The Effect of Pilates Training Combined with Fascial Massage on Upper Cross Syndrome in Office Workers

Liao Jiang

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

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

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ABSTRACT

Upper Cross Syndrome (UCS) is a common musculoskeletal disorder found mainly in sedentary office workers and is characterized by tightness and weakness of the muscles of the neck, shoulders, and upper back. Pilates training relieves or corrects UCS by activating and exercising deep muscles through regular, controlled movements with breathing to enhance muscle control and balance. In addition, fascial massage is a method of loosening tissue adhesions, relieving pain, enhancing proprioceptive function, and reducing somatic dysfunction, either unassisted or using various fascial massage devices. The rehabilitative properties of Pilates training and fascial massage allow them to be used as a specific form of helping the UCS population to reduce symptoms and improve quality of life, and should be increasingly understood and studied.

The purposes of this study was twofold: (1) Investigate the effect of Pilates training combined with fascial massage on UCS in office workers; (2) Compare the effects of Pilates training combined with fascial massage with Pilates training alone on UCS in office workers.

In this study, literature method, test method and mathematical statistics method were used to study the intervention effect of Pilates training combined with fascial massage on UCS. A total of 34 cases of UCS participated in this study and were divided into experimental and control groups, with Pilates training combined with fascial massage in the experimental group and Pilates training in the control group. Before and after the intervention, the relevant indexes were tested (sagittal static assessment, 3D body scanning simulation score (FHA, FSA), cervical spine range of motion (ROM), pain level, the neck disability index (NDI), etc.). The test results were statistically analyzed using SPSS26.0, and the independent sample t-test was used for the basic information of the subjects in the two groups before the intervention; the independent sample t-test was used for the between-group comparison; and the paired sample t-test was used for the within-group comparison. Combining the results of between-group and within-group comparisons, the intervention effect of Pilates training combined with fascial massage on UCS population was explored.

The main conclusions were as follows:

(1) The effectiveness of the comprehensive intervention program of Pilates training combined with fascial massage was verified. The experimental results showed that Pilates training combined with fascial massage could effectively improve the relevant indicators (3D body scan simulation scores (FHA, FSA), cervical spine range of motion (ROM), pain level, neck disability index (NDI), etc.) of UCS in office workers.

(2) Demonstrated the advantages of the combined intervention. Compared with Pilates training alone, Pilates training combined with fascial massage was found to be effective in improving the patient-related indices on UCS in office workers (3D body scanning simulation score (FHA, FSA), cervical spine range of motion (ROM), pain level, the neck disability index (NDI), etc.)

Keyword : Upper Cross Syndrome, Pilates Training, Fascial Massage

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Liao Jiang

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List of Abbreviations

Abbreviations	Full name in English
DNF	Deep Neck Flexor
FHA	Forward Head Angle
FSA	Forward Shoulder Angle
LS	Levator Scapulae
LT	Lower Trapezius
MF	Median Frequency
MPF	Mean Power Frequency
MT	Middle Trapezius
NDI	The Neck Disability Index
PM1	Pectoralis Major
PM2	Pectoralis Minor
ROM	Range of Motion
SCM	Sternocleidomastoid
sEMG	Surface Electromyography
UCS	Upper Crossed Syndrome
UT	Upper Trapezius
VAS	Visual Analogue Score

CHAPTER 1

INTRODUCTION

1. Background

China Internet Network Information Center (CNNIC) released the 52nd Statistical Report on Internet Development in China in Beijing. The report shows that as of June 2023, the number of Internet users in China reached 1.079 billion, an increase of 11.09 million compared with December 2022, and the Internet penetration rate reached 76.4%. As of June this year, the number of online payment users in China reached 943 million, an increase of 31.76 million from December 2022, accounting for 87.5% of the overall number of Internet users. While people are enjoying various conveniences brought by technology, their body postures are also undergoing special changes, and one of the more common postural disorders is "upper cross syndrome" (CNNIC, 2023).

Upper crossed syndrome (UCS) is a common musculoskeletal disorder characterized by muscle tension and weakness in the neck, shoulders, and upper back (Chang, Choo, Hong, Boudier-Revéret, & Yang, 2023).Mujawar et al. also specified that the joints that lead to shoulder and cervico-thoracic region (especially atlanto-occipital and glenohumeral joints) The most common postural problem that results in dysfunction is known as upper crossed syndrome (UCS) (Mujawar & Sagar, 2019). Nowadays, health is negatively impacted by bad habits brought about by excessive use of technology such as cell phones, televisions, computers, and tablets. Bending over in an abnormal position while using these devices can cause various mechanical loads on the neck and upper back region, increased thoracic kyphosis leading to rounding of the shoulders, etc., leading to poor posture and causing UCS (Mubeen, et al., 2016). Upper Cross Syndrome is a common problem in the workplace, occasionally causing workers to be unable to get to work on time (Karkousha, Yousef, Abdel Raoof, & Grase, 2023).

Patients with upper-cross syndrome are mainly concentrated in sedentary office workers, which is closely related to their occupational characteristics. For example, IT workers, clerical workers, factory workers, laboratory workers, designers and other groups. In a survey on the physical condition of office workers (Duvall et al., 2020), it was found that these workers usually adopt a prone or relaxed position while sitting at their desks for long periods of time at work. The habitual slouched posture of prolonged sitting can lead to shortening of the pectoral muscles, especially the pectoralis minor, resulting in rounded shoulders. The study assessed the body postures of 200 employees of the Bank of Communications using postural assessment measures and the results showed that poor body postures such as rounded shoulders and slouching accounted for 44% of the total number of employees (Hui, 2015). Due to the nature of their work, they need to constantly program, organize documents, handle goods, complete experiments, design works, and so on. However, this prolonged sedentary behavior and lack of regular activities can easily lead to tension and imbalance of weak muscle groups, as well as abnormal postures such as forward head tilt, hunchback, and rounded shoulders. When muscles are held in one position for long periods of time (e.g., prolonged desk work and use of electronic devices) or undergo repetitive movements (e.g., over-exercise of the pectoral muscles at the expense of the antagonist muscles), the tonic system (postural system) is strengthened and the chronotropic system is weakened, leading to muscle imbalances and postural abnormalities such as head forward tilt (increased cervical flexion-forward), hunching (increased thoracic flexion-backward), and rounding of the shoulder blades (scapular translation) increased) (Bing, 2017).UCS is the anterior-posterior crossing of the upper trapezius (UT), scapular tendonitis, pectoralis major (PM1), pectoralis minor (PM2), and other overly tense and overly weak muscles on the upper side of the human trunk, such as the deep neck flexors (DNF), middle trapezius (MT), and lower trapezius (LT) (viewed from the side in an “X “ shape) (Bae, Lee†., Shin,, & Lee, 2016;.Page,P.,2016). Postural abnormalities associated with upper crossed disorder include forward head posture (FHP), cervical lordosis, excessive thoracic lordosis, elongated and enlarged shoulders (rounded shoulders), and increased scapular wing internal rotation and abduction (Morris, Bonnefin, & Darville, 2015).

The diagnostic criteria for upper crossed syndrome are: excessive forward head extension, rounded shoulders (excessive upward and forward shoulder joints), hunchback (excessive posterior convexity of the thoracic spine), and scapular winging (anterior and inward tilting of the scapulae with upward rotation), etc., a disease duration of more than 3 months, a total score of sagittal static postural assessment of greater than or equal to 6 points, a visual analog score of greater than or equal to 3 points on the VAS, a distance of the shoulder crest of greater than or equal to 1 centimeter, and an imaging or other examinations without specific organic lesions, no obvious signs of cervical spondylosis, and decreased quality of life (Xiong Yuan, 2017).

The main etiology of upper cross syndrome is muscle imbalance, and there are two views on the principle of muscle imbalance: one is neurological and the other is biomechanical; the neurological principle of muscle imbalance suggests that, due to the different functions performed by the muscles of the human body, which leads to the tendency of muscles to be imbalanced (Yunqi, 2017), the corresponding neurons will control the corresponding muscles to maintain the stability of the joints, and to change the muscle balance, leading to incorrect body posture. Muscles may become imbalanced as a result of adaptation or dysfunction. Such muscle imbalances may be functional or pathologic. In UCS, neck and chest muscles such as the suboccipital muscles, sternocleidomastoid (SCM), scapularis, pectoralis major and minor, rhomboids, and upper trapezius (UT) tighten or shorten, whereas neck and back muscles such as the deep neck flexors (DNF), serratus anterior (SA), rhomboids, middle trapezius (MT), and lower trapezius (LT) weaken, stretch, and inhibit. Tightness of the suboccipitals, scapulars, and dorsal UT crosses ventrally with tightness of the pectoralis major, SCM, and scalp muscles; weakness of the ventral DNF crosses with the SA, rhomboids, MT, and LT (Izraelski, J, 2012). This anterior-posterior crossing of unbalanced muscle patterns often leads to changes in the physiologic curvature of the spine (especially the cervical and thoracic spine), which in turn manifests specific postural changes, i.e., abnormal body postures, such as forward tilting of the head, an abnormally large cervico-thoracic spine physiologic curvature and pterygoid scapulae, spasticity of the shoulder and neck muscles with a sensation of pain, and a decrease in cervical spine joints and shoulder joints mobility, which in turn affects respiration, accompanied by dizziness, tightness in the chest, arm The opposite group of muscle imbalances in UCS results in postural disturbances, upper extremity dysfunction, atlanto-occipital, cervicothoracic, and glenohumeral joint dysfunction (Bayattork, Seidi, Minoonejad, Andersen, & Page, 2020). Weakness of the diaphragm and accumulation of fatigue in the auxiliary respiratory muscles result in short, tense breaths.

Upper Cross Syndrome is primarily a problem with body posture and muscle balance.The areas of pain that tend to be clinically present in people with UCS include the neck, shoulders and chest. Muscles in the neck, like the sternocleidomastoid and upper trapezius muscles, become tight and shortened. The muscles of the shoulder, like the pectoralis minor and scapular lifting muscles, will also be in tension. Patients may experience pain and stiffness in the neck, especially after prolonged periods of bowing the head or holding a position, and the pain may worsen or even headaches may occur. The shoulders are also prone to soreness and heaviness, and there is a feeling of limited range of motion. In addition, due to the tension and shortening of the chest muscles, it may lead to poor breathing, which can cause a stuffy and uncomfortable chest (Zhilv, Z, 2018). Abnormal body posture not only causes physical and mental pain to individuals, but also affects people's quality of life and sense of well-being. Therefore, restoring the biomechanics of the head, neck, and shoulder muscles to a balanced state, correcting poor body postures, and alleviating the pain of people with UCS are extremely important for improving the quality of life of people with UCS as well as for promoting socioeconomic development. Nowadays, the treatment methods for UCS at home and abroad mainly include physical factor therapy, manipulative therapy, and exercise therapy, and exercise therapy has always been the focus of research in the field of sports rehabilitation (Wang Xueqiang, W. Y.， 2020), which plays a significant and positive role in the rehabilitation process of UCS.

Pilates is an exercise founded in 1914, named after its founder (Joseph H. Pilates), Mr. Joseph Pilates, and was first used in the rehabilitation of injured soldiers (Song, C. C., & Wang, J., 2007). 1926, it was established in New York City, New York City, USA, where it was used as a studio, and was a neighbor of the famous New York City Ballet. 1928 and onwards, it was mainly used for the rehabilitation of ballet dancers and to improve the performance of dance movements. After 1928, Pilates was mainly used for the rehabilitation of ballet dancers and to improve the expressive power of dance movements. Nowadays, a large number of scholars study the role of Pilates in the restoration of physical function and improvement of body posture

(GonzálezGálvez Noelia, 2022). Pilates training can relieve muscle tension, strengthen muscle strength, improve the stability of joints, and promote the health of the body systems, and it is easy and convenient to operate, with a high degree of safety for people in the rehabilitation training period, and it has also been widely used in rehabilitation therapy . Pilates has strong functional characteristics, because of this, the research on Pilates at home and abroad is mostly applied research, using Pilates as a training tool for sports rehabilitation and a functional intervention.

Pilates training follows the six principles of focus, precision, control, core, breathing and fluidity (Zhenwei, W. ,2016). Pilates training focuses on precise muscle control and can target weak muscles in the upper body while stretching tight muscles. For people with upper cross syndrome, the pectoral muscles are usually tight, while the rhomboids and trapezius middle and lower bundles of the back are weak. Some of the movements in Pilates, such as the "legs up kick", "seated obliques training", "freestyle" and "inverted V-shaped The back muscles can be effectively exercised by doing the "double leg kicks", "seated obliques", "freestyle" and "inverted V" movements. When doing the "Double Leg Kick", the pectoral muscles will be stretched, while the rhomboids and the middle and lower trapezius muscles in the back will be contracted; the "Seated Trapezius Exercise" mainly strengthens the middle and lower trapezius muscles; when doing the "Freestyle" movement, the back muscles will be stretched, while the middle and lower trapezius muscles in the back will be contracted; when doing the "Inverted V" movement, the back muscles will be stretched. When doing the "freestyle" action, the back muscles contract, and the arms and legs swing up and down like swimming, which strengthens the back muscles and enhances the muscle strength to counteract the tension of the chest muscles, and the "inverted V" action stretches the pectoral muscles, relieves the tension of the chest muscles, and helps to improve the muscle imbalance between the front and back of the body. Imbalance. Pilates training focuses on the participation of the core muscles.During the exercise process, the abdominal, pelvic floor and lower back muscles will be fully mobilized. For example, Pilates "pelvic pendulum", "single-leg retraction", in doing "pelvic pendulum" action, can make the pelvic floor muscles and lower back muscles to be strengthened; do In the "one-legged pullback" movement, the abdominal area should be continuously tightened to keep the body stable. This core activation provides good support for the spine and helps to correct poor spinal posture caused by muscle imbalances in patients with upper crossed syndrome. When the core is stabilized, it reduces the overcompensation of the neck and shoulder muscles, as people with upper crossed syndrome often overwork the neck and shoulder muscles to maintain balance due to imbalances in the strength of the muscles of the upper body (Marseille, P.,2012). In addition, Pilates training emphasizes proper alignment and control of the body. A neutral spine position is required throughout the exercise, with the head, neck, shoulders, and the rest of the body in the correct position (Ma, Y. H., 2010). This kind of precise body control training helps the patient to perceive the correct posture of his/her own body, thus gradually correcting the poor posture of the head tilted forward and hunched back caused by the upper crossed syndrome. For example, in the "upward" and "neck extension" movements, the spine is required to roll sequentially to maintain the correct alignment, which can help patients strengthen their sense of control over the position of the spine and improve their ability to self-adjust their body posture.

Pilates training focuses on working with breathing patterns. Research results indicate that 8 weeks of Pilates or Aqua-Pilates training can improve lung function by about 34% and can improve breathing capacity in people with a history of COVID-19 (Bagherzadeh Rahmani B., 2022). The method of breathing during Pilates training helps to relax the body and reduce muscle tension. It uses lateral breathing, also known as intercostal breathing. During breathing, it enables the ribs to expand and contract laterally like a cage, which can help to relax the tense muscles in the chest, improve the chest-holding posture, and the spine is better stretched and stabilized to avoid exacerbating upper cross syndrome due to poor posture. At the same time, correct breathing can also provide sufficient oxygen for muscle movement, enhance muscle function, and assist in improving the physical condition of patients with Upper Cross Syndrome. For example, when performing the "Pilates Standing Series" with lateral breathing, the muscles can work better and help the body to maintain the correct posture.

Zeng Renjie (Jie, 2021) recruited 33 subjects with upper cross syndrome aged 18-60 years old and randomized them into 16 experimental and 17 control groups using the random number table method. The experimental group underwent Pilates training 3 times a week for 1 hour each time, and the control group kept their original lifestyle unchanged. The total sagittal plane static postural assessment score, distance from the shoulder crest to the ear screen, FHA, FSA, and VAS were measured before and after 12 weeks of training. The results of the study showed that Pilates training could reduce shoulder and neck pain, improve cervical spine dysfunction and cervical spine joint mobility. Pilates training can effectively improve muscle imbalance and correct abnormal body posture in patients with upper crossed syndrome by changing the activation pattern of muscles; Pilates, as a simple and easy-to-use exercise therapy, is worthy of promotion and application in the treatment and rehabilitation of patients with upper crossed syndrome. However, a review of domestic and international literature found that there are relatively few empirical studies on the use of Pilates to intervene in upper crossed syndrome, whereas studies have shown that Pilates training has a significant effect on improving the degree of neck pain, restoring normal physiological curvature, and correcting abnormal postures, such as hunchback, in people with upper crossed syndrome. Therefore, research on the effects of Pilates training on upper crossed syndrome needs to be further developed.

Fascial massage operates on the fascia of the body. Fascia is a layer of connective tissue that runs through the body, encircling muscles, muscle groups, blood vessels, and nerves (Bracht, P., 2018). This type of massage applies appropriate pressure, stretching, and friction to the fascia through specific techniques, such as using fingers, elbows, or specialized massage tools, to improve the elasticity and flexibility of the fascia, relieve tension and adhesions in the fascia, promote muscle relaxation, alleviate pain, and to help the body maintain good motor function and posture (Bracht, P.,2018). Fascial massage is a form of myofascial release that typically affects myofascial activity and joint ROM (joint range of motion) (Beardsley and Skalabot, 2015). Various tools such as foam shafts or roller massagers are commonly used (Behara, B., & Jacobson, B., 2015) as well as fascial guns for myofascial release and relief of myofascial pain symptoms (Patel G R, Vedawala N, 2023).

The role of fascial massage is to relax the tight myofascia, to avoid tissue adhesion, to help muscle recovery and so on. Some experts and scholars have studied the role of fascial massage on body posture.This training method can solve the problem of tight muscles.The muscles can be well relaxed by fascial massage after each exercise, which helps neuromuscular regulation and mechanical relaxation, and restores the balance of muscle strength, which not only promotes the formation of a good body posture, but also prevents sports injuries.Ruivo et al. (Ruivo, Carita, & Pezarat-Correia, 2016) conducted an 8-month fascial stretching training on 15-17 year old adolescents with symptoms of forward head tilt, and the results were very significant, while the corrective effect was maintained before and after the end of the training. This suggests that by stretching the fascia, it can help to alleviate the symptoms of head forward tilt in adolescents with head forward tilt symptoms.

Fascial massage has a positive therapeutic and preventive effect on upper crossed syndrome (Ahmed K, Shaukat A, Noor R, 2022). When upper crossed syndrome is present, the fascia around the tense muscles such as the pectoral and scapular raisers also become tense. These tense fascia can be relaxed by fascial massage such as using a foam shaft (Cheatham S W, Kolber M J, Cain M2015), massaging the pectoralis major, pectoralis minor, latissimus dorsi, and upper trapezius bundles focusing on sore and tense areas of the muscles, rolling for 30 - 60 seconds at a time, relaxing the pectoralis major, pectoralis minor, and the fascia around the neck to alleviate muscle tension and reduce muscle soreness. At the same time, the fascial gun can also be reasonably used to effectively release the fascia in key areas such as the sternocleidomastoid, scapular retinaculum, pectoralis, and upper trapezius bundle, etc. Through specific manipulation techniques and appropriate force control, and with the high-frequency vibration of the fascial gun (Xin, D. L.,2020), it helps to relax these muscle tissues, and alleviate the muscular tension, aches and pains, and stiffness due to prolonged poor postures or overuse state (Wu, Q., Wen, X. P., & Li, H. W. ,2023), which in turn plays a role in improving and regulating a series of physical discomforts and body posture problems caused by upper crossed syndrome. In addition, fascial massage can also improve muscle extensibility and promote the restoration of normal muscle function, which helps to strengthen the relatively weak muscles to improve body posture and play an auxiliary role in correcting upper crossed syndrome. When using a foam shaft and a fascial gun to perform fascial massage to improve upper crossed syndrome (Ju, S K, 2023), it is important to pay attention to moderate strength to avoid excessive force that may cause damage to the body. If abnormalities such as increased pain occur during massage, the operation should be stopped.

The main rationale for combining fascial massage and Pilates training is their complementary effects on bodily functions. Fascial massage focuses on relaxing fascial tissues, relieving muscle tension and adhesions, and improving flexibility and joint range of motion (Halperin and Aboodarda, 2014), whereas Pilates training emphasizes the activation of the core muscles and the training of muscular strength, which allows precise control of body movements (Lee, K. ,2021). Combining the two, fascial massage creates a good myofascial condition for Pilates training (Kiyono R,Onuma R,2022), which reduces the risk of sports injuries; while Pilates training strengthens the muscle strength after the massage, which improves the body's overall mobility and postural control. Upper cross syndrome is mainly caused by poor posture and imbalance of muscle strength between the front and back of the body, where tense muscles pull the bones out of their normal position and gradually develop this syndrome. Pilates training emphasizes correct body alignment and postural control, focusing on precise muscle activation (Song, C. C., & Wang, J.,2007), while fascial massage helps to relax tense muscles and fascia and correct poor posture.If the two are combined, they may play a more significant role in targeting upper cross syndrome and adjusting poor posture. Pilates training may improve postural problems caused by upper crossed syndrome, while fascial massage may relieve the series of tense muscle and fascial adhesions that occur in upper crossed syndrome and increase the range of motion of the cervical spine (Ahmed K, Shaukat A, Noor R, 2022).Aneis et al. (Aneis, El-Badrawy, El-Ganainy, & Atta, 2022) conducted a randomized controlled trial on 40 patients with UCS. A multimodal approach including ergonomically recommended postural correction exercises, MET, cervical spine stabilization exercises, and scapulothoracic stabilization exercises was applied to 20 patients (intervention group) and the results were compared to 20 patients who received only MET. The intervention group showed significant improvements in pain (measured by VAS), dysfunction (Neck Disability Index, NDI), craniofacial angle (CVA), and shoulder sagittal angle (SSA) (photogrammetric), suggesting that the multimodal approach was more effective than the single rehabilitation approach. Therefore, the combination of the two may better promote physical recovery and reduce problems such as rounded shoulders and hunchbacks, laying a theoretical foundation for this study.

Combined with a large number of references, in which Pilates training as an intervention modality for upper crossed syndrome is rare, and Pilates combined with fascial massage for the treatment of upper crossed syndrome is even rarer; according to the characteristics of Pilates and its rehabilitation properties, it is increasingly recognized as a special and important means of exercise intervention, an effective tool to help people at different stages of life and in different physical conditions to improve their physical function and treat their diseases and research. In addition, relevant studies have shown the effectiveness of fascial massage in improving upper cross syndrome. This paper combines the two to verify if they are more effective in affecting office workers with upper crossed syndrome. According to the research statistics, most of the rehabilitation training needs to be adhered to for about 3 months, and the training arrangement of Pilates combined with fascial massage for upper crossed syndrome, this study, by collecting and organizing the research ideas of the previous researchers, takes the office worker population suffering from upper crossed syndrome as the research object, and integrates the fascial massage into Pilates training; designs the targeted Pilates training movements for upper crossed syndrome, and the upper crossed syndrome We designed targeted Pilates training movements for Upper Cross Syndrome, as well as rehabilitation scoring indexes for Upper Cross Syndrome, and evaluated the scientificity and reasonableness of the training methods; we conducted a 12-week experiment on the experimental subjects, and after the experiment, we compared the test data of the experimental subjects before and after the experiment, and compared the data of the experimental subjects between the two groups, and verified whether the combination of Pilates and Fascial Massage could improve the patients' body postures, cervical vertebrae disability indexes, cervical vertebrae range of motion, pain, surface electromyography and other indexes more effectively.

2. Research Problems

1. To examine whether Pilates training, when combined with fascial massage, has an intervention effect on UCS in office workers?

2. To investigate the differences in the effects of Pilates training in combination with fascial massage versus Pilates training alone on upper crossover syndrome in office workers.

2. Objectives

1. There is a significant difference in the effectiveness of Pilates training combined with fascial massage in improving UCS in office workers.

2. Compare the effects of Pilates training combined with fascial massage with Pilates training alone on UCS in office workers

3. Hypothesis

1. The experimental results showed that both the experimental group and the control group had an ameliorative effect on the upper crossed syndrome.

2. It is hypothesized that Pilates training combined with fascial massage is superior to Pilates training alone in the treatment of upper cross syndrome in office workers.

4. Significance

1.Theoretical significance

(1) Enrich the theoretical system of rehabilitation treatment for upper crossed syndrome and provide scientific basis for the rehabilitation method of multidisciplinary combination. By studying the joint action mechanism of Pilates training and fascial massage, we can further understand the pathophysiological process of upper crossed syndrome and provide new ideas and methods for the research in related fields.

(2) To fill the gap of the applied research of Pilates training combined with fascial massage in the office population with upper crossed syndrome, to promote the cross-fertilization of rehabilitation medicine, sports medicine and other disciplines, and to promote the development of related disciplines.

2.Practical significance

(1) Provide an effective rehabilitation treatment option for office workers with upper crossed syndrome to help them improve their posture, reduce pain, and improve their quality of life and work efficiency. Pilates training combined with fascial massage is easy to accept, relatively stable and safe when applied, and suitable for promotion and application in office or home.

(2) Improve the office population's concern and attention to their own health, guide them to develop good working and living habits, and prevent the occurrence of upper-cross syndrome. By publicizing and promoting the results of this research, it can promote the dissemination of the concept of healthy office, reduce the economic burden and health loss caused by upper-cross syndrome to individuals and the society, and help to realize the health of all people.

5. Definition of concepts

1. Upper cross syndrome

Upper Cross Syndrome (UCS) is a syndrome of abnormal body posture due to an imbalance in muscle strength. The muscles on the anterior side of the upper body such as the pectoralis major, pectoralis minor, scapularis, and rhomboids are tense and shortened while the muscles on the posterior side of the upper body such as the middle and lower trapezius muscles, rhomboids, serratus anterior, and deep cervical flexors are flaccid and lengthened, and an imbalance in the strength of these two groups of muscles leads to the typical postural changes of a forward tilt of the head, an increase in the anterior projection of the cervical vertebrae, rounded shoulders, and a chesty chest, where the starting and ending points of the anterior and posterior muscles of the body will be joined in a line that resembles an An “X” crosses the line between the front and back muscles of the body (Izraelski, J,2012).

2. Pilates

Pilates is an exercise system created and popularized by Joseph Pilates (1883-1967), a renowned German sports rehabilitation expert, to strengthen muscles, improve flexibility and coordination, improve posture, and promote overall health. This unique exercise system emphasizes the importance of the core to improve the practitioner's overall health by consciously controlling the body, ensuring proper muscle recruitment sequence and bone alignment, concentrating on the details of the movement, and working with targeted breathing patterns (Zhenwei, W. ,2016).

3. Fascial massage

Fascial massage is a massage therapy technique based on the human fascial system. From an anatomical point of view, fascia is a kind of fibrous connective tissue spread all over the body, which wraps around muscles, bones, nerves, blood vessels and other structures to form a continuous three-dimensional network system. Fascial massage is to improve the viscoelasticity of the fascia, reduce the contracture, adhesion and tension of the fascia, promote the mechanical conduction, nutrient exchange and nerve signaling within the fascia through professional manipulation or the use of tools on the fascial tissues in order to ultimately achieve the purpose of alleviating pain, improving muscle function, increasing the mobility of the joints, and promoting the recovery of the overall function of the body. Commonly used tools include foam rollers, fascia guns, massage shafts (roller massagers), massage balls, etc.

4. Office workers

Office workers are a group of people in various types of organizations (e.g., enterprises, government agencies, institutions, social organizations, etc.) who use the office as their main workplace. They usually use office equipment (such as computers, printers, etc.) to complete their work tasks. The work content is mostly transactional, managerial or professional, like handling documents, data entry, planning and copywriting, financial management, personnel management and many other matters. These employees generally work indoors in a relatively stable working environment, and their working hours are relatively regular, usually following the normal work schedule of their organizations.

5. Definition of relevant technical parameters and indicators

BMI: is the English abbreviation of Body Mass Index (Body Mass Index), which is a standard used internationally to measure the degree of fatness and thinness of the human body and whether it is healthy or not. It is calculated by dividing weight (kg) by height (m) squared (BMI = weight (kg) ÷ $height^2$ (m^2)).

