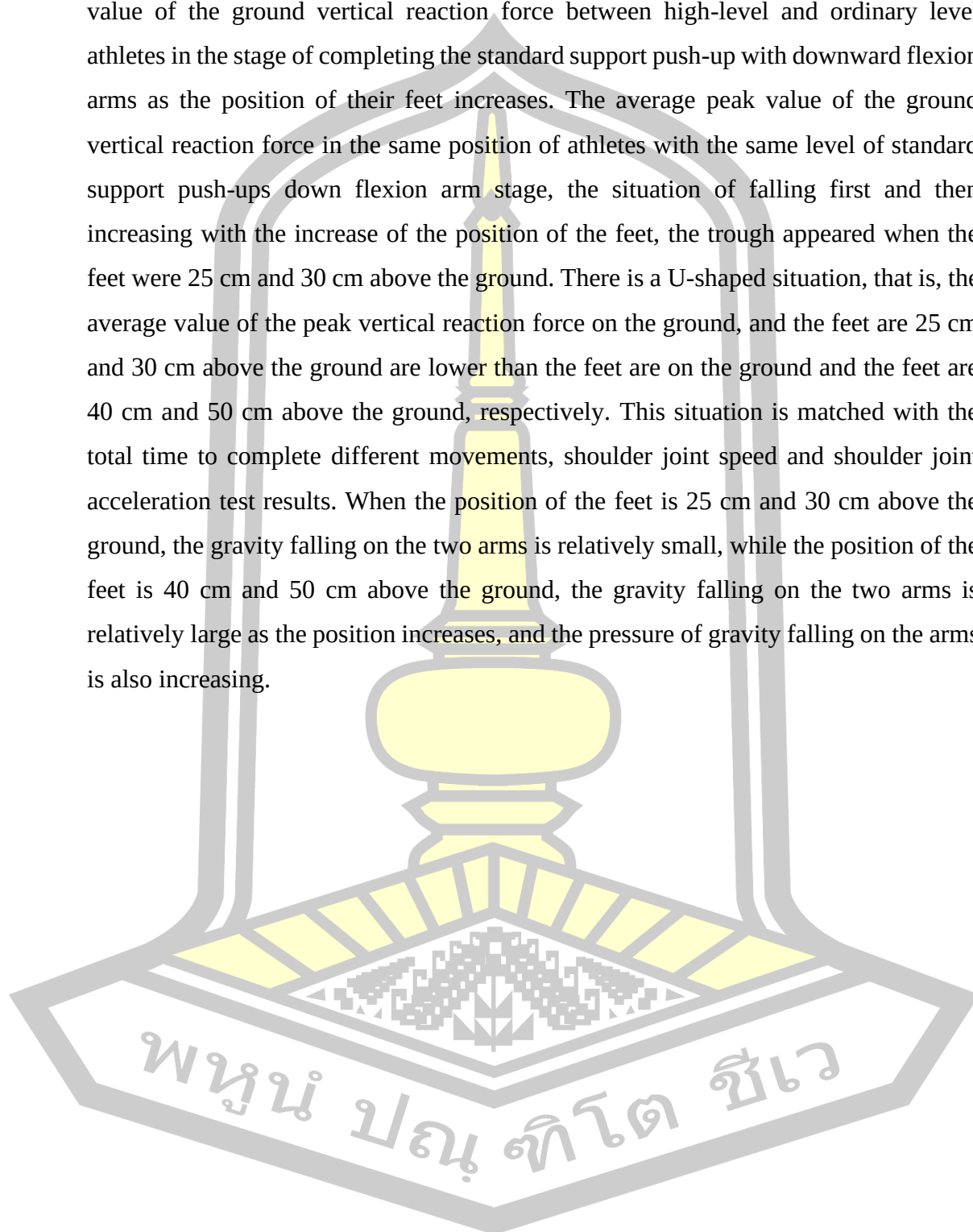
Exercise level	Foot height	$\bar{X} \pm S$	P
High level	0cm	471.28±15.83	<0.01
Intermediate level		454.01±25.84	
High level	25cm	433.84±18.84	<0.01
Intermediate level		421.74±18.62	
High level	30cm	427.36±26.35	<0.01
Intermediate level		415.17±26.04	
High level	40cm	487.35±18.88	<0.01
Intermediate level		475.06±19.18	
High level	50cm	491.94±19.77	<0.01
Intermediate level		479.55±20.05	

As can be seen from Table 116, there are significant differences in the peak value of the ground vertical reaction force between high-level and intermediate level athletes in the stage of completing wide-supported push-ups with downward flexion arms as the position of their feet increases. The average peak value of the ground vertical reaction force in the same position wide support push-up down flexion stage of the same level athletes, with the increasing of the position of the feet, fell first and then increased. The peak value of the trough appeared when the feet were 25 cm and 30 cm above the ground. There is a U-shape, that is, the left and right shoulder joints with the feet 25 cm and 30 cm above the ground are lower than the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing.

Table 117 Comparison of the peak value of ground vertical reaction force between high-level and ordinary level athletes in the stage of standard support push-up and bend arms (N)

Exercise level	Foot height	$\bar{X} \pm S$	P
High level	0cm	396.15±94.34	<0.01
Ordinary level		378.82±93.91	
High level	25cm	355.27±84.67	<0.01
Ordinary level		337.82±84.24	
High level	30cm	326.45±25.82	<0.01
Ordinary level		309.18±26.56	
High level	40cm	441.36±80.19	<0.01
Ordinary level		423.96±79.45	
High level	50cm	514.21±13.1	<0.01
Ordinary level		496.70±13.79	

As can be seen from Table 117, there are significant differences in the peak value of the ground vertical reaction force between high-level and ordinary level athletes in the stage of completing the standard support push-up with downward flexion arms as the position of their feet increases. The average peak value of the ground vertical reaction force in the same position of athletes with the same level of standard support push-ups down flexion arm stage, the situation of falling first and then increasing with the increase of the position of the feet, the trough appeared when the feet were 25 cm and 30 cm above the ground. There is a U-shaped situation, that is, the average value of the peak vertical reaction force on the ground, and the feet are 25 cm and 30 cm above the ground are lower than the feet are on the ground and the feet are 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing.



2.4.4.2 Comparative analysis of peak characteristics of ground vertical reaction force in the upward pushing stage

Table 118 Comparison of peak value of ground vertical reaction force in push-up stage of standard support for high level and intermediate level athletes (N)

Exercise level	Foot height	$\bar{X} \pm S$	P
High level	0cm	664.03±5.62	<0.01
Intermediate level		651.98±5.09	
High level	25cm	608.62±40.37	<0.01
Intermediate level		596.47±40.76	
High level	30cm	658.50±15.00	<0.01
Intermediate level		646.25±15.15	
High level	40cm	673.77±19.55	<0.01
Intermediate level		661.42±19.18	
High level	50cm	777.47±15.24	<0.01
Intermediate level		765.02±14.67	

As can be seen from Table 118, there are significant differences in the peak value of ground vertical reaction force in the push-up stage of standard support push-ups with the increasing of foot position between high-level and intermediate level athletes. The average peak value of the ground vertical reaction force in the push-up stage of the same level athletes with the same position of the standard support push-up, the situation of falling first and then increasing with the increase of the position of the feet, the trough appeared in the feet 25 cm and 30 cm above the ground. There is a U-shaped situation, that is, the average value of the peak vertical reaction force on the ground, with the feet 25 cm and 30 cm above the ground lower than the feet on the ground, and the feet 40 cm and 50 cm above the ground. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the

feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing.

Table 119 Comparison of the peak value of ground vertical reaction force between high level and ordinary level athletes in the push up stage of broad support push-up (N)

Exercise level	Foot height	$\bar{X} \pm S$	P
High level	0cm	876.03±6.59	<0.01
Ordinary level		881.06±6.53	
High level	25cm	804.25±31.55	<0.01
Ordinary level		786.87±31.13	
High level	30cm	822.82±28.02	<0.01
Ordinary level		805.31±27.81	
High level	40cm	887.64±27.12	<0.01
Ordinary level		870.02±27.62	
High level	50cm	898.66±19.53	<0.01
Ordinary level		880.91±19.96	

As can be seen from Table 119, in the stage of push-up with standard support, there are significant differences in the peak average value of the ground vertical reaction force in the stage of push-up with standard support in the same position between high-level and ordinary athletes as their feet continue to increase. The average peak value of the ground vertical reaction force in the push-up stage of the same level athletes with the same position of the standard support push-up, the situation of falling first and then increasing with the increase of the position of the feet, the trough appeared in the feet 25 cm and 30 cm above the ground. There is a U-shaped situation, that is, the average value of the peak vertical reaction force on the ground, with the feet 25 cm and 30 cm above the ground lower than the feet on the ground, and the feet 40 cm and

50 cm above the ground. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing.

2.4.5 Comparative analysis of surface myoelectric characteristics of push-ups

2.4.5.1 Comparative analysis of activation sequence (activation time) of related muscles in the stage of downward flexion

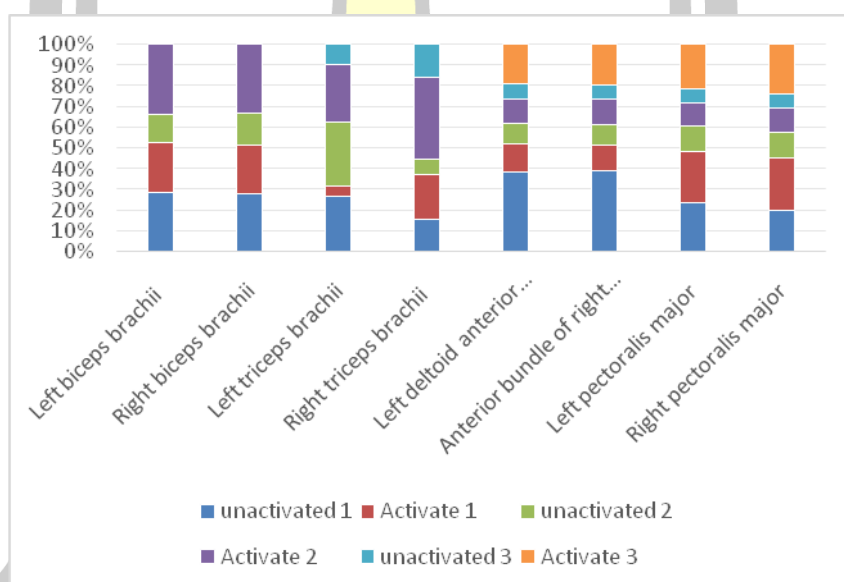


Figure 98 Comparison of muscle activation sequence of high-level athletes in the downward stage of standard support push-ups

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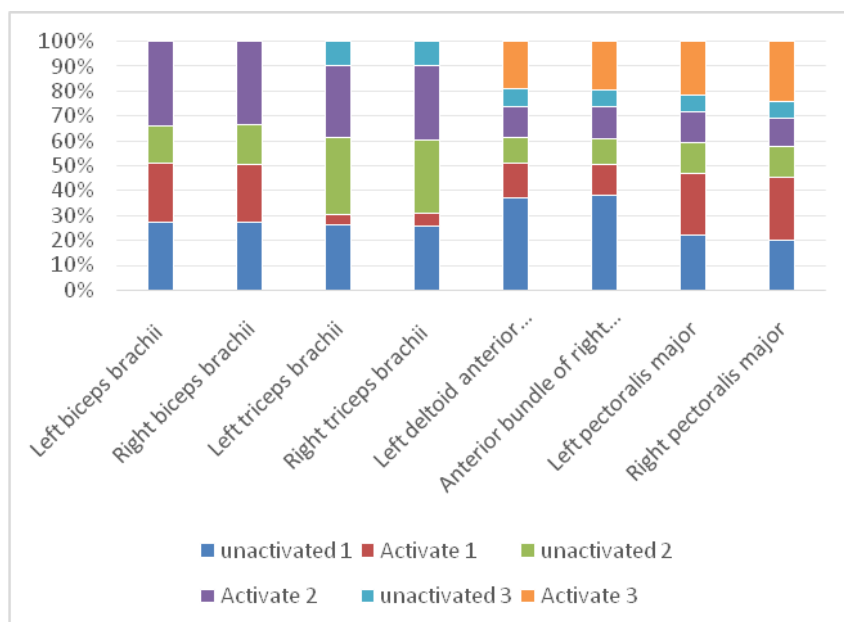


Figure 99 Comparison of muscle activation sequence of intermediate level athletes in the downward stage of standard support push-ups

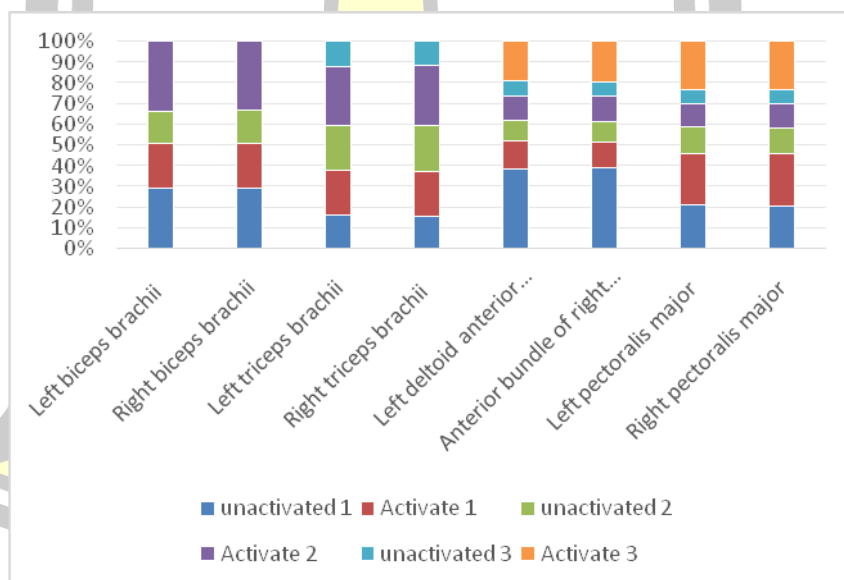


Figure 100 Comparison of muscle activation sequence of normal athletes in the downward stage of standard support push-ups

Figure 79, Figure 81 and Figure 82 show that the left and right deltoid anterior tract is activated first in the activation sequence (activation time) of relevant muscles for high-level athletes, intermediate athletes and ordinary athletes, as the bent arm and body center of gravity drop in the down bend phase of the standard push-up. It

was followed by left and right biceps, left and right pectoralis major, and left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the downward phase of the completion of the movement. This indicates that no matter the movement ability and movement level are different, the muscle activation order (activation time) is consistent when completing the same push-up action, and there is no difference between each other.