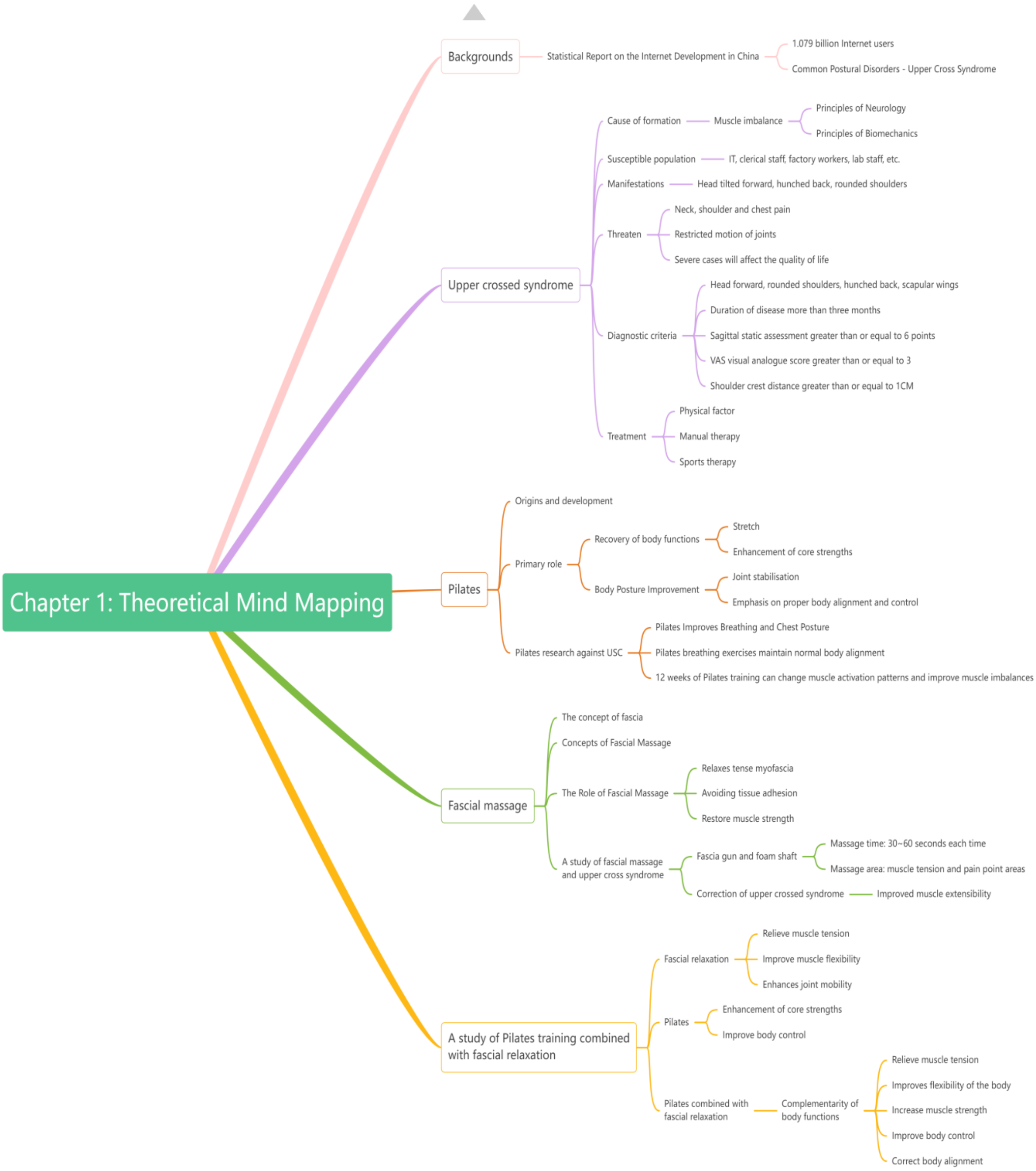
Forward Head Angle: The angle between the line formed by the external auditory canal and the cervical vertebrae in the sagittal plane of the human body and the vertical reference line.

Forward Shoulder Angle: The angle between the shoulder crest and a vertical reference line in the sagittal plane of the human body (e.g., a line connecting the spinal ramus and other landmarks) to measure the forward tilt of the shoulder.

Mean Power Frequency (MPF): is the weighted average of the frequencies in the power spectrum of an EMG signal. It is calculated by multiplying each frequency component by its corresponding power value, adding all these products, and finally dividing by the total power to obtain the result as the Mean Power Frequency.

Median Frequency (MF):In spectral analysis of EMG signals, the frequency value that divides the area under the power spectral density function curve of the EMG signal into left and right equal parts is the median frequency.

6. Theoretical research mind map



CHAPTER 2

REVIEW LITERATURE

This is an experimental study to investigate the effect of Pilates training combined with fascial massage on indicators related to upper crossed syndrome (3D body scanning simulation scores (FHA, FSA), cervical spine range of motion (ROM), surface electromyography (sEMG), pain level, and neck dysfunction index (NDI). The following literature was referenced for this study.

1. Upper crossed syndrome

1.1 Definition and clinical presentation of upper crossed syndrome

1.2 Pathogenesis of upper crossed syndrome

1.3 Diagnostic criteria for upper crossed syndrome

1.4 Dangers of Upper Cross Syndrome

1.5 People Prone to Upper Cross Syndrome

1.6 Current Research Status and Issues in Treatment Options for Upper Cross Syndrome

2. Pilates Training

2.1 Overview of Pilates

2.2 Research on the principles and functions of Pilates training

2.3 Application of Pilates Training in Rehabilitation

2.4 Effects of Pilates Training on Upper Cross Syndrome

3. Fascial Massage

3.1 Overview of Fascial Massage

3.2 Mechanisms of Fascial Massage

3.3 Mechanism of action of fascial massage

3.4 Effects of Fascial Massage on Upper Cross Syndrome

4. A study of the correlation between Pilates training, fascial massage and upper crossed syndrome

5. Research on related test indexes

5.1. cervical range of motion

5.2 Surface electromyography (sEMG)

5.3 Change in pain level (visual analog score, VAS)

5.4 Neck Disability Index (NDI)

1. Upper Cross Syndrome

1.1 Definition and clinical presentation of upper crossed syndrome

1.1.1 Definition

Upper crossed syndrome refers to a specific crossed pattern of muscle strength imbalance in the neck and chest due to prolonged poor postures, such as forward head tilt, rounded shoulders, chest inclusion, and so on. Among them, the tense muscle groups mainly include pectoralis major, pectoralis minor, upper trapezius, scapular raisers, etc., while the elongated and weakened muscle groups include deep cervical flexors, middle and lower trapezius and rhomboids.

1.1.2 Clinical manifestations

Physical abnormalities: the patient's head is in the anterior position of the coronal plane of the body, and the earlobe is usually located in front of the shoulder crest, appearing as a forward head tilt; the shoulder is forward and inwardly retracted, and when viewed from the side, the angle between the shoulder and the mid-axis line of the body increases, appearing as a rounded shoulder; the chest is inwardly recessed, the anterior-posterior diameter of the thorax decreases, and the scapulae may appear as an abduction and winged protuberance, appearing as a contained chest.

Painful symptoms: neck pain, mostly caused by tension and strain of the muscles at the back of the neck, the pain can radiate to the occiput, shoulder and even the upper limbs; shoulder pain, commonly seen around the acromion of the shoulder, due to the tension of the upper trapezius muscle and scapular retinaculum muscle, as well as the imbalance in the strength of rotator cuff muscle groups, resulting in increased pain during shoulder activities, especially when performing movements such as lifting up and abduction.

Functional disorders: cervical spine activity is restricted, and the range of head flexion, extension and rotation activities is reduced, affecting the daily life of raising the head, turning the head and other actions; decreased respiratory function, the deformity of the thoracic changes will limit the expansion of the lungs, resulting in respiratory depth and frequency is affected, the long-term can cause a reduction in lung capacity, decreased endurance; the emergence of nerve compression symptoms, the severe upper cross syndrome may lead to nerve compression, such as brachial plexus nerves Compression can cause symptoms such as numbness and weakness of the upper extremities.

1.2 Pathogenesis of upper crossed syndrome

It has been found that the pathogenesis of upper crossed syndrome involves the following main aspects:

1.2.1 Muscle Imbalance Theory

Muscle imbalance is a state in which there is an incongruity between the various muscle groups of the body in terms of strength, length and sequence of activation. Normally, the muscles work in concert with each other to maintain the body's balance and proper movement patterns. When this balance is disrupted, muscle imbalance occurs. Office workers are sedentary, their bodies lack movement, and their muscles are maintained in one state for a long time. When sitting for long periods of time, the muscles of the body do not get sufficient movement and stretching, e.g., the muscles of the back are elongated while the muscles of the chest and the front of the shoulders are in a constant state of contraction, resulting in an imbalance of muscle strength.Vladimir Janda's research states that upper crossed syndrome is also known as proximal or shoulder girdle crossed syndrome. In upper crossed syndrome (UCS), the dorsally tight upper trapezius and scapular raisers cross back and forth with the ventrally tight pectoralis major and pectoralis minor. The weak deep anterior cervical flexors cross back and forth with the weak lower and middle trapezius muscles. This pattern of imbalance causes joint dysfunction, particularly at the atlanto-occipital C4-

C5 joints, cervicothoracic joints, glenohumeral joints, and the T4-T5 segments (Janda, 1997).Janda suggests that upper crossed syndrome is a categorical pattern of muscular imbalance, and that muscle imbalances commonly result in weakness produced by reciprocal inhibition due to antagonistic muscle tension. There are individual differences in the degree of muscle tension and weakness, but very little difference in the pattern of imbalance. This pattern in turn leads to changes in body posture, joint dysfunction and joint degeneration. Thus, upper crossed syndrome is caused by muscle imbalances. Muscle imbalances are impaired imbalances between muscle groups that are easily tensed or shortened and those that are easily inhibited. (Szeto, G. P., Straker, L., & Raine, S.. 2002)suggest that muscle imbalance is a protective adaptive response resulting from chronic pain that is accompanied by diminished active and increased antagonist muscle strength, and that muscle imbalance characterized by active muscle activation and antagonist inhibition may increase the risk of injury (Szeto, G. P., Straker, L., & Raine, S., 2002).In patients with upper crossed syndrome, the stability of the shoulder and neck is disrupted, which means that the dynamic balance system is disrupted. The muscles around the shoulder and neck are not relaxed for a long time, which produces strain, leading to weakening of the muscles around the shoulder and neck, which over time leads to deformation of the cervical vertebrae and restriction of movement. Long-term displacement of the neck and shoulder without treatment can lead to an overall imbalance of the myofascial skeleton.

The muscle imbalances in upper crossed syndrome are located in the neck, chest, and back and are caused by an imbalance in muscle strength on the cross diagonal between the front and back of these three areas, as shown in Figure 1. Eventually, it leads to forward neck tilt and rounded shoulder symptoms, which can lead to headaches, dizziness, shoulder pain, and weakness in the trapezius and scapular lifting muscles. Upper crossed syndrome primarily involves the following tense and weak muscles and related areas:

① Tight muscle:

Pectoralis major muscle: starts from the medial half of the clavicle, sternum, 1st-6th rib cartilage, and ends at the crest of the greater tuberosity of the humerus. Long-term tension of the pectoralis major muscle will pull the shoulder joint inward and forward, leading to round shoulder, shoulder joint internal rotation, scapula forward extension, causing pain and discomfort in the shoulder and neck, which is an important factor in the formation of upper crossed syndrome.

Pectoralis Minor: Located on the deep side of the pectoralis major muscle, it begins at the 3rd-5th ribs and ends at the rostral eminence of the scapula. Its role is to pull the scapula forward and down. Long-term tension can cause the scapula to extend forward and the medial edge of the scapula to move away from the spine, forming a winged scapula and causing shoulder and neck pain.

Upper trapezius muscle: starts from the external occipital bump, the collateral ligament, all thoracic vertebral spinous processes, and ends at the outer 1/3 of the clavicle, the acromion, and the scapular ridge. Long-term tension will lead to scapula upward shift, shrug, affect the normal position of the cervical spine, triggering shoulder and neck pain.

Scapular Tilting Muscle: Located on the deep side of the trapezius muscle, it starts from the transverse processes of the upper 4 cervical vertebrae and ends at the upper angle of the scapula. Its function is to lift up the scapula and make the scapula rotate downward, long-term tension will cause the scapula to move upward, neck pain and discomfort.

Sternocleidomastoid muscle: It starts from the front of the sternal handle and the sternal end of the clavicle, and ends at the mastoid process of the temporal bone. Prolonged tension will cause the head to extend forward, affecting the normal curvature of the cervical spine.

Obliques: located on both sides of the neck, divided into anterior, middle and posterior oblique muscles. When the obliques are tense, they assist the sternocleidomastoid muscle in bringing the head forward and may compress nerves and blood vessels, leading to symptoms such as numbness in the upper extremities.

Latissimus dorsi: Starts at the spinous processes of the lower six thoracic vertebrae, all lumbar spinous processes, the median sacral crest and the posterior iliac crest, etc., and ends at the crus of the lesser tuberosity of the humerus. Tension of the latissimus dorsi muscle pulls down the humerus and internally rotates the shoulder joint, exacerbating abnormalities such as rounded shoulders

① Weak muscle:

Middle and Lower Trapezius Bundle: The main function of the middle and lower trapezius bundle is to retract and lower the scapula. When upper crossed syndrome occurs, this part of the muscle is too weak to fight against the tension of the upper trapezius bundle, resulting in an abnormal position of the scapula.

Rhomboids: located on the deep side of the trapezius muscle, they are divided into the rhomboids major and minor. Its function is to bring the scapula closer to the spine. In patients with upper crossed syndrome, the rhomboids are underpowered, making it difficult to maintain the scapula in the correct position.

Anterior serratus: Located on the lateral side of the thorax, it connects the scapula to the ribs, and its main function is to pull the scapula forward. The weak serratus anterior muscle is unable to effectively stabilize the scapula, making the scapula prone to abnormal postures such as forward extension.

Deep Cervical Flexors: Located in the deep layers of the neck, they are mainly responsible for the forward flexion of the neck. In patients with upper crossed syndrome, the deep cervical flexors are weak and unable to maintain the normal curvature of the cervical spine, resulting in forward extension of the head.

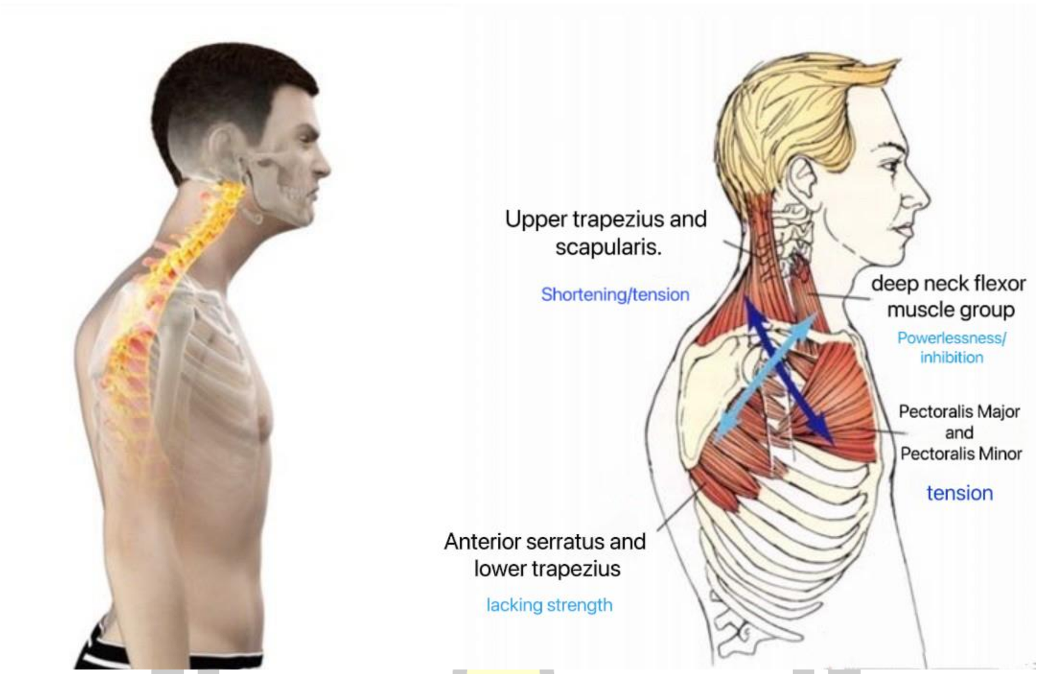


Figure 1 Diagram of muscle imbalances in upper cross syndrome

1.2.2 Poor body posture

Poor body posture refers to the arrangement of body parts that do not conform to the normal physiological structure and mechanical principles of the human body at rest or during movement. This kind of incorrect body posture maintained for a long time will cause adverse effects on the body. Office workers work for a long time, so that the head and neck lean forward. For example, when the eyes gaze at the computer screen, in order to see the screen content, the head will unconsciously stretch forward, while the shoulders will also be forward to the inward, chest concave, over time the formation of a bad posture. According to Zeng Renjie, upper cross syndrome arises because poor posture leads to the disruption of the normal biomechanical structure of the human body, changing the muscle length and causing an imbalance in the antagonist muscles, and the muscle imbalance will lead to the relative weakening of a unit link in the chain structure, and the body maintains a certain posture for a long period of time, and the relevant muscle groups will undergo force changes to adapt to this posture (Jie, 2021). Bing C et al. (Cai Bing, 2017) concluded that the causative factors of upper crossed syndrome include poor head and neck posture, improper motor posture, and sympathetic nerve stimulation. Poor head and neck posture, resulting in an imbalance of the head, shoulder, and neck muscles is the main pathogenesis of upper crossed syndrome. This imbalance leads to impaired movement patterns and postural changes, which in turn increase joint stress and produce pain and inflammation. Chronic pain and inflammation can exacerbate poor postural changes in the body.

1.2.3 Theory of pain

Pain is caused by nerve impulses generated by stimulation of sensory nerve endings, which are conducted through afferent nerve fibers to the central nervous system (including the spinal cord and brain). In the process, various injurious stimuli (e.g., mechanical, chemical, and thermal stimuli) activate the nociceptors, causing action potentials to be generated in the nerve fibers, and these signals undergo complex modulation and integration in the central nervous system, ultimately generating the sensation of pain. Muscle pain is a complex sensory response produced by the body when muscle tissue is stimulated, including sensations such as soreness, tingling, swelling, or burning of the muscle. This pain may occur as a result of muscle overuse, strain, strain, spasm, or an inflammatory response, metabolic disorders, or other factors that stimulate the nerve endings within the muscle, and is an important signal of abnormal or impaired muscle function. The exacerbation of upper crossed syndrome is closely related to the pain theory. Upper Cross Syndrome is a state of muscle strength imbalance caused by chronic poor posture, and is commonly seen in people who are sedentary.Poor posture (Tsang, So, Lau, Dai, & Szeto, 2018). The imbalance of muscle strength between the anterior and posterior sides of the body, with tense and shortened muscles on the anterior side and lengthened and weakened muscles on the posterior side, triggering muscle fiber damage and metabolite accumulation, leading to pain; long-term muscle imbalance also initiates an inflammatory response, with inflammatory mediators stimulating nerve endings and increasing neurosensitivity, exacerbating pain; at the same time, tense muscles compress peripheral nerves, and changes in body posture affect nerve travel and spatial location, resulting in In addition, prolonged pain stimulation causes central sensitization of the central nervous system, which further amplifies pain perception, and pain persists and is easily triggered and exacerbated, which in turn exacerbates poor posture and muscle imbalance, exacerbating the symptoms of upper crossed syndrome.Abnormal dystonia is an important feature of the biomechanical imbalance in upper crossed syndrome; dystonia is an involuntary, sustained, fine contractile force. Abnormal localized muscle tissue tone squeezes and pulls on nerves and blood vessels, resulting in pain (Glombiewski, Tersek, & Rief, 2008). Pain reflexively exacerbates muscle tension, which causes peripheral microcirculatory disturbances, allowing pain-causing factors to accumulate locally, creating a vicious cycle of "pain-tension-microcirculatory disturbances-pain," leading to peripheral soft tissue fibrosis. Peripheral soft tissue fibrosis. Reduced elasticity and plasticity of muscle fibers in fibrotic soft tissues further alters local muscle tone and circulatory disturbances progress. Reduced elasticity and plasticity of soft tissues leads to a decrease in their functional status and motor compliance, which is mainly characterized by exogenous biomechanical homeostatic disorders.In patients with UCS, this manifests as abnormal tension between the chest and back muscle groups. Over-activated muscles in upper cross syndrome tend to fatigue and metabolic waste products, such as lactic acid, build up in the muscles, irritating nerve endings and causing pain. Furthermore, muscle imbalances alter the forces on the bones, burdening the muscles around the joints and further exacerbating pain.

The literature suggests that the pathogenesis of upper crossed syndrome is a complex multifactorial interactive process in which muscle imbalance, poor posture and pain theories are interrelated and work together. Muscle imbalance plays a central role in the pathogenesis, poor posture is an important trigger for muscle imbalance, and pain forms a vicious circle with muscle imbalance and poor posture. For office workers, specific work patterns such as sedentary and sedentary work are important factors that lead to the development of poor posture, which in turn leads to muscle imbalance and related pain problems. In-depth study of these mechanisms is crucial for the development of effective prevention and treatment strategies for office workers.

1.3 Diagnostic criteria for upper cross syndrome

Regarding the diagnostic criteria for Upper Crossing Syndrome (UCS): UCS is the anterior-posterior (X-shaped) crossing (X-shaped in lateral view) of overly tense muscles (e.g., upper trapezius (UT), scapularis, pectoralis major (PM1), and pectoralis minor (PM2)) with overly weak muscles (e.g., deep neck flexors (DNF), middle trapezius (MT), and lower trapezius (LT)). This pattern of muscle imbalance is accompanied by specific postural changes such as forward head tilt, rounded shoulders (excessive upward and forward movement of the shoulder joints), pterygoid scapulae (anteriorly tilted and inwardly retracted scapulae with upwardly directed posterior convexity), and increased cervical kyphosis and thoracic kyphosis (Janda, 1997). Hyperextension of the head, hyper-elevation and anterior tilt of the scapular tilting muscles, hyperextension of the thoracic spine, mandibular protrusion, hyperextension of the upper cervical vertebrae in the head and neck flexion test, elevation of the scapular tilting muscles prior to shoulder abduction of 60°, and hyperextension of the scapulae with inward and downward posterior convexity during completion of push-ups in the kneeling position; ≥1 cm of acromion distance, a total score of ≥6 on the sagittal static postural assessment, a duration of disease of 2 months to 12 months, and no signs of significant cervical spondylosis (Yuan,. 2018), excluding patients with diabetes mellitus, hypertension, malignant tumors, and other diseases.Seo-Yeung gu et al. classified the severity of superior cruciate syndrome, classifying those with a distance of 1 cm or less between the lateral shoulder centerline and the lateral ear centerline as the normal group, those with a distance of 1-2. 5 cm between the lateral shoulder centerline and lateral ear centerline as the mild superior cruciate syndrome group, and those with a distance of 2.5-5 cm as the moderate superior cruciate syndrome group, with a distance of 2.5-5 cm as the moderate superior cruciate syndrome group, and with a distance of 2.5-5 cm as the mild superior cruciate syndrome group. 5 cm for the moderate upper crossed syndrome group (Gu, Hwangbo, & Lee, 2016).VAS visual analog score of 3-8 or higher (shoulder, neck and other parts of the body) (Yunqi, 2017); integrating the criteria proposed by domestic and international experts, we summarize the diagnostic criteria as follows: excessive forward head extension, rounded shoulders (excessive upward and forward movement of the shoulder joint), hunchback (excessive posterior convexity of the thoracic vertebrae), and pterosynovial scapulae (anteriorly tilted scapulae with an inwardly retracted and upwardly rotated scapulae), etc., a duration of the disease of more than 3 months, a VAS visual analog score greater than or equal to 3, acromion-to-acromion distance greater than or equal to 1 cm, no specific organic lesions on imaging, no obvious cervical spondylosis, and decreased quality of life.

1.4 Dangers of Upper Cross Syndrome

SKirthika noted that upper crossed syndrome can cause health problems such as myofascial trigger points, cervicogenic headaches, impingement syndrome, neck pain, rotator cuff injuries, and decreased lung capacity, which can seriously affect people's daily lives.Chao Ming Ng noted that upper crossed syndrome can cause dizziness, shoulder and neck pain, and symptoms that limit shoulder movement.Gu Seo-Yeung et al.(Gu, Hwangbo, & Lee, 2016)studied the effects of position sense in 60 patients with varying degrees of upper crossed syndrome and learned that cervical spine position sense can be severely decreased with the postural misalignment caused by upper crossed syndrome. This can lead to a decreased sense of balance and position. With upper crossed syndrome, the shoulder and neck muscles are passively exerted by the forward head tilt, and the associated muscles are fatigued by prolonged tightness and contraction due to prolonged periods of head bowing. Long-term non-improvement causes an imbalance in the static system of the muscles around the neck and shoulders, and some of the muscles produce muscle fatigue, which finally triggers symptoms such as chronic injury, spasm, and fibrosis, and the cervical vertebrae in the neck will undergo degeneration and deformation of the cervical vertebrae physiological curvature, while the mobility is affected. When the nerves and blood vessels in the neck are compressed and irritated, symptoms such as shoulder and neck pain, numbness in the arms, and deformation of body posture will occur. According to Kang, upper crossed syndrome causes a variety of symptoms including craniocervical and cervicothoracic junction stress, glenohumeral joint instability, and many musculoskeletal related symptoms in the head, neck, and shoulders (Kwon, Son, and Lee, 2015).Studies have found that UCS poses a serious health threat in some developed countries. It is considered a work-related musculoskeletal disorder because it results in a significant number of days off work and associated compensation and disability costs (Sim, Lacey, & Lewis, 2006). According to Barrett, proper posture is necessary for optimal functional performance during daily activities. Awkward postures such as stooping and hunching put constant stress on the joints, and when the joints are under constant stress, degenerative conditions can quickly develop, leading to muscle imbalances and pain. If muscle imbalances continue to develop, they can lead to altered movement patterns and joint damage, resulting in further dysfunction (Barrett, O'Keeffe, O'Sullivan, Lewis, & McCreesh, 2016). According to Bakhsh, H.R, some of the daily activities involving poor posture are usually related to occupation. Postural deviations can be exacerbated by repetitive tasks or long periods of continuous work. For example, patients with incorrect posture are more likely to develop musculoskeletal injuries after lifting or carrying heavy objects compared to other patients with correct posture (Bakhsh et al., 2021).UCS occasionally presents with dyspnea. This is due to the inability of the ribs to fully expand to allow lung inflation. The main muscles involved in respiration include the diaphragm, intercostal muscles, scalp muscles, transverse abdominal muscles (TRA), pelvic floor muscles and deep spinal intrinsic muscles. All of these muscles help stabilize the spine and breathing. Therefore, decreased thoracic spine mobility and involvement of the accessory respiratory muscles are responsible for respiratory dysfunction in UCS.

In summary, upper crossed syndrome has many dangers. It can lead to myofascial trigger points, cervicogenic headaches, neck pain, rotator cuff injuries, etc. It causes dizziness, shoulder and neck pain, as well as symptoms limiting shoulder movement, and it can also cause a severe decrease in the sense of cervical spine position, leading to a decreased sense of balance. At the same time, when suffering from upper crossed syndrome, the shoulder and neck muscles are passively exerted, and long-term tightness and contraction are easy to fatigue, resulting in an imbalance of the static system of the muscles around the neck and shoulder, triggering chronic injuries, spasms, fibrosis and other symptoms, so that the neck and cervical vertebrae degeneration, cervical vertebrae physiological curvature deformation, the degree of mobility is affected by the cervical nerves and blood vessels compression and stimulation of the neck and shoulder pain, numbness of the arm, body posture deformation and other symptoms. In addition, upper crossed syndrome is regarded as a work-related musculoskeletal disorder in some developed countries, which involves poor posture related to occupation, and office workers are susceptible to musculoskeletal injuries due to repetitive work or prolonged continuous work that can aggravate postural deviations. Moreover, upper crossed syndrome may occasionally lead to dyspnea due to reduced mobility of the thoracic spine and involvement of the accessory respiratory muscles, resulting in the inability of the ribs to fully inflate to achieve lung inflation. Muscles involved in respiration, such as the diaphragm and intercostal muscles, help to stabilize the spine and respiration, and upper crossed syndrome can affect their function. Upper crossed syndrome not only seriously affects the quality of life and work efficiency of office workers, but also has an impact on socio-economic development.

1.5 People Prone to Upper Cross Syndrome

According to Nasser et al. 2021, the prevalence of upper crossed syndrome was 32.43% among office workers, 24.32% among drivers, 27.03% among housewives, and 16.22% among teachers (Naseer & Tauqeer, 2021). The office population is more likely to suffer from upper cross syndrome, mainly because they maintain poor posture for long periods of time. When in the office, many people will unconsciously look down at computer and cell phone screens, leaving the cervical spine in forward flexion for a long time. At the same time, sitting for a long time will make the shoulder muscles tense and the chest muscles shorten, while the muscles of the back are stretched and weakened. When the muscles hold a posture for a long time or perform repetitive motions, they will strengthen the tonus system (single-jointed muscles) and weaken the tensor system (multi-jointed muscles), which will lead to muscular imbalance and trigger abnormal postures such as the upper cross where the head is tilted forward (increased anterior curvature of the cervical spine), the back is hunched over (increased posterior curvature of the thoracic spine), and the rounded shoulders (increased scapulae increased abduction) in the upper crossed posture (Bing, 2017).

Li Hui assessed the body posture of 200 employees of the Bank of Communications of China using postural assessment measurements, and the results of the study showed that poor body posture such as round shoulders and hunchback accounted for 44% of the total. It can be seen that abnormal body postures such as round shoulders, hunchback, and forward head tilt have become the prone and hardest-hit areas of the office population, and the incidence rate is highly youthful (Hui, 2015). As poor body posture is very likely to cause other diseases, which in turn affects people's quality of life, the country has also begun to pay great attention to problems such as abnormal body posture.

Literature results show that, both at home and abroad, the susceptibility of upper cross syndrome is mainly concentrated in the long-term sedentary office population, which is inextricably linked to the characteristics of the occupations they are engaged in. Upper cross syndrome has become a common occupational disease in the workplace, with a highly youthful incidence.

1.6 Current Research Status and Issues in Treatment Options for Upper Cross Syndrome

A search of the China Knowledge Network, ScienceDirect, and WebScience databases revealed that the main treatments currently used in upper crossed syndrome rehabilitation research are exercises to correct patients' faulty postures and improve muscle imbalances. Treatment programs that use various types of exercises and techniques to correct abnormal posture and restore neuromuscular imbalances are effective in reducing pain and improving neck disorders and postural deviations.

Karimian et al. conducted a comparative study in 2019 of 12 UCS faculty members at the National College of Sports Medicine with an exercise program that included self-myofascial release, stretching, and strengthening exercises. After 12 weeks of exercise, the experimental group showed significant reductions in anterior head posture, shoulder angle, and kyphosis compared to the 11 controls who did not participate in the program (Karimian, Rahnama, Ghasemi, & Lenjannejadian, 2019).In 2011, Chuan-Yong Jiang and X. Zheng used a combination of medication combined with heat and massage to treat patients with UCS. The results proved that this combined treatment approach was effective (Jiang Chuan-Yong, 2011).Dong Yeon Kang et al. randomly recruited 20 college students to perform neck deep flexion training using a pressure biofeedback device. They investigated the effects of deep neck flexion training on maintaining head forward tilt, muscular endurance, and neck mobility, and measured the cranial spine angle.The results showed a significant increase in cervical range of motion. This feedback instrument can be used to maintain cervical mobility and increase muscular endurance in patients with forward head tilt (Zuanqin, 2023). In the same year, Zhanjia, Hua Jiajia et al. treated 30 UCS patients by combining the MET technique with conventional rehabilitation. Therapists diagnosed the cause of the patient's pain and used the appropriate MET according to different disease characteristics, instructing the patient to perform muscle resistance contractions in a specific way, position, and force. The results showed that the method was effective. Subsequently, Zang Jia, Hua Jiajia et al. combined MET with conventional rehabilitation therapy (including low-frequency pulsed electrical stimulation of the neck and muscle massage therapy) to train cervicothoracic erector spinae in 45 female UCS patients. The results showed that MET combined with conventional therapies was effective in relieving symptoms, improving neck pain and dysfunction, and improving the patients' motor abilities in patients with UCS (Łukasik et al., 2017).

R.M. Ruivo et al. selected patients with symptoms of head forward tilt and rounded shoulders and conducted a 32-week rehabilitation training in physical education class, measuring the angle between the sagittal plane of the head and the neck and shoulder before and after the intervention, and the results showed that the training effect was significant and maintained after stopping the training (Ruivo et al., 2016). Zhilv, Z used the BST functional rehabilitation method to treat UCS, and the results showed that the method was effective in improving the patients' cervicothoracic physiological curvature, joint disorders, neck and shoulder muscle strength, head forward tilt, and scapular function. Xiong Yuan used three methods of Tai Chi Tui Na, Muscle Energy Technique, and Kinesiology Cloth Patch to intervene with UCS patients, and the results of the study showed that. The three methods showed improvement in improving neck and shoulder pain, scapular girdle, head forward tilt, and cervical spine of the patients (Zhilv, Z, 2018).Arshadi et al. utilized kinesiology training to correct muscle imbalances in 30 male UCS patients.Exercise program includes stretching, strengthening and stabilization exercises. They are performed 3 times a week for 8 weeks for 50 minutes. Stabilization exercises were performed mainly on the craniocervical joint and the scapularis brevis muscle with the aim of restoring balance around the scapularis brevis muscle. The results showed significant differences in EMG activity between the UT, SCM, and SA. the decrease in SCM activity mirrored the increase in DNF activity. Their study showed that an 8-week corrective exercise program helped to correct muscle imbalances in patients with UCS (Arshadi, Ghasemi, and Samadi, 2019).Nitayarak et al. performed grouped weight-bearing exercises aimed at scapular stabilization on 40 women with UCS, including MT, LT, trapezius, and SA, with 10 repetitions in each group, 3 days a week that lasted 4 weeks. Neck and shoulder angles were assessed by side-view photographs using a computer program. Mesothoracic curve, pectoralis minor length and scapular muscle strength were also measured. The results showed that subjects in the exercise group showed significant improvement in neck and shoulder angle, pectoralis minor length and scapular muscle strength compared to the control group, but there was no significant change in the range of the mid-thoracic curve. Therefore, it has been suggested that scapular stabilization training may improve neck-shoulder posture, scapular muscle imbalance and thoracic kyphosis (Nitayarak and Charntaraviroj, 2021).

As can be seen above, treatment options for upper crossed syndrome are varied and effective. The main ones include training to correct faulty posture and improve muscle imbalances, such as self-myofascial release, stretching, and strengthening exercises. A combination of medications combined with heat and massage has also proven effective. Deep neck flexion training using pressure biofeedback devices can increase cervical range of motion, and MET techniques combined with rehabilitation therapy (including low-frequency pulsed electrical stimulation of the neck and muscle massage therapy) can alleviate symptoms, improve pain and dysfunction, and improve movement ability. In addition, correcting muscle imbalances through exercise training and performing group weight-bearing exercises aimed at scapular stabilization can also improve the patient's condition in various ways, such as restoring balance around the scapularis muscle and improving neck and shoulder posture. These treatment options provide a variety of choices and pathways for the rehabilitation of patients with upper crossed syndrome from different perspectives and modalities.Treatment options for Upper Cross Syndrome are primarily focused on correcting poor posture and improving muscle imbalances.

Pilates, as a method of conditioning the body by stretching and strengthening specific muscles through movement, enhancing posture, relieving muscular tension, and improving alignment and flexibility, is very helpful in strengthening, rebalancing, and realigning the body. It is very helpful in increasing an individual's body awareness and reducing the risk of strains or injuries due to body imbalances. Self-myofascial release and massage have also been sought to improve upper cross syndrome. Unfortunately, however, there are fewer studies on promoting upper cross through Pilates training, none of which have resulted in a systematic exercise and manipulation system for upper cross syndrome, and it is also important to explore whether combining Pilates training with myofascial massage will exert a greater rehabilitative effect on upper cross syndrome.

The above literature study on upper crossed syndrome concludes that upper crossed syndrome is a condition of imbalanced muscle strength in the neck and chest due to prolonged poor posture, with a complex pathogenesis and multiple clinical manifestations and hazards. It is defined as the formation of a crossover pattern in which specific muscle groups are strained and weakened due to poor posture. Clinical manifestations include postural changes such as forward head tilt, rounded shoulders, and chest retention; pain symptoms such as neck and shoulder pain that can radiate; and dysfunctions such as limited cervical spine mobility, decreased respiratory function, and nerve compression symptoms. Pathogenesis involves muscle imbalance theory, i.e., the imbalance of the strength and length of the body's muscle groups, office workers are sedentary and maintain poor posture for long periods of time is an important trigger, resulting in muscle imbalance, which leads to joint dysfunction, etc.; poor posture destroys the normal biomechanical structure of the human body, resulting in muscular imbalance and pain; the theory of pain elaborates on the pain caused by poor posture to the muscular imbalance and pain, and the pain and muscular imbalance, poor posture form a vicious circle. The pain theory explains that pain is caused by muscle imbalance due to poor posture, and that pain and muscle imbalance form a vicious circle. The diagnostic criteria for upper crossed syndrome include physical manifestations such as excessive head extension, rounded shoulders, hunchback, winged scapula, as well as duration of illness, VAS score, and acromion distance, and the exclusion of other medical conditions. Studies have shown that upper crossed syndrome is harmful in many ways, causing myofascial trigger points, headaches, neck pain, rotator cuff injuries, decreased lung capacity, affecting the sense of balance and cervical spine position, as well as chronic muscle damage, cervical spine degeneration, neurovascular compression, and respiratory distress. Office workers are the high incidence of upper cross syndrome, closely related to the characteristics of the occupation, has become a common occupational disease in the workplace and is a trend of rejuvenation. Currently, there are various treatment options with certain effects, mainly correcting the wrong posture and improving the muscle imbalance training, such as self-myofascial release, stretching, strengthening exercises, etc., but also including massage, pressure biofeedback device neck deep flexion training, MET technology combined with low-frequency pulse electrical stimulation of the neck and muscle massage therapy, exercise training to correct the muscle imbalance, and scapular stabilization training. Comprehensive background information and reference to the current state of research is provided for the study of Pilates combined with fascial massage for office workers with upper crossed syndrome. First, the high prevalence of upper crossed syndrome among office workers and its serious impact on this population are clarified, highlighting the need for research on this group. Second, the pathogenesis, clinical manifestations and diagnostic criteria of upper crossed syndrome are elaborated in detail, providing a theoretical basis for the accurate identification and understanding of the research subjects in subsequent studies. In terms of treatment options, it was pointed out that targeted exercise therapy, self-myofascial release, and massage had a significant effect on improving upper crossed syndrome. This provides an entry point and research direction for conducting research on Pilates combined with myofascial massage. By understanding the strengths and limitations of existing treatments, the potential value and effectiveness of Pilates combined with fascial massage as an innovative modality can be better assessed, providing a comprehensive frame of reference and a comparative basis for the design, implementation and evaluation of the effects of the study, which will help to promote the search for and development of more effective treatments for Upper Cruciate Syndrome, and to improve the health and quality of work of office workers.

2. Pilates training

This study examines the use of Pilates training in rehabilitation, the literature includes: an overview of Pilates, principles of Pilates training , the use of Pilates training in rehabilitation, and the effects of Pilates training on upper cross syndrome.

2.1 Overview of Pilates

Joseph Pilates was a sickly child, but his parents were gymnasts and he was exposed to and practiced various sports from an early age, which provided him with a good foundation for the creation of Pilates. Mr. Pilates has dedicated his life to the development and promotion of Pilates, helping doctors in concentration camps rehabilitate post-surgical patients, founding the Pilates Institute, and later, with his wife, the Pilates Studio, which provides targeted therapeutic exercise training for those in need. From the 500 individual movements created in the early days, a variety of schools and training equipment came into being, collectively known as the Pilates Movement Training System. As fitness became more popular, Pilates began to enter the public eye more and more. 2000 saw the introduction of the Pilates program to China, and the development of the Pilates program grew in popularity. Pilates in the club, training institutions and other rapid development, in colleges and universities also set Pilates as an independent course, but in colleges and universities has not been popularized. The scope of Pilates has been expanded, not only for rehabilitation training, but also appeared in other sports activities in the auxiliary exercises. Nowadays, Pilates has been recognized, applied and promoted in many fields such as rehabilitation physiotherapy, mass fitness and dance performance.

Pilates training is a comprehensive body workout that is characterized by a unique combination of movements, precise breath control and core strengthening. Pilates training focuses on the body as a whole, activating the deep muscles through a series of targeted movements, enhancing muscular endurance and strength, while improving flexibility, balance and coordination. Now Pilates training can be divided into two kinds of mat training and apparatus training. When training on the mat, the body touches the ground with a large area and strong stability, which is suitable for beginners and the general public. In this study, we mainly used Pilates mat training method combined with fascial massage to promote the improvement of office workers' upper cross syndrome.

2.2 Research on the principles and functions of Pilates training

Pilates training should follow the principles of breathing, concentration, precision, control, balance, core and fluidity（Andrade,L.S.,2015；Pilates,J. H.2024） Pilates training should be combined with breathing, concentration, precision, control and balance to achieve the multiple purposes of strengthening the core muscles of the human body, flexibility, and improving body posture and shaping the body (Cong, L. J., 2006). Pilates training emphasizes the quality, precision and control of movements, activating the muscles in a specific sequence at an appropriate rhythm, doing the best movements with the least amount of force, and activating the right muscle groups at the right point in time, i.e., economy and efficiency of movement patterns. The ultimate goal of Pilates is to achieve total physical wellness so that the body does not need a brain to think, and the automated body can take advantage of the maximum mechanics to achieve optimal balance and health. The following is an application of Pilates training principles to improve office worker upper cross syndrome.

Breathing is a very important part of Pilates practice, all exercises should be accompanied by complete, rhythmic breathing. The use of lateral breathing during Pilates training helps to correct the poor posture of the upper crossed syndrome by activating the abdominal muscles to stabilize the spine, improve thoracic mobility, and relax the tense muscles of the chest.

Concentration means focusing on specific target muscles during Pilates training so that they can better activate weak muscles during training, thus effectively improving the abnormal body posture of upper crossed syndrome.

Precision focuses on practicing just the right movements, being aware of which part of the asana should move first and which part should move second, and reinforcing this awareness during practice. The principle of precision facilitates patients with upper crossed syndrome to precisely locate and activate weak muscles (such as the middle and lower trapezius bundles, rhomboids), and at the same time accurately relax tense muscles (such as pectoral muscles, obliques), so that the muscles of various parts of the body can be restored to a normal state of tension through the precise adjustment of movements, thus improving the physical problems caused by upper crossed syndrome.

Control means that when practicing Pilates, the amplitude of movements should be set according to the body's ability. The principle of control in Pilates training enables the practitioner to precisely control the movements in the Upper Cross Syndrome Improvement Training, to activate the shoulder, back and neck muscles in a controlled manner, to enhance the muscle strength and at the same time to improve the muscle imbalance, and to gradually correct the undesirable body posture.

The principle of balance refers to the balanced coordination of muscle strength and joint movement of all parts of the body; it can help Upper Cross Syndrome patients coordinate the muscle strength of the front and back of the body, so that the overly tight pectoral muscles and weak back muscles, etc. can reach a balance, and promote the normalization of body posture.

Core refers to the core of the body, and the core principles of Pilates emphasize the involvement of the core (abdomen, abdominal muscles, lower back, etc.). For upper crossed syndrome, activating the core can enhance the stability of the body. By strengthening the core muscles, it can better share the pressure of the shoulder and neck muscles, assist in adjusting the balance of muscle strength, and help to pull the thorax back to the correct position, alleviating the symptoms of upper crossed syndrome.

Fluidity refers to the body's natural and fluidity in following the principles and techniques of Pilates exercise, with each asana moving on to the next in the proper sequence and at the most efficient pace, resulting in purposeful and conscious movement and the continued application of the principles and techniques of Pilates exercise in daily life (Zhenwei, W. , 2016).

Song Cuicui et al. researched the principles of Pilates and concluded that Pilates exercise can combine the respiratory system, maintain body posture, and enhance the function of muscle balance and coordination (Song, C. C., & Wang, J.,2007). In conclusion, Pilates training can enhance people's control over their bodies, establish efficient movement patterns, change muscle activation patterns, stretch stiff and tight muscle groups in the body, and reestablish the balance of muscles and fascia, thus improving the stability of the spine, correcting poor body postures, and promoting physical and mental harmony.

2.3 Application of Pilates Training in Rehabilitation

Patti et al. researchers concluded that Pilates is an exercise that works deep muscles through regular, controlled movements with breathing to enhance muscle control and balance (Patti et al.,2015). Jenny Liu et al. concluded that Pilates postpartum training helps to improve maternal body composition and promote the recovery of pelvic floor muscle tone (Liu, et al . , 2016).Found that Pilates training had a significant enhancement effect on patients' upper abdominal muscle strength, lower abdominal muscle strength, trunk extension muscle strength, and internal and external abdominal obliques (to the right) muscle strength (Zhao, Z. L. ,2018). The results of the literature study suggest that Pilates training can restore muscle tone, promote the development of deep muscles, increase the strength of weak muscles, and promote the balanced development of muscle strength.

Carrasco-Poyatos M et al. compared the effects of Pilates training and muscle training on balance, body composition, and cognitive functioning in older women and found that the Pilates group showed better improvements than the muscle training group, promoting physical flexibility and balance in older women (Carrasco-Poyatos M, er al . ,2019).

Newell D et al. observed the effects of Pilates training on balance and gait parameters in 10 older adults (67.8 ± 5.0) in a community setting. After an 8-week Pilates training program, the community-dwelling older adults showed a reduction in anterior-posterior directional postural sway, a decrease in the Fall Risk Index (FRI), and significant improvements in stride length, gait cycle, walking speed, and the coefficient of variation of stride length. This study suggests that Pilates training improves static balance and gait parameters and reduces fall risk in community-dwelling older adults (Newell D et al., 2012).

Oliveira L et al. compared the effects of static stretching and Pilates on flexibility after 3 months of separate interventions in healthy older women over the age of 60 years and found that static stretching exercises only improved range of motion in spinal flexion and hip flexion, whereas Pilates also improved spinal extension, ankle hooking dorsiflexion, and tensing dorsiflexion, suggesting that Pilates training was superior to static stretching in improving flexibility with the static stretching exercises (Oliveira L et al., 2016). From the above, it can be seen that Pilates training has improved balance, flexibility and cognitive function in older adults, which can effectively improve range of motion, maintain postural balance and reduce the risk of falls in older adults.

Mazloum, V et al. compared the effects of Pilates and stretching exercises on pain scores, lumbar curvature, lumbar anterior flexion mobility, and lumbar spine dysfunction indices in patients with chronic nonspecific lower back pain. It was concluded that Pilates training was superior to stretching in improving pain, joint mobility, and lumbar spine function levels, and that the Pilates group had better retention of efficacy than the stretching group at one-month follow-up (Mazloum, V et al., 2022). Zhao, Z. L selected 28 patients with C-type scoliosis from Jilin University, divided them into Pilates training group and Schrott exercise group, and conducted a 12-week exercise intervention for 60 minutes three times a week, and finally evaluated the corrective effect of Pilates training on C-type scoliosis. The results of the study showed that Pilates training was very effective in improving lumbar, thoracic back, and neck pain in patients with type C scoliosis, as well as in improving shoulder height problems (Zhao, Z. L.,2018). Cazotti et al. found that after 12 weeks (2 times/week, 60 minutes/session) of training in the Pilates group, 3 months of Pilates apparatus combined with mat exercise training significantly relieved pain and improved cervical spine function and quality of life in patients with chronic neck pain (de Araujo Cazotti, , er al., 2018). The above shows that Pilates training is effective in improving neck pain, joint mobility, and high and low shoulder problems, suggesting that Pilates training can be applied to studies related to improving poor body posture and pain due to poor body posture, and laying a theoretical foundation for the study of the effects of Pilates training combined with myofascial massage on the upper crossover syndrome of office workers.

In summary, Pilates training has become a filler tool in medical therapy and has received much attention in the field of sports rehabilitation. In the previous study of upper crossed syndrome, it was concluded that the etiology and mechanism of upper crossed syndrome mainly include muscle imbalance, poor posture, and pain leading to exacerbation of symptoms. Pilates training offers significant advantages in a number of ways. In terms of promoting balanced muscle development, it can exercise deep muscles, enhance muscle control and balance, help improve maternal body composition and pelvic floor muscle tone, and also enhance muscle strength in various parts of the body, promote balanced muscle strength, which is beneficial to the recovery of muscle imbalance in upper crossed syndrome. In terms of improving poor body posture, Pilates training can reduce postural sway in the elderly, optimize gait parameters, improve flexibility and range of motion, and also has a good effect on improving the body posture of scoliosis patients. In terms of pain relief, patients with chronic non-specific lower back pain and chronic neck pain have significant effects on pain, joint mobility and related functions. Taken together, these effects suggest that Pilates training is suitable for the treatment of upper crossed syndrome.

2.4 Effects of Pilates Training on Upper Crossing Syndrome

Upper cross syndrome, as a common body image problem, brings many discomforts and health risks to patients. Pilates training, as a comprehensive physical training method, has received a lot of attention in the rehabilitation field in recent years. Pilates training focuses on activating the deep core muscles to improve stability and control of the body. At the same time, it promotes muscle relaxation and activation through specific breathing patterns. The movements of Pilates training are designed to cover multiple parts of the body, allowing precise conditioning and control training to be implemented according to the specifics of the muscles to improve upper cross syndrome. First, muscle balance is improved. Pilates training strengthens weak muscles in upper cross syndrome (Emery K, 2008), such as deep cervical flexors, middle and lower trapezius, etc., and stretches tight muscles, such as pectoralis major and pectoralis minor. The second is to correct poor posture. Ji

Wenqing,Sun Yuan confirmed that Pilates training can reduce cervical spine pain in upper crossed syndrome and improve the “C” shaped spine and rounded shoulders and chested posture in the lateral view of upper crossed syndrome (Ji, W. Q., & Sun, Y. , 2018), mainly through a series of targeted movements, adjusting the position of the head, neck and shoulders, improving the round shoulders, head forward lead and other poor posture. Third, pain relief. Pilates training relieves pain symptoms and improves quality of life by reducing muscle tension in the neck and shoulders. Through experimental research, Li Yinghui concluded that Pilates exercise can effectively improve shoulder and neck pain, neck dysfunction, correct abnormal posture, increase neck muscle strength and lung capacity of female college students with upper crossed syndrome, and compared with conventional exercise therapy, Pilates exercise intervention has a better effect on the functional recovery of female college students with upper crossed syndrome （Li, Y. H., 2023). Fourth, physical function enhancement. Pilates training enhances the range of motion and flexibility of the shoulder and neck joints, and improves the body's ability to move.

A synthesis of the existing literature shows that Pilates has been shown to be effective in improving the level of neck pain, restoring normal physiological curvature, and correcting abnormal postures, such as rounded shoulders and chest, in people with upper cross syndrome. Pilates is a precise sculpting exercise that uses movements to stretch and strengthen specific muscles to condition the body, improve poor posture, and increase an individual's body awareness (Worth Y, 2004). Pilates training reduces the risk of strains or injuries due to body imbalances. Pilates teaches people to recognize their musculoskeletal strengths and weaknesses and equips them with the knowledge to correct and rebalance their entire body mechanics (Rajalaxmi JP et al., 2018). (Yin, Chushan, 2019) concluded that Pilates training + conventional therapeutic interventions may be the best treatment for patients with cervical spondylosis and the efficacy can be maintained for a longer period of time (Yin, et al .,2021）.Pilates training has a positive effect on upper crossed syndrome. However, further studies are still needed to optimize the training protocol and to clarify the optimal frequency and intensity of training in order to improve the therapeutic effect. In order to provide a more scientific and effective basis and guidance for the rehabilitation treatment of upper crossed syndrome. At the same time, Pilates training can be further promoted and applied in clinical practice, combined with other rehabilitation therapies, to provide patients with a more comprehensive and personalized rehabilitation treatment plan, and to help patients better recover their health.

To summarize, Pilates training is a scientific training method aimed at improving physical function, shaping good posture, and enhancing physical and mental health. Pilates training has many positive implications in the field of rehabilitation, especially in the treatment of upper cross syndrome. The origin and development of Pilates has gone through the process from the creation of Joseph Pilates to the present day, which is widely used in many fields, and the training methods include mat training and equipment training. In this study, we mainly used the safer and low-cost Pilates mat training combined with myofascial massage to improve the Upper Cross Syndrome of office workers. Pilates training follows the principles of breathing, concentration, precision, control, balance, core and fluidity, which each have their own unique roles in improving upper cross syndrome, such as the principle of breathing helps to correct poor posture, the principle of concentration can activate weak muscles, the principle of precision can accurately locate and adjust the muscles, the principle of control can accurately control the movement to correct poor posture, the principle of balance promotes the coordination of body parts, the principle of core can enhance the stability of the body to assist in adjusting muscle strength, and the principle of stability helps to adjust muscle strength. The principle of balance promotes the coordination of all parts of the body, the principle of core enhances the stability of the body and assists in adjusting muscle strength, and the principle of fluidity realizes natural and smooth exercises and applies to daily life. In the application of rehabilitation, Pilates training is helpful for the recovery of maternal body composition and pelvic floor muscle tone, enhances the muscle strength of different parts of the body and promotes the balanced development of muscle strength, improves the balance, flexibility and cognitive function of elderly women, reduces the risk of falling, and is effective in improving chronic non-specific lower back pain, chronic neck pain and scoliosis, laying a theoretical foundation for its application in the treatment of upper crossed syndrome. The theoretical basis for its use in the treatment of upper crossed syndrome has been established. For upper crossed syndrome, Pilates training has a prominent role in improving muscle balance, correcting poor posture, relieving pain, and enhancing physical function, which can strengthen weak muscles, stretch tense muscles, reduce cervical pain, improve poor posture, relieve muscle tension to improve quality of life, and enhance joint range of motion and flexibility. Comprehensive existing literature, Pilates training is effective in improving the multiple problems of the upper cross syndrome population, but further research is needed to optimize the training program, to clarify the optimal training frequency and intensity, in order to provide a more scientific and effective basis and guidance for rehabilitation therapy, and at the same time, in clinical practice, combined with other means of rehabilitation to promote the application of rehabilitation therapy, to provide a more comprehensive and personalized rehabilitation treatment program, to help patients recover their health. The program will provide patients with a more comprehensive and personalized rehabilitation program, and help them recover their health.

3. Fascial massage

3.1 Overview of Fascial Massage

Fascial massage is a form of manipulative therapy that targets the body's fascial system. Fascia is a layer of connective tissue throughout the body that wraps around muscles, bones, organs and other structures to provide support and protection for the body and is involved in force transmission and coordination of body movement. Fascial massage applies pressure, stretching and other stimuli to the fascia through specific maneuvers and techniques to improve the state of the fascia, relieve pain, and promote the recovery of body functions.

The concept and practice of fascial massage can be traced back to ancient civilizations. In traditional Chinese medicine, there are similar tui na and massages that focus on improving the body's condition by adjusting the meridians and qi and blood, and the meridians are related to the fascia to some extent. In the West, there were also records of massage therapy in the ancient Greek and Roman periods, and although the methods at that time were different from modern fascial massage, they laid the foundation for its development. With the continuous progress of anatomy, physiology and other medical sciences, people's understanding of fascia gradually deepened, and in the late 20th century, some rehabilitation therapists and sports coaches began to pay attention to the role of fascia in the rehabilitation of sports injuries and the enhancement of physical performance, and gradually developed a more systematic fascial massage techniques and theories. For example, Thomas Myers proposed the theory of "Anatomical Train", which emphasizes the wholeness and continuity of the fascia, and has had a significant impact on the practice and teaching of fascial massage.

3.2 Mechanism of action of fascial massage

The mechanical mechanism of action of fascial massage restores fascial elasticity and tone. Fascia's elasticity and tone can become abnormal after prolonged poor posture, excessive exercise or injury. Studies have shown that when massage is performed using a foam shaft, by repeatedly rolling it out, like combing through stray threads, the fascial fibers are restored to their normal course, which improves the elasticity of the fascia, relaxes tight fascia (Cavanaugh, Aboodarda, Hodgson, & Behm, 2016), avoids tissue adhesions, aids in muscle recovery, and so on. (Kelly, 2016) et al. In their study, the experimental group used a foam shaft to perform fascial massage on the plantarflexor muscle groups of the dominant leg, with a relaxation time of 30s/group for 3 groups; the ankle abduction angle was measured at 0, 5, 10, 15, and 20 min after relaxation, respectively, and it was found that the ankle abduction angle after relaxation in the experimental group was significantly greater than that of the control group, and this gap could be maintained. It was found that the ankle dorsiflexion angle of the experimental group was significantly greater than that of the control group after relaxation, and this difference could be maintained for more than 20 minutes. Normally, the fascia contains an appropriate amount of water to maintain its lubricity and elasticity. Fascial massage promotes fluid exchange within the fascia, allowing excess water to escape while allowing fresh tissue fluid to enter. This helps to reduce the swelling of the fascia and improve its transportation of nutrients.

The neurophysiologic mechanism of action of fascial massage is the stimulation of receptors to relieve pain. A variety of receptors are distributed in the fascia. When performing fascial massage, appropriate pressure stimulation activates mechanoreceptors and inhibits signaling from injury receptors. (Patel G R, Vedawala N, 2023) During massage of tense neck fascia, it was found by neurophysiological testing that fascial gun for massage stimulates receptors in the fascia, which transmit signals to the brain, which releases neurotransmitters such as endorphins, which reduces the pain sensation. The patients' pain scores were significantly reduced after receiving fascial massage treatment, further confirming the mechanism of action of fascial massage in relieving pain by stimulating the receptors.

The biochemical mechanism of action of fascial massage is to promote the removal of cellular metabolites: in fascial tissues, cellular metabolism produces various wastes. Massage accelerates local blood circulation, allowing metabolic wastes such as lactic acid to be carried away more quickly. Wu Qiang et al. Fascial relaxation using a fascial gun as a massage tool can reduce the pain of delayed muscle soreness, promote the recovery of flexibility and strength qualities, and improve muscle electrophysiology; fascial gun relaxation is better than conventional stretching for delayed muscle soreness recovery (Wu, Q., Wen, X. P., & Li, H. W.,2023).