2.4.5.2 Comparative analysis of integrated EMG values of related muscles in the stage of downward flexion

Table 120 Comparison of integrated EMG value between high-level and intermediate level athletes in the downward stage of standard support push-ups

Muscle	Group	$\bar{X} \pm S$	P
Left biceps brachii	High level	119.66±1.43	<0.01
	Intermediate level	116.09±1.47	
Right biceps brachii	High level	120.06±1.88	<0.01
	Intermediate level	116.49±1.92	
Left triceps brachii	High level	494.37±2.36	<0.01
	Intermediate level	490.80±2.39	
Right triceps brachii	High level	490.10±2.88	<0.01
	Intermediate level	486.53±2.88	
Left deltoid anterior fasciculus	High level	134.28±2.91	<0.01
	Intermediate level	130.71±2.97	
Anterior bundle of right deltoid	High level	133.07±1.69	<0.01
	Intermediate level	129.50±1.77	
Left pectoralis major	High level	265.30±1.89	<0.01
	Intermediate level	261.73±1.91	
Right pectoralis major	High level	262.59±1.78	<0.01
	Intermediate level	259.02±1.80	

Table 120 shows that there is a significant difference between the integrated EMG values of the measured muscles in the left and right biceps, the left and right deltoid anterior bundle, the left and right triceps, and the left and right pectoralis major muscles in the pairwise comparison between high-level and intermediate level athletes when they complete the standard support push-up and bend the arms. This shows that high-level athletes and intermediate-level athletes have different levels of upper limb muscle and trunk muscle development due to different training years and athletic abilities. When completing the same push-up movement, the accuracy and effect are different, and high-level athletes are better than intermediate-level athletes.

2.4.5.3 Comparative analysis of activation sequence (activation time) of related muscles in the push up stage

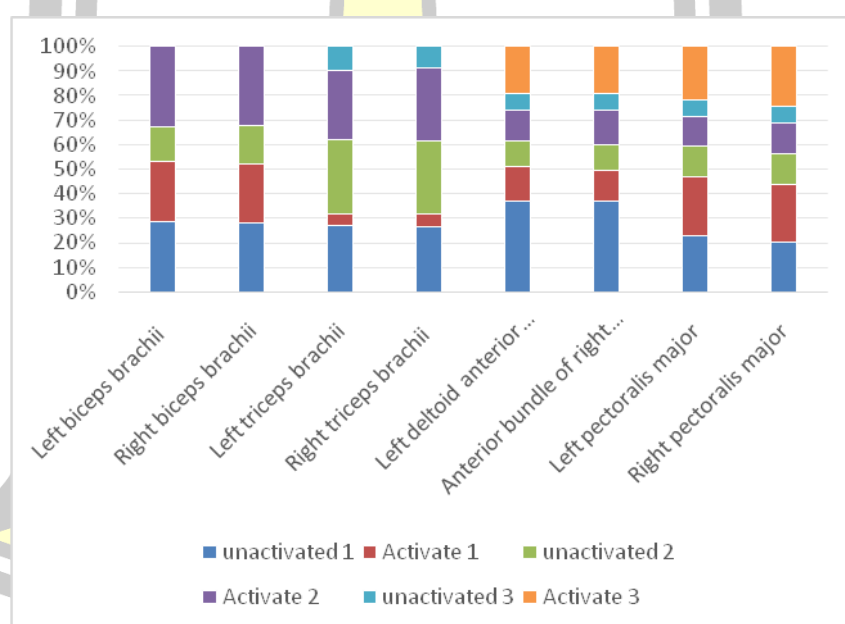


Figure 101 Comparison of muscle activation sequence of high-level athletes in the up push stage of standard support push-ups

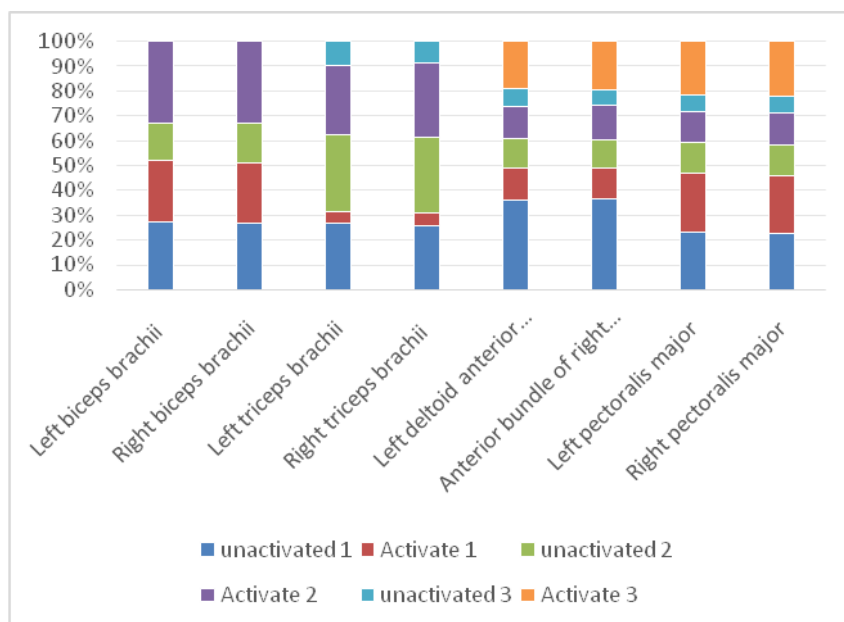


Figure 102 Comparison of muscle activation sequence of intermediate level athletes during the push-up phase of standard support push-ups

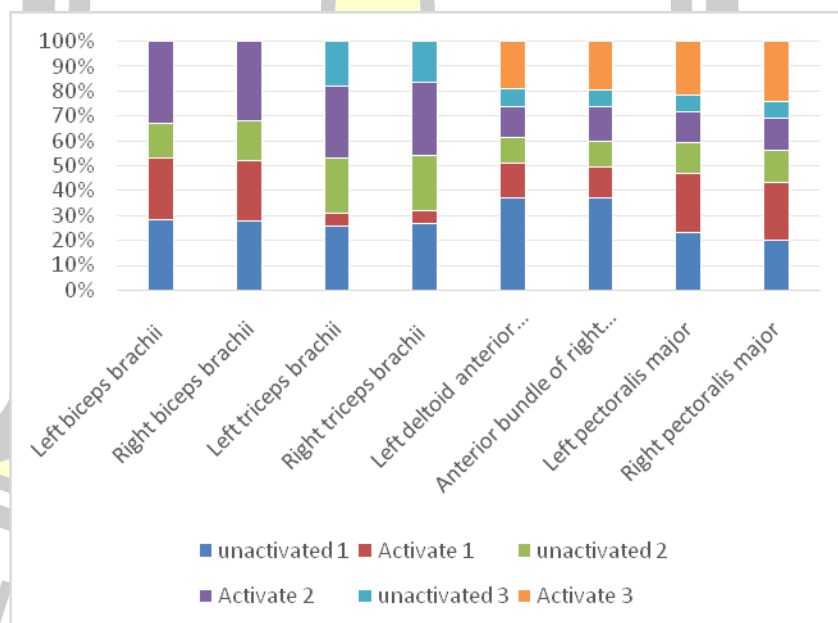


Figure 103 Comparison of muscle activation sequence of normal level athletes during the push-up phase of standard support push-ups

As can be seen from Figure 83, Figure 84 and Figure 85, high-level athletes, intermediate athletes and ordinary athletes, with the arms straighter and the body's center of gravity gradually upward, the activation sequence (activation time) of

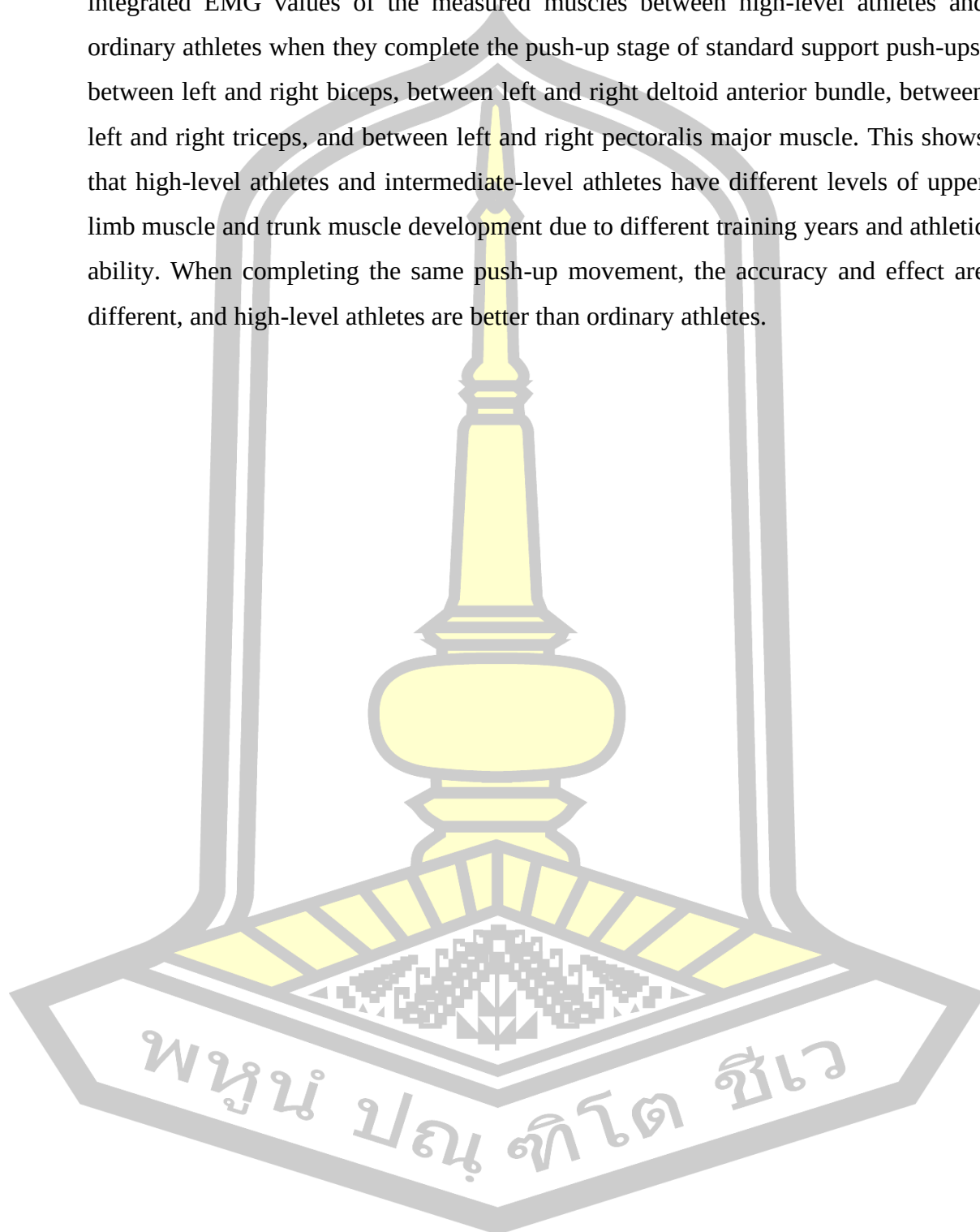
relevant muscles is that the left and right deltoid anterior tract is activated first in the push-up stage of completing the standard support push-up movement. It was followed by left and right pectoralis major, left and right triceps, and left and right biceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the upward phase of the completion of the movement. This indicates that no matter the movement ability and movement level are different, the muscle activation order (activation time) of the push-up stage of the same push-up movement is the same, and there is no difference between each other.

2.4.5.4 Comparative analysis of integrated EMG values of related muscles in the stage of upward pushing

Table 121 Comparison of integrated EMG value between high-level and ordinary level athletes in the upward stage of standard support push-ups

Muscle	Group		P
Left biceps brachii	High level	113.98±2.01	<0.01
	Ordinary level	112.54±2.08	
Right biceps brachii	High level	114.12±2.85	<0.01
	Ordinary level	112.69±2.91	
Left triceps brachii	High level	501.32±3.22	<0.01
	Ordinary level	499.89±3.21	
Right triceps brachii	High level	496.83±3.78	<0.01
	Ordinary level	495.39±3.77	
Left deltoid anterior fasciculus	High level	143.46±2.52	<0.01
	Ordinary level	142.02±2.39	
Anterior bundle of right deltoid	High level	141.92±2.69	<0.01
	Ordinary level	140.48±2.58	
Left pectoralis major	High level	274.14±2.69	<0.01
	Ordinary level	272.71±2.58	
Right pectoralis major	High level	271.53±2.90	<0.01
	Ordinary level	270.09±2.78	

As can be seen from Table 118, there are significant differences in the integrated EMG values of the measured muscles between high-level athletes and ordinary athletes when they complete the push-up stage of standard support push-ups, between left and right biceps, between left and right deltoid anterior bundle, between left and right triceps, and between left and right pectoralis major muscle. This shows that high-level athletes and intermediate-level athletes have different levels of upper limb muscle and trunk muscle development due to different training years and athletic ability. When completing the same push-up movement, the accuracy and effect are different, and high-level athletes are better than ordinary athletes.