In conclusion, the mechanism of action of fascial massage mainly includes promoting the elastic recovery of fascial tissues, improving blood circulation, and relieving pain and muscle tension. For upper crossed syndrome, fascial massage may improve muscle imbalance by relaxing the tense fascia in the neck, shoulder and other parts of the body, thus relieving the symptoms of upper crossed syndrome, such as reducing neck pain. It may adjust fascial adhesions and tension caused by long-term poor posture to a certain extent, thus promoting the recovery of normal muscle and fascial function, which lays a theoretical foundation for this paper to study its effect on upper crossed syndrome.

3.3 Classification of Fascial Massage

Fascial massage is categorized according to whether or not tools are used as follows: (1) unarmed fascial massage: directly with both hands on all parts of the body of the fascia operation, the massage therapist can rely on the sense of touch to accurately perceive the state of the fascia and the degree of muscle tension, so as to flexibly adjust the strength and direction of the massage. Common techniques include kneading, pressing, dialing and so on. For example, kneading can be done through the palm of the hand or the fingers of the kneading back and forth, so that the fascia to get soothing and relaxation; press method is to use the fingers or the palm of the hand on a specific part of the pressure, stimulate the fascia and the surrounding tissue; plucking method like plucking the strings, the fascia of the transverse or longitudinal plucking, in order to loosen the adhesion of the fascia. (2) Tool-assisted fascial massage: with the help of various tools to carry out fascial massage, can be more effective in applying pressure and stimulation, expanding the scope of action of the massage, common tools, such as foam shafts, fascial gun, fascial ball, massage stick and so on. Foam shaft can be used for large area of muscle and fascia relaxation, through the body's own pressure on the foam shaft rolling on the back, legs and other parts of the fascia to produce extrusion and stretching effect; fascia gun is suitable for small area of in-depth massage, accurate and adjustable strength; fascia ball is suitable for small areas of the deep fascia for accurate massage, such as plantar joints; massage stick can be used to specific parts of the point or rolling massage, such as the back of the legs. The Fascia Ball is suitable for precise massage of small areas of deep fascia, such as the plantar crevice, and the Stick can be used for pointing or rolling on specific areas, such as the muscles and fascia at the back of the leg.

The use of tools for fascial massage is more suitable for self-fascial massage or in some fitness and rehabilitation scenarios than hand-pressing. On the one hand, the rational use of tools can be more accurate and stable control of the massage strength and direction, such as the fascial gun can be adjusted through the gear to achieve a specific intensity of stimulation, for the deeper layers of fascia and muscle can be effective. On the other hand, tool massage can expand the scope of action of the massage, such as foam shaft can cover a large area of the back muscle groups, to enhance the efficiency of the massage. In addition, tools massage can reduce the physical burden of the massage practitioner, such as fascial gun can realize self-massage, convenient and quick. Fascial massage using tools such as the foam shaft has been reported to alter tissue extensibility (Curran et al., 2008) and restore reduced tissue length (Junker &Stoggl, 2015). (Patel G R, Vedawala N. 2023) Studies have concluded that the use of a fascial gun to release fascial pain is more effective in relieving neck pain and improving neck mobility and improving TMJ function.

Numerous studies to demonstrate that foam shafts and fascial guns play an effective role in self-fascial release (Beardsley & Skarabot, 2015). Compared to other tools, the foam shaft has the advantage of being able to use the body's own weight to carry out large-area rolling massage, which is easy to operate autonomously and can effectively relax the fascia of large muscle groups in the back; while the fascial gun has the advantage of being able to relax the muscles and fascia more efficiently and deeply through high-frequency vibration compared to other massage tools and is easy to operate, allowing for precise control of the massage area and intensity on one's own, and the fascial gun can serve as a standardized tool in terms of time, intensity, and convenience, as well as in terms of time, intensity, and convenience, as compared to manual massage. can be used as a standardized intermediary application in terms of time, intensity, and convenience, and has the advantage of being self-applicable to a variety of areas in addition to specific areas (Choi & Yoon, 2020). Foam shafts typically come in two sizes, standard (6 inches by 36 inches or 5 centimeters by 90 centimeters) and half size (6 inches by 18 inches or 5 centimeters by 45 centimeters) (Cheatham et al., 2015). Foam shafts are usually made of expanded polyethylene high-density foam (Couture et al., 2015). Foam shafts for fascial massage are all designed to transfer pressure to the target tissue, the operator places their weight on the foam shaft which transfers the pressure to the target tissue and then the operator performs a rolling motion Cheatham et al.Studies in the literature have shown that foam shafts for fascial massage have a positive effect on the improvement of upper cross syndrome and can be effective in preventing muscle adhesions (Halperin et al., 2014). Vibrating foam shafts combined with elastic band training for upper crossed syndrome can effectively improve pain and motor function in patients (Chao-Ping Tang, 2019).Cheatham S W et al. SMR using foam shafts or roller massagers appears to have a short-term effect on increasing joint ROM without negatively affecting muscle performance and may help to attenuate the decline in muscle performance and DOMS after high-intensity exercise (Cheatham S W, Kolber M J, Cain M, 2015). Individuals who perform fascial relaxation with a foam shaft feel a significant reduction in the intensity of neck pain and improved neck mobility (Saratcha ndran & Desai, 2013), making it a suitable fascial massage tool to use for office workers to improve upper cross syndrome. The Fascia Gun, full name is Myofascial Relaxation Massage Gun (Fascia Gun), is a new soft tissue rehabilitation instrument, which can be understood as a portable version of electric Deep Muscle Stimulator (DMS). (Mengman, S., 2023) The massage gun can be used between groups. When muscle tension is felt, the fascial gun can be used for about 15 seconds with the aim of stimulating the muscles.Use the Fascial Gun between sets to reactivate tired muscles and prepare them for the next set; Post-exercise: The body is in a state of high tension and needs a relaxing massage. Target tense muscles for about 1-2 minutes. Target the muscle bellies, avoiding joints and bony areas. After a busy day of relaxation, the myofascial gun can be used for about 10 min, the intensity should not be too high, massage a muscle group not more than 1 min. Lin Longjie, Huang Peng study used a fascial gun with a rotational speed of 3200r/min, the use of fascial guns to relax the patient's tense and shortened muscles, to restore the normal hydrostatic balance of the muscles, mainly for the upper trapezius, pectoralis major, and pectoralis minor muscles of the patients with the upper cross syndrome. Fascial gun therapy was applied to the upper trapezius, pectoralis major, and pectoralis minor muscles of patients with upper crossed syndrome, and the head forward tilt angle, rounded shoulder angle, and acromial distance of patients with upper crossed syndrome decreased, which indicated that the symptoms of head forward tilt and rounded shoulder and thoracic embrace of the patients had been effectively improved (Lin, L. J., & Huang, P. , 2023). The study surface foam shaft and fascial gun can effectively improve cervical ROM, pain, and upper trapezius muscle tone, which can be applied for improving cervical range of motion, pain, and muscle tone in subjects with neck pain (Ju, S K, 2023), and thus improving upper crossed syndrome. Therefore, in this study, foam shaft and fascial gun were mainly used in the selection of fascial massage tools. The specific operation method of the foam shaft was to stay for 15 seconds when finding the muscle sore spot; when the soreness decreased, the foam shaft was utilized to roll over the relaxation area for 15 times. The specific operation method of the fascial gun is to place the gun head in the relaxation area to move in a slow, even manner, and massage for less than 1 minute.

3.4 Effect of fascial massage on upper cross syndrome

Upper crossed syndrome is a common postural problem with poor posture, the main features of which include rounded shoulders, hunched back, and forward tilt of the head, which is closely related to factors such as muscle tension and fascial adhesions. Fascial massage as a physical therapy has received much attention in recent years in improving upper crossed syndrome. (Moore M K. 2004) discusses the therapeutic management of upper crossed syndrome and cervicogenic headaches, mentioning the use of chiropractic care, myofascial release, and exercise. The study showed that in the treatment of one patient, who was adjusted using a high-speed, short-lever arm manipulation procedure (Diversified Technique) and given myofascial fascial release and cryotherapy, the patient's symptoms improved and the headaches did not recur in subsequent rehabilitation, and this literature explores the principles of upper crossed syndrome and the role of related fascial therapies. Langevin et al. suggested that decreased relative sliding between the fascial layers was responsible for low back pain, and that fascial massage increased the distance the fascia traveled and contributed to the relief of low back pain. It has also been suggested that pain relief is associated with improved circulation with fascial massage. Fascial massage training improves vascular function, increases circulation, reduces tissue swelling, accelerates muscle lactate drainage, promotes inflammation elimination and tissue repair, and ultimately reduces muscle pain (Langevin et al., 2011).Jiang, et al. suggested that the combination of the Fascial Balancing Technique and exercise therapy could significantly improve the FHA and FSA of UCS students, reduce the total score of sagittal static assessment, thus correcting the poor posture and adjusting the posture of UCS, and its efficacy was better than exercise therapy alone (Jiang, F., et al.,2020). Fascial massage can relieve chronic neck pain with better results. by relieving tense fascia in the neck and shoulders. It can be effective in reducing chronic neck pain (Brück, K, et al., 2021).Fascial tightness is a common cause of chronic neck pain that is often overlooked and can further lead to neck disability and limited range of motion, but myofascial release can be beneficial in both acute and chronic cases. Research findings have shown that fascial therapy and fascial manipulation techniques are equally effective in improving pain, range of motion, and function in the management of neck pain, with fascial therapy showing more improvement in cervical extension and right-sided flexion range of motion compared to fascial pushing techniques (Batool, Shakil-ul-Rehman et al., 2023). It provides a reference point for improving tight muscle problems caused by upper crossed syndrome through fascial massage.Tianhao Chen proposed a holistic view of applying fascia to improve the quality of flexibility, arguing that the key to reducing the rate of joint injuries lies in improving the flexibility of the adjacent large joints to minimize the effects of adverse force lines, and that the flexibility and mobility of the shoulder joint can be well improved by applying fascial massage to the latissimus dorsi, pectoralis major, deltoid, teres major, teres minor, supraspinatus, and infraspinatus muscles surrounding the shoulder joint (Tianhao, C. 2018).Constructing a human motor chain model based on the myofascial chain theory, it was pointed out that weak links and motor compensations may appear in the human motor chain due to various factors, which affects the motor function (Niu Yonggang., 2016). The weak links appearing in Niu Yonggang's model may be related to muscle imbalance in upper crossed syndrome, providing a new perspective for understanding and improving upper crossed syndrome. The relationship between fascial massage and upper crossed syndrome has also been addressed in some rehabilitation medicine or physical therapy related studies.For example, in some studies on comprehensive rehabilitation treatment of upper crossed syndrome, fascial massage is used as one of the treatments, which is combined with other treatments, such as exercise training and physical factor therapy, to observe its effect on the improvement of patients' symptoms. In clinical practice, fascial massage as an important part of the integrated treatment of upper crossed syndrome, combined with other rehabilitation training methods, to provide patients with more effective means of treatment, to help improve the quality of life and physical function.

To summarize, fascial massage, as an important therapeutic modality for the human fascial system, has a profound historical origin and constantly developing modern theoretical techniques. From the point of view of its mechanism of action, in terms of mechanics, it can repair the abnormal elasticity and tension of the fascia caused by poor posture, excessive exercise or injury, and promote the exchange of fluids within the fascia to maintain its normal function; in terms of neurophysiology, it can stimulate the fascial receptors to alleviate the pain; in terms of biochemistry, it can help to accelerate the local blood circulation, remove metabolic wastes, and alleviate the muscular tension and aches and pains. These mechanisms of action explain the positive significance of fascial massage on the recovery of body functions in an all-round way, and also provide theoretical support for its application in the treatment of upper crossed syndrome. From the classification point of view, fascial massage can be divided into unarmed and tool-assisted two categories. Unarmed fascial massage can be flexibly perceived and adjusted by virtue of the massage therapist's two-handed operation; tool-assisted massage, with the help of foam shafts, fascial guns and other tools, can more accurately and efficiently expand the scope of massage and control the intensity of the massage, which is widely used in self-massage and rehabilitation, fitness scenarios, among which, the foam shafts and fascial guns have a significant effect on improving the state of the myofascial muscles, especially in the improvement of the cervical spine activities related to the upper crossed syndrome, pain, and muscle tension. muscle tone associated with upper crossed syndrome.

Upper crossed syndrome is characterized by rounded shoulders, hunchback and forward head tilt, which are closely related to muscle tension and fascial adhesion. Fascial massage is closely related to upper crossed syndrome, and it is one of the effective physical therapy tools to improve upper crossed syndrome. Numerous studies and clinical practices have shown that fascial massage, either alone or in combination with other treatments, is effective in improving symptoms in patients with upper crossed syndrome. This close relationship is important for this paper to study the effect of Pilates training combined with fascial massage on upper crossed syndrome. It provides a theoretical basis and practical reference for the study of Pilates training combined with fascial massage, and helps to understand the possible synergistic effects when the two are combined in the treatment of upper crossed syndrome, for example, they may promote each other in the improvement of muscular balance and the alleviation of fascial adhesion, which may be more effective in improving the posture and reducing the symptoms of patients with upper crossed syndrome, and in improving the patients' quality of life and physical function. It can help us better understand the role of fascia in upper crossed syndrome and provide direction and basis for subsequent research and clinical application.

4 . A study of the correlation between Pilates training, fascial massage and upper crossed syndrome

Anatomically, upper crossed syndrome involves tension and imbalance in the pectoral and trapezius muscles and other muscles, resulting in adhesions and contractures in the fascia as well. Fascial massage works directly on the fascia to loosen adhesions and restore its elasticity. Pilates, on the other hand, focuses on the body's core control and precise muscle activation, strengthening weak muscles and improving muscle strength balance through specific movements. When Pilates is combined with fascia, on the one hand, Pilates training can further stimulate the fascia to play a better role in supporting and transmitting strength; on the other hand, the improvement of the fascia can also enhance the effect of Pilates training, so as to make the body's movement control and postural adjustment more precise and efficient. Therefore, it is likely that the combination of Pilates and fascia will produce better improvements in upper cross syndrome and be more effective than Pilates training alone. However, more empirical studies are needed to test this hypothesis.

Karkousha RN et al. randomized 40 UCS participants (females) into 2 groups, Group A (control) and Group B (experimental), both of which received 2 sessions per week for 4 weeks. Both groups received 2 treatments per week for 4 consecutive weeks. group A received a traditional physiotherapy program including stretching, strength and postural correction exercises while group B received a Pilates exercise program. The primary outcome measures were balance, spinal curvature, craniovertebral angle (CV), and rounded shoulders, while the Neck Disability Index (NDI) and Visual Analog Scale (VAS) were used as secondary outcome measures. Measurements were recorded before and after treatment. The results showed that a Pilates training program was superior to a traditional physical therapy program in improving spinal curvature, balance, and function, as well as reducing pain in patients with UCS (Karkousha RN, Yousef JE, 2024). This provides a basis for understanding the role of Pilates training in upper cross syndrome and also serves as a comparison and reference for studying the effects of combining it with fascial massage.

Senthilkumar P K et al. investigated the combined effects of myofascial trigger point therapy and rehabilitation exercises on male software professionals with upper cross syndrome. Results showed that patients in the treatment group reduced pain intensity and improved joint mobility and neck flexor index. A treatment program consisting of myofascial trigger point therapy and rehabilitation exercises may be more effective in reducing pain intensity and improving range of motion (ROM) and cervical flexor indices in male software professionals with upper crossed syndrome （Senthilkumar P K）.Patel G R et al. found that myofascial release therapy and myofascial related therapies with corrective exercises were effective in reducing pain and functional disability, increasing cervical spine range of motion, and better postural development (Patel G R). were effective (Patel G R, Vedawala N, 2023). This suggests that fascia-related massage or therapy may alleviate symptoms of upper crossed syndrome by acting on related tissues such as myofascia and modulating their physiology. Previous studies in the literature have also shown that the use of foam shafts and fascial guns as fascial massage tools have shown significant results in improving UCS. Fascial massage is mainly used to improve UCS by relaxing the tense muscles and fascial adhesion, while Pilates training is mainly used to strengthen the weak muscles, whether the combination of the two has a better effect on the improvement of UCS needs to be studied in depth.

The effects of Pilates exercises and myofascial release on balance, trunk muscle endurance and flexibility in patients with multiple sclerosis showed that Pilates exercises combined with myofascial release were effective in improving functional balance in patients with MS (Hosswini A H, Sedaghati P, 2022). It suggests that Pilates training and myofascial massage may have a positive effect on the improvement of postural balance, providing implications for this paper to combine the two to improve upper crossed syndrome. Pilates training adjusts body posture by training muscle strength and control, whereas fascial massage addresses factors that interfere with proper body alignment due to fascial issues. The combination of the two may more comprehensively target the causes of abnormal body posture in upper crossed syndrome, e.g., while strengthening the back muscles through Pilates training to improve hunchback, fascial massage relaxes the thoracic fascia and reduces its pull on the body posture, resulting in a better correction of body posture. This paper combines the two modalities to verify whether they have significant improvement effects on upper cross syndrome in office workers, and compares the differences in the effects of single Pilates training and Pilates training combined with fascial massage.

5. Study of relevant test indicators

5.1. cervical range of motion

5.1.1 Front head angle, front shoulder angle (FHA, FSA)

(Zhang Enming, 2016) In a study on the morphological characteristics of deep neck muscles and their correlation with neck and shoulder posture in female chronic neck pain patients, the anterior head angle (FHA) and the anterior shoulder angle (FSA) were measured using a static postural assessment and posture screening system. (Thigpen CA 2009) et al. also used the Static Posture Assessment and Posture Screening System method to obtain FHA and FSA values in their study of the effects of head and shoulder posture on scapular mechanics and muscle activity during overhead work. (Zhihua, Z.,2023) In the study of the effects of different sports programs on the intervention of cervical lordosis in general college students, static postural assessment was performed using a head posture spinal curvature meter to measure FHA and FSA.The head anterior angle is a commonly used index for assessing the neck posture at rest in patients with cervical lordosis, and it has been widely used in clinical assessment and diagnosis with a certain degree of validity. If the value of the head anterior angle is too large, reaching more than 46°, it shows cervical scoliosis (Shaghayegh FB , 2016). Round shoulder, also known as thoracic shoulder, is a semicircular arc formed by bending the shoulder forward. The angle of the round shoulder is greater than 52°. Symptoms of scapular anteversion and kyphosis are manifested as rounded shoulders when the acromion is anteriorly displaced (relative to the 7th cervical spinous process) and the earlobe is located anteriorly to the acromion, with a vertical distance of ≥1 CM between the two.

5.1.2 Cervical spine range of motion (ROM)

ROM in the medical field usually refers to the Range of Motion (ROM) of a joint. From an anatomical and physiological point of view, it refers to the maximum amount of movement that a joint is able to make in all directions, reflecting the flexibility and functional status of the joint. (Mckee MD 2000) argues that ROM is an extremely important and commonly used assessment method in rehabilitation medicine. For patients with limb movement dysfunction due to various reasons, in addition to examination before treatment, several evaluations during and after treatment are required to determine the effectiveness of treatment and the patient's final functional status. The commonly used examination tools are the universal protractor and the square disk protractor. (Song Fan 2002) in a study on the effects of different examiners and different examination tools on cervical mobility found that the square disk protractor was reproducible and reliable in testing cervical mobility. (Li Junpeng 2002) concluded that the cervical mobility meter (CROM) is one of the more studied cervical mobility measurement devices. The advantage of the cervical mobility meter over a simple inclinometer is that it does not require the measurer to repeatedly change position while measuring another facet. (Youdas 1991) studied a variety of measurement methods and concluded that the cervical mobility meter is superior to general gauges and visual inspection. (Hole,1995) also concluded after a comparative study with a single facet meter that the meter was significantly more reliable than a single facet meter. Researchers such as Yongtai Xue 2019 found that the protractor and motion analysis 3D motion capture analysis system had better measurement consistency and higher repeatability. (Li Junpeng 2002) argued that changes in cervical spine mobility are important to reflect the function of the cervical spine. The normal mobility of the cervical spine is 35-45° of flexion and extension in the neutral position, 45° of lateral bending from side to side, and 60-80° of rotation from side to side. The study showed that the cervical extension and flexion mobility was (83.31±27.42)° in normal people ≤55 years old, and (74.85±6.38)° in ≥55 years old, with no significant difference between men and women, while the cervical extension and flexion mobility of patients with cervical spondylosis was significantly decreased. This suggests that cervical spine mobility is clinically important for the early diagnosis of cervical spondylosis, judgment of cervical spine segment function and localization diagnosis.

In summary, changes in cervical ROM are very important for reflecting the function of the cervical spine, and ROM is also an extremely important and commonly used assessment method in rehabilitation medicine. Evaluation of patients with limb motor dysfunction due to various causes can determine the treatment effect and the final functional status of the patient. In the selection of testing instruments, the square disk protractor was finally chosen because of its good reproducibility, high reliability, and simplicity in testing cervical ROM.

5.2 Surface electromyography (sEMG)

Surface electromyography (sEMG) is academically defined as the bioelectrical signals recorded from the surface of a muscle via electrodes during the activity of the neuromuscular system. madelecineP (Madeleine, Xie, Szeto, & Samani, 2016) found that the bioelectrical signals captured by surface electromyography (sEMG) during human movement can to a some extent reflect the state of neuromuscular activity and level of function. sEMG was first applied in competitive sports to explore the order of recruitment and the proportion of activation of each muscle during the completion of a given movement. Today, sEMG is widely used to assess changes in shoulder and neck pain, changes in muscle function after fatigue, and changes in muscle dysfunction. sEMG is analyzed mainly by time-domain and frequency-domain metrics. Frequency domain analysis is to analyze EMG signals in the frequency dimension, which can reflect the changing state of neuromuscular fatigue. Median frequency (MF), mean power frequency (MPF) and median frequency slopes (MFs) are frequency domain indicators of EMG signals. MPFs and MFs are commonly used to determine muscle fatigue when it occurs during dynamic or static movements. For example, when the EMG spectrum shows signs of shifting to the left, indicating muscle fatigue, the MPF and MF of the EMG spectrum will decrease, suggesting that the muscle has insufficient tolerance and poor fatigue resistance. Therefore, when muscle fatigue and fatigue resistance increase, MPF and MF will increase. Zhu Qingguang et al. (Zhu Qingguang, 2012) observed the effects of manipulation and traction on patients with cervical spondylosis and found that the MPF and MF of neck muscles in the manipulation group were significantly higher than those in the traction group, suggesting that neck muscle fatigue in patients with cervical spondylosis can be improved by combining muscle relaxation and joint repositioning techniques.

5.3 Change in pain level (visual analog score, VAS)

Accurate assessment is a prerequisite for treatment, and efforts have been made at home and abroad to integrate an assessment scale that can both distinguish the nature of pain and clarify pain intensity. Currently, studies usually use the Visual Analog Scale (VAS) to assess pain intensity, which has high reliability and validity, and is especially more sensitive than the McGill Pain Questionnaire in assessing muscle pain. The Visual Analog Scale (VAS) is a common clinical measure of pain intensity. It allows for more objective scoring and more objective evaluation of the effectiveness of pain treatment. It has the following advantages: (1) objective, sensitive, and intuitive; (2) easy to be understood by subjects; (3) requires less money; (4) quick and easy to administer and record; (5) suitable for frequent reuse; and (6) suitable for use by untrained personnel. Zhou (Zhou, Petpichetchian, & Kitrungrote, 2011), after using the Pain Assessment Scale (PAS) with chronic pain patients and healthy patients of different ages, concluded that the VAS was the most acceptable, simple, and least misunderstood scale in terms of face validity. The Visual Analog Scale (VAS) was introduced by Huskisson EC in 1974. According to the VAS scoring system, the mean performance of mild pain is 2.57 ± 1.04; for moderate pain, the mean is 5.18 ± 1.41; and for severe pain, the mean is as high as 8.41 ± 1.35. This data provides us with specific quantitative information about the performance of the different pain levels on the VAS scale, which helps us to more accurately assess and understand pain levels (Heller GZ, 2016). Higher levels of shoulder and neck pain in subjects indicate more severe upper crossed syndrome pain symptoms.

5.4 Neck Disability Index (NDI)

The Neck Disability Index (NDI), introduced in 1991 by Vernon H et al. The NDI questionnaire was designed and developed to quantify the impact of cervical spine dysfunction on daily life.Cote P (Côté, Cassidy, Carroll, & Kristman, 2004) states that the NDI was developed from the Oswestry Low Back Pain Index and was originally designed to assess cervical spine dysfunction in patients with neck pain and acute neck sprains, assessing neck pain and associated symptoms, as well as the impact on the ability to perform activities of daily living, and is therefore applicable to a wide range of cervical spine disorders; Ralph E et al. (Gay, Madson, & Cieslak, 2007) found the NDI to have good validity and reliability, is applicable to many types of cervical spondylosis, and is widely used in English-speaking countries, (Gay, Madson, & Cieslak, 2007) found that the scale has good validity and reliability, is applicable to many types of cervical spondylosis, and is widely used in English-speaking countries. In recent years, the NDI has been translated into French, Swedish, Dutch, Brazilian, Korean, etc. Ackelman B, Vos CJ, Cook C, Lee H, et al. conducted a related validity and reliability study of the (NDI), which showed that the translated version of the scale is suitable for the respective countries with good validity and reliability (Ackelman & Lindgren,. 2002).

In summary, testing for upper crossed syndrome involves several aspects of metrics and methods.

In terms of cervical range of motion, the anterior head angle (FHA) and anterior shoulder angle (FSA) are important parameters to assess. Measurement of the anterior head angle and anterior shoulder angle is carried out by forming an angle with a specific delineation and connection. The anterior head angle assesses the neck posture at rest in patients with cervical kyphosis, and a large value suggests that the cervical spine is anteriorly convex; and the indicators related to the anterior shoulder angle can be used to determine the condition of rounded shoulders. Cervical joint mobility (ROM) is extremely important in rehabilitation medicine, and is commonly measured by universal protractor and square disc protractor, among which the square disc protractor has the advantages of repeatability and reliability.ROM test requires the subject to sit, the researcher will place the protractor according to specific operations and record the degrees of cervical joints in different directions, and take the average value of the measurements several times, and the normal cervical spine mobility ranges from about 35-45 degrees of forward flexion, about 35-45 degrees of backward extension, and about 35-45 degrees of backward extension. Normal cervical spine mobility ranges from forward flexion of about 35-45 degrees, backward extension of about 35-45 degrees, left and right lateral flexion of about 45 degrees each, and left and right rotation of about 60-80 degrees each, whereas cervical spine extension and flexion mobility is significantly decreased in patients with cervical spondylosis, indicating that cervical spine mobility is clinically important for the diagnosis of superior cruciate syndrome, among other things.

Surface electromyography (sEMG) can reflect the state of neuromuscular activity and function level, which is analyzed by time-domain indicators and frequency-domain indicators. Frequency-domain analysis is commonly used to analyze the median frequency (MF), mean power frequency (MPF), and slope of median frequency (MFs), etc. When muscle fatigue occurs, the MPF and MF decrease, and the improvement of neck muscle fatigue can make the MPF and MF increase. The ME6000 Telemetric EMG Tester was used to collect the EMG signals, and the MegaWin software was used to convert the data and calculate the parameter values. The electrodes were placed according to specific requirements, and the pectoralis major, upper and lower trapezius muscles were selected as the test muscles. The electrodes were attached after wiping the skin according to the specified steps, and the subjects were required to carry out preparatory activities before the maximal voluntary isometric contraction test, and there were different requirements on the movement of different muscles during the test.

The change of pain level was assessed by the visual analog scale (VAS) method, which has high reliability and validity, and has the advantages of objectivity, sensitivity, and intuition, etc. Subjects ticked a 10-cm line with a scale according to their own shoulder and neck pain, and the different pain levels were quantified with the corresponding mean values, which could be used to more accurately assess the pain level.

The Neck Disability Index (NDI) was developed by Vernon H et al. and is applicable to a wide range of cervical spine disorders, with good validity and reliability, and is available in translated versions in several countries.The NDI questionnaire consists of 10 self-reported questions covering multiple dimensions, with 6 response options for each question, and the degree of dysfunction can be determined based on the total score, which can be categorized into different grades such as no apparent dysfunction, mild, moderate, severe, and profound dysfunction, etc. The NDI questionnaire can be used as a tool to assess the degree of dysfunction. There are different levels of dysfunction such as no apparent dysfunction, mild, moderate, severe and very severe dysfunction. These tests provide a comprehensive and scientific basis for the assessment and study of upper crossed syndrome from different perspectives.

CHAPTER 3

RESEARCH DESIGN

This chapter describes the overall design of the study, including test subjects, instrumentation, data collection procedures, and training program development. Among them, the test subjects were the personnel with upper crossed syndrome (UCS). The instrumentation was 3D body analyzer, telemetry EMG tester, joint activity tester, and visual analog scoring. In terms of test subject selection, the inclusion and exclusion criteria for test subject selection and the detailed operation process of the test data collection program were introduced. In order to ensure the quality and effectiveness of the training, this chapter demonstrates the specific method of fascial relaxation and the specific program of Pilates training intervention, and the overall research framework is as follows.

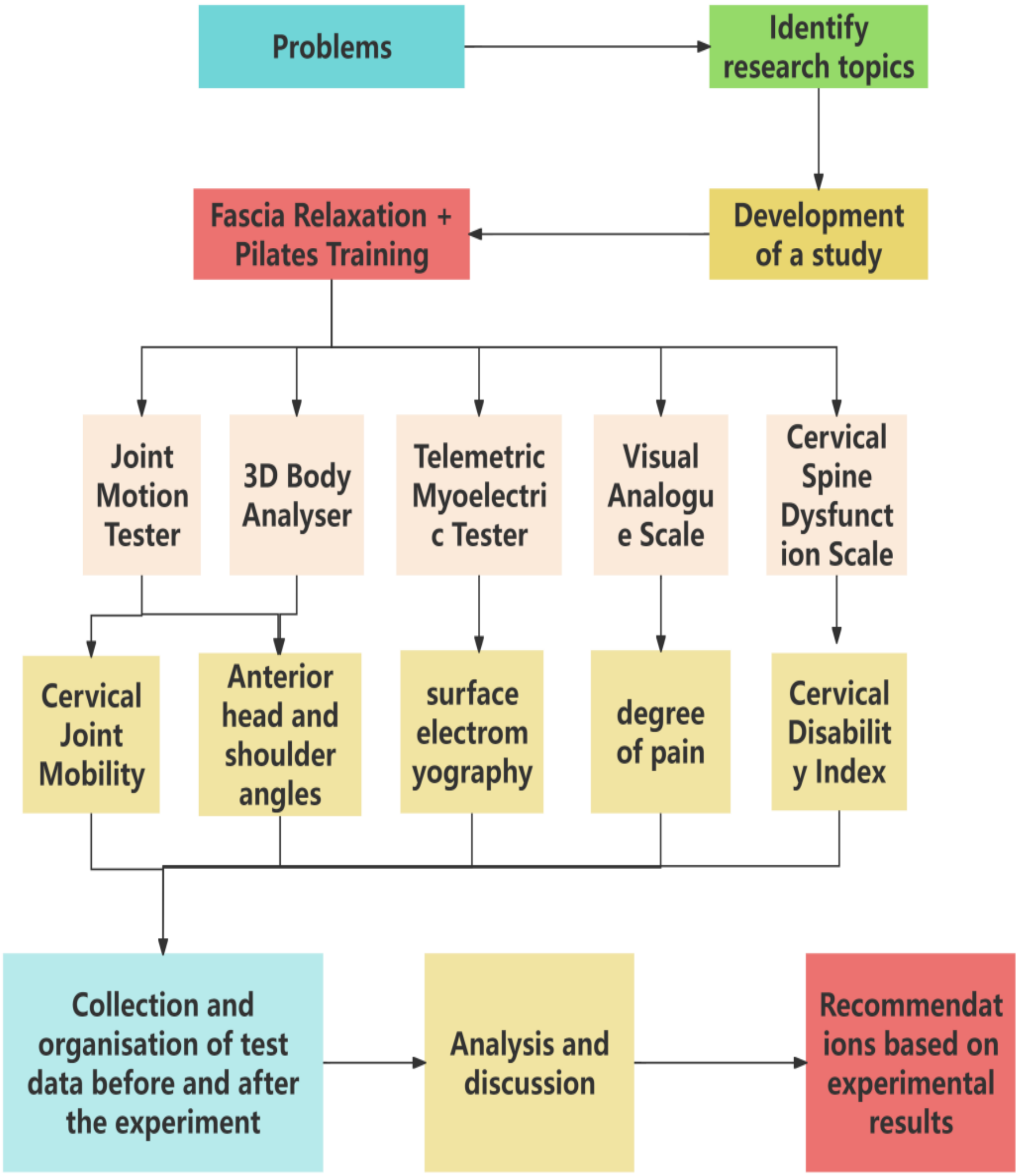


Figure 2 Research Framework

1. Pre-experiment

1. Purpose of the experiment

The purpose of this pre-trial is to preliminarily validate and verify the improvement of Pilates-related interventions on the symptoms of patients with upper crossed syndrome. The specific assessment indexes cover five aspects: anterior head angle (FHA), anterior shoulder angle (FSA), cervical spine range of motion (ROM), surface electromyography (sEMG), visual analog score (VAS) and neck disability index (NDI) in order to comprehensively evaluate the effect of Pilates training combined with myofascial massage on the alleviation of symptoms of upper crossed syndrome.

2. Trial Subjects

Subjects will be recruited both online and offline to ensure that they are between the ages of 25 and 60 and meet the diagnostic criteria for upper crossed syndrome. Online recruitment will be done through the use of WeChat social media platforms, while offline recruitment will be done through public lectures, posters and flyers. Ten subjects are planned to be recruited and divided into two groups for pre-testing, with five in each group, to ensure that these subjects have not participated in similar studies and promise not to repeat into subsequent experiments.

3. Experimental Methods

(1) Grouping and intervention

Grouping: 10 subjects were randomly divided into two groups of 5 each. One group was pretested with Pilates training + fascial massage (hereinafter referred to as "test group"), and the other group was pretested with Pilates training only (hereinafter referred to as "control group").

Intervention:

Control group: Pilates training in accordance with the established protocol, focusing on strengthening shoulder and spinal mobility to improve posture and reduce symptoms of upper crossed syndrome.

Experimental group: On the basis of Pilates training, add myofascial relaxation and activation training, such as rolling massage with a fascial gun or foam shaft, targeted muscle stretching, etc., in order to promote myofascial flexibility and blood circulation, to relieve muscle tension and pain, and then Pilates training in accordance with the established program.

(2) Training cycle and data collection

Training cycle: the pre-testing cycle was September-November 2023, a total of 3 months. Both groups of subjects completed the scheduled training program within the same time period.

Data Collection: Before the start of the pretest, at the end and at key time points in between, the above five assessment indicators were measured and recorded for both groups of subjects. Specifics included, but were not limited to: measurement of angular changes in FHA and FSA using specialized equipment; assessment of ROM by means of a cervical mobility tester; recording of sEMG data using a surface electromyograph; assessment of subjects' pain level using the VAS scale; and application of the NDI questionnaire to assess the impact of neck dysfunction on daily life. Subjects were also encouraged to record training logs and subjective feelings for a more comprehensive understanding of the intervention effects.

4.Test analysis and results

(1) Data organization and analysis: the collected data were organized and counted in excel to ensure the accuracy and completeness of the data. Statistical analysis: Independent sample t-test, ANOVA, etc. were used to statistically analyze the assessment indexes of the two groups of subjects.

(2) Difference analysis: the assessment indexes of the two groups of subjects were compared horizontally and vertically, and after independent samples t-test, the data of the two groups were significantly different ($P < 0.05$) Through statistical analysis, it can be initially judged that Pilates has a significant improvement effect on the symptoms of the upper cross syndrome. However, the experimental group showed

a better improvement effect than the control group group in a number of assessment indicators.

5. Conclusion

Based on the data analysis and comparison of differences in the trial results, the following conclusions were drawn:

Pilates training interventions have a positive effect on symptom improvement in patients with upper cross syndrome. Adding fascial massage to Pilates training further improves symptom improvement in patients. Pilates training + fascial massage had a more significant advantage in improving the anterior head angle, anterior shoulder angle, cervical spine range of motion, visual analog score (VAS), and neck disability index (NDI), but the variability of surface electromyography and other indicators was not significant. The improvements in visual analog scores and neck disability index verified the positive effects of Pilates and Pilates + Fascial Massage on patients' subjective perception and quality of daily life. In summary, this pre-test preliminarily verified the effectiveness of Pilates training and Pilates training + fascial massage in the treatment of upper crossed syndrome, which provides strong support for further in-depth research and promotion.

2. Experimental Research Process

The experimental research process included randomized grouping, experimental apparatus, experimental period, test items, data collection procedures and statistical analysis.

According to the pre-test results and related literature review, different exercise therapies for upper crossed syndrome were analyzed, and the upper crossed rehabilitation test indexes were finally set; combined with the suggestions from expert interviews, the Pilates training program was finally determined. In this study, the working population with upper-cross syndrome was used as the research subjects; it was determined that the training cycle of the experimental group was 12 weeks (3 months), and the experimental group performed 10-minute fascial relaxation training before Pilates exercise, and then Pilates training was performed 3 times a week for 1 hour each time (each session consisted of 10-minute warm-up, 45-minute arousal training, spinal flexibility training and weight-bearing training, and 5 The control group only performed Pilates training 3 times per week for 1 hour (each session consisted of a 10-minute warm-up, a 45-minute wake-up, spinal flexibility and weight training, and a 5-minute relaxation and easing exercise).

The results of the study are as follows: compare the cervical spine dysfunction index, cervical spine joint mobility, pain level, surface electromyography and other indexes before and after the experiment of the patients with upper crossover, empirically test the effect of Pilates training combined with fascial massage on promoting the upper crossover syndrome of the office population; formulate a Pilates training program to improve the poor posture of the patients with the upper crossover syndrome of the office population; and put forward specific countermeasures for the prevention and improvement of the problems of the upper crossover syndrome of the office population. To develop a Pilates training program to improve the poor posture of office workers with upper crossed syndrome. To propose specific countermeasures to prevent and improve the problem of Upper Cross Syndrome in the office population, and to improve the posture and cervical spondylosis subhealth of the office population. The following is the roadmap of the experiment.

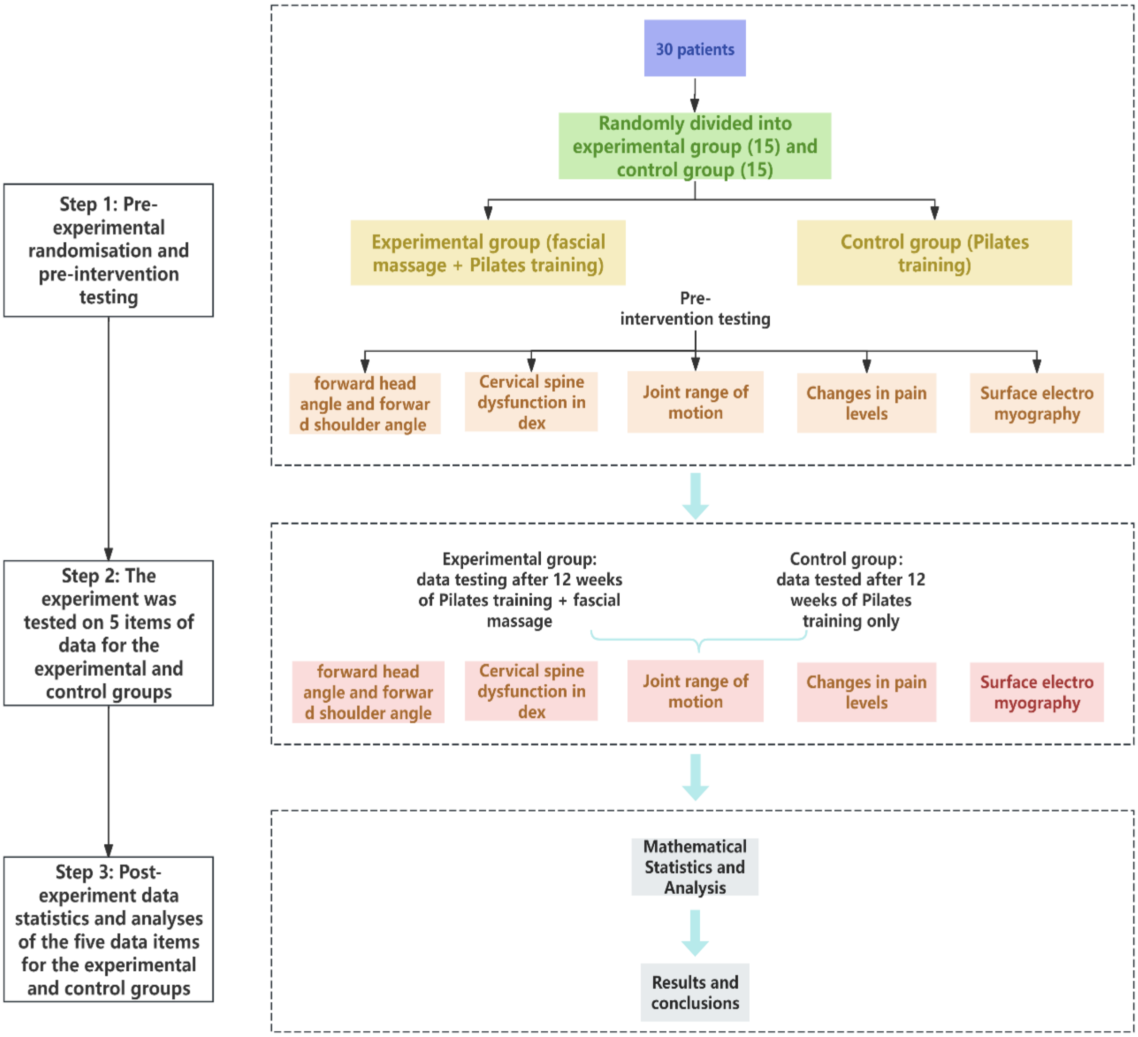


Figure 3 The research roadmap

3. Pilates Training Program Development

The Pilates training program in this study was based on the combined opinions of five experts and the pathogenesis of UCS (Muscle Imbalance Theory) to determine the asanas, the duration of the asana practice, the number of times the different asanas should be practiced, and the intervals between Pilates training.

The study was designed in four parts with the following objectives: in the first part, the experimental group was targeted to relax overly tense muscles (upper trapezius bundle, pectoralis major, etc.) through fascial training. This part was implemented in the experimental group only; see Appendix A for details of the fascia gun and foam shaft for fascial massage.In the second part, both the experimental and control groups underwent warm-up exercises and and designed movements to re-educate the subjects' posture in the pelvis, spine, and head and neck postures for postural re-education and to develop their proprioception and awareness of the neutrality of the body (spine, pelvis, etc.). Then, asanas such as breathing and pelvic clock are used to activate the body so that the subjects can gradually shift their attention to themselves and enhance their ability to concentrate and control their bodies.Breathing training, pelvic clock are the most basic of all movements, good breathing patterns and pelvic movement control are key to practicing advanced asanas. The third part was joint flexibility and muscle training. Both the experimental and control groups were trained to flex the spine through spinal rolls, neck extension exercises, and seated spinal rotation to improve flexibility of the spine, promote joint alignment of the spine with the pelvis, and thus improve the abnormal physiological curvature of the spine in the UCS population. Spinal rolling and seated spinal rotation exercises can increase the flexibility of the cervical and thoracic joints and promote the improvement of cervical and thoracic joint mobility, as well as to prepare for the later weight-bearing training; in addition, through the seated oblique muscles, one-legged retracement, freestyle and other asanas in the unarmed training, it can change the abnormal order of muscle recruitment in the UCS population, and enhance the strength of the muscles of the back (obliques, obliques, etc.) and core muscles (lumbar and back muscles, etc.). (low back muscles, etc.) and core muscles (low back abdominal muscles and gluteal muscles, etc.), thus strengthening the core muscles (low back abdominal muscles and gluteal muscles, etc.). In the fourth part, the experimental group and the control group went through relaxation and easing exercises to gradually restore the subjects' body and mind to a stable and relaxed state.

1-4 weeks: the main purpose is to let the trainee better adapt to the movement principles and requirements of Pilates, understand the movement essentials, re-educate the trainee's brain through Pilates asana, so that the trainee can establish the correct proprioception and movement patterns (correct muscle activation sequence), the time schedule of asana and the determination of the basis of asana are the same as the above, in order to reflect the principle of gradual progression, we set the number of repetitions for the first stage of training at 10 times. In order to reflect the principle of gradual training, we set the number of repetitions of the first phase of training to 10 times, the rest time between asanas to 10 seconds, the rest time between groups to 20 seconds, the rest time between asanas and the rest time between groups refer to the “Mat Pilates Teacher Training” settings, as shown in Table 1.

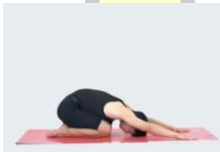
5-8 weeks: On the basis of the previous training, more inhibited (weak) muscles were mobilized to participate in the correct movement pattern, so that the subjects could enhance the nervous system's ability to control the muscles in the process of exercise, and to strengthen and consolidate the training effect of the 1-4 weeks. At the same time, as the subjects' physical function continued to adapt and improve, we increased the number of repetitions of the training and reduced the rest time between sets, setting the number of repetitions for the second phase of training at 15, the rest time between asanas at 10 seconds, and the rest time between sets at 15 seconds.

9-12 weeks: Based on the training in weeks 1-8, subjects were allowed to gain better body control during the integrated movements, restore the original biomechanics of the spine, and allow the stabilizing and power muscles of the pelvis, shoulders and neck to play their respective roles, thus making the musculoskeletal system of the body more balanced. At the same time, we have reduced the rest time between asanas and sets by setting the number of repetitions in Phase III at 15, with a 5-second rest time between asanas and a 10-second rest time between sets.

Table 1 Pilates exercise intervention program

Training Phase	Exercise Program	Target muscle	Photograph	Training repetitions (rep/s)	Number of training sets (s)	Length of rest between asanas (s)	Intergroup rest Duration of rest (s)
Fascial relaxation (note: experimental group only)	Using a fascial gun to relax the upper trapezius, sternocleidomastoid, pectoralis major and pectoralis minor muscles	Upper trapezius, sternocleidomastoid, pectoralis major, pectoralis minor	 	Superior trapezius fasciculus 1.5min Sternocleidomastoid 1min Pectoralis major, pectoralis minor 2min			
	Use a foam shaft to relax the scapular, latissimus dorsi and cervical extensor muscle groups	Latissimus dorsi, serratus anterior, scapulars	   	Latissimus dorsi 2min Serratus anterior 1min Scapularis 1.5min Neck extensors 1			
	Breathing exercises	Intercostal muscles, abdominal muscles, Pectoralis major, diaphragm		120s			

Wake-up call (exercise)	Shoulder flexion and extension	Pectoralis major, deltoid, latissimus dorsi, large round muscles		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Squat (exercise)	Gluteus maximus, quadriceps		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Standing Heel Lift	Gastrocnemius, Flounder		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Pelvis Clock	Rectus abdominis, internal and external abdominal obliques, transverse abdominis muscles		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
Muscle training	Neck-pulling exercise	Deep cervical flexors (cervicalis longus, Cephalic longus, anterior rectus of the head,lateral rectus cephalicus		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Seated rhomboid training	Rhomboid, middle trapezius		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Single-legged pullback	Pectoralis major, abdominal muscles, hip flexor groups		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10

Muscle training	Deep Cervical Flexor Stabilization	Scapularis, cephalic semispinalis		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	double legged upper kick	Back extensor group, hamstrings		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Freestyle stroke	Dorsal extensor group (medicine)		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
Relaxation exercise	Baby style	Extensor digitorum longus (lower back)		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Inverted V-style	Pectoralis major, dorsal extensor groups, Hamstrings		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10
	Spin upwards	Interosseous muscle, multifidus muscle		1-4weeks :10rep 5-8weeks :15rep 9-12weeks :15rep	1-4weeks :1 5-8weeks :1 9-12weeks :1	1-4weeks :10 5-8weeks :10 9-12weeks :5	1-4weeks :20 5-8weeks :15 9-12weeks :10

(Note: This training program focuses on stretching muscle groups that are tight in upper crossed syndrome, such as: pectoralis major, pectoralis minor, subscapularis, latissimus dorsi, levator scapulae, upper trapezius fasciculus, vastus roundus, sternocleidomastoid, and obliques; and focuses on strengthening muscle groups that are weak in the muscles that are weak in upper crossed syndrome; such as rhomboid, middle trapezius fasciculus, lower trapezius fasciculus, vastus roundus, infraspinatus, serratus anterior, and deep cervical flexor.)

4. Participant

My unit has the existing Zigong First People's Hospital and Zigong Fourth People's Hospital as its affiliated hospitals, which brings convenience to the implementation and control of the empirical research and helps to improve the accuracy of the experimental results.Randomized controlled trial, formula:$N1=N2=2[(\mu\alpha+\mu\beta)\sigma/\delta]2$; N1, N2 represent the sample size of the intervention group and the control group, respectively; set the test level of $\alpha=0.05$, $\beta=0.1$, through the table, we can see that the $\mu\alpha=1.96$, $\mu\beta=1.282$; σ represents the estimate of the standard deviation of the two books, which can be replaced by the two standard deviations of the two samples in the calculation; δ represents the difference in the mean of two samples; bring the above data into the formula to get N1=N2=14, and then consider the 20% sample loss rate, then the total sample size of the intervention group and the control group is 17. The difference between the two samples is δ. Bringing the above data into the formula yields N1=N2=14, and considering the 20% sample attrition rate, the individual sample sizes of the intervention and control groups are 17, and the total sample size is 34. Because two people in the experimental group did not complete the intervention according to the plan during the experimental process and withdrew voluntarily; one person in the control group did not participate in the post-intervention assessment due to personal reasons, and one did not complete the intervention program. Therefore, 30 effective subjects were finally recruited for this study.

The office population (study population) of this paper will be recruited both online and offline, online through the WeChat platform, and offline through public welfare lectures, posters, and flyers. The public lectures were held in Sichuan Health and Rehabilitation Vocational College, the Rehabilitation Center of Zigong No. 4 People's Hospital, and the Rehabilitation Department of Zigong No. 1 People's Hospital. After recruitment and systematic evaluation, a total of 30 subjects met the inclusion criteria; details of the 30 subjects are shown in Table 2.

Table 2 Subject Information

Subject number	Age (years)	Distinguishing between the sexes	Nature of work	Workplace
1	25	Female	Office Clerk	Zigong prefecture level city in Sichuan
2	32	Male	Programmer	Zigong prefecture level city in Sichuan
3	40	Female	Principals	Zigong prefecture level city in Sichuan
4	28	Male	Advertising copywriter	Zigong prefecture level city in Sichuan
5	35	Female	Accountants	Zigong prefecture level city in Sichuan
6	25	Male	Schoolchildren	Zigong prefecture level city in Sichuan
7	38	Female	Telephone customer service	Zigong prefecture level city in Sichuan
8	45	Female	Hiring out	Zigong prefecture level city in Sichuan
9	57	Male	Scientific researcher	Zigong prefecture level city in Sichuan
10	26	Female	Cashier	Zigong prefecture level city in Sichuan
11	36	Male	Principals	Zigong prefecture level city in Sichuan
12	27	Female	Physiotherapists	Zigong prefecture level city in Sichuan
13	42	Female	Physiotherapists	Zigong prefecture level city in Sichuan
14	31	Male	Surgeon	Zigong prefecture level city in Sichuan
15	29	Female	Principals	Zigong prefecture level city in Sichuan
16	37	Female	CPPCC Clerk	Zigong prefecture level city in Sichuan
17	25	Female	Schoolchildren	Zigong prefecture level city in Sichuan
18	39	Female	Animation Designer	Zigong prefecture level city in Sichuan

19	33	Male	Accountants	Zigong prefecture level city in Sichuan
20	26	Male	Schoolchildren	Zigong prefecture level city in Sichuan
21	34	Female	First aid	Zigong prefecture level city in Sichuan
22	28	Male	Automotive Engineer	Zigong prefecture level city in Sichuan
23	41	Male	Shopper's guide	Zigong prefecture level city in Sichuan
24	30	Female	Physiotherapist s	Zigong prefecture level city in Sichuan
25	34	Female	Surgeon	Zigong prefecture level city in Sichuan
26	43	Male	Sales	Zigong prefecture level city in Sichuan
27	55	Male	Accountants	Zigong prefecture level city in Sichuan
28	47	Female	Office Clerk	Zigong prefecture level city in Sichuan
29	43	Female	Scientific researcher	Zigong prefecture level city in Sichuan
30	38	Male	Game programmer	Zigong prefecture level city in Sichuan

Average age: 35.5 years old, of which 14 are male and 16 are female; nature of work: mainly office work, service industry, creative design, education, medical care, scientific research and so on.

Age range: 25-60 years old (Individuals in this age group have usually completed their studies and their physical and mental states are relatively stable. According to China's current statutory retirement system, 60 years old is the retirement age limit. The age distribution of employees in most enterprises is concentrated between 25 and 60 years old. In addition, people between the ages of 25 and 60 are often at a mature stage in their careers and have accumulated a wealth of work experience. At the same time, individuals in this age group usually show a strong ability to learn and adapt. Based on the above comprehensive assessment of work status, time allocation, and physical and mental status, the age range of 25 to 60 years old was selected as the age range for this study.)

5. Sampling Process

1.Subject selection, inclusion criteria:

The following diagnostic criteria were met; all subjects had normal respiration, pulse and other physical signs, could understand speech and had no cognitive impairment; were between 25-60 years old; had obvious somatic problems such as neck exploration, rounded shoulders, hunchback, FHA ⩾ 46° , FSA ⩾ 52° ; and VAS visual analog scores of ⩾ 3 points.

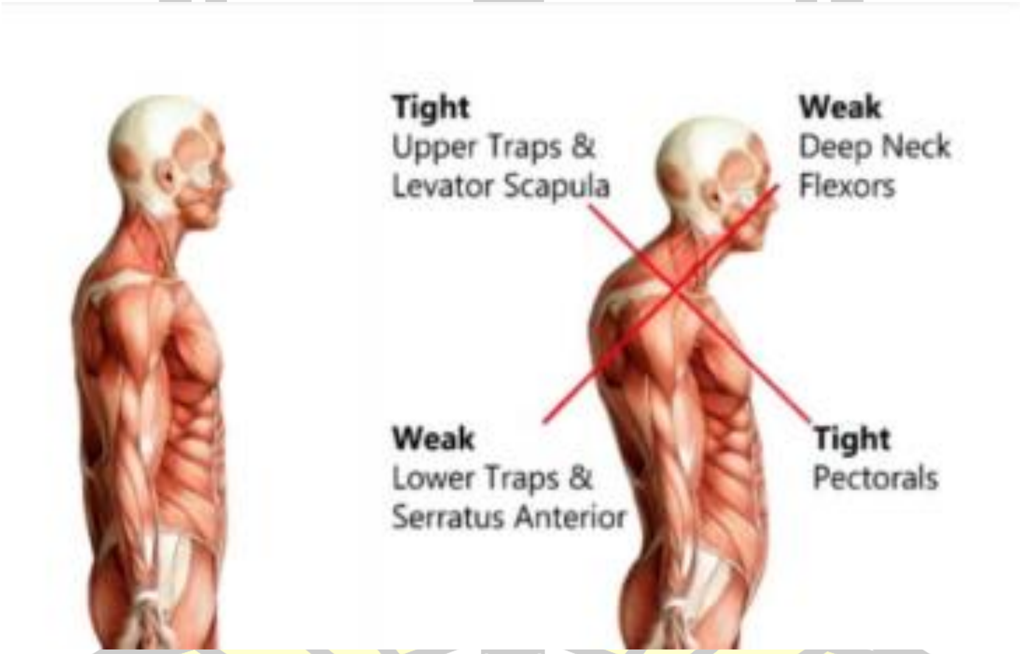


Figure 4 Upper Cross Syndrome Comparison Chart

Patients with a certain degree of neck and shoulder pain, stiffness, muscle tightness and other discomforts, accompanied by limited neck and shoulder activities; those who exclude congenital cervical spine saki shape, bone tumors, bone tuberculosis and other bone and joint diseases by imaging examination; those who voluntarily participate in the program and voluntarily sign the informed consent form, and who are able to complete the examination and training according to the requirements.

2. Exclusion Criteria

Those who do not meet the above criteria; those who have ever suffered from mental illness or drug use; those who have obvious degenerative disease of cervical intervertebral discs, history of neck and shoulder trauma or surgery; those who have serious cardiac, hepatic, renal or pulmonary insufficiency, bone tumors, bone tuberculosis, pregnant women, and those who are dysfunctional after surgery;Those who have received other treatments or participated in other sports within 3 months; those who are unable to continue to receive teaching and training guidance or quit halfway;

3. Exclusion Criteria and Disengagement Criteria

Those who did not meet the inclusion criteria and were mistakenly included. Those who met the inclusion criteria and were included but did not train normally according to the experimental plan after inclusion. Subjects who withdrew during the experiment because they did not complete the intervention according to the experimental plan for various reasons and could not judge the effect;Subjects who had serious adverse reactions during the experiment or who were unwilling to continue to participate in the experiment.

6. Test Tools

The identification of assessment indicators and tests (dependent variables) has been described above. In terms of tool selection, the validity of static postural assessment and postural screening systems has also been demonstrated in the relevant literature.

1. in this study, we mainly used the three-dimensional body analyzer for calibration tests of (FHA, FSA).