CHAPTER V

DISCUSSIONS AND CONCLUSIONS

1. Discussion

1.1 Biomechanical characteristics of push-ups performed by high-level athletes

1.1.1 Kinematic characteristics

(1) Time characteristics

Time is the difference between the time when the movement ends and the time when the movement begins. The duration of movement is an important kinematic parameter to measure the quality of sports performance and movement technique . (Pan,2018)

The kinematics characteristics of the high-level athletes' push-ups are as follows: the total time of the standard support push-ups is between 0.95 s and 1.16 s, and the two sides are high and the middle is low as the load increases. The total time of wide support push-ups is between 0.94 seconds and 1.29 seconds, and the law of high on both sides and low in the middle is also presented with the increase of load. The total time of standard support high-five push-ups is between 1.15 seconds and 1.33 seconds, and the law of high on both sides and low in the middle is presented with the increase of load; The total time of wide support push-ups is between 1.23 seconds and 1.37 seconds, and it also shows a law of high on both sides and low in the middle as the load increases.

In terms of the total time to complete the push-up movement, the average time to complete the complete movement of the high-level athletes is also different with the increasing of the position of the feet. There is no significant difference between the average time spent in push-ups with the feet on the ground and the feet 25 cm above the ground; There was also no significant difference between the average time spent in push-ups with feet on the ground and with feet 30 cm above the ground; There is a significant difference between the average time spent in push-ups with the feet on the

ground and those with the feet 40 cm above the ground; There is also a very significant difference between the average time spent in push-ups with your feet on the ground and those with your feet 50 cm above the ground.

Among the four postures, the time spent in the bending down stage was less than that in the pushing up stage, and the general time spent in the wide support push-up was less than that in the standard posture.

What is the reason for this pattern? This study suggests that there are two factors that affect the time of athletes to complete push-ups, one is the center of gravity of the human body, and the other is the Angle of the arm and torso at the shoulder joint. As the position of the feet and the supporting position of the hands of the test volunteers continue to change, the center of gravity of the human body also has different characteristics with the change of the relative position, that is, the force acting on the arms also changes differently, which is the different load proposed in this study.

When completing the standard push-up, the feet are on the ground, the body's center of gravity is vertical down, the head position is higher than the feet because of the arm support, and the body's own weight falls on the feet more than the weight on the hands, so the difficulty of completing the action is relatively low, the completion of the action is easier, and the time is relatively less. Interestingly, with the elevation of the position of the feet, the load of the human body's own weight on the hands gradually increases, and the total time to complete the movement is relatively less than that of standard push-ups when the feet are 25 cm and 30 cm above the ground, because the appropriate posture is more conducive to the completion of the movement. The position of the feet 25 cm and 30 cm above the ground is the best position for the push-up movement, and the completion of the movement is easier and easier to complete, resulting in a reduction in the time to complete the movement. However, as the position of the feet continues to rise, the load of the body's own weight on the hands gradually increases again, and the time to complete the movement is more obvious when the feet are 40 cm and 50 cm above the ground. (Xu,2011)

At the same time, the completion of the push-up movement is also affected by the change of the Angle of the arm and the torso, and the Angle between the arm

and the torso when the feet are 25 cm and 30 cm above the ground is about 90° , which is the most appropriate Angle to complete the push-up movement, resulting in the completion of the movement is easier than other positions, and the completion of the time is less. (Yuan,2011)

(2) Velocity characteristics

The peak speed of shoulder joint in the downward flexion stage is manifested in the speed of completing movements. In the downward flexion stage of push-ups, standard support and wide support push-ups, the peak speed of shoulder joint presents a law of low on both sides and high in the middle with the increase of load; In the push up stage of push-ups, standard support and wide support push-ups, the peak speed of shoulder joint, with the increase of load on both sides of the low middle high law, and the left and right shoulder joint speed peak has a significant difference, that is, inconsistent situation.

Peak velocity characteristics of shoulder joint during the lower flexion phase. With the continuous increase of the position of the feet, the peak speed of the shoulder joint in the stage of standard push-ups with the same position is different between the left shoulder joint and the right shoulder joint, sometimes the left shoulder is higher than the right shoulder, sometimes the right shoulder is higher than the left shoulder, and there is no typical rule. In standard push-ups with feet 25 cm and 30 cm above the ground, the peak speed of the shoulder joint in the downward flexion phase is higher than the value when the feet are in other positions, which also causes these two positions to take less time than the other positions. This is related to the proper position and Angle of the completion of the action to complete the action with better quality. (Wang,2002)

At the same time, it was also found that the average peak speed of both the left shoulder joint and the right shoulder joint showed an inverted U-shaped pattern in the downward flexion stage of the standard support push-up. That is, the average peak shoulder joint speed of push-ups with feet 25 cm above the ground and feet 30 cm above the ground is higher than that of push-ups with feet on the ground, feet 40 cm above the ground and feet 40 cm above the ground. This pattern is the exact opposite of what

happens when you complete a full push-up. This also shows that the less time it takes to complete the same distance, the faster the speed, and the more time it takes, the slower the speed. (Tian,2016)

(3) Angle characteristics of the lowest elbow joint in flexion

At the lowest point of the push-up stage, the elbow joint Angle of standard support and wide support push-up showed a gradual increase with the increase of load, and the peak Angle of the left and right elbow joint was significantly different, that is, inconsistent. This shows that the strength of the athlete's left and right arms is unequal, that is, the athlete's arm has dominant side and non-dominant side upper limb muscles, and the size of the joint height is controlled by the muscle strength, resulting in the phenomenon of unequal peak Angle of the left and right elbow joints at the lowest point.

At the lowest position of the stage of completing the standard support push-up, the feet of the high-level athlete are placed in different positions of the standard support or wide support push-up, and the Angle of the left elbow joint and the right elbow joint of the same athlete are not equal. The reason is that there is a superior strength of the upper limb of the human arm, that is, the muscle development of the same person's left arm and the right arm is inconsistent, and the strength between them is inconsistent, resulting in the same action to complete the push-up at the lowest point of the left elbow joint and the right elbow joint Angle is not equal. This phenomenon is highly consistent with the rule of the lowest point of the depression stage of high-level athletes and ordinary athletes after completing the standard support push-ups. (Fang,2022,Tian,2016)

(4) Peak angular velocity characteristics of shoulder joint

The peak angular velocity of the shoulder joint of the high-level athletes in the stage of completing the standard support push-up and bending the arms, the left shoulder joint and the right shoulder joint are inconsistent, and there are some differences. The angular speed of the shoulder joint of the high-level athletes increased with the completion of the standard support push-up movement, and then decreased after increasing the position of the feet, and the peak appeared in the feet were 25 cm

and 30 cm above the ground. There is an inverted U-shape, that is, the left shoulder joint and the right shoulder joint with the feet 25 cm and 30 cm above the ground are above the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. (Wu, 2020)

The peak angular velocity of shoulder joint in push-ups, standard support and wide support push-ups, showed a law of low on both sides and high in the middle with the increase of load; In the push up stage of push-ups, standard support and wide support push-ups, the peak angular velocity of shoulder joint shows a law of low on both sides and high in the middle as the load increases, and there is a significant difference in the peak angular velocity of left and right shoulder joints, that is, inconsistent situation. The reason for this situation is that there are dominant and non-dominant upper limb muscles on both sides of the human arm. The strong arm muscle strength of the dominant side causes the peak angular velocity of the dominant side shoulder to be higher than that of the non-dominant side.

1.1.2 Dynamic characteristics

High level In the stage of wide support push-up down flexion, the peak of the ground vertical reaction force in the stage of wide support push-up down flexion at the same position, with the increasing position of the feet, the first drop and then increase, the peak trough appears in the feet are 25 cm and 30 cm above the ground. There is a U-shape, that is, the left and right shoulder joints with the feet 25 cm and 30 cm above the ground are lower than the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing. (Luo,2018)

In the vertical reaction force of push-ups, the peak value of the reaction force in the push-up stage was lower than that in the push-up stage, and the peak value

of the reaction force in the push-up stage was lower than that in the push-up stage of the push-up stage. The reaction force of both the down and up phases of the wide support push-up is higher than that of the standard support push-up. Push-up down stage, the center of gravity moves down, the arm muscles control the body's falling speed, and the direction of force is consistent downward, however, the push up stage, the arm muscles need to overcome the downward gravity of the body, so that the vertical reaction force in the push up stage is greater than the vertical reaction force in the downward stage in the same posture and the same load pushup. From the phenomenon of muscle activation, it can also be seen that in the push up stage, the triceps and deltoid anterior fasciculus activation must overcome body gravity, and muscle contraction produces a better push up the body, which also causes the vertical reaction force in the push up stage to be greater than that in the downward stage.

1.1.3 Surface EMG characteristics

As the flexion of the arms and the weight of the body decreased, the relevant muscle activation sequence (activation time) was first activated by the left and right deltoid anterior fasciculus, followed by the left and right biceps, the left and right pectoralis major, and the left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the downward phase of the completion of the movement. This indicates that the muscle activation sequence (activation time) of push-ups with different postures and different loads is consistent, and there is no difference between each other. (Wu, 2020; liu,2021)

1.2 Biomechanical characteristics of push-ups performed by intermediate level athletes

1.2.1 Kinematic characteristics

(1) Time characteristics

The kinematics characteristics of the intermediate level athletes' push-ups are as follows: the total time of the standard support push-ups is between 1.21 seconds and 1.39 seconds, and the two sides are high and the middle is low as the load increases.

The total time of wide support push-ups is between 1.20 seconds and 1.49 seconds, and it also shows a law of high on both sides and low in the middle with the increase of load. The total time of standard support high-five push-ups is between 1.34 seconds and 1.53 seconds, with the increase of load showing a law of high on both sides and low in the middle; The total time of wide support push-ups is between 1.41 seconds and 1.58 seconds, and it also shows a law of high on both sides and low in the middle as the load increases.

In terms of the total time to complete the push-up movement, the average time for intermediate level athletes to complete the full movement is also different with the increasing of the position of their feet. There is no significant difference between the average time spent in push-ups with the feet on the ground and the feet 25 cm above the ground; There was also no significant difference between the average time spent in push-ups with feet on the ground and with feet 30 cm above the ground; There is a significant difference between the average time spent in push-ups with the feet on the ground and those with the feet 40 cm above the ground; There is also a very significant difference between the average time spent in push-ups with your feet on the ground and those with your feet 50 cm above the ground.

Among the four postures, the time spent in the bending down stage was less than that in the pushing up stage, and the general time spent in the wide support push-up was less than that in the standard posture.

As the position of the feet and the supporting position of the hands of the test volunteers continue to change, the center of gravity of the human body also has different characteristics with the change of the relative position, that is, the force acting on the arms also changes differently, which is the different load proposed in this study. Therefore, this study proposed that there are two factors affecting the time of athletes completing push-ups, one is the center of gravity of the human body, and the other is the Angle of the arm and torso at the shoulder joint (Pan,2018).

When completing the standard push-up, the feet are on the ground, the body's center of gravity is vertical down, the head position is higher than the feet because of the arm support, and the body's own weight falls on the feet more than the

weight on the hands, so the difficulty of completing the action is relatively low, the completion of the action is easier, and the time is relatively less. Interestingly, with the elevation of the position of the feet, the load of the human body's own weight on the hands gradually increases, and the total time to complete the movement is relatively less than that of standard push-ups when the feet are 25 cm and 30 cm above the ground, because the appropriate posture is more conducive to the completion of the movement. The position of the feet 25 cm and 30 cm above the ground is the best position for the push-up movement, and the completion of the movement is easier and easier to complete, resulting in a reduction in the time to complete the movement. However, as the position of the feet continues to rise, the load of the body's own weight on the hands gradually increases again, and the time to complete the movement is more obvious when the feet are 40 cm and 50 cm above the ground. (Xu,2011)

At the same time, the completion of the push-up movement is also affected by the change of the Angle of the arm and the torso, and the Angle between the arm and the torso when the feet are 25 cm and 30 cm above the ground is about 90° , which is the most appropriate Angle to complete the push-up movement, resulting in the completion of the movement is easier than other positions, and the completion of the time is less. (Yuan,2011)

(2) Velocity characteristics

The peak speed of the shoulder joint of intermediate level athletes is shown in the speed of the completed movement in the stage of push-up and downward flexion. In the stage of push-up and downward flexion, the peak speed of the shoulder joint presents a law of low on both sides and high in the middle as the load increases. In the push up stage of push-ups, standard support and wide support push-ups, the peak speed of shoulder joint, with the increase of load on both sides of the low middle high law, and the left and right shoulder joint speed peak has a significant difference, that is, inconsistent situation.