2. Commonly used tools for checking the range of motion (ROM) of the cervical spine include the universal protractor and the square disk protractor, as well as the cervical spine mobility meter (CROM). However, since the CROM requires special

training for the measurer and is highly influenced by the level of training, and the square disk protractor has reproducibility and credibility in testing the cervical spine mobility, the square disk protractor was ultimately chosen in this study for cervical spine mobility Therefore, the square disk goniometer was chosen for cervical spine mobility measurements in this study.

3. The Neck Disability Index (NDI), a commonly used questionnaire for assessing neck function, has been widely used with good reliability and validity. The Visual Analog Scale (VAS), as a simple measure of pain intensity in clinical practice, can objectively score changes in pain level and provide a more objective evaluation of the effectiveness of pain treatment, and is the most acceptable, simple, and least misunderstood scale.

4. Surface electromyography (sEMG) was first applied in the field of competitive sports to study the recruitment sequence and activation ratio of each muscle during the completion of a certain movement. It can capture the bioelectrical signals during human movement, reflecting to a certain extent the state of neuromuscular activity and functional level. Currently, sEMG is widely used in assessing changes in the level of shoulder and neck pain, changes in the functional status of muscles after fatigue, and changes in muscle dysfunction. In this experiment, sEMG was used to detect the functional status of muscles related to upper crossed syndrome.

By means of relevant tools, attention was paid to the changes in subjects' body posture problems (FHA, FSA), Neck Disability Index (NDI), cervical spine mobility, pain level (VAS), and surface electromyography (sEMG) values corresponding to the 5 main indicators. To design a fascial massage combined with Pilates training method for upper crossed syndrome and conduct a 12-week empirical study.

Table 3 Main Instruments

Instrumentation	firms
3D Body Analyzer	Hongtaisheng (Beijing) Health Technology Co.
Joint Mobility Gauge	Shenzhen Mingruida Plastic Products Co.
Visual Analog Score (VAS) Scale	Huskisson EC
Surface electromyography	Beijing Jinfa Technology Co.

Figure 5 Main instruments

7. Data collection procedures

1. Composition and duties of the test team

According to the five evaluation indexes, a total of five people were selected for this experiment, and the pre- and post-experimental data were measured and recorded for the anterior head angle (FHA), the anterior shoulder angle (FSA), the cervical range of motion (ROM), the surface electromyography (sEMG), the visual analog scores (VAS), and the Neck Disability Index (NDI), and the five people selected passed the experimental training, and the specific information is as follows.

Table 4 Data collector information

Name	Title	Work unit	Working experience	Test content
A1	Associate professor	Sichuan Health Rehabilitation Vocational College	Senior Fitness Instructor	Surface EMG electrical signal data
A2	Tutors	Sichuan Health Rehabilitation Vocational College	Senior Fitness Instructor	Head forward reach, rounded shoulder angle measurement
A3	Tutors	Sichuan Health Rehabilitation Vocational College	Senior Pilates Instructor	Measurement of Cervical spine range of motion (ROM)
A4	Tutors	Sichuan Health Rehabilitation Vocational College	Senior Physical Education Teacher	Neck Disability Index (NDI)
A5	Tutors	Sichuan Health Rehabilitation Vocational College	Senior Yoga Instructor	Change in pain levels

2. Testing time and place

Testing place: Sichuan Health and Rehabilitation Vocational College, Pilates training room

Test time: Test preparation (Nov 25, 2023), official test (Apr 6, 2024) Experimental Objectives

3. Test methods

3.1 Forward Head Angle and Forward Shoulder Angle (FHA, FSA)

Test method: Draw a vertical line along the seventh cervical vertebra and the horizontal plane, then take the seventh cervical vertebra as the starting point and connect the line to the ear screen, the angle formed by the vertical line from the seventh cervical vertebra to the ear screen and the connecting line is the head anterior angle (FHA); and then make a vertical line along the seventh cervical vertebra and the horizontal plane, take the seventh cervical vertebra as the starting point and connect the line to the shoulder crest, the angle formed by the vertical line and the connecting line from the seventh cervical vertebra to the shoulder crest is the forward shoulder angle (FSA). As shown in Figure 2, FSA is measured in degrees and is accurate to 0.01. FHA ≥ 46° and FSA ≥ 52° can be recognized as upper crossed syndrome. Test Procedure:Subjects were tested sequentially according to the order of the group list, and the testers tested the subjects' forward head angle (FHA) and shoulder anterior angle (FSA) sequentially, and after the tests were completed, the corresponding values were recorded.

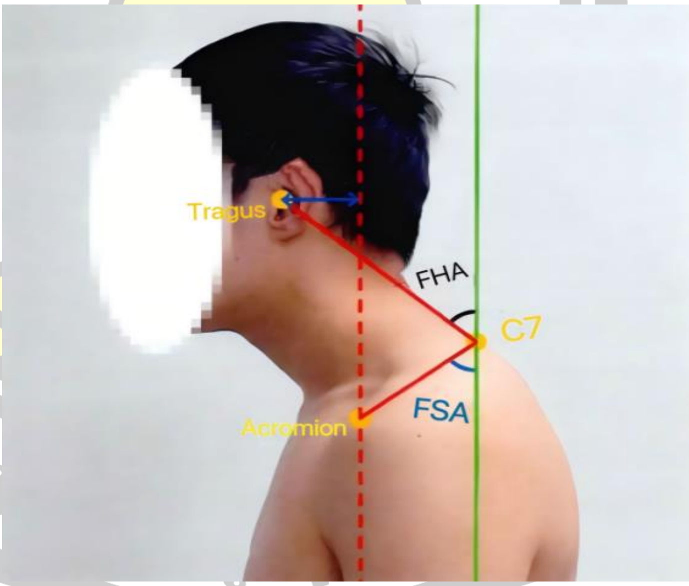


Figure 6 FHA and FSA Test Method Schematic

3.2 Cervical spine range of motion (ROM)

Cervical spine mobility measurement mainly uses cervical spine mobility meter (CROM), test method: before and after the intervention, the person in charge of the evaluation uses a protractor; test requirements for the subject sitting position, the researcher puts the fixed arm on the proximal or fixed bone, the axis of the axis of the bony marking point, the mobile arm is placed on the distal or movable bone, the record of the subject's cervical spine joints in the directions of flexion, extension, sideways bending (left and right), rotation (The degree of cervical flexion, extension, lateral flexion (left and right), and rotation (right and left) were recorded, and the subjects were reminded to move to the maximum degree they could achieve during the measurements, but to avoid excessive activity due to muscle compensation, as shown in Figure 7. Measurements were taken 3 times and the average value was taken. Normal range of cervical spine mobility: forward flexion: about 35° to 45°; backward extension: about 35° to 45°; left and right lateral flexion: about 45° each; left and right rotation: about 60° to 80° each Test Procedure: Subjects were tested in the order of the list of the group, and the testers tested the cervical spine joints of the subjects in flexion-extension, lateral flexion (left and right), and rotation (left and right) directions, and the corresponding values were recorded after the tests were completed. After completion of the test, the corresponding values were recorded.

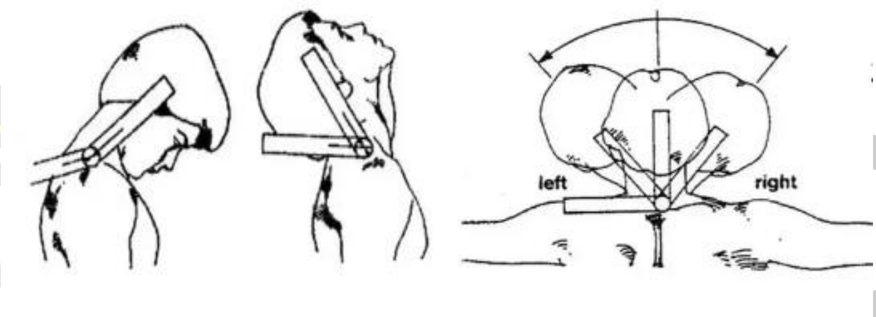


Figure 7 Cervical Spine Range of Motion (ROM) Test Method Chart

3.3. surface electromyography (sEMG)

Test Methods: Firstly, the EMG signals of the UCS population were collected using the ME6000 telemetric EMG tester; secondly, the MegaWin software was utilized to convert the collected data into Fourier spectra and calculate the MPF and MF parameter values of each muscle. Surface EMG electrode placement: The overactive pectoralis major (PM1), upper trapezius (UT), and the overinhibited lower trapezius (LT) were selected as the test muscles. First, a medical swab was moistened with 75% medical alcohol; second, the skin surface of the test muscle was wiped with the moistened medical swab; finally, after the skin surface of the test muscle was sufficiently dry, the electrodes were pasted along the direction of the muscle, and the electrodes were placed as shown in Fig. x. The electrodes were placed as shown in Fig. x, and the electrodes were placed as shown in Fig. 8.

Figure 8 Schematic diagram of surface EMG measurements

The two electrodes were placed on the left and right sides of the midpoint, and the reference electrode was placed 2 cm below the midpoint of the two electrodes. Determination of the position of the LT electrodes: the 10th thoracic vertebrae was 45 degrees to the right, and the midpoint of the lower angle of the scapula was located 1.5 cm in the direction of the spine, then the two electrodes were placed in turn on the left and right sides of the midpoint, with the two electrodes 1 cm apart, and the reference electrode was placed 2 cm below the midpoint of the two electrodes. The reference electrode was placed at the midpoint of the two electrodes.

Maximum Voluntary Isometric Contraction: Prior to the test, the subject completed a 10-minute preparatory activity. The EMG signals from each muscle were recorded for 10 seconds of maximum voluntary isometric contraction (MVIC) while the subject completed the test maneuver. Each muscle was tested 3 times, with a 30-second rest between each test, and the average of the 3 tests was used as a calibration value. After each muscle was tested, a 2-minute rest period was allowed before testing the next muscle.

For the UT maximal voluntary contraction test, the subject was asked to sit on a chair, look straight ahead, and place both feet flat on the ground, then abduct the left shoulder and raise the scapula for 10 s, while the person in charge of the evaluation was asked to apply a resistance above the subject's shoulder; the same was done for the right trapezius superior fasciculus test.

PM1 maximal voluntary contraction test method: when testing the left pectoralis major muscle, first let the subject lie on the mat, then let the subject do horizontal flexion of the right shoulder joint and hold it for 10s, at the same time, the person in charge of the evaluation is required to apply a resistance to the left with his hand on the palm of the subject's hand; when testing the right pectoralis major muscle, the cervical spine movement of the subject is in the opposite direction, and the other matters are also the same.

LT maximal voluntary contraction test method: when testing the left trapezius infraspinatus, first let the subject lie flat on the mat, raise the big arm on both sides of the head, then let the subject do downward pressure on the scapula and hold it for 10s, at the same time the person in charge of the evaluation needs to apply resistance on the proximal end of the humerus with the hand, and do the same when testing the right trapezius infraspinatus. The normal values of surface electromyography are as follows; rhomboid muscle: during isometric contraction with shrugging and other movements, the RMS value is usually around 30 - 150 μV; sternocleidomastoid muscle: during isometric contraction with head turning and other related movements, the RMS value may be around 20 - 100 μV, and during isometric contraction of the pectoralis major muscle: the electromyographic amplitude may be elevated to around 50 - 150 microvolts (μ V), which may vary with different individuals and contraction degrees; latissimus dorsi muscle: during isometric contraction of the pectoralis major muscle, the electromyographic amplitude may be elevated to around 50 - 150 microvolts (μ V), which may vary with different individuals and contraction levels. During isometric contraction of the pectoralis major muscle, the EMG amplitude may increase to about 50 - 150 μ V, depending on the individual and the degree of contraction; the EMG amplitude of the latissimus dorsi muscle may reach about 30 - 120 μ V, which may vary depending on the individual exertion.

Test procedure: Subjects were tested according to the order of the group list, and the tester tested the pectoralis major (PM1), upper trapezius (UT), and lower trapezius (LT), and the corresponding values were recorded after the test was completed.

3.4 Change in pain level (visual analog score, VAS)

Test method: A visual analog scale (VAS) was used to assess pain intensity. The basic assessment method is to use a 10-cm line with 11 scales, with the “0” end and the “10” end, with the 0 score representing no pain and the 10 score representing the The most intense pain. The further to the right the scale the subject examines, the more to the right the subject's pain is, and the further to the right the scale the subject chooses, the more intense the pain the subject is feeling at the moment. The subject puts a check mark √ under the corresponding scale according to the pain in his/her shoulder and neck. In this paper, the inclusion criterion of upper crossed syndrome is that the visual analog score of VAS is ≥ 3 points; test procedure: the testers distributed the visual analog score sheet, and the subjects ticked under the corresponding scale according to their own shoulder and neck pain, and the score sheet was collected on the spot after the test was completed.

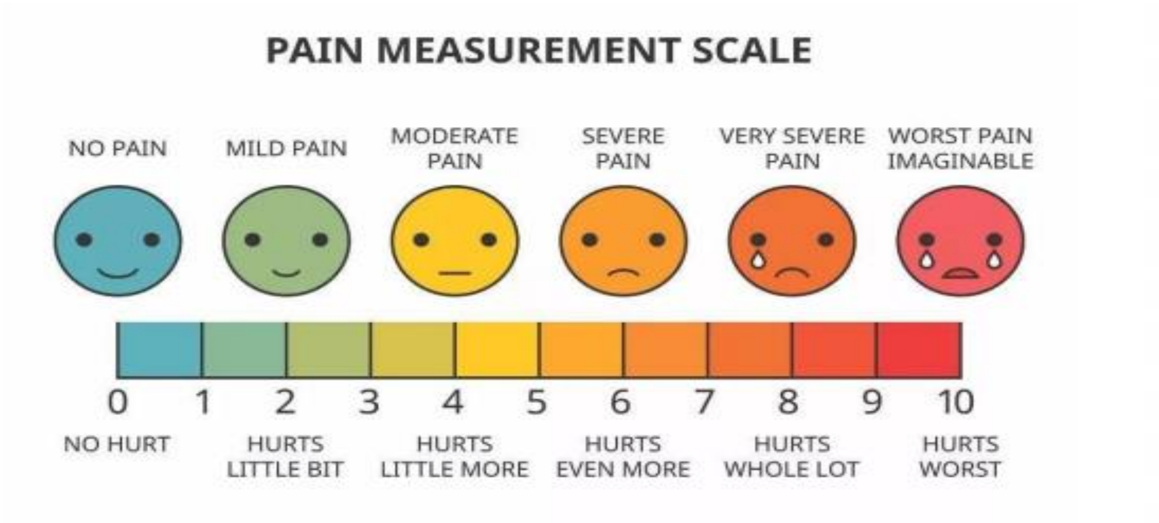


Figure 9 Pain Measurement Scale

3.5 Neck Disability Index (NDI)

The Neck Disability Index (NDI) is a commonly used questionnaire for assessing neck function with good reliability and validity. The NDI consists of 10 self-reported questions covering activities of daily living (7 dimensions), attention (1 dimension) and pain (2 dimensions). Each question has 6 response options with a maximum score of 5 and a minimum score of 0. See Appendix B for details. The NDI scores are usually graded as follows: 0 - 4: basically no cervical spine dysfunction, can be regarded as a good functional status; 5 - 14: mild cervical spine dysfunction; 15 - 24: moderate cervical spine dysfunction; 25 - 34: severe cervical spine dysfunction. 35 and above indicates very severe dysfunction, basically unable to take care of oneself and needing great help. See Appendix I for details. For details, please refer to Appendix B. Test Procedure: The tester will distribute the dysfunction assessment questionnaire, and the subjects will tick the boxes in front of the corresponding options according to their actual situation, and the assessment questionnaires will be collected on the spot after the questionnaires are completed.

4.Test Preparation

4.1 Validity and reliability test

A total of five experts were interviewed before the experiment, respectively engaged in rehabilitation medicine, sports human science, orthopedics, athletic training, fitness instruction, Pilates training and other programs, all of whom are front-line participants and researchers who have been engaged in rehabilitation medicine and athletic training for a long time. They have rich experience in exercise for rehabilitation and exercise for health, and are able to combine the characteristics of Pilates training and upper crossover syndrome to provide scientific advice on the testing indexes for the rehabilitation aspects of Pilates treatment for upper crossover syndrome. Secondly, a targeted Pilates training program was designed for the subjects and experts were asked to evaluate the scientific and rational nature of the training program.

The experts' opinions on the overall structure of the article were that some of them thought that the existing Pilates training programs lacked sufficient consideration of individual patient differences in the overall structure. For example, there is no sufficiently detailed stratified training guidance for patients with upper crossed syndrome with different disease severity and physical underlying conditions. Experts suggest that the training program should be further refined into different levels of beginner, intermediate and advanced according to the patient's specific conditions, such as the degree of muscle imbalance, range of joint movement, and the presence of other concurrent problems, etc., to ensure that the content and intensity of the training at each stage accurately matches the patient's current physical state, and to improve the effectiveness and safety of the training.

Experts' comments on the selection and organization of movements: Some experts pointed out that although the selection of Pilates movements in the program covers a wide range of types, the relevance of some of the movements to the core problems of upper crossed syndrome needs to be strengthened. For example, some of the movements may focus more on flexibility and less directly on improving muscle strength imbalances and postural corrections, which are key to Upper Cross Syndrome. Experts' suggestion: Re-evaluate and filter the movements, and prioritize those Pilates movements that can effectively activate and strengthen the weak muscles related to Upper Cross Syndrome (e.g., deep neck flexors, middle and lower trapezius, anterior serratus, etc.), and at the same time stretch and relax the tense muscles (e.g., pectoralis major, pectoralis minor, rhomboid muscles, etc.). And to rationalize the sequence of movements, follow the principle of first activation, then strengthening, then stretching, so that the training process is more scientific and efficient.

Finally, the adjusted training program will be submitted to five of the experts for review. The experts will check the reasonableness and effectiveness of the training plan, assess the appropriateness, and assign a rating: (Program Objective Consensus: I0C) scale, +1 rating considered appropriate, 0 rating not considered appropriate, and -1 rating unsuitable. The training program was determined based on expert opinion to ensure a passing I0C rating.

After determining the final Pilates training program, a 12-week experimental study was conducted on the experimental group and the control group; finally, the post-test data of the two groups of subjects were collected and compared with the pre-test data in order to verify the therapeutic effect of Pilates training combined with myofascial relaxation training on the upper-crossing syndrome; and to propose the preventive and ameliorative measures for the office population to prevent and ameliorate the "upper-crossing syndrome" problem with specific countermeasures. In this study, the results were compared both longitudinally and horizontally, mainly in terms of the 5 main indicators of subjects' postural problems, cervical spine dysfunction index, joint mobility, changes in pain level, and surface electromyographic signals.

Table 5 List of expert interviews

Names	Position	Specialty
A	Resident Physician	Athletic Rehabilitation
B	Resident Physician	Athletic Rehabilitation, Myofascial Chain Rehabilitation, Pilates
C	Professors, teachers	sports training
D	Associate Professor, Senior Pilates Instructor	Pilates (rehabilitation)

E	Professor, Senior Laboratory Technician	sports medicine

4.2 Information collected during the test preparation stage

General information: height, weight, age, gender, work nature of the subject. To ensure the smooth running of the formal test; e.g., 3d somatometer placement and installation points, tightness of EMG electrode fixation, test time, etc. to reduce the impact of site conditions on the accuracy of the test instrument.

5. Formal testing

5. 1 Test preparation

According to the problems found in the preparation stage of the test, remove all hidden dangers that may affect the accuracy of the test, install and debug the equipment, and make good preparations for the test. Use the 3d human body measurement instrument, the measurement of body posture requires the subjects to bare the upper body (ladies wearing sports undershirts), wearing sports shoes usually worn during training. Before the test started, all subjects were numbered and recorded. Warm-up activities were carried out before the start of the test, and the EMG electrodes were attached after sufficient warm-up.

5.2 Test Procedure

In order to better check the stability and consistency of the test results and reduce the error; the subjects completed three tests in numbered order. Experts were invited at the testing site to evaluate the completion of the movement and select the one with complete data collection and best quality for data storage. After the first subject to complete the test and save the test data, the second subject to start the test, in turn, to complete the test of all subjects and properly save the test data. The end of the test. After the test, organize and return the test instrument as soon as possible.

5.3 Precautions

Ensure that the subject fully understands the requirements and procedures of the test, and that the athlete warms up sufficiently before the test to avoid sports injuries. Employ professional operators to operate the testing instruments to ensure the safety of the instruments. After the test, backup the test data of each place to ensure the safety of the test data.

8. Data analysis

Use Excel 2010 software to statistically analyze the data measured by the two groups of subjects before and after the experiment, use SPSS 26.0 software to carry out independent samples t-test and paired samples t-test on the test data, analyze the processed data for longitudinal difference and significance comparison, and then carry out cross-sectional difference and significance comparison analysis to analyze the differences of each index and draw the conclusions of the experiment.

CHAPTER 4

RESEARCH RESULTS AND ANALYSIS

In this chapter, the experimental pre-test and post-test data were analyzed using SPSS according to the purpose of the research. For continuous variables, descriptive statistics were calculated using mean ($\bar{X}$) and standard deviation (SD). An outlier test was performed on the data from Pilates training as well as Pilates training combined with fascial massage to test whether the data conformed to a normal distribution (< 0.05). For data that conformed to normal distribution, t-tests were used, an independent samples t-test was performed on the pre-intervention baseline data. Independent samples t-tests were also used before and after the intervention to explore between-group differences; paired t-tests were used to assess within-group changes over time. For data that did not conform to normal distribution, non-parametric tests were used, Mann-Whitney U tests were used for between-group data, and Wilcoxon rank sum tests were used for within-group data.

In this research, the results will be assessed by analyzing various indices including forward head angle (FHA), forward shoulder angle (FSA), cervical spine range of motion (ROM), Surface electromyography (sEMG), visual analogue score (VAS) and neck disability index (NDI). The units of the indexes involved in the data analysis process in this chapter are described as follows: the units of FHA, FSA and cervical ROM in each direction are “degrees”, abbreviated as “°”; the unit of sEMG is “hertz”, abbreviated as “Hz”, the unit of VAS as “point”, and the unit of NDI is “percentage”, abbreviated as “%”.

These indices will be analyzed to comprehensively assess the effectiveness of two training methods (Pilates training and Pilates training combined with fascial massage) on the UCS population. Subsequently, the feasibility of implementing both sets of exercise interventions was verified.

1. Baseline demographic characteristics

Independent samples t-test was performed on the baseline characteristics information of the subjects in the two groups before the intervention, and the results, as shown in Table 6.

The experimental group had a mean age of 35.87±9.09 years, while the control group had 35.40±8.24 years, with no significant difference (p=0.884). Similarly, the experimental group's mean height was 1.68±0.07 meters, compared to 1.67±0.08 meters for the control group, also showing no significant difference (p=0.671). Regarding weight, the experimental group averaged 68.13±7.89 kg, and the control group 65.81±7.58 kg, with no significant difference found (p=0.419). Lastly, BMI comparisons revealed no significant difference between the experimental group's 20.24±1.64 and the control group's 19.68±1.46 (p=0.332).These results showed that there was no significant difference in the basic information of the subjects in the two groups, such as age, height, weight and BMI, and they were homogeneous.

Table 6 Comparison of demographic characteristics between groups

	Experimental Group		Control Group		*t*	*p*
	$\bar{X}$	SD	$\bar{X}$	SD		
Age (year)	35.87	9.09	35.40	8.24	0.147	0.884
Height (m)	1.68	0.07	1.67	0.08	0.429	0.671
Weight (kg)	68.13	7.89	65.81	7.58	0.821	0.419
BMI (kg/m^2)	20.24	1.64	19.68	1.46	0.987	0.332

2. Investigate the effect of Pilates training combined with fascial massage on UCS in office workers

2.1 Comparison of indicators before and after intervention in the experimental group

Paired-sample t-tests were performed on the indicators before and after the intervention in the experimental group, and the results are shown in **Table 7**.

2.1.1 Forward Head Angle (FHA) and Forward Shoulder Angle (FSA)

The paired samples t-tests were conducted before and after the intervention for

FHA and FSA of the experimental group, respectively, and the results are shown in Table 7. The FHA before the intervention was 49.07±2.49, and after the intervention was 39.13±4.47, t=10.258, p=0.000. The FSA before the intervention was 56.87±4.24, and after the intervention was 47.07±4.18, t= 5.711, p=0.000. This indicates that there were significant differences for FHA and FSA values of the subjects between the before and after intervention, both FHA and FSA after the intervention were significantly lower than before the intervention, suggesting that Pilates training combined with fascial massage significantly improved both head forward tilt and rounded shoulder conditions in the subjects.

2.1.2 Cervical Spine Range of Motion (ROM)

2.1.2.1 Cervical flexion ROM and extension ROM

Paired samples t-tests were performed on flexion and extension ROM before and after the intervention of the experimental group, respectively, and the results are shown in Table 7. Flexion ROM in the pre-intervention was 36.13±2.88, and in post-intervention was 38.33±2.94, t=-2.471, p=0.027. Extension ROM in the pre-intervention was 30.73±6.24, and in post-intervention was 40.93±3.69, t=-10.945, p=0.000. This shows that both flexion and extension ROM of the subjects in the experimental group produced significant differences before and after the intervention, and both flexion and extension ROM were significantly higher after the intervention than before the intervention.

2.1.2.2 Cervical left lateral flexion ROM and right lateral flexion ROM

Paired samples t-tests were performed on the left and right lateral flexion ROM before and after the intervention of the experimental group, and the results are shown in Table 7. The left lateral flexion ROM in the pre-intervention was 32.4±3.31, and in the post-intervention was 35.60±5.12, t=-4.298, p=0.001, and for the right lateral flexion ROM in the pre-intervention was 32.00±4.26, in the post-intervention was 35.40±5.14, and t=-2.706, p=0.017. This shows that both left and right lateral flexion ROM of the subjects in the experimental group produced significant differences before and after the intervention, and that both left and right lateral flexion ROM were significantly higher after the intervention than before.

2.1.2.3 Cervical left rotation ROM and right rotation ROM

The paired-sample t-tests were performed on the left and right rotation ROM of the subjects before and after the intervention in the experimental group, and the results are shown in Table 7. The left rotation ROM before the intervention was 51.47±9.98, the left rotation ROM after the intervention was 67.80±6.92, t=-9.055, p=0.000. and for the right rotation ROM before the intervention was 51.93±10.13 before the intervention, right rotation ROM after the intervention was 69.27±7.43, t=-12.066, p=0.000. t=-12.066, p=0.000, indicating that both left and right rotation ROM of the subjects in the experimental group produced significant differences before and after the intervention, and that both left and right rotation ROM were significantly higher after the intervention than before.

2.1.3 Surface Electromyography (sEMG) frequency domain indexes

2.1.3.1 MPF and MF of the left UT

The paired sample t-tests were conducted on the sEMG results of the left UT before and after the intervention of the experimental group, and the results were as shown in Table 7. The MPF before the intervention was 65.49±4.41, and the MPF after the intervention was 77.86±4.55, t=-13.609, p=0.000, which indicated that there was a highly significant difference between the MPFs before and after the intervention of the experimental group, and compared to the pre-intervention, the MPFs of the experimental group after the intervention were significantly elevated; MF before the intervention was 59.98±3.86, and MF after intervention was 74.54±4.08, t=-29.226, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the experimental group, and compared to before the intervention, MF in the experimental group after the intervention was significantly elevated.

2.1.3.2 MPF and MF of the right UT

The paired sample t-test was conducted on the sEMG results of the right UT before and after the intervention of the experimental group, and the results were shown in Table 7. The MPF before the intervention was 68.05±4.41, and the MPF after the intervention was 81.31±5.54, with t=-14.782, p=0.000, which indicated that there was a highly significant difference between the MPFs before and after the intervention of the experimental group, and compared to before the intervention, the

MPFs of the experimental group after the intervention were significantly elevated; MF before intervention was 58.98±5.22, and MF after intervention was 73.02±5.32, t=-19.656, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the experimental group, and compared to before intervention, MF in the experimental group after intervention was significantly elevated.

2.1.3.3 MPF and MF of the left LT

Paired-sample t-test was performed on the sEMG results of the left LT before and after the intervention of the experimental group, and the results were shown in Table 7. The MPF before the intervention was 67.27±4.75, and the MPF after the intervention was 59.50±3.64, with t=5.205, and p=0.000, which indicated that there was a highly significant difference between the MPF before and after the intervention of the experimental group, and that compared to before the intervention, the MPF of the experimental group after the intervention was significantly reduced ; MF before intervention was 60.99±4.78 and after intervention was 48.89±4.16, t=10.798, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the experimental group, and compared to before intervention, MF was significantly lower in the experimental group after intervention.

2.1.3.4 MPF and MF of right LT

The paired sample t-test was conducted on the sEMG results of the right LT before and after the intervention of the experimental group, and the results were shown in Table 7. The MPF before the intervention was 64.11±4.28, and the MPF after the intervention was 58.53±2.91, with t=10.774 and p=0.000, which indicated that there was a highly significant difference between the MPF before and after the intervention of the experimental group, and compared to before the intervention, the MPF of the experimental group after the intervention was significantly lower; MF before intervention was 57.85±6.26, and MF after intervention was 52.38±3.66, t=5.616, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the experimental group, and compared to before intervention, MF in the experimental group after intervention was significantly lower.

2.1.3.5 MPF and MF of left PM1

The paired-sample t-tests were conducted on the sEMG results of the left PM1 before and after the intervention of the experimental group, and the results were as shown in Table 7. The MPF was 65.97±5.28 before the intervention, and 81.33±4.74 after the intervention, with t=-110.851 and p=0.000, which indicated that there was a highly significant difference between the MPFs before and after the intervention of the experimental group, and compared to before the intervention, the MPFs of the experimental group after the intervention were significantly higher; MF before intervention was 62.18±5.90, and MF after intervention was 68.00±4.09, t=-11.538, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the experimental group, and compared to before intervention, MF in the experimental group after intervention was significantly higher.

2.1.3.6 MPF and MF of the right PM1

Paired-sample t-tests were conducted on the sEMG results of the right PM1 before and after the intervention of the experimental group, and the results were shown in Table 7. The MPF before the intervention was 66.19±5.45, and that after the intervention was 82.60±5.75, t=-38.829, p=0.000, which indicated that there was a highly significant difference between the MPF before and after the intervention of the experimental group, and that compared to before the intervention, the MPF of the experimental group after the intervention was significantly higher; MF before intervention was 58.54±4.18, and MF after intervention was 66.38±3.92, t=-12.955, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the experimental group, and compared to before intervention, MF in the experimental group after intervention was significantly higher.

2.1.4 Visual Analogue Score (VAS)

Paired samples t-test was conducted on the results of VAS of the experimental group before and after the intervention, and the results are shown in Table 7. The VAS score before the intervention was 4.33±1.29, and the VAS after the intervention was 0.47±0.64, t=16.358, p=0.000, which indicates that there is a significant difference in VAS of the experimental group before and after the intervention, and that compared to before the intervention, the experimental group's VAS were significantly lower. It indicates that Pilates training combined with fascial massage can effectively reduce the pain level of UCS population.

2.1.5 Neck Disability Index (NDI)

Paired sample t-test was conducted on the results of NDI before and after the intervention of the experimental group, and the results were shown in Table 7. The NDI before the intervention was 23.87±3.50, and the NDI after the intervention was 3.33±1.63, t=25.172, p=0.000, which indicated that there was a highly significant difference in the NDI of the experimental group before and after the intervention, and that compared to before the intervention, the NDI of the experimental group after the intervention was significantly reduced. It indicates that Pilates training combined with fascial massage can effectively reduce the cervical spine dysfunction in UCS population.

Table 7 Comparison of indicators pre- and post-test in the experimental group

Indicators			Experimental Group		Control Group		t	p
			$\bar{X}$	SD	$\bar{X}$	SD		
Body posture	FHA		49.07	2.49	48.87	2.23	0.232	0.819
	FSA		56.87	4.24	56.93	4.48	-0.042	0.967
Cervical Spine range of motion (ROM)	Flexion		36.13	2.88	36.07	2.46	0.068	0.946
	Extension		30.73	6.24	31.53	5.58	-0.370	0.714
	Left lateral flexion		32.40	3.31	31.87	3.27	0.444	0.661
	Right lateral flexion		32.00	4.26	31.87	3.80	0.091	0.929
	Left rotation		51.47	9.98	53.13	10.27	-0.451	0.656
	Right rotation		51.93	10.13	51.80	9.69	0.037	0.971
Surface electromyography (sEMG) frequency domain	Left UT	MPF	65.49	4.41	65.89	5.09	-0.230	0.820
		MF	59.98	3.86	59.33	5.37	0.376	0.710
	Right UT	MPF	68.05	4.41	67.60	4.66	0.277	0.783
		MF	58.98	5.22	59.06	4.83	-0.045	0.964
	Left LT	MPF	67.27	4.75	67.09	6.34	0.090	0.929
		MF	60.99	4.78	60.15	5.12	0.461	0.648

indexes	Right LT	MPF	64.11	4.28	64.33	4.25	-0.137	0.892
		MF	57.85	6.26	57.00	5.17	0.405	0.688
	Left	MPF	65.97	5.28	66.34	5.30	-0.193	0.848
	PM1	MF	62.18	5.90	62.18	5.87	0.000	1.000
	Right	MPF	66.19	5.45	66.17	5.81	0.011	0.991
	PM1	MF	58.54	4.18	58.85	5.31	-0.179	0.859
Visual Analogue Score (VAS)			4.33	1.29	4.27	1.28	0.142	0.888
Neck Disability Index (NDI)			23.87	3.50	24.53	3.16	-0.547	0.588

Note: *Significant difference between groups (p<0.05); **Significant difference between groups (p<0.01); *** Significant difference between groups (p<0.001)

2.2 Comparison of indicators before and after intervention in the control group

Paired-sample t-tests were performed on the indicators before and after the intervention in the control group, and the results are shown in **Table 8**

2.2.1 Forward Head Angle (FHA) and Forward Shoulder Angle (FSA)

Paired samples t-tests were performed on the FHA and FSA before and after the intervention in the control group, and the results are shown in Table 8. FHA before the intervention was 48.87±2.23 and after the intervention was 43.27±5.12, t=4.568, p=0.000. FSA before the intervention was 56.93±4.48 and after the intervention was 51.73±5.12, t=3.693, p=0.002, indicating that both FHA and FSA values were significantly improved in control subjects after the intervention.

2.2.2 Cervical Spine Range of Motion (ROM)

2.2.2.1 Cervical flexion ROM and extension ROM

Paired samples t-tests were conducted before and after the intervention for flexion and extension ROM of the control subjects and the results are shown in Table 8. For flexion ROM before the intervention was 36.07±2.46, and after the intervention was 37.93±3.33 , t=-2.5, p=0.0.025. Extension ROM before the intervention was 31.53±5.58, after the intervention was 37.13±4.00, t=-6.635, p=0.635. p=0.000. These results indicated that flexion and extension ROM were significantly improved in the control subjects after the intervention.

2.2.2.2 Cervical Left lateral flexion ROM and right lateral flexion ROM

Paired samples t-tests were performed on the left and right lateral flexion ROM before and after the intervention in the control group, and the results are shown in Table 8. The left lateral flexion ROM before the intervention was 31.87±3.27, and after the intervention was 35.27±5.38, t=-3.925, p=0.002. The right lateral flexion ROM before the intervention was 31.87±3.80, and after the intervention was 34.27±4.77, t=-2.526, p=0.024. These results indicated that both left and right lateral flexion ROM in the control group were significantly improved after the intervention.

2.2.2.3 left rotation ROM and right rotation ROM

Paired samples t-tests were performed on the left and right rotation ROM before and after the intervention in the control group and the results are shown in Table 8. Left rotation ROM before the intervention was 53.13±10.27 and after the intervention was 61.27±8.61 t=-6.997, p=0.000. Right rotation ROM before the intervention was 51.80±9.69 and after the intervention was 61.33±6.86 , t = -10.731, p=0.000. These results indicated that there was a significant increase in the subjects' left and right rotation ROM after the intervention.

2.2.3 Surface Electromyography (sEMG) frequency domain indexes

2.2.3.1 MPF and MF of left UT

The paired-sample t-tests were conducted on the sEMG results of the left UT before and after the intervention in the control group, and the results were shown in Table 8. The MPF before the intervention was 65.89±5.09, and the MPF after the intervention was 72.74±5.23, with t=-6.437 and p=0.000, indicating that there was a highly significant difference between the MPF before and after the intervention in the control group, and compared to before the intervention, the MPF in the control group after the intervention was significantly elevated; MF before intervention was 59.33±5.37, and MF after intervention was 68.49±4.50, t=-8.636, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the control group, and compared to before intervention, MF was significantly elevated in the control group after intervention.

2.2.3.2 MPF and MF of right UT.

The paired sample t-test was performed on the sEMG results of the right UT before and after the intervention in the control group, and the results were shown in Table 8. The MPF was 67.60±4.66 before the intervention, and 77.05±4.77 after the intervention, t=-8.009, p=0.000, which indicated that there was a highly significant difference between the MPF of the control group before and after the intervention, and compared to the before the intervention, the MPF in the control group after the intervention was significantly elevated; MF before intervention was 59.06±4.83, and MF after intervention was 67.71±4.89, t=-13.675, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the control group, and compared to before intervention, MF was significantly elevated in the control group after intervention.

2.2.3.3 MPF and MF of left LT

Paired sample t-tests were performed on the sEMG results of the left LT before and after the intervention in the control group, and the results were shown in Table 8. The MPF was 67.09±6.34 before the intervention, and 62.08±6.48 after the intervention, with t=5.204 and p=0.000, indicating that there was a highly significant difference between the MPF before and after the intervention in the control group, and compared with the pre-intervention period, the MPF of the control group was significantly lower after the intervention ; MF before intervention was 60.15±5.12 and after intervention was 52.48±4.83, t=10.959, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the control group, and compared to before intervention, MF in the control group was significantly lower after intervention.

2.2.3.4 MPF and MF of the right LT

Paired sample t-test was performed on the sEMG results of the right LT in the control group before and after the intervention, and the results were shown in Table 8. The MPF was 64.33±4.25 before the intervention, and 60.91±5.11 after the intervention, with t=3.406 and p=0.004, indicating that there was a highly significant difference between the MPF of the control group before and after the intervention, and that compared to before the intervention, the MPF in the control group after the intervention was significantly reduced ; MF before intervention was 57.00±5.17 and after intervention was 56.76±5.71, t=0.491, p=0.631, indicating that there was no significant difference in MF before and after intervention in the control group.

2.2.3.5 MPF and MF of left PM1

The paired-sample t-tests were conducted on the sEMG results of the left PM1 before and after the intervention in the control group, and the results were shown in Table 8. The MPF before the intervention was 66.34±5.30, and the MPF after the intervention was 75.92±6.36, t=-22.325, p=0.000, which indicated that there was a highly significant difference in the MPF before and after the intervention of the control group, and compared to before the intervention, the MPF of the control group after the intervention was significantly higher; MF before intervention was 62.18±5.87, and MF after intervention was 65.37±6.09, t=-15.372, p=0.000, indicating that there was a highly significant difference in MF before and after intervention in the control group, and compared to before intervention, MF in the control group after intervention was significantly higher.

2.2.3.6 MPF and MF of the right PM1

Paired sample t-test was performed on the sEMG results of the right PM1 before and after the intervention in the control group, and the results were shown in Table 8. The MPF before the intervention was 66.17±5.81, and that after the intervention was 75.59±6.88, with t=-10.054 and p=0.000, indicating that there was a highly significant difference between the MPF before and after the intervention in the control group, and that compared to before the intervention, the MPF in the control group after the intervention was significantly higher; MF before intervention was 58.85±5.31, and MF after intervention was 62.61±5.12, t=-3.838, p=0.002, indicating that there was a highly significant difference in MF before and after intervention in the control group, and compared to before intervention, MF in the control group after intervention was significantly higher.

2.2.4 Visual Analogue Score (VAS)

Paired samples t-test was conducted on the results of VAS of the control group before and after the intervention, and the results are shown in Table 8. The VAS score before the intervention was 4.27±1.28, and the VAS after the intervention was

1.00±0.76, t=13.163, p=0.000, which indicates that there is a significant difference in VAS before and after the intervention, and that compared to before the intervention, the control group's VAS after the intervention was significantly lower. It indicates that Pilates training can effectively reduce the pain level in UCS population.

2.2.5 Neck Disability Index (NDI)

Paired samples t-test was conducted on the results of NDI before and after the intervention of the control group, and the results were shown in Table 8. The NDI before the intervention was 24.53±3.16, and the NDI after the intervention was 7.20±3.00, t=20.025, p=0.000, which indicates that there is a highly significant difference in the NDI before and after the intervention of the control group, and that compared to before the intervention, the NDI of the control group after the intervention was significantly lower. It indicates that Pilates training can effectively reduce cervical spine dysfunction in UCS population.

Table 8 Comparison of indicators pre- and post-test in the control group

Indicators			Pre-test		Post-test		t	p
			$\bar{X}$	SD	$\bar{X}$	SD		
Body posture	FHA		48.87	2.23	43.27	5.12	4.568	0.000***
	FSA		56.93	4.48	51.73	5.12	3.693	0.002**
Cervical spine range of motion (ROM)	Flexion		36.07	2.46	37.93	3.33	-2.5	0.025*
	Extension		31.53	5.58	37.13	4.00	-6.635	0.000***
	Left lateral flexion		31.87	3.27	35.27	5.38	-3.925	0.002**
	Right lateral flexion		31.87	3.80	34.27	4.77	-2.526	0.024*
	Left rotation		53.13	10.27	61.27	8.61	-6.997	0.000***
	Right rotation		51.80	9.69	61.33	6.86	-10.731	0.000***
Surface electromyography (sEMG) frequency domain	Left UT	MPF	65.89	5.09	72.74	5.23	-6.437	0.000***
		MF	59.33	5.37	68.49	4.50	-8.636	0.000***
	Right UT	MPF	67.60	4.66	77.05	4.77	-8.009	0.000***
		MF	59.06	4.83	67.71	4.89	-13.675	0.000***
	Left LT	MPF	67.09	6.34	62.08	6.48	5.204	0.000***
		MF	60.15	5.12	52.48	4.83	10.959	0.000***

indexes	Right LT	MPF	64.33	4.25	60.91	5.11	3.406	0.004**
		MF	57.00	5.17	56.76	5.71	0.491	0.631
	Left	MPF	66.34	5.30	75.92	6.36	-22.325	0.000***
	PM1	MF	62.18	5.87	65.37	6.09	-15.372	0.000***
	Right	MPF	66.17	5.81	75.59	6.88	-10.054	0.000***
	PM1	MF	58.85	5.31	62.61	5.12	-3.838	0.002**
Visual Analogue Score (VAS)			4.27	1.28	1.00	0.76	13.163	0.000***
Neck Disability Index (NDI)			24.53	3.16	7.20	3.00	20.025	0.000***

Note: *Significant difference between groups ($p<0.05$); **Significant difference between groups ($p<0.01$); *** Significant difference between groups ($p<0.001$)

Table 9 Comparison of indicators pre- and post-test in the experimental group

Indicators			Pre-test		Post-test		*t*	*p*
			$\bar{X}$	SD	$\bar{X}$	SD		
Body posture	FHA		49.07	2.49	39.13	4.47	10.258	0.000***
	FSA		56.87	4.24	47.07	4.18	5.711	0.000***
Cervical spine range of motion (ROM)	Flexion		36.13	2.88	38.33	2.94	-2.471	0.027*
	Extension		30.73	6.24	40.93	3.69	-10.945	0.000***
	Left lateral flexion		32.40	3.31	35.60	5.12	-4.298	0.001**
	Right lateral flexion		32.00	4.26	35.40	5.14	-2.706	0.017*
	Left rotation		51.47	9.98	67.80	6.92	-9.055	0.000***
	Right rotation		51.93	10.13	69.27	7.43	-12.066	0.000***
Surface electromyography (sEMG) frequency domain indexes	Left UT	MPF	65.49	4.41	77.86	4.55	-13.609	0.000***
		MF	59.98	3.86	74.54	4.08	-29.226	0.000***
	Right UT	MPF	68.05	4.41	81.31	5.54	-14.782	0.000***
		MF	58.98	5.22	73.02	5.32	-19.656	0.000***
	Left LT	MPF	67.27	4.75	59.50	3.64	5.205	0.000 ***
		MF	60.99	4.78	48.89	4.16	10.798	0.000 ***
	Right LT	MPF	64.11	4.28	58.53	2.91	10.774	0.000***
		MF	57.85	6.26	52.38	3.66	5.616	0.000***
	Left PM1	MPF	65.97	5.28	81.33	4.74	-110.851	0.000***
		MF	62.18	5.90	68.00	4.09	-11.538	0.000***
	Right PM1	MPF	66.19	5.45	82.60	5.75	-38.829	0.000***
		MF	58.54	4.18	66.38	3.92	-12.955	0.000***
Visual Analogue Score (VAS)			4.33	1.29	0.47	0.64	16.358	0.000***
Neck Disability Index (NDI)			23.87	3.50	3.33	1.63	25.172	0.000***

Note: *Significant difference between groups (p<0.05); **Significant difference between groups (p<0.01); *** Significant difference between groups (p<0.001)

3. Compare the effects of Pilates training combined with fascial massage with Pilates training alone on UCS in office workers

Between-group comparisons of the indicators in the experimental and control groups were made using independent samples t-tests. The results of intergroup comparisons before the intervention are shown in **Table 9**, and the results of intergroup comparisons after the intervention are shown in **Table 10**.

3.1 Forward Head Angle (FHA) and Forward Shoulder Angle (FSA)

This research employed the assessment of FHA and FSA to conduct a static evaluation of the participants' body posture. An independent sample t-test was performed on the FHA and FSA of the two groups before the intervention, and the results are presented in Table 9. FHA in the experimental group was 49.07±2.49, while in the control group was 48.87±2.23, with t=0.232 and p=0.819. Regarding FSA, in the experimental group was 56.87±4.24, and in the control group was 56.93±4.48, with t=-0.042 and p=0.967. These results indicate that there were no significant differences in FHA and FSA values between the two groups of participants before the intervention.

Independent samples t-tests were performed on the FHA and FSA of the subjects in both groups after the intervention, and the results are shown in Table 10, FHA in the experimental group was 39.13±4.47 and in the control group was 43.27±5.12, with t=-2.335 and p=0.026. For FSA, in the experimental group was 47.07±4.18 and in the control group was 51.73±5.12, with t=-2.734 and p=0.011. These results indicate that there were significant differences between the FHA and FSA values of the subjects in both groups after the intervention. The FHA and FSA of experimental group were significantly lower than control group.

3.2 Cervical Spine Range of Motion (ROM)

In this research, we recorded the changes in cervical spine ROM in UCS patients before and after the intervention and analyzed the effects.

3.2.1 Cervical flexion ROM and extension ROM

Independent samples t-tests were conducted on the ROM for flexion and extension in the two groups of subjects prior to the intervention, with the results presented in Table 9. For flexion ROM, the ROM of experimental group was

36.13±2.88, while the control group was 36.07±2.46, with t=0.068, p=0.946. For extension ROM, the ROM of experimental group was 30.73±6.24, while the control group was 31.53±5.58, with t=-0.370, p=0.714. These results suggest that there were no significant differences in either flexion or extension ROM between the two groups prior to the intervention.

Independent samples t-tests were conducted on the flexion ROM and extension ROM of the two groups of subjects after the intervention, and the results are shown in Table 10. For flexion ROM, 38.33±2.94 in the experimental group and 37.93±3.33 in the control group, t=0.349, p=0.720. And for extension ROM, 40.93±3.69 in the experimental group and 37.13±4.00 in the control group, t=2.704, p=0.012. This indicates that there is no significant difference in flexion while there is a significant difference in extension ROM of the two groups of subjects after the intervention.

3.2.2 Cervical left lateral flexion ROM and right lateral flexion ROM

An independent samples t-test was performed on the left and right lateral flexion ROM of the subjects in the two groups before the intervention, and the results are shown in Table 9. For the left lateral flexion ROM, 32.4±3.31 in the experimental group and 31.87±3.27 in the control group, t=0.444, p=0.661, and for the right lateral flexion ROM, 32.00±4.26 in the experimental group and 31.87±3.80 in the control group, t= 0.091, p=0.929. These results suggest that there was no significant difference in left and right lateral flexion ROM between the two groups of subjects before intervention.

Independent samples t-test was performed on the left and right lateral flexion ROM of the two groups of subjects after the intervention, and the results are shown in Table 10. The left lateral flexion ROM was 35.60±5.12 in the experimental group and 35.27±5.39 in the control group, t=0.174, p=0.863, and for the right lateral flexion ROM was 35.40±5.14 in the experimental group and 34.27±4.77 in the control group, t=0.626, p=0.536. These results indicate that there was no significant difference in left and right lateral flexion ROM between the two groups of subjects after the intervention.

3.2.3 Cervical left rotation ROM and right rotation ROM

Independent samples t-tests were conducted to compare the left and right rotation ROM between the two groups of subjects before the intervention. The results, as presented in Table 9, reveal that for left rotation ROM, experimental group was 51.47±9.98, control group was 53.13±10.27, t = -0.451 and p= 0.656. This indicates no significant difference between the groups for left rotation ROM. Similarly, for right rotation ROM, experimental group was 51.93±10.13, control group was 51.80±9.69，t=0.037，p=0.971. This further confirms that there was no statistically significant difference in right rotation ROM between the two groups before the intervention.

Independent samples t-tests were performed on the left and right cervical rotation ROM the subjects in the two groups after the intervention, and the results are shown in Table 10. For left rotation ROM: 67.8±6.92 in the experimental group and 61.27±8.61 in the control group, t=2.291, p=0.030. For right rotation ROM: 69.27±7.43 in the experimental group and 61.33±6.86 in the control group, t= 3.038, p=0.005. There was a significant difference in the ROM of left and right cervical rotation in both groups of subjects after the intervention.

3.3 Surface Electromyography (sEMG) frequency domain indexes

In this research, the sEMG equipment was used to measure the left and right upper trapezius (UT) fasciculus, lower trapezius (LT) fasciculus and pectoralis major (PM1) of the subjects. The frequency domain indexes include mean power frequency (MPF) and median frequency (MF), which can intuitively reflect the changes of muscle function (e.g., anti-fatigue ability) in the UCS population, and it is an important basis for evaluating the effect of the intervention.

3.3.1 MPF and MF of the left UT

The independent samples t-tests were conducted on the sEMG results of the left UT of the two groups of subjects before the intervention, and the results were shown in Table 9. The MPF of the experimental group was 65.49±4.41, and that of the control group was 65.89±5.09, t=-0.230, p=0.820, indicating that there was no significant difference in the MPF of the two groups of subjects before intervention;

the MF of the experimental group was 59.98±3.86 and MF in the control group was 59.33±5.37, t=0.376, p=0.710, indicating that there was no significant difference in MF between the two groups of subjects before the intervention.

An independent samples t-test was performed on the sEMG results of the left UT of the two groups of subjects after the intervention, and the results are shown in Table 10. The MPF of the experimental group was 77.86±4.55, and that of the control group was 72.74±5.23, t=2.858, p=0.008, which indicates that there was a significant difference between the two groups of subjects after the intervention, and that the MPF of the experimental group was significantly higher than that of the control group. MF was 74.54±4.08 in the experimental group and 68.49±4.50 in the control group, t=3.859, p=0.001, indicating that there was a significant difference in MF between the two groups of subjects after the intervention, and that the MF of the experimental group was significantly higher than that of the control group.

3.3.2 MPF and MF of right UT

The independent samples t-test was performed on the sEMG results of the right UT of the two groups of subjects before the intervention, and the results were shown in Table 9. The MPF of the experimental group was 68.05±4.41, and that of the control group was 67.60±4.66, t=0.277, p=0.783, indicating that there was no significant difference in the MPF between the two groups of subjects before the intervention; and the MF of the experimental group was 58.98±5.22, the MF of the control group was 59.06±4.83, t=-0.045, p=0.964, indicating that there was no significant difference in MF between the two groups of subjects before the intervention.

An independent samples t-test was performed on the sEMG results of the right UT of the two groups of subjects after the intervention, and the results are shown in Table 10. The MPF of the experimental group was 81.31±5.54, and that of the control group was 77.05±4.77, t=2.260, p=0.032, indicating that there was a significant difference between the MPF of the two groups of subjects after the intervention, and that the MPF of the experimental group was significantly higher than that of the control group. MF of the experimental group was 73.02±5.32 and that of the control group was 67.71±4.89, t=2.848, p=0.008, indicating that there was a significant difference in MF between the two groups of subjects after the intervention, and that the MF of the experimental group was significantly higher than that of the control group.

3.3.3 MPF and MF of the left LT

An independent samples t-test was performed on the sEMG results of the left LT in the two groups of subjects before the intervention, and the results are shown in Table 9. The MPF of the experimental group was 67.27±4.75, and that of the control group was 67.09±6.34, t=0.090, p=0.929, which indicated that there was no significant difference in the MPF of the two groups of subjects before the intervention; and the MF of the experimental group was 60.99±4.78, and that of the control group was 60.15±5.12, t=0.461, p=0.648, indicating that there was no significant difference in MF between the two groups of subjects before the intervention.

Independent samples t-test was performed on the sEMG results of the left LT of the two groups of subjects after the intervention, and the results are shown in Table 10. The MPF of the experimental group was 59.50±3.64, and that of the control group was 62.08±6.48, t=-1.343, p=0.193, which indicated that there was no significant difference in the MPF of the two groups of subjects after the intervention; the MF of the experimental group was 48.89±4.16 and MF of the control group was 52.48±4.83, t=-2.185, p=0.037, indicating that there was a significant difference in MF between the two groups of subjects after the intervention, and MF of the experimental group was significantly lower than that of the control group.

3.3.4 MPF and MF of right LT

The independent samples t-test was performed on the sEMG results of the right LT of the two groups of subjects before the intervention, and the results were shown in Table 9. The MPF of the experimental group was 64.11±4.28, and that of the control group was 64.33±4.25, t=-0.137, p=0.892, indicating that there was no significant difference in the MPF of the two groups of subjects before the intervention; the MF of the experimental group was 57.85±6.26 in the experimental group was 57.00±5.17, t=0.405, p=0.688, indicating that there was no significant difference in MF between the two groups of subjects before the intervention.

An independent samples t-test was performed on the sEMG results of the right LT of the two groups of subjects after the intervention, and the results are shown in Table 10. The MPF of the experimental group was 58.53±2.91, and that of the control group was 60.91±5.11, with t=-1.563 and p=0.129, which indicates that there was no significant difference in the MPF of the two groups of subjects after the intervention. The MF of the experimental group was 52.38±3.66 and MF of the control group was 56.76±5.71, t=-2.500, p=0.019, indicating that there was a significant difference in MF between the two groups of subjects after the intervention, and MF of the experimental group was significantly lower than that of the control group.

3.3.5 MPF and MF of left PM1

The independent samples t-test was conducted on the sEMG results of the left PM1 of the two groups of subjects before the intervention, and the results were shown in Table 9. The MPF of the experimental group was 65.97±5.28, and that of the control group was 66.34±5.30, t=-0.193, p=0.848, indicating that there was no significant difference in the MPF of the two groups of subjects before the intervention; the MF of the experimental group was 62.18± 5.90 in the experimental group and 62.18±5.87 in the control group, t=0.000, p=1.000, indicating that there was no significant difference in MF between the two groups of subjects before the intervention.

Independent samples t-test was performed on the sEMG results of the left PM1 of the two groups of subjects after the intervention, and the results are shown in Table 10. The MPF of the experimental group was 81.33±4.74, and that of the control group was 75.92±6.36, t=-2.643, p=0.013, indicating that there was a significant difference in MPF between the two groups of subjects after the intervention, and that the MPF of the experimental group was significantly higher than that of the control group; The MF of the experimental group was 68.00±4.09 and that of the control group was 65.37±6.09, t=1.388, p=0.176, indicating that there was no significant difference in the MF of the two groups of subjects after the intervention.

3.3.6 MPF and MF of right PM1

The independent samples t-test was conducted on the sEMG results of the right PM1 of the two groups of subjects before the intervention, and the results were shown in Table 9. The MPF of the experimental group was 66.19±5.45, and that of the control group was 66.17±5.81, t=-0.011, p=0.991, indicating that there was no significant difference in the MPF of the two groups of subjects before the intervention; the MF of the experimental group was 58.54± 4.18 in the experimental group and 58.85±5.31 in the control group, t=-0.179, p=0.859, indicating that there was no significant difference in MF between the two groups of subjects before the intervention.

An independent samples t-test was performed on the sEMG results of the right PM1 of the two groups of subjects after the intervention, and the results are shown in Table 10. The MPF of the experimental group was 82.60±5.75, and that of the control group was 75.59±6.88, t=3.031, p=0.005, indicating that there was a significant difference in MPF between the two groups of subjects after the intervention, and that the experimental group's MPF was significantly higher than that of the control group; The MF of the experimental group was 66.38±3.92 and that of the control group was 62.61±5.12, t=2.265, p=0.031, indicating that there was a significant difference in MF between the two groups of subjects after the intervention, and that the MF of the experimental group was significantly higher than that of the control group.

3.4 Visual Analogue Score (VAS)

In this research, the visual analogue score (VAS) was utilized to assess the pain level of the subjects. As a subjective pain assessment tool, the VAS is able to intuitively reflect the changes in pain perception in the UCS population, and is an important subjective basis for evaluating the effectiveness of treatment.

Independent samples t-test was performed on the results of the VAS of the two groups of subjects before the intervention, and the results are shown in Table 9. The VAS of the experimental group was 4.33±1.29, and the VAS of the control group was 4.27±1.28, with t=0.142, and p=0.888, which indicates that there was no significant difference in the VAS of the subjects in the two groups before the intervention.