Peak velocity characteristics of shoulder joint during the lower flexion phase. As the position of the feet continues to increase, there is a difference between the peak speed of the left shoulder joint and the right shoulder joint, sometimes the left

shoulder is higher than the right shoulder, sometimes the right shoulder is higher than the left shoulder, and there is no typical rule. In standard push-ups with feet 25 cm and 30 cm above the ground, the peak speed of the shoulder joint in the downward flexion phase is higher than the value when the feet are in other positions, which also causes these two positions to take less time than the other positions. This is related to the proper position and Angle of the completion of the action to complete the action with better quality. (Liu,2021,Wang,2002)

At the same time, it was also found that the average peak speed of both the left shoulder joint and the right shoulder joint showed an inverted U-shaped pattern in the downward flexion stage of the standard support push-up. That is, the average peak shoulder joint speed of push-ups with feet 25 cm above the ground and feet 30 cm above the ground is higher than that of push-ups with feet on the ground, feet 40 cm above the ground and feet 40 cm above the ground. This pattern is the exact opposite of what happens when you complete a full push-up. This also shows that the less time it takes to complete the same distance, the faster the speed, and the more time it takes, the slower the speed. (Tian,2016, Liu,2021)

(3) Angle characteristics of the lowest elbow joint in flexion

In the lowest position of an intermediate level athlete when completing a standard support push-up, the feet of an intermediate level athlete are placed at different positions in a standard support or wide support push-up, and the Angle of the left elbow joint and the right elbow joint of the same athlete are unequal. The reason is that there is a superior strength of the upper limb of the human arm, that is, the muscle development of the same person's left arm and the right arm is inconsistent, and the strength between them is inconsistent, resulting in the same action to complete the push-up at the lowest point of the left elbow joint and the right elbow joint Angle is not equal. This phenomenon is highly consistent with the rule of the lowest point of the depression stage when the high-level athletes complete the standard support push-up. (Tian,2016)

At the lowest point of the push-up stage, the elbow joint Angle of standard support and wide support push-up showed a gradual increase with the increase of load, and the peak Angle of the left and right elbow joint was significantly different, that is,

inconsistent. This shows that the strength of the athlete's left and right arms is unequal, that is, the athlete's arm has dominant side and non-dominant side upper limb muscles, and the size of the joint height is controlled by the muscle strength, resulting in the phenomenon of unequal peak Angle of the left and right elbow joints at the lowest point.

(4) Peak angular velocity characteristics of shoulder joint

In the push-up stage, the intermediate level athletes completed the standard support and wide support push-ups, and the peak angular velocity of shoulder joint showed a law of low on both sides and high in the middle with the increase of load; In the push up stage of push-ups, standard support and wide support push-ups, the peak angular velocity of shoulder joint shows a law of low on both sides and high in the middle as the load increases, and there is a significant difference in the peak angular velocity of left and right shoulder joints, that is, inconsistent situation. The reason for this situation is that there are dominant and non-dominant upper limb muscles on both sides of the human arm. The strong arm muscle strength of the dominant side causes the peak angular velocity of the dominant side shoulder to be higher than that of the non-dominant side.

The peak angular velocity of shoulder joint of intermediate level athletes was different between left shoulder joint and right shoulder joint in the stage of standard support push-up and bend arm. The angular speed of the shoulder joint of the intermediate level athletes increased with the completion of the standard support push-up movement, and then decreased after increasing the position of the feet, and the peak appeared in the feet were 25 cm and 30 cm above the ground. There is an inverted U-shape, that is, the left shoulder joint and the right shoulder joint with the feet 25 cm and 30 cm above the ground are above the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. (Wu, 2020)

1.2.2 Dynamic characteristics

In the vertical reaction force of the intermediate level athletes, the peak value of the reaction force in the push-up stage of the standard support push-up is lower than that in the push-up stage, and the peak value of the reaction force in the push-up stage of the broad support push-up is lower than that in the push-up stage. The reaction

force of both the down and up phases of the wide support push-up is higher than that of the standard support push-up. Push-up down stage, the center of gravity moves down, the arm muscles control the body's falling speed, and the direction of force is consistent downward, however, the push up stage, the arm muscles need to overcome the downward gravity of the body, so that the vertical reaction force in the push up stage is greater than the vertical reaction force in the downward stage in the same posture and the same load pushup. From the phenomenon of muscle activation, it can also be seen that in the push up stage, the triceps and deltoid anterior fasciculus activation must overcome body gravity, and muscle contraction produces a better push up the body, which also causes the vertical reaction force in the push up stage to be greater than that in the downward stage.

At the intermediate level, the peak of the vertical reaction force on the ground in the stage of completing the wide support push-up and bending the arms, in the same position, the peak value of the vertical reaction force on the ground fell first and then increased with the increasing position of the feet, and the peak value of the trough appeared when the feet were 25 cm and 30 cm above the ground. There is a U-shape, that is, the left and right shoulder joints with the feet 25 cm and 30 cm above the ground are lower than the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing. (Luo,2018)

1.2.3 Surface EMG characteristics

In intermediate level athletes, with the lower flexion of the arms and the lower weight of the body, the relevant muscle activation sequence (activation time) is first activated by the left and right deltoid anterior bundle, followed by the left and right biceps, the left and right pectoralis major, and the left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the downward phase of the completion of the

movement. This indicates that the muscle activation sequence (activation time) of push-ups with different positions and different loads is consistent, and there is no difference between each other. (Wu, 2020; liu,2021)

1.3 Biomechanical characteristics of push-ups performed by ordinary athletes

1.3.1 Kinematic characteristics

(1) Time characteristics

The kinematics characteristics of the general level athletes' push-ups are as follows: the total time of the standard support push-ups is between 1.25 seconds and 1.43 seconds, and the two sides are high and the middle is low as the load increases. The total time of wide support push-ups is between 1.24 seconds and 1.44 seconds, and the law of high on both sides and low in the middle is also presented with the increase of load. The total time of standard support high-five push-ups is between 1.39 seconds and 1.52 seconds, and the law of high on both sides and low in the middle is presented with the increase of load. The total time of wide support push-ups is between 1.47 seconds and 1.61 seconds, and it also shows a law of high on both sides and low in the middle as the load increases.

In terms of the total time to complete the push-up movement, the average time to complete the complete movement of the ordinary level athletes is also different with the increasing of the position of the feet when completing the wide support push-up. There is no significant difference between the average time spent in push-ups with the feet on the ground and the feet 25 cm above the ground; There was also no significant difference between the average time spent in push-ups with feet on the ground and with feet 30 cm above the ground; There is a significant difference between the average time spent in push-ups with the feet on the ground and those with the feet 40 cm above the ground; There is also a very significant difference between the average time spent in push-ups with your feet on the ground and those with your feet 50 cm above the ground.

Among the four postures, the time spent in the bending down stage was less than that in the pushing up stage, and the general time spent in the wide support push-up was less than that in the standard posture.

As the position of the feet and the supporting position of the hands of the test volunteers continue to change, the center of gravity of the human body also has different characteristics with the change of the relative position, that is, the force acting on the arms also changes differently, which is the different load proposed in this study. Therefore, this study proposed that there are two factors affecting the time of athletes completing push-ups, one is the center of gravity of the human body, and the other is the Angle of the arm and torso at the shoulder joint (Pan,2018).

When completing the standard push-up, the feet are on the ground, the body's center of gravity is vertical down, the head position is higher than the feet because of the arm support, and the body's own weight falls on the feet more than the weight on the hands, so the difficulty of completing the action is relatively low, the completion of the action is easier, and the time is relatively less. Interestingly, with the elevation of the position of the feet, the load of the human body's own weight on the hands gradually increases, and the total time to complete the movement is relatively less than that of standard push-ups when the feet are 25 cm and 30 cm above the ground, because the appropriate posture is more conducive to the completion of the movement. The position of the feet 25 cm and 30 cm above the ground is the best position for the push-up movement, and the completion of the movement is easier and easier to complete, resulting in a reduction in the time to complete the movement. However, as the position of the feet continues to rise, the load of the body's own weight on the hands gradually increases again, and the time to complete the movement is more obvious when the feet are 40 cm and 50 cm above the ground. (Xu,2011)

At the same time, the completion of the push-up movement is also affected by the change of the Angle of the arm and the torso, and the Angle between the arm and the torso when the feet are 25 cm and 30 cm above the ground is about 90°, which is the most appropriate Angle to complete the push-up movement, resulting in the completion of the movement is easier than other positions, and the completion of the time is less. (Yuan,2011)

(2) Velocity characteristics

The peak speed of shoulder joint of ordinary level athletes in the stage of push-up and downward flexion is shown in the speed of completing the movement. In the stage of downward flexion, standard support and wide support push-up, the peak speed of shoulder joint presents a law of low on both sides and high in the middle with the increase of load; In the push up stage of push-ups, standard support and wide support push-ups, the peak speed of shoulder joint, with the increase of load on both sides of the low middle high law, and the left and right shoulder joint speed peak has a significant difference, that is, inconsistent situation.

Peak velocity characteristics of shoulder joint during the lower flexion phase. As the position of the feet continues to increase, there is a difference between the peak speed of the left shoulder joint and the right shoulder joint, sometimes the left shoulder is higher than the right shoulder, sometimes the right shoulder is higher than the left shoulder, and there is no typical rule. In standard push-ups with feet 25 cm and 30 cm above the ground, the peak speed of the shoulder joint in the downward flexion phase is higher than the value when the feet are in other positions, which also causes these two positions to take less time than the other positions. This is related to the proper position and Angle of the completion of the action to complete the action with better quality. (Liu,2021,Wang,2002)

At the same time, it was also found that the average peak speed of both the left shoulder joint and the right shoulder joint showed an inverted U-shaped pattern in the downward flexion stage of the standard support push-up. That is, the average peak shoulder joint speed of push-ups with feet 25 cm above the ground and feet 30 cm above the ground is higher than that of push-ups with feet on the ground, feet 40 cm above the ground and feet 40 cm above the ground. This pattern is the exact opposite of what happens when you complete a full push-up. This also shows that the less time it takes to complete the same distance, the faster the speed, and the more time it takes, the slower the speed. (Tian,2016, Liu,2021)

(3) Angle characteristics of the lowest elbow joint in flexion

At the lowest point of the push-up stage, the elbow joint Angle of the standard support and the wide support push-up showed a gradual increase with the increase of load, and the peak Angle of the left and right elbow joint was significantly different, that is, inconsistent. This shows that the strength of the athlete's left and right arms is unequal, that is, the athlete's arm has dominant side and non-dominant side upper limb muscles, and the size of the joint height is controlled by the muscle strength, resulting in the phenomenon of unequal peak Angle of the left and right elbow joints at the lowest point.

In the lowest position of the stage of completing the standard support push-up, the feet of the ordinary horizontal athletes are placed in different positions of the standard support or wide support push-up, and the Angle of the left elbow joint and the right elbow joint of the same athlete are not equal. The reason is that there is a superior strength of the upper limb of the human arm, that is, the muscle development of the same person's left arm and the right arm is inconsistent, and the strength between them is inconsistent, resulting in the same action to complete the push-up at the lowest point of the left elbow joint and the right elbow joint Angle is not equal. This phenomenon is highly consistent with the rule of the lowest point of the depression stage when the high-level athletes complete the standard support push-up. (Tian,2016)

(4) Peak angular velocity characteristics of shoulder joint

In the push-up stage, the average level athletes completed the standard support and wide support push-ups, and the peak angular velocity of shoulder joint showed a law of low on both sides and high in the middle with the increase of load. In the push up stage of push-ups, standard support and wide support push-ups, the peak angular velocity of shoulder joint shows a law of low on both sides and high in the middle as the load increases, and there is a significant difference in the peak angular velocity of left and right shoulder joints, that is, inconsistent situation. The reason for this situation is that there are dominant and non-dominant upper limb muscles on both sides of the human arm. The strong arm muscle strength of the dominant side causes

the peak angular velocity of the dominant side shoulder to be higher than that of the non-dominant side.

The peak angular velocity of shoulder joint in the stage of standard support push-ups and bend arms, the left shoulder joint and the right shoulder joint are not consistent, and there are some differences. The angular speed of the shoulder joint of the ordinary level athletes increases with the completion of the standard support push-ups, and then decreases after increasing the position of the feet, and the peak value appears when the feet are 25 cm and 30 cm above the ground. There is an inverted U-shape, that is, the left shoulder joint and the right shoulder joint with the feet 25 cm and 30 cm above the ground are above the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. (Wu, 2020)

1.3.2 Dynamic characteristics

In the vertical reaction force, the peak value of the reaction force in the push-up stage is lower than that in the push-up stage, and the peak value of the reaction force in the push-up stage is lower than that in the push-up stage of the push-up stage. The reaction force of both the down and up phases of the wide support push-up is higher than that of the standard support push-up. Push-up down stage, the center of gravity moves down, the arm muscles control the body's falling speed, and the direction of force is consistent downward, however, the push up stage, the arm muscles need to overcome the downward gravity of the body, so that the vertical reaction force in the push up stage is greater than the vertical reaction force in the downward stage in the same posture and the same load pushup. From the phenomenon of muscle activation, it can also be seen that in the push up stage, the triceps and deltoid anterior fasciculus activation must overcome body gravity, and muscle contraction produces a better push up the body, which also causes the vertical reaction force in the push up stage to be greater than that in the downward stage.

In the general level, the peak of the vertical reaction force on the ground in the stage of bending arms with wide support push-ups and bending arms with wide support push-ups at the same position fell first and then increased with the increasing position of the feet, and the peak of the trough appeared when the feet were 25 cm and

30 cm above the ground. There is a U-shape, that is, the left and right shoulder joints with the feet 25 cm and 30 cm above the ground are lower than the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing. (Luo,2018)

1.3.3 Surface EMG characteristics

As the flexion of the arms and the weight of the body decreased, the relevant muscle activation sequence (activation time) was first activated by the left and right deltoid anterior bundle, followed by the left and right biceps, the left and right pectoralis major and the left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the downward phase of the completion of the movement. This indicates that the muscle activation sequence (activation time) of push-ups with different positions and different loads is consistent, and there is no difference between each other. (Wu, 2020; liu,2021)

1.4 Comparative analysis of biomechanical characteristics of push-ups performed by athletes of different levels

1.4.1 Kinematic characteristics

(1) Time characteristics

In terms of the total time to complete the push-up movement, the average time to complete the complete movement of the high-level athletes is also different with the increasing of the position of the feet. There is no significant difference between the average time spent in push-ups with the feet on the ground and the feet 25 cm above the ground; There was also no significant difference between the average time spent in

push-ups with feet on the ground and with feet 30 cm above the ground; There is a significant difference between the average time spent in push-ups with the feet on the ground and those with the feet 40 cm above the ground; There is also a very significant difference between the average time spent in push-ups with your feet on the ground and those with your feet 50 cm above the ground. (Xu,2011)

This law is also present in the intermediate level athletes and ordinary level athletes of the same exercise level athletes, complete different loads of push-up movements. It can be seen that athletes at the same exercise level, with the elevation of the position of their feet, the weight of the body borne by their hands gradually increases, and the total time taken to complete the movement also gradually increases. The total time from the time when the feet are placed on the ground to the time when the feet are 30 cm above the ground is not significantly increased, and the time when the feet are 40 cm above the ground is significantly increased. At the same time, it also reflects that there is no significant difference between the average total time spent when the feet are 25 cm to 30 cm above the ground and the average total time spent when the feet are placed on the ground, regardless of the standard support or wide support state, but there is a significant difference and a very significant difference when the feet are 40 cm or more above the ground.

Whether it is high level and intermediate level athletes, or high level and average level athletes, there is a significant difference in the average total time between them to complete the same load of push-ups. The average time of high-level athletes is less than that of intermediate level athletes and less than that of ordinary level athletes. These results indicate that the athletic ability of high-level athletes to complete standard support push-ups, wide support push-ups, standard support high-five push-ups and wide support high-five push-ups is higher than that of intermediate level athletes and ordinary level athletes. On the one hand, the training time of high-level athletes is relatively long, and the upper limb muscle development is better than that of intermediate level and ordinary level athletes; On the other hand, the accuracy and economy of the high-level athletes to complete the push-up movement are better than the other two different levels of athletes.

(2) Velocity characteristics

With the increasing of the position of the feet, the average peak speed of the shoulder joints in the stage of the same position of the standard push-up is different between the left shoulder joints and the right shoulder joints. The average peak value of shoulder joint speed of high level and ordinary level athletes with their feet on the ground in the push-up stage, the left shoulder joint and the right shoulder joint have a very significant difference. In addition, with the remaining feet 25 cm above the ground, feet 30 cm above the ground, feet 40 cm above the ground, and feet 50 cm above the ground, there was no significant difference between the average peak speed of the left and right shoulder joints of the high-level and ordinary athletes.

At the same time, it was also found that the average peak speed of both the left shoulder joint and the right shoulder joint showed an inverted U-shaped pattern in the downward flexion stage of the standard support push-up. That is, the average peak shoulder joint speed of push-ups with feet 25 cm above the ground and feet 30 cm above the ground is higher than that of push-ups with feet on the ground, feet 40 cm above the ground and feet 40 cm above the ground. This pattern is the exact opposite of what happens when you complete a full push-up. This also shows that the less time it takes to complete the same distance, the faster the speed, and the more time it takes, the slower the speed.

(3) Angle characteristics of the lowest elbow joint in flexion

In the lowest position of the standard support push-up down flexion stage, the average Angle of the lowest elbow joint in the same position of the standard support push-up down flexion stage is significantly different between the left elbow joint and the right elbow joint as the position of the feet continues to increase. With the increasing of the position of the feet, the Angle of the elbow joint at the lowest position of the lower bend gradually increased.

At the lowest position in the stage of low bending arms with wide support, the average Angle of the lowest elbow joint in the stage of low bending arms with high and intermediate level athletes increased with the position of their feet, no matter the left elbow joint or the right elbow joint pairwise comparison was very significant. With

the increasing of the position of the feet, the Angle of the elbow joint at the lowest position of the lower bend gradually increased.

At the same time, it is also found that the Angle of the left elbow joint and the right elbow joint of the same group of athletes is not equal when the feet are placed in different positions of the standard support or wide support push-up. The reason is that there is a superior strength of the upper limb of the human arm, that is, the muscle development of the same person's left arm and the right arm is inconsistent, and the strength between them is inconsistent, resulting in the same action to complete the push-up at the lowest point of the left elbow joint and the right elbow joint Angle is not equal. This phenomenon is highly consistent with the rule of the lowest point of the depression stage of high-level athletes and ordinary athletes after completing the standard support push-ups.

(4) Peak angular velocity characteristics of shoulder joint

With the increasing of the position of the feet, the average angular speed of the shoulder joint in the stage of the same position of the standard support push-up and the bending arm, no matter the left shoulder joint or the right shoulder joint pairwise comparison, there are very significant differences. The angular speed of shoulder joint of athletes of the same level increased with the completion of the standard support push-up movement, and then decreased after increasing the position of the feet, and the peak appeared in the feet were 25 cm and 30 cm above the ground. There is an inverted U-shape, that is, the left shoulder joint and the right shoulder joint with the feet 25 cm and 30 cm above the ground are above the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is consistent with the total time taken to complete different actions and the test results of shoulder joint speed, the less time used, the faster the speed, the faster the angular speed, on the contrary, the more time, the slower the speed, the slower the angular speed.

1.4.2 Dynamic characteristics

With the increasing of the position of the feet, the average peak value of the vertical reaction force of the ground in the stage of the same position of the wide support push-up was significantly different from that of the intermediate level athletes. The average peak value of the ground vertical reaction force in the same position wide support push-up down flexion stage of the same level athletes, with the increasing of the position of the feet, fell first and then increased. The peak value of the trough appeared when the feet were 25 cm and 30 cm above the ground. There is a U-shape, that is, the left and right shoulder joints with the feet 25 cm and 30 cm above the ground are lower than the feet on the ground, and the feet 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing.

In the stage of push-ups with standard support, the average peak value of ground vertical reaction force in the stage of push-ups with standard support in the same position is significantly different between high-level and ordinary athletes with increasing foot position. The average peak value of the ground vertical reaction force in the same position of athletes with the same level of standard support push-ups down flexion arm stage, the situation of falling first and then increasing with the increase of the position of the feet, the trough appeared when the feet were 25 cm and 30 cm above the ground. There is a U-shaped situation, that is, the average value of the peak vertical reaction force on the ground, and the feet are 25 cm and 30 cm above the ground are lower than the feet are on the ground and the feet are 40 cm and 50 cm above the ground, respectively. This situation is matched with the total time to complete different movements, shoulder joint speed and shoulder joint acceleration test results. When the position of the feet is 25 cm and 30 cm above the ground, the gravity falling on the two arms is relatively small, while the position of the feet is 40 cm and 50 cm above the

ground, the gravity falling on the two arms is relatively large as the position increases, and the pressure of gravity falling on the arms is also increasing.

1.4.3 Surface EMG characteristics

(1) Activation sequence (activation time) of related muscles in the lower flexion stage

In advanced, intermediate and ordinary athletes, as the arms are bent and the weight of the body is lowered during the lower flexion phase of the standard push-up, the relevant muscle activation sequence (activation time) is first activated by the left and right deltoid anterior fasciculus, followed by the left and right biceps, the left and right pectoralis major, and the left and right triceps. The left and right deltoid anterior fasciculus and the left and right pectoralis major muscles are continuously activated throughout the downward phase of the completion of the movement. This indicates that no matter the movement ability and movement level are different, the muscle activation order (activation time) is consistent when completing the same push-up action, and there is no difference between each other.

(2) The integrated EMG value of the muscles involved in the downward flexion stage

There is a significant difference between the left and right biceps, the left and right deltoid anterior bundle, the left and right triceps, and the left and right pectoralis major muscles in the pairwise comparison between high-level and intermediate level athletes when they complete the standard support push-up and bend the arms. This shows that high-level athletes and intermediate-level athletes have different levels of upper limb muscle and trunk muscle development due to different training years and athletic abilities. When completing the same push-up movement, the accuracy and effect are different, and high-level athletes are better than intermediate-level athletes.

1.5 Shortcomings of the research and expectations of future research

(1) Only two-dimensional high-speed photography was considered in the design of this study. As a result, the three-dimensional data of shoulder and elbow angles of volunteers completing movements could not be collected more accurately during data collection and feature analysis, and the preliminary equipment and preparatory work could be done well in the follow-up study.

(2) A total of 12 volunteers were recruited for this study, among which 4 male volunteers were recruited for each level of the high-level group and the intermediate combined ordinary level group. Due to the limited sample size of each group, data analysis with a large sample size is not possible. The biomechanical characteristics of push-ups in athletes of different genders and different ages have not been studied, which will be the follow-up research direction of this study.

2. Conclusions

2.1 Athletes of different sports levels take different time to complete push-ups of the same posture, and there is a significant difference between each other, and the complete time of high-level athletes is less than that of medium-level and ordinary athletes.

2.2 Athletes of the same athletic level take different time to complete push-ups with different loads, and there are significant differences or very significant differences among them. Athletes with advanced level take less time than those with intermediate level and ordinary level.

2.3 There is a rule of U in the complete time for athletes of the same level to complete push-ups with different loads, that is, the time for completing push-ups with feet 25cm and 30cm above the ground is slightly less than that for feet on the ground, while the time for completing push-ups with feet 40cm and 50cm above the ground is longer than that for feet 25cm and 30cm above the ground. Push-ups with feet 50 cm above the ground took the most time.

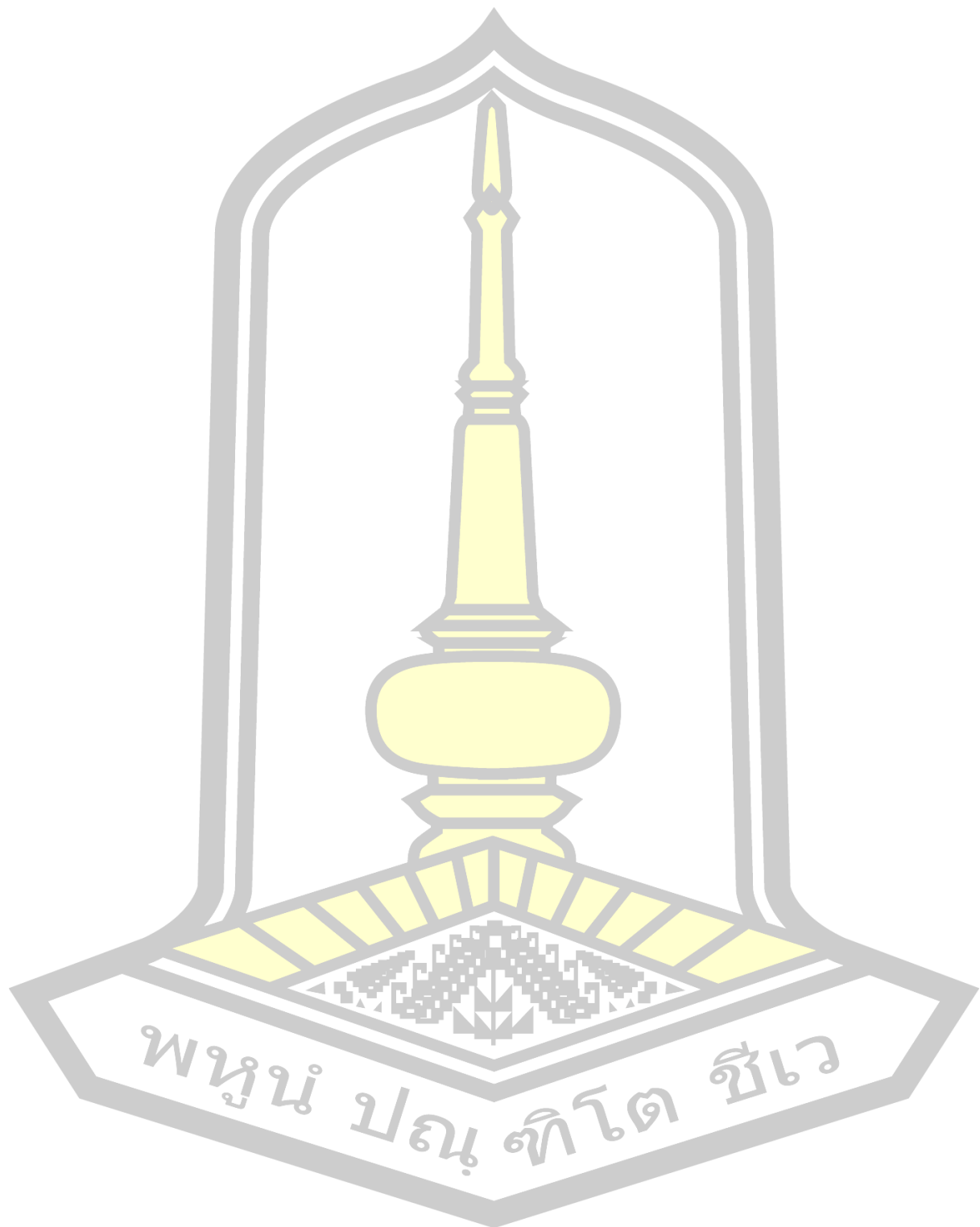
2.4 When athletes of the same level complete push-ups with different loads, the ground vertical reaction force in the upward pushing stage is greater than that in the downward bending arm stage.

2.5 When athletes of the same level complete push-ups with different loads, the speed of left shoulder joint and right shoulder joint is inconsistent in the downward flexion stage and the upward push stage, and there are some differences.

2.6 When athletes with different levels complete push-ups with different positions or different loads, there are differences in the Angle of the elbow joint at the lowest point of the downward flexion arm, and the Angle of the elbow joint of high-level athletes is smaller than that of intermediate level and ordinary athletes.



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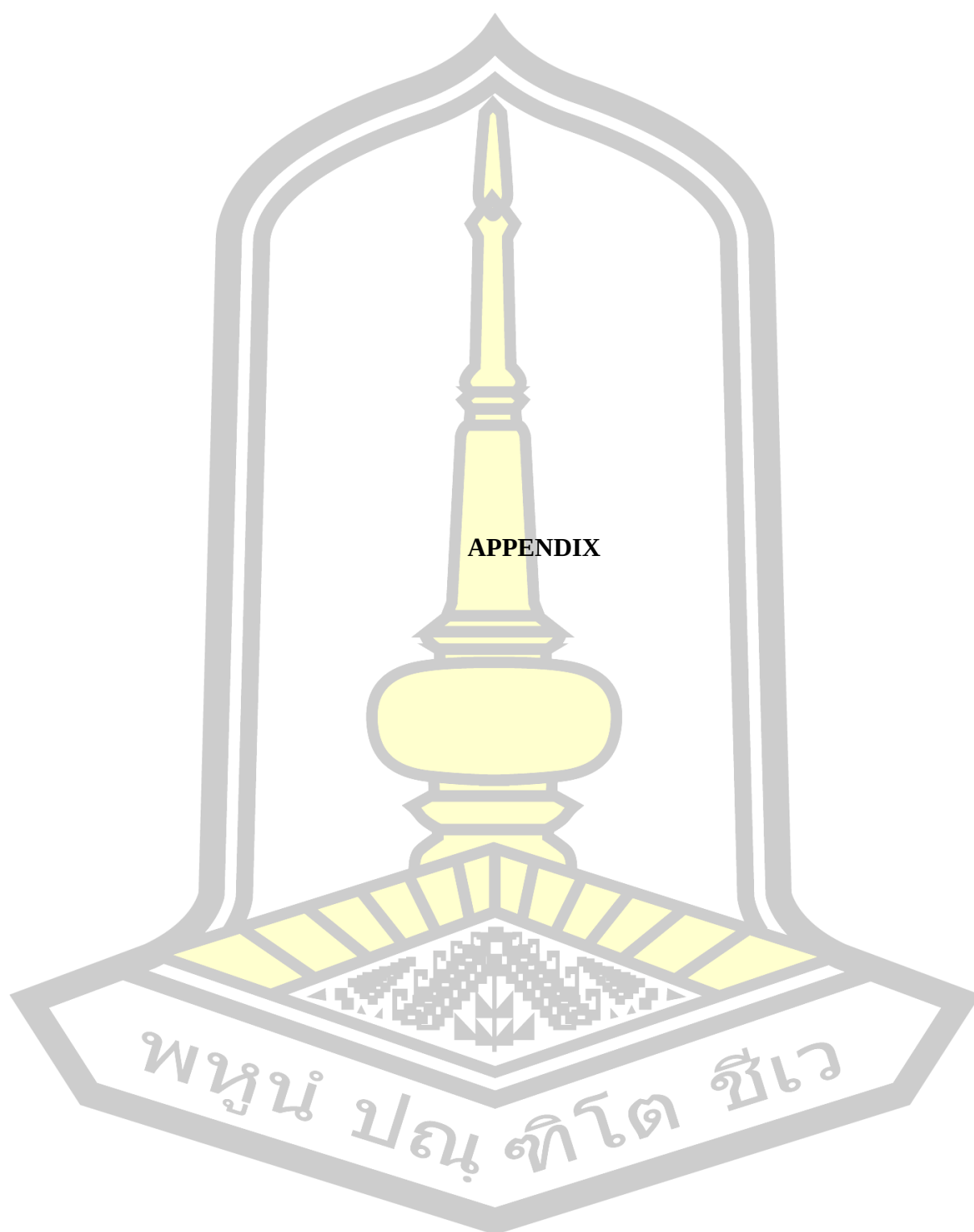
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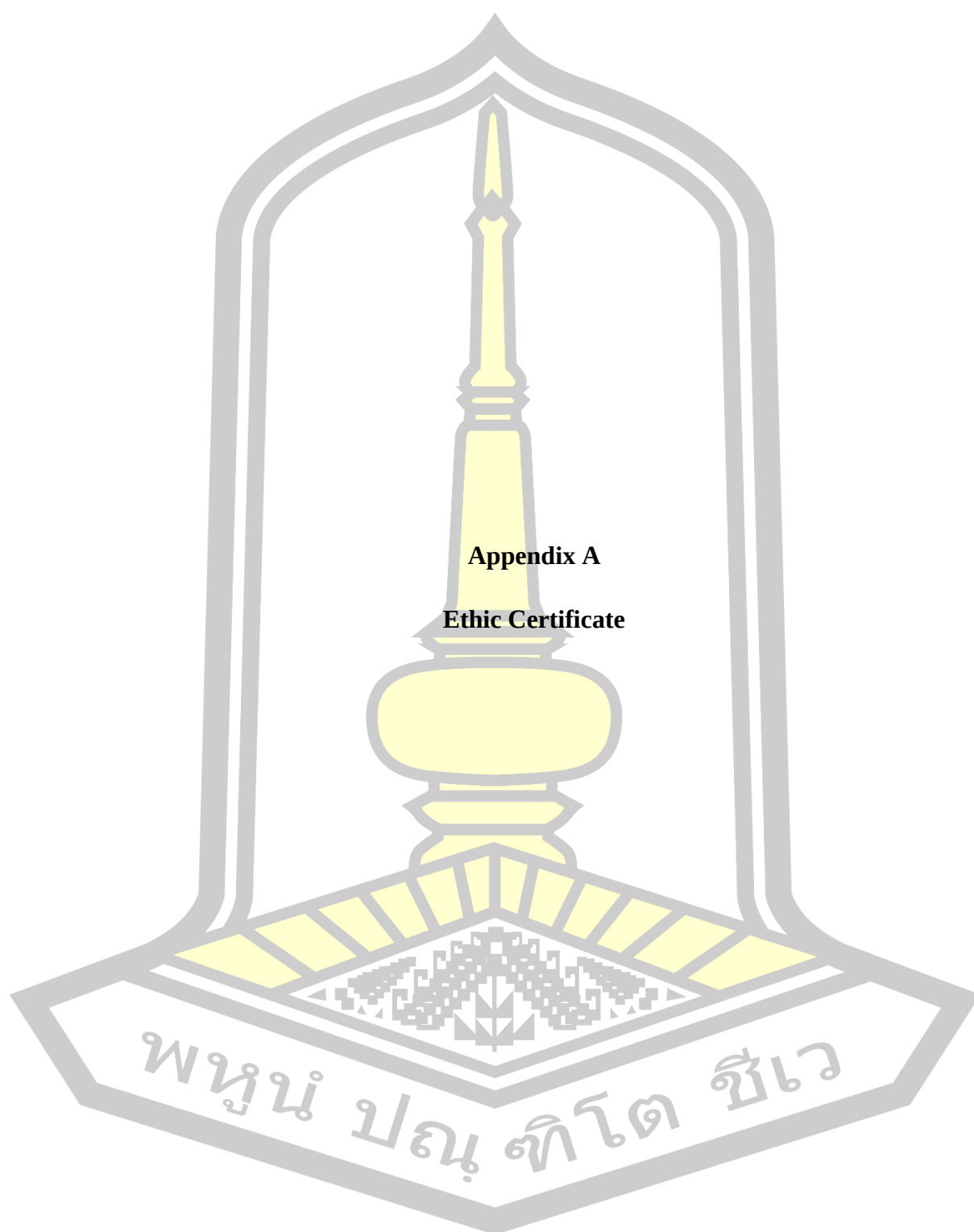
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**MAHASARAKHAM UNIVERSITY ETHICS COMMITTEE FOR
RESEARCH INVOLVING HUMAN SUBJECTS**

Certificate of Approval

Approval number: 511-359/2023

Title : Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise.

Principal Investigator : Runping Wu

Responsible Department : Faculty of Education

Research site : Chengdu city, Sichuan province, China

Review Method : Expedited Review

Date of Manufacture : 30 November 2023

expire : 29 November 2024

This research application has been reviewed and approved by the Ethics Committee for Research Involving Human Subjects, Mahasarakham University, Thailand. Approval is dependent on local ethical approval having been received. Any subsequent changes to the consent form must be re-submitted to the Committee.

Ratree S.

(Asst. Prof. Ratree Sawangjit)

Chairman

Approval is granted subject to the following conditions: (see back of this Certificate)

All approved investigators must comply with the following conditions:

1. Strictly conduct the research as required by the protocol;
2. Use only the information sheet, consent form (and recruitment materials, if any), interview outlines and/or questionnaires bearing the Institutional Review Board's seal of approval ; and return one copy of such documents of the first subject recruited to the Institutional Review Board (IRB) for the record (if applicable);
3. Report to the Institutional Review Board any serious adverse event or any changes in the research activity within five working days;
4. Provide reports to the Institutional Review Board concerning the progress of the research upon the specified period of time or when requested;
5. If the study cannot be finished within the expire date of the approval certificate, the investigator is obliged to reapply for approval at least two month before the date of expiration.
6. All the above approved documents are expired on the same date of the previously approved protocol (Protocol Number.....)

* A list of the Institutional Review Board members (names and positions) present at the meeting of Institutional Review Board on the date of approval of this study has been attached (per requested). All approved documents will be forwarded to the principal investigator.



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Clarification documents for the volunteers who Experiment

Dear all Subject

Because I (Runping Wu, PhD candidate, Health and Sport Science, Educational Faculty, Mahasarakham University) conducting research on "Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise". You may not benefit directly from participating in this research project. However, the research results of this project may support your coaching team in improving training methods and decision-making, thereby helping to improve the training effectiveness of you and your teammates in gymnastics training.

After being recommended by your coach and interviewed by the researcher, you are eligible to be a volunteer for this study. If you decide to participate in this study, you will be asked to provide your basic personal information. If you feel uncomfortable or uncomfortable with certain questions, you have the right not to answer them.

You and 9 other athletes will participate in a sports biomechanics testing project, with the following requirements: (1) Naked your upper body, wear tight shorts provided by researchers, and wear sports shoes that you usually train and compete in. (2) During the test, you need to stick Electromyography patches on the abdominal skin surface of your 14 muscles and install Electromyography testers, including Triceps, Biceps, forearm extensor, Pectoralis major, Deltoid muscle, Rectus abdominis muscle, and Latissimus dorsi muscle. If necessary, you need to disinfect the skin of the relevant area with alcohol and shave off the hair, which will not cause harm to health. (3) Complete the "Push-up" and "high five Push-up" in the designated area, and raise both feet on the horizontal ground by 20cm, 30cm, 40cm and 50cm respectively. Each person is required to successfully complete two times in each posture and each kind of foot lifting position.

You also have the right to withdraw from the program at any time without prior notice. And not participating in or withdrawing from the research project will not affect you in any way. Your Basic personal information will be retained and not disclosed to the public. Your Basic personal information will only be used for this study, and the relevant data will be destroyed after the study is completed. All participants' data will be encrypted and stored on the researcher's computer. Set the password for the folder where the data is saved, and set the computer boot password. After the end of the experiment, all the experimental data on the experimental instrument will be deleted to ensure that the experimental data will not be leaked during the collection process. The analysis and digitization of the experimental data is carried out on the researchers' computers to ensure that there is no risk of data leakage. We will only use comprehensive information and data for reporting and will not disclose personal information of volunteers. You will not be paid or charged for the study.

If you have questions about the research Please feel free to contact us at (Runping Wu-Health and Sport Science, Educational Faculty, Mahasarakham University, Phone: +8618980092585). If you were not treated as described or want to know your rights while participating in the research, you can contact at "Human Research Ethics Committee Mahasarakham University, Division of Research and Academic Service Promotion Mahasarakham University "Tel.+6643-754416 Internal number 1755

Sincerely

Runping Wu
(Runping Wu)

Researcher



Experimental instruments and procedures

1 Test Instrument

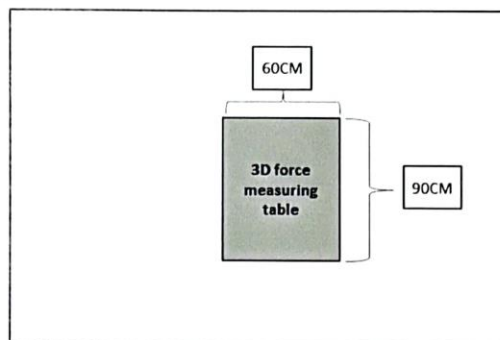
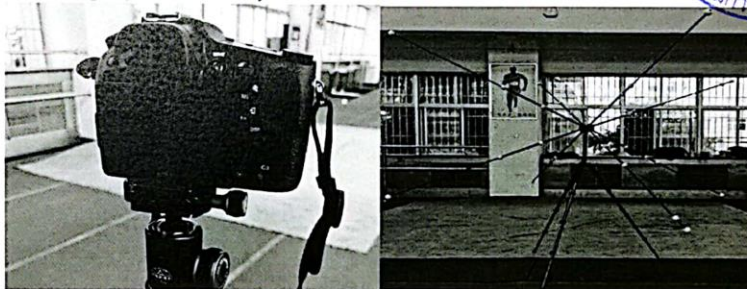


Figure 1 Test site layout diagram

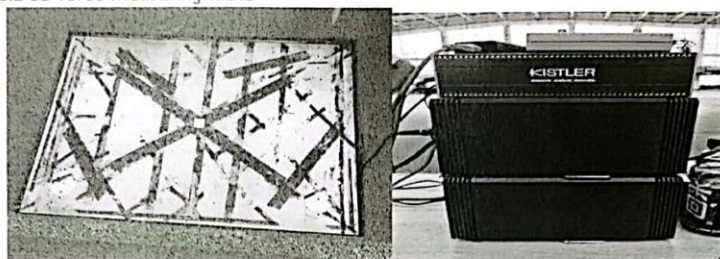
1.1 3D High-speed camera system



Schematic Diagram of High Speed Camera

Japanese SONY-RX10IV cameras, a set of SIMI Motion software of SIMI company, calibration frame using Agger 3D DTL framework calibration. 3D high-speed camera system can be used in the study of human movement, which can truly reproduce the movement and movement trajectory of athletes, and output the movement data of each link of athletes at any time, such as displacement, speed, angular speed, etc., so as to facilitate quantitative analysis. Combined with the principles of human physiology and physics, the research and improvement methods can make the observation of human movement get rid of the state of relying purely on experience. Enter the theoretical, digital era. 3D high-speed camera is a non-contact measurement, which has the advantages of not imposing extra load on the human body, not interfering with the body movement and measuring close to the actual condition. The detection and processing of human motion information takes human motion as the research object. Measure and analyze the displacement, velocity, acceleration and joint Angle of each part of the human body in the process of movement. 3 D high speed camera system is mainly used to study the kinematic characteristics of motion technology.

1.2 3D force measuring table



Three-dimensional dynamometer

One 3D force measuring table (Swiss KISTLER). Kistler 3D force bench test system is mainly used in the field of gait and balance analysis. It can accurately obtain the ground force, friction force, pressure and other parameters of different gait and posture. In this study, the ground force, friction force and pressure parameters of athletes' take-off action are mainly tested, and the ratio of push off force to body weight is calculated by combining with the athletes' body weight, so as to construct the mechanical characteristics of athletes' push off take-off stage.

1.3 The Wireless surface electromyography (EMG) system



Schematic diagram of EMG equipment

American NORAXON surface myoelectric wireless telemetry system, with up to 4000HZ EMG acquisition frequency, USB power supply and connected to the PC end, transmission range of 30m, sampling frequency is optional 2000Hz or 4000Hz, sensor size 37*24.5*16.5mm length, width and height, weight 14g; Sensor base size 174*92*169mm length, width and height, weight 545g; Signal receiver size 261*36*29mm, weight 185g, with 16 channels.

The wireless surface electromyography test system can simultaneously collect 16-channel electromyography signal, real-time wireless data transmission, support the analysis of common indicators in the time domain and frequency domain of electromyography, such as mean value, maximum value, minimum value, root mean square amplitude (RMS), integrated electromyography (IEMG), power spectrum (PSD), and customized analysis. The wireless electromyography test system can obtain data such as the order of muscle work done and the amount of work done when athletes perform difficult movements without affecting their performance. Through data analysis, the surface EMG characteristics of athletes performing the technical movements can be obtained.

In addition to the professional equipment for sports biomechanics testing, we also need to use some common tools, such as laptops, during the testing process. Two computers, including Ariel 3D

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motion image analysis system, 3D force measuring table data analysis software, electromyography data analysis system, electromyography and force measuring table synchronization system, and an external synchronizer are installed.

2 Test Time and test location

Test site: Sports biomechanics Laboratory, Xi 'an Sports University.

Test time: Test preparation (late May 2023), formal test (early September 2023).

3 Test procedure and precautions

3.1 Preparing for Tests

According to the problems found in the test preparation, eliminate all the hidden dangers that may affect the accuracy of the test, install and debug the equipment and make preparation for the test. All subjects were asked to bare the upper half of their bodies, wear high-stretch tight shorts, and wear their usual training sneakers. All subjects were numbered and recorded before the test began. Warm-up activities were performed before the test began, and EMG electrodes were applied after full warm-up.

The electrode sticking personnel and test athletes should keep neutral, use double-sided tape to fix the most prominent position of the muscle belly along the longitudinal axis of the muscle, use elastic bandages to fix it, and then wear Skin-tight garment to prevent the electrode from slipping or falling off during exercise. Take the right side as an example (extensor of forearm, Biceps, Triceps, Deltoid muscle, Latissimus dorsi muscle, Pectoralis major). Open the electrodes on the test athlete. Verify if the computer can connect to the electrode and perform signal detection.

3.2 Test Process

The athletes completed the Push-up in numbered order. Three judges were invited to evaluate the action completion of the test site, and one judge with complete Kinematics data collection and the highest action quality was selected for data storage. After the first subject completes the test and saves the test data, the second subject starts the test in sequence and completes the tests for all subjects, and properly saves the test data. After the testing is completed, arrange and return the testing instruments as soon as possible.



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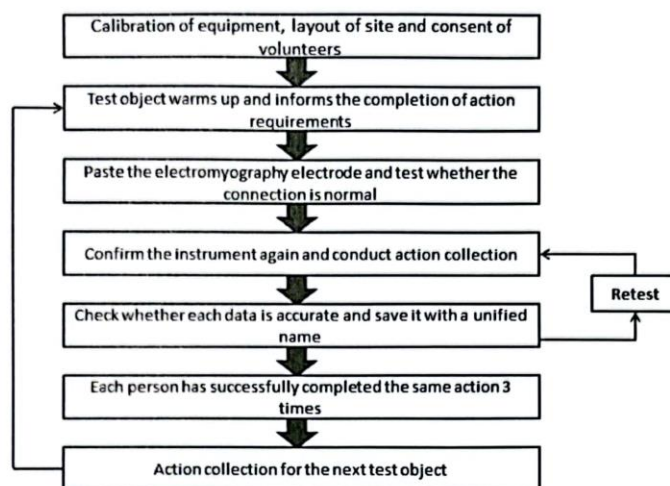


Figure 2 Test flow chart

3.3 Precautions

3.3.1 Test participants' sports safety and security

Ensure that participants fully understand the testing requirements and procedures, and ensure that volunteers participating in the testing fully warm up before the formal testing to avoid sports injuries. At the same time, please ask the doctor to bring a medical bag for the marked examination. If participants experience sports injuries during the testing process, doctors can provide medical services and provide timely services to the volunteers participating in the testing.

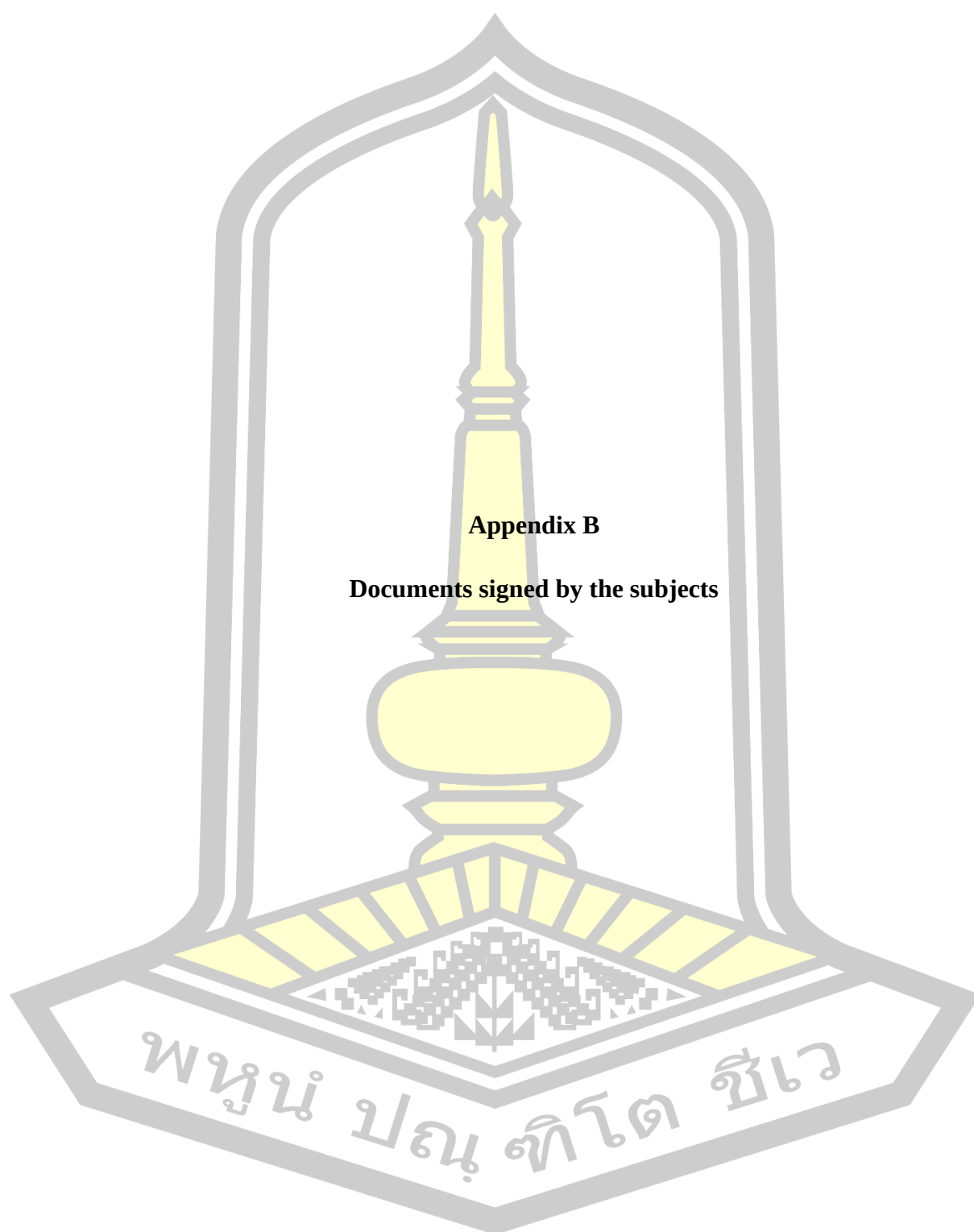
3.3.2 Safety assurance of experimental instrument operation

The test equipment is operated by professional operators to ensure the accuracy of the experimental data collection and the safety of the instrument.

3.3.3 Security assurance of test data

After the test, the test data will be saved to the researcher's special computer to ensure the safety of the test data.





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Study informed consent from the volunteer head coach

I (Mr.) Jiaying Surname Zhou Age 1963 Year.
 House number Village No. Sub-district Hongguang District Beilin
 province Shanxi
 Convenient phone 13519113356

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on " Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise ", the explanatory text consists of Full details about the purpose of the research, details of the research. I agree with the value of the study, I am aware of the benefits to be gained and the risks that may arise from participating in the study. Include guidelines for possible problems. Explanations and answers to any questions from the head of the research project were also received.

The researcher promised to keep confidential information about my gymnastics team. In addition, anonymous or private information may not be made available to the public alone. The findings will be presented in the form of an overview, which is a summary of the findings for academic purposes only.

"As the volunteer's referrer and coach, I gave them permission to participate in the study." I agree that my recommended volunteers can withdraw from the study at any time. This will have no impact and will not result in the loss of any right to study or work in the future.

sign Jiaying Zhou Head coach
 (.....Mr. Jiaying Zhou.....)
 Date 02.12.2023

sign Runping Wu researcher
 (Mr. Runping Wu)
 Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Zilong Surname Tang Age 26 Year Beilin
 House number Village No. Sub-district Han Guang District
 province Shan Xi
 Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on "Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise", the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

As well as the testimony from the researcher that will keep my information confidential. In addition, not anonymously or private information individually to the public. The results of the research will be presented in the form of an overview that is a summary of the research results for academic purposes only.

"In participating as a volunteer of this research project I join voluntarily." And I can withdraw from this study at any time. If I wish which will not have any effect and will not lose any rights in study or work that I will receive in the future.

sign Zilong Tang Volunteers
 (.....)
 Date 02.12.2023

sign Jiaying Zhou witness
 (..... Mr. Jiaying Zhou)
 Date 02.12.2023

sign Runping Wu researcher
 (Mr. Runping Wu)
 Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Bowen Surname Li Age 25 Year.
House number Village No. Sub-district Hanguang District Beilin
province Shan Xi
Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on " Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise ", the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

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sign Bowen Li Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Long Surname Tang Age 26 Year.
House number Village No. Sub-district Hengguang District Bei Lin
province Shan Xi
Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on " Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise ", the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

As well as the testimony from the researcher that will keep my information confidential. In addition, not anonymously or private information individually to the public. The results of the research will be presented in the form of an overview that is a summary of the research results for academic purposes only.

"In participating as a volunteer of this research project I join voluntarily." And I can withdraw from this study at any time. If I wish which will not have any effect and will not lose any rights in study or work that I will receive in the future.

sign Long Tang Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Wen Surname Li Age 28 Year.
House number Village No. Sub-district Han Guang District Bei Lin
province Shan Xi
Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on " Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise "; the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

As well as the testimony from the researcher that will keep my information confidential. In addition, not anonymously or private information individually to the public. The results of the research will be presented in the form of an overview that is a summary of the research results for academic purposes only.

"In participating as a volunteer of this research project I join voluntarily." And I can withdraw from this study at any time. If I wish which will not have any effect and will not lose any rights in study or work that I will receive in the future.

sign Wen Li Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Cheng Surname Li Age 21 Year.
House number Village No. Sub-district Hanguang District Beilin
province Shan Xi
Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on " Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise ", the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

As well as the testimony from the researcher that will keep my information confidential. In addition, not anonymously or private information individually to the public. The results of the research will be presented in the form of an overview that is a summary of the research results for academic purposes only.

"In participating as a volunteer of this research project I join voluntarily." And I can withdraw from this study at any time. If I wish which will not have any effect and will not lose any rights in study or work that I will receive in the future.

sign Cheng Li Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Mengqiao Surname Peng Age 22 Year.
House number Village No. Sub-district Hanguang District Beilin
province Shanxi
Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on "Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise", the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

As well as the testimony from the researcher that will keep my information confidential. In addition, not anonymously or private information individually to the public. The results of the research will be presented in the form of an overview that is a summary of the research results for academic purposes only.

"In participating as a volunteer of this research project I join voluntarily." And I can withdraw from this study at any time. If I wish which will not have any effect and will not lose any rights in study or work that I will receive in the future.

sign Mengqiao Peng Volunteers
(.....)
Date 02, 12, 2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02, 12, 2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02, 12, 2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Kaikun Surname Wang Age 21 Year.
House number Village No. Sub-district Hanguang District BeiLin
province Shan Xi
Convenient phone

Read the explanation / listen to the explanation from Mr. Runping Wu about volunteering in the research project on " Biomechanical Characteristics Analysis of Athletes' Body Muscle Groups in Push Up Exercise ", the explanatory text consists of Full details about the purpose of the research, details of the research. That I have to do and be treated, the benefits that I may gain from the research and the risks that may arise from participating in the study. Including guidelines for questions that may arise throughout. It has also received an explanation and an answer to any questions from the research project leader.

As well as the testimony from the researcher that will keep my information confidential. In addition, not anonymously or private information individually to the public. The results of the research will be presented in the form of an overview that is a summary of the research results for academic purposes only.

"In participating as a volunteer of this research project I join voluntarily." And I can withdraw from this study at any time. If I wish which will not have any effect and will not lose any rights in study or work that I will receive in the future.

sign Kaikun Wang Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

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I (Mr.) Peng Surname Wang Age 22 Year.
House number Village No. Sub-district Hanguang District Bei Lin
province Shan Xi
Convenient phone

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sign Peng Wang Volunteers
(02.12.2023)
Date

sign Jiaying Zhou witness
(Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Yang Li Surname Li Age 21 Year.
House number Village No. Sub-district Hanguang District Beilin
province Shan Xi
Convenient phone

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sign Yang Li Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers

(For volunteers over 18 years old)

I (Mr.) Xin Surname Zhang Age 22 Year.
 House number Village No. Sub-district Hanguang District Beilin
 province Shanxi
 Convenient phone

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sign Xin Zhang Volunteers
 (.....)

Date 02.12.2023

sign Jiaying Zhou witness
 (..... Mr. Jiaying Zhou

Date 02.12.2023

sign Runping Wu researcher
 (Mr. Runping Wu)

Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Ping Surname Gao Age 22 Year.
House number Village No. Sub-district Hanguang District Beilin
province Shan Xi
Convenient phone

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sign Ping Gao Volunteers
(.....)
Date 02.12.2023

sign Jiaying Zhou witness
(..... Mr. Jiaying Zhou)
Date 02.12.2023

sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023



ECMSU01-07.10 English 2023

Informed consent form for research from volunteers
(For volunteers over 18 years old)

I (Mr.) Tiale Surname Wang Age 22 Year.
House number Village No. Sub-district Hanguang District Beilin
province Shan Xi
Convenient phone

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sign Tiale Wang Volunteers
(.....)
Date 02.12.2023

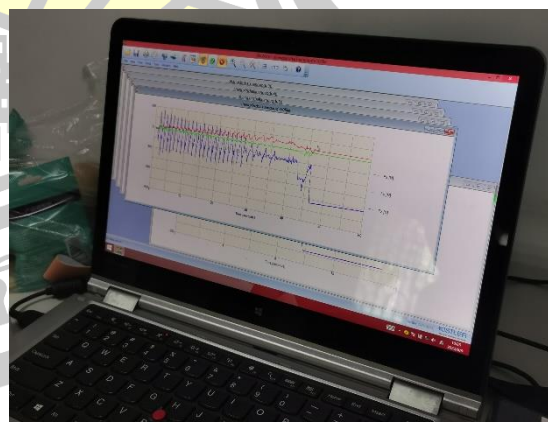
sign Jiaying Zhou witness
(.....Mr. Jiaying Zhou)
Date 02.12.2023

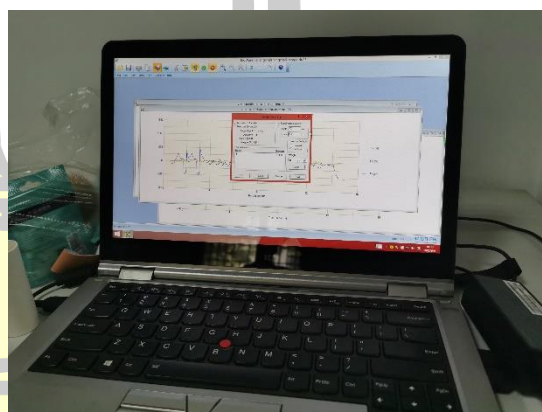
sign Runping Wu researcher
(Mr. Runping Wu)
Date 02.12.2023





Pre-test seminar





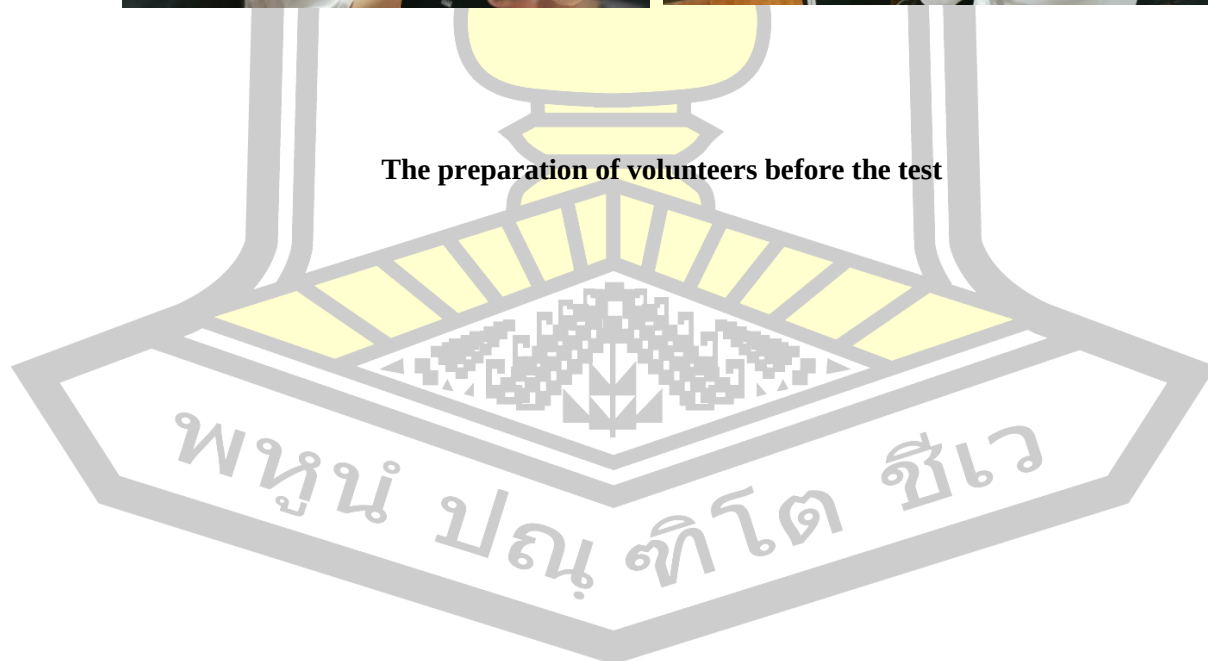


Debugging of instruments and equipment before testing



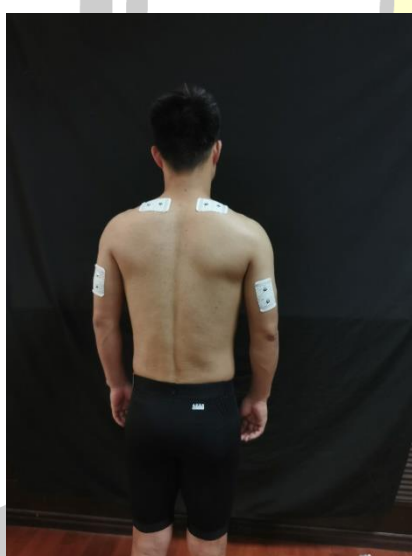
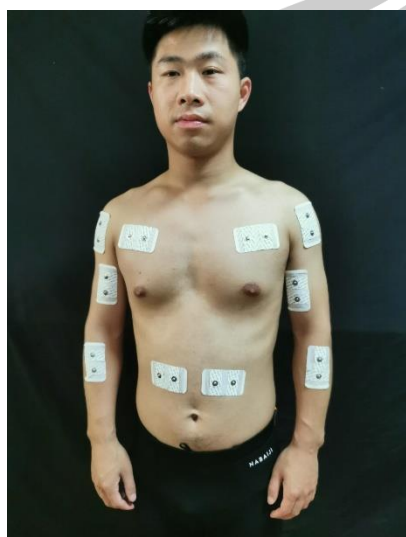


The preparation of volunteers before the test





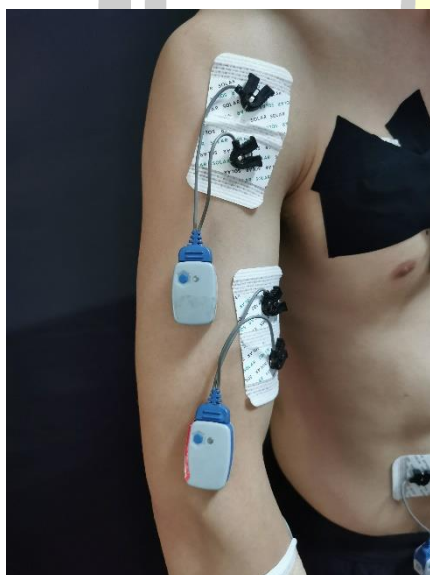
The preparation of volunteers before the test



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The preparation of volunteers before the test





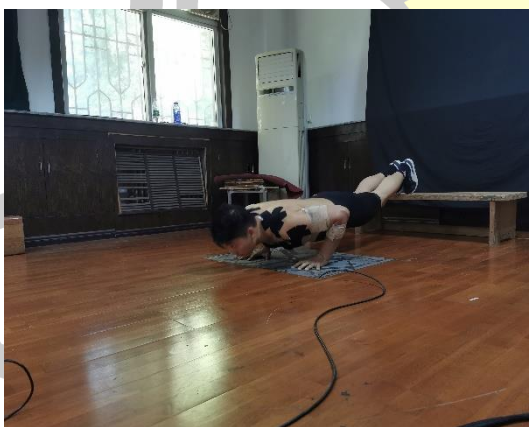
The preparation of volunteers before the test



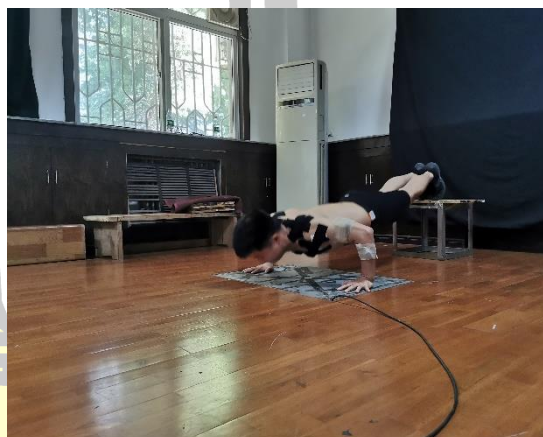


Test site





Test site



Test site

BIOGRAPHY

NAME	Runping Wu
DATE OF BIRTH	August 25, 1966
PLACE OF BIRTH	Shiqian County, Guizhou Province, China
ADDRESS	Lanshan Meishu Community 44-1-2, Tianfu New District, Chengdu City, Sichuan Province, China
POSITION	Professor
PLACE OF WORK	Chengdu Normal University No. 99, East Section, Haik Road, Wenjiang District, Chengdu City, Sichuan Province, China
EDUCATION	1983 to 1987 Bachelor's Degree , Physical Education, Chengdu Sports University 1987 to 1990 Master's Degree , Physical Education, Wuhan Sports University 2021 to 2024 Doctor of Philosophy Program in Exercise and Sport Science, Mahasarakham University
Research grants & awards	Research on the Construction of Physical Education Specialty, Chengdu Normal University
Research output	1.The reform status and model construction of college physical education under the background of sunshine sports 2.The evolution characteristics and development reflection of the 1-9 National Civil Games 3. Experimental research on the optimal teaching scheme of horse jumping with separate legs 4. Optimized teaching scheme design for straddling the horse with different legs 5. Discussion on the teaching steps of handspring optimization

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