Independent samples t-test was conducted on the results of VAS of the two groups of subjects after the intervention, and the results are shown in Table 10. The VAS of the experimental group was 0.47±0.64, and the VAS of the control group was 1.00±0.76, with t=-2.086, p=0.046, which indicates that there is a significant difference between the two groups of subjects after the intervention. And the VAS of experimental group was significantly lower than control group.

3.5 Neck Disability Index (NDI)

In this research, the neck disability index (NDI) questionnaire was used to assess the degree of cervical spine impairment of the subjects, which can intuitively reflect the changes in the degree of cervical spine limitation in the UCS population, and it is an important basis for evaluating the effectiveness of the treatment. The reduction of the NDI indicates that the cervical spine dysfunction has been significantly improved, and the quality of life of the subjects has been improved.

Independent samples t-test was performed on the NDI results of the two groups of subjects before the intervention, and the results were shown in Table 9. The NDI of the experimental group was 23.87±3.50, and that of the control group was 24.53±3.16, t=-0.547, p=0.588, indicating that there was no significant difference in the NDI of the two groups of subjects before the intervention.

An independent samples t-test was performed on the NDI results of the two groups of subjects after the intervention, and the results are shown in Table 10. The NDI of the experimental group was 3.33±1.63, and that of the control group was 7.20±3.00, with t=-4.379 and p=0.000, indicating that there was a highly significant difference in the NDI between the two groups of subjects after the intervention, and that the NDI of experimental group was significantly lower than control group.

Table 10 Comparison of indicators between groups in the pre-test

Indicators			Experimental Group		Control Group		t	p
			$\bar{X}$	SD	$\bar{X}$	SD		
Body posture	FHA		49.07	2.49	48.87	2.23	0.232	0.819
	FSA		56.87	4.24	56.93	4.48	-0.042	0.967
Cervical Spine range of motion (ROM)	Flexion		36.13	2.88	36.07	2.46	0.068	0.946
	Extension		30.73	6.24	31.53	5.58	-0.370	0.714
	Left lateral flexion		32.40	3.31	31.87	3.27	0.444	0.661
	Right lateral flexion		32.00	4.26	31.87	3.80	0.091	0.929
	Left rotation		51.47	9.98	53.13	10.27	-0.451	0.656
	Right rotation		51.93	10.13	51.80	9.69	0.037	0.971
Surface electromyography (sEMG) frequency domain indexes	Left UT	MPF	65.49	4.41	65.89	5.09	-0.230	0.820
		MF	59.98	3.86	59.33	5.37	0.376	0.710
	Right UT	MPF	68.05	4.41	67.60	4.66	0.277	0.783
		MF	58.98	5.22	59.06	4.83	-0.045	0.964
	Left LT	MPF	67.27	4.75	67.09	6.34	0.090	0.929
		MF	60.99	4.78	60.15	5.12	0.461	0.648
	Right LT	MPF	64.11	4.28	64.33	4.25	-0.137	0.892
		MF	57.85	6.26	57.00	5.17	0.405	0.688
	Left PM1	MPF	65.97	5.28	66.34	5.30	-0.193	0.848
		MF	62.18	5.90	62.18	5.87	0.000	1.000
	Right PM1	MPF	66.19	5.45	66.17	5.81	0.011	0.991
		MF	58.54	4.18	58.85	5.31	-0.179	0.859
Visual Analogue Score (VAS)			4.33	1.29	4.27	1.28	0.142	0.888
Neck Disability Index (NDI)			23.87	3.50	24.53	3.16	-0.547	0.588

Note: *Significant difference between groups (p<0.05); **Significant difference between groups (p<0.01); *** Significant difference between groups (p<0.001)

Table 11 Comparison of indicators between groups in the post-test

Indicators			Experimental Group		Control Group		t	p
			X̄	SD	X̄	SD		
Body posture	FHA		39.13	4.47	43.27	5.12	-2.335	0.026*
	FSA		47.07	4.18	51.73	5.12	-2.734	0.011*
Cervical spine range of motion (ROM)	Flexion		38.33	2.94	37.93	3.33	0.349	0.720
	Extension		40.93	3.69	37.13	4.00	2.704	0.012*
	Left lateral flexion		35.60	5.12	35.27	5.39	0.174	0.863
	Right lateral flexion		35.40	5.14	34.27	4.77	0.626	0.536
	Left rotation		67.8	6.92	61.27	8.61	2.291	0.030*
	Right rotation		69.27	7.43	61.33	6.86	3.038	0.005**
Surface electromyography (sEMG) frequency domain indexes	Left UT	MPF	77.86	4.55	72.74	5.23	2.858	0.008**
		MF	74.54	4.08	68.49	4.50	3.859	0.001**
	Right UT	MPF	81.31	5.54	77.05	4.77	2.260	0.032*
		MF	73.02	5.32	67.71	4.89	2.848	0.008**
	Left LT	MPF	59.50	3.64	62.08	6.48	-1.343	0.193
		MF	48.89	4.16	52.48	4.83	-2.185	0.037*
	Right LT	MPF	58.53	2.91	60.91	5.11	-1.563	0.129
		MF	52.38	3.66	56.76	5.71	-2.500	0.019*
	Left PM1	MPF	81.33	4.74	75.92	6.36	2.643	0.013*
		MF	68.00	4.09	65.37	6.09	1.388	0.176
	Right PM1	MPF	82.60	5.75	75.59	6.88	3.031	0.005**
		MF	66.38	3.92	62.61	5.12	2.265	0.031*
Visual Analogue Score (VAS)			0.47	0.64	1.00	0.76	-2.086	0.046*
Neck Disability Index (NDI)			3.33	1.63	7.20	3.00	-4.379	0.000***

Note: *Significant difference between groups (p<0.05); **Significant difference between groups (p<0.01); *** Significant difference between groups (p<0.001)

CHAPTER 5

SUMMARY, DISCUSSION AND SUGGESTIONS

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This research is to apply Pilates training and Pilates training combined with fascial massage to the UCS population for 12 weeks to investigate whether it can effectively improve the body posture (FHA, FSA), cervical spine range of motion (ROM), surface electromyography (sEMG), pain level (visual analogue score, VAS), and neck disability index (NDI) of the UCS population. The researchers can summarize the results of the research as follows:

1. Research objectives

2. Research hypothesis

3. Summary

4. Discussion

5. Suggestion

1. Research Objectives

1. Investigate the effect of Pilates training combined with fascial massage on UCS in office workers.

2.Compare the effects of Pilates training combined with fascial massage with Pilates training alone on UCS in office workers

2. Research hypothesis

1. The experimental results showed that both the experimental group and the control group had an ameliorative effect on the upper crossed syndrome.

2. It is hypothesized that Pilates training combined with fascial massage is superior to Pilates training alone in the treatment of upper cross syndrome in office workers.

3. Summary

After applying Pilates training and Pilates combined with fascial massage for 12 weeks of intervention in the UCS population, the indicators of FHA, FSA, ROM, sEMG, VAS, and NDI in the UCS population can be summarized as follows:

(1) The baseline characteristics information of the subjects showed that the mean age was 35.64 years, with a standard deviation of 1.56; the mean height was 1.68m, with a standard deviation of 0.01; the mean weight was 66.97kg, with a standard deviation of 1.41; and the mean BMI was 19.96kg/m2, with a standard deviation of 0.28.

(2) Comparison between groups found that FHA, FSA, ROM (extension, left rotation and right rotation), MPF (left and right upper trapezius, left and right pectoralis major), MF (left and right upper trapezius, left and right lower trapezius, and right pectoralis major), VAS, and NDI were significant different; but ROM (flexion, left flexion, and right flexion), MPF (left and right lower trapezius), MF (left pectoralis major) did not different

(3) Comparison within group found that FHA, FSA, ROM, MPF (left and right upper trapezius, left and right lower trapezius, left and right pectoralis major), MF (left and right upper trapezius, left and right lower trapezius, left and right pectoralis major), VAS, and NDI in the experimental group were significant different; and FHA, FSA, ROM, MPF (left and right upper trapezius, left and right lower trapezius, and left and right pectoralis major), MF (left and right upper trapezius, left lower trapezius, left and right pectoralis major), VAS, and NDI in the control group were significantly different, and in MF of the right lower trapezius was no difference.

4. Discussion

The main objective of this research was to verify the effects of two intervention programs, Pilates training alone and Pilates training combined with fascial massage, on various indicators such as body posture (FHA, FSA), cervical spine ROM, sEMG, VAS, and NDI in the UCS population. Therefore, we discuss the results of the comparison of each index between and within groups, respectively.

4.1 Investigate the effect of Pilates training combined with fascial massage on UCS in office workers

The results of the study suggest that Pilates combined with myofascial massage is effective for UCS, which is consistent with the previous hypothesis, as reflected in the improvement in the results of the indicators, as follows.

4.1.1 Forward Head Angle (FHA) and Forward Shoulder Angle (FSA)

In this research, a within-group comparison of the UCS population after 12 weeks of Pilates training and Pilates combined with fascial massage revealed that there was a significant difference between the FHA and FSA values of the experimental group before and after the intervention, with the FHA and FSA of the experimental group being significantly lower than those of the pre-intervention group, and that the control group showed the same trend. This suggests that both Pilates training alone and Pilates training combined with fascial massage can significantly improve body posture in the UCS population.

Similar to our findings, several previous studies have confirmed the efficacy of Pilates training in improving abnormal body postures. In one research of 66 preschoolers aged 5-6 years old who received Pilates sessions twice a week for 10 weeks, the control group continued their daily routines and assessed postural assessment using the New York Posture Rating Scale test and found positive improvements in FSA (Ozturk & Unver, 2022). Another research, after 38 weeks of Pilates training for adolescents with thoracic kyphosis, found that the Pilates group improved thoracic kyphosis in a relaxed standing position; no differences were seen in the control group of students who participated in only two regular physical education classes and did not participate in any specific or structured exercise program that differed from the regular physical education classes, and the difference between the two groups was significant. In addition, significantly fewer participants in the Pilates group suffered from hyperlordosis than in the control group at the end of the program. Participants practicing Pilates achieved a near-normal angle of thoracic curvature and achieved a mean value that was not too close to the upper limit of lumbar curvature (González-Gálvez, Marcos-Pardo, Albaladejo-Saura, López-Vivancos, & Vaquero-Cristóbal, 2023).

Body posture reflects the mechanical relationship between the body's muscles, bones, nervous system and internal organs. Correct body posture not only ensures the normal functioning of the organs, but also keeps the body in a stable state (Yongxin, 2017). Incorrect posture or deviation from the optimal posture can cause abnormal stress on the body, lead to postural deviations and even increase the risk of injuries. Vladimir Janda has proposed that UCS is a postural abnormality that refers to specific altered patterns of muscular activation (especially in the muscles of the neck, trunk and scapula) and altered patterns of movement (LS dyskinesia), as well as postural deviations (forward head and shoulder posture, and increased thoracic kyphosis) (Morris, Greenman, Bullock, Basmajian, & Kobesova, 2006; P. Page, 2011b). FHA is the angle at which the head is tilted forward relative to the neutral position of the body. Under normal conditions, the head should be located on the neutral axis of the body in a natural balance. However, in the UCS population, the tension and imbalance of the neck muscles, especially the anterior muscles such as sternocleidomastoid (SCM) and rhomboid, and the weakness of the posterior muscles such as deep cervical flexors, lead to over-extension of the head forward, resulting in the head-forward tilted posture. Head-forward posture is a malposition associated with increased thoracic kyphosis and anterior shoulder position characterized by forward displacement of the head relative to the line of gravity and resulting in hyperextension of the upper cervical vertebrae (C1-C3) and flexion of the lower cervical vertebrae (C4-C7), which is the result of altering the position of the head relative to the line of gravity (Abd El-Azeim, Mahmoud, Mohamed, & El-Khateeb, 2022). The FSA is the angle at which the LS is internally rotated relative to the neutral position of the body. As one of the typical symptoms of UCS, rounded shoulders, a faulty body shape that appears as a hunchback, is characterized by the shoulders remaining internally rotated, the chest is sunken, and the prolonged forward tilting of the scapulae creates excessive stress and increases muscle tension. The pectoralis major muscle (PM1) is not sufficiently stretched by forward inward contraction, and on the contrary, the PM1 is not stretched by prolonged contraction, which makes the elasticity deteriorate. In patients with rounded shoulders, the muscles with the greatest increase in muscle tone are the upper trapezius (UT) and the pectoralis minor (PM2) (Gunaydin, Ertekin, & Gunaydin, 2022).

Pilates, as an exercise therapy that emphasizes postural awareness and direct attention to movement patterns, helps to improve flexibility, strength, overall body control, and endurance (Hayden et al., 2021). Amanda Greene, et al. performed the AlignaBod Postural Screening, Upper Abdominal Manual Muscle Test, Lower Leg Test, Straight Leg Raise Test, and the Modified Thomas Test on 20 female dancers. Attended a 14-week dance program without Pilates and had a second assessment. After that, a 14-week, twice-weekly Pilates program was then attended. The research ended with a final assessment and qualitative data was collected on participants' perceptions of their experiences. The analysis showed that attending dance classes alone did not produce significant changes in posture, but after the Pilates intervention the number of postural misalignments decreased. The prevalence of forward head tilt, knee hyperextension and ankle rotation anterior or posterior were all significantly reduced. All participants reported that they felt Pilates improved their core stability, pelvic alignment, strength, and body awareness (Ahearn, Greene, & Lasner, 2018).

Therefore, based on the results of previous studies, the present research re-educated subjects on their pelvic, spinal, head and neck postures through the pelvic clock during the warm-up exercise of Pilates to develop their proprioception and awareness of the body. This focus potentially activates proprioceptive somatosensory areas in the cortex, subsequently enhancing proprioception via a feedforward mechanism. Based on our research outcomes, Pilates training can be regarded as a viable option for improving cervical proprioception. In a prior research, patients with chronic non-specific neck pain underwent a six-week clinical Pilates program, with joint position error measurements conducted before and after the intervention. The results revealed a significant improvement in cervical proprioception among participants engaging in clinical Pilates exercises (Sahiner Picak & Yesilyaprak, 2023).

At the same time, Pilates training can improve the abnormal muscle activation and movement patterns and some postural deviations that are commonly found in UCS populations by enhancing the activation of the core muscles (P. Page, 2011b). Altered muscle activation in the UCS population includes deep neck flexor (DNF), middle trapezius muscle (MT) and lower trapezius muscle (LT), and anterior serratus underactivity (P. Page, 2011a). In Pilates asanas, seated rhomboids, kicks, and bow swings， strengthen the DNF, the muscles of the back, and the core muscles. Prone spinal stretch and cat's back stretching target the spinal extensor muscles. One research found that twelve weeks (24 sessions) of Pilates training produced significant improvements in muscle function (leg push-ups, chest push-ups, curls, core) and posture (8 measures plus a total score), even in women who had been exercising for at least 1 year (range 12-48 months) (Otto et al., 2004).

The neck-pulling exercise, seated rhomboid training, single-legged pullback, deep cervical flexor stabilization, double-legged pullback, deep cervical flexor stabilization and freestyle stroke were used in this research. These asanas are effective in strengthening the DNF, back muscles and core muscles thereby strengthening the recruitment of weak muscles, weakening the recruitment of tense muscles, and improving muscular imbalances, which in turn improves the FHA and FSA, and corrects the poor body posture of the UCS population.

In addition, we believe that Pilates' improvement in posture may also be related to its improvement in respiratory function. Changes in head and neck position have a direct effect on respiratory function (Zafar, Albarrati, Alghadir, & Iqbal, 2018). The effects of Pilates on respiratory function have been previously demonstrated. In one research that found a statistically significant increase in the remaining cardiovascular and respiratory variables after 8 weeks of Pilates training in healthy, normal subjects. The results of this research suggest that Pilates training has an effect on cardiovascular and respiratory variables (Lee, G., Lee, D.-Y., & Yu, J., 2011). In this research, most of the Pilates movements were performed in conjunction with breathing, which can lead to an increase in respiratory muscle strength. When respiratory muscle function is increased, the sequence of respiratory muscle activation is restored. This resulted in improved round-shoulder posture during the calm breathing state, when the auxiliary respiratory muscles (e.g., UT, PM1, etc.) were hardly involved in respiratory activity, and internal rotation of the upper limbs and chest-holding were improved. By systematically strengthening the respiratory muscles and fine-tuning the breathing pattern, we can gradually and effectively improve the hyperflexion of the thoracic segment. This improvement is not only limited to the thoracic region, but also has a profound effect on the head and neck posture, promoting the balance and coordination of the whole upper body posture.

Fascia is the connective tissue associated with muscles that forms a continuous three-dimensional matrix between myofilaments, muscle fibers, and muscle bundles. It wraps around individual muscles and connects different muscles. Fascial tissue forms a structural support for a systemic, continuous three-dimensional viscoelastic matrix (Klingler, Velders, Hoppe, Pedro, & Schleip, 2014). The fascial structures at the cervical spine include two parts: the superficial cervical fascia and the deep cervical fascia. The superficial cervical fascia mainly surrounds the vastus cervicis muscle and contains adipose tissue. While the deep cervical fascia is further subdivided into three layers, which surround the neck muscles, organs, and vascular and neural bundles, forming complex fascial sheaths and fascial gaps. These structures play an important role in maintaining the stability of the neck and protecting the neck organs (Prabu Raja et al., 2022). Fascial massage in the fascial chain theory is the relaxation of connective tissues in the body, usually superficial fascia, deep fascia, ligaments and muscles. Its fundamental purpose is to regulate the metabolism of the region, so that the muscle strength and tension around it can be more balanced, the joint position can function better, and the mechanical effect can be best responded to. At the same time, it can also release the fascial adhesion, improve the elasticity of the fascia, and relieve the tension of the fascia and the muscle, which can improve the physiological function of the body, and finally, promote the formation of a good body posture.

For the UCS population, when the body is in a prolonged posture such as working at a desk or looking down at a cell phone, the anterolateral fascial chains (including the PM1, PM2, and UT, etc.) will be under constant tension and have increased tension. The tension in these muscles pulls the anterior fascial chain, which in turn pulls the shoulders and chest forward, resulting in forward head tilt and reduced or absent cervical lordosis. At the same time, the posterior fascial chains (including rhomboids, MT, LT, and DNF) are stretched or become weak and ineffective in countering the pull of the anterior muscles. This imbalance in the anterior and posterior fascial chains further exacerbates the rounded-shoulder hunchback posture. According to the fascial chain theory, in this case, the tense muscle chains should be released first, and then the weak muscle groups should be strengthened (Wang Gang, 2019). Fascial massage affects these fascial changes and is therefore recommended for the treatment of chronic pain. The goal is to reduce pain, restore optimal muscle length, improve function, and relieve tissue compression in the fascial system (Overmann, Schleip, Anheyer, & Michalak, 2024), thereby improving FHA and FSA of the UCS population and help them to restore normal body posture.

In this research, Pilates training combined with fascial massage had a significant improvement in improving FHS and FSA. This may be due to the fact that Pilates training and fascial massage can simultaneously enhance the strength of the weak muscle groups of the shoulder and neck, relax the tense muscle groups, and restore the normal physiological properties of the muscles, thus improving the muscular imbalance of the UCS population, which is more helpful for them to regain the normal static body posture.

4.1.2 Cervical Spine Range of Motion (ROM)

This research conducted a 12-week Pilates training and a Pilates training combined with fascial massage interventions on the subjects, respectively. ROM in various directions of the cervical spine was measured before and after the interventions. The results of within-group comparisons showed that there were significant differences in the ROM of flexion, extension, left lateral flexion, right lateral flexion, left rotation, and right rotation before and after the intervention in the experimental group, and the ROM after the intervention was significantly higher than that before the intervention. Similarly, in the control group, there were also significant differences in the ROM of flexion, extension, left lateral flexion, right lateral flexion, left rotation, and right rotation before and after the intervention, with the ROM after the intervention being significantly higher than that before the intervention. This indicates that both Pilates training alone and Pilates training combined with fascial massage are effective in improving joint mobility.

Similar to our findings, in a study by yang minli (Yang minli, 2012), 60 patients with lumbar disc herniation were treated with traction therapy and a combination of traction and Pilates, and it was found that lumbar spine mobility improved significantly after 4 and 8 weeks.

Joint mobility is the maximum ROM that can be achieved during joint movement. And the changes in active joint motion limitations of patient's after rehabilitation can be evaluated by regular measurements of ROM. When the head is tilted forward and the body posture will change significantly, which also affects the normal physiological curvature of the spine. The poor posture leads to an increase in tension in the peripheral muscle groups of the cervical spine, while the distribution of abnormal stresses around the joints affects proprioception and causes disorders of the small cervical joints. In addition to the joints, ligaments and muscles are also the main factors affecting the activity of the cervical spine. The muscles that play a dominant role in the neck are the UT group, and it is the muscle strength that can be changed in a short time. Due to the effect of kinetic and muscular chains, alterations in LS movement patterns (LS dyskinesia) and specific postural changes occur, including a forward head and shoulder posture, as well as increased thoracic kyphosis. The reduction or even loss of cervical curvature in the UCS population has a direct impact on cervical anterior flexion and posterior extension mobility. In addition, changes in cervical curvature may lead to uneven pressure distribution between cervical joints, accelerating degenerative changes in the cervical spine. At the same time, due to long-term muscle imbalance and uneven joint pressure distribution, the cervical joints may gradually become stiff, further limiting the ROM of the cervical spine (Bayattork et al., 2020).

Pilates training, as a kind of exercise therapy, can further improve the joint mobility by adjusting the muscle imbalance. The PM1, PM2 and SCM muscles of UCS people are in a state of tension for a long period of time, and the shortening of these muscles will limit the flexion and rotation of the cervical vertebrae, which will cause the cervical spine ROM to decrease; and the muscles of the posterior back such as the rhomboid muscles, MT, LT, and the anterior serratus muscles have been stretched or become weak and cannot provide sufficient support and stability for the cervical spine, further limiting its ROM. In Pilates training, the flexibility of the thoracic spine joints is increased through training postures such as spinal flexibility training (e.g. baby style) and seated spinal rotation, which promotes joint alignment of the spine and pelvis and improves the abnormal physiological curvature of the spine and spine in people with UCS, and thus improves the flexibility of the spine and spinal column. At the same time, this type of flexibility exercise also stretches muscles and ligaments to increase the flexibility of the thoracic spine and other joints, and promotes the flexibility of the cervical spine (Feng Ling, 2015). Minli Yang suggested that this may be related to its ability to stretch the soft tissues of the trunk, move the lumbar spine joints, enhance the strength of the lumbar, abdominal and dorsal muscles, relieve lumbar muscle spasms, and correct the imbalance of muscle strength (Yang Minli, 2012). Spinal flexibility training postures such as baby style and inverted V-style used in this research can promote the improvement of cervical spine ROM, and thus improve the flexibility of the spine.

Pilates training can also be used to promote the sensory input of the neck through dynamic training, raise more motor units, activate the deep muscle groups of the neck and shoulder, and put the spine in the correct position, so as to relax the excessively tense muscles, and some movements can play a role in stretching the spine and relaxing the muscles of the neck, shoulder, and back, so as to increase cervical spine ROM (Guo Yuwei, 2022). neck-pulling exercise used in this research can effectively strengthen the DNF, seated rhomboid training can effectively strengthen the shoulder and neck muscles. Dynamic training promotes sensory input to the neck, thus improving the ROM of the cervical spine

In addition, the improvement of respiratory function by Pilates training also helps to improve the poor posture of population with UCS. The underlying mechanism may be that the inspiratory muscles, in addition to the respiratory function, also have a role in regulating posture and maintaining body stability. UT, PM1, and other auxiliary inspiratory muscle function enhancement can relax the paravertebral muscles, thus improving joint mobility. In a research (Li Xiaoyan, 2020). Pilates intervention was carried out on 400 volunteers with spinal deformity, and it was found that Pilates training was effective in correcting spinal deformity in college students, especially for patients with one-level spinal deformity in the cervical, lumbar, and spinal curvature of curvature of the curvature of the spine, the angle of each curvature was lowered by a different degree, and compared with the pre-intervention period, it had a significant change, greatly improved the body shape of the university students, thus preventing the further development of spinal deformity; patients with secondary spinal deformity completely changed the status quo of head traction due to uneven muscle strength. The results of this research also demonstrated the effective ameliorative effect of Pilates on abnormal body shape, which is consistent with our findings. In this research, the subjects were awakened through breathing and pelvic arousal training to reshape the normal breathing pattern, while breathing exercises were consistently used throughout the training process, thus improving the function of auxiliary respiratory muscles such as the UT and PM1, and thus improving the cervical spine joint mobility in the UCS population.

Fascial massage techniques can relieve muscle tension and stiffness by relieving muscle tension and stiffness, such as fascial sports stretch relaxation, foam axis fascial massage, and fascial massage ball relaxation. It also reduces muscle stickiness and makes the muscles easier to stretch and activate, thus improving joint mobility. the muscles of the UT, PM1 and PM2 in the back of people with UCS are chronically tense, which further affects the fascial tissues that encircle these muscles, resulting in the fascia becoming tense as well. In addition, prolonged muscle tension and poor posture may lead to adhesions between the fascia and muscles, and between the fascia and fascia, resulting in the formation of striated, nodular masses. These adhesions can further restrict muscle and joint mobility, resulting in limited cervical spine ROM. The compression and stretching during fascial massage promotes local blood circulation, providing sufficient oxygen and nutrients to the tissues while carrying away metabolic wastes, which helps in the repair and recovery of the tissues.

Relief of inflammation and pain: chronic muscle tension and stiffness can lead to localised inflammation and pain. Fascial massage relieves this inflammation and pain, creating favourable conditions for improved joint mobility. Re-establishment of neuromuscular efficiency: fascial massage techniques stimulate receptors in the muscles, fascia and connective tissues with specific pressure, which can correct malfunctions due to cumulative cycles of damage. This helps to re-establish neuromuscular efficiency, allowing the muscles to respond more accurately to nerve signals, thus improving the accuracy and fluidity of joint movements. Fascial massage using a fascia gun and foam shaft prior to Pilates training in the experimental group of subjects in this research reduced pain and helped restore normal physiological properties of the muscles, resulting in a more effective Pilates training intervention afterwards.

4.1.3 Surface Electromyography (sEMG) frequency domain indexes

In this research, MPF and MF values of the UT, LT, and PM1 muscles on the left and right sides of both groups of subjects were collected before and after the 12-week intervention, respectively. For the MPF values, comparisons within-groups revealed the following: In the experimental group, the MPF values of the UT and PM1 on both sides were significantly increased after the intervention compared to before, while the MPF values of the LT on both sides were decreased. In the control group, the MPF values of the UT and PM1 on both sides were significantly increased after the intervention, but the MPF values of the LT on both sides were decreased compared to before the intervention. For MF values, within-group comparisons revealed that: In the the experimental group, LT and the PM1 on both the left and right sides significant increase after intervention, but there was a significant decrease in the MF values of the LT on both the left and right sides from the pre-intervention level; In the control group, there was no significant difference in the MF values of the right LT, but the MF values of UT and PM1 were significantly higher on both the left and right sides after the intervention, the values of the left LT were decreased. The decrease in MPF and MF values of the LT may be due to the fact that it is a weaker muscle group in the upper cross syndrome population, and the presence of fatigue suggests that the LT has increased recruitment after getting adequate exercise.

Previously, it was also found in a research (Jie, 2021) that the MPF and MF of the left and right LT showed a decreasing trend after simple Pilates training, indicating that fatigue appeared in the LT, and the emergence of fatigue indicated that the LT had an increased degree of recruitment after sufficient exercise, which suggests that Pilates training can increase the activation of weak muscle groups such as the LT. Therefore, the results of this research demonstrated that both Pilates training alone and Pilates training combined with relaxation exercise are effective in improving muscle fatigue resistance.

sEMG signals are bioelectrical changes produced by the neuromuscular system when performing activities. In the analysis of sEMG signals, MPF and MF are two important indexes, which reflect the characteristics of muscle activities from different perspectives respectively. MPF indicates the frequency where the centre of gravity of the signal power spectrum is located, i.e. the average frequency of the signal energy distribution, which is one of the effective indicators to assess the state of muscle fatigue. As muscle fatigue deepens, MPF decreases. MF is the frequency in the middle of the signal energy distribution, i.e., the frequency point where the signal power spectrum is divided into two equal parts. The calculation of MPF and MF is usually based on the Fast Fourier Transform (FFT) of the signal or the estimation of the power spectral density. Previous clinical studies have demonstrated that, in both dynamic and static exercise, as fatigue deepens, the MPF and MF will shift from high to low frequencies as influenced by the signal conduction velocity of the muscle fibres, the amplitude index of the sEMG signal increases, and the Fourier spectral curves undergo varying degrees of leftward shifts, leading to corresponding decreases in the MPF and MF (Fang Boru, 2024), and when the muscle fatigue degree improves, the MPF and MF will also improve (Jie, 2021).

Pilates training, as an exercise that emphasises quality, precision and control of movement, may be used to improve muscle resistance to fatigue by activating the muscles in a specific sequence at an appropriate tempo and adjusting muscle activation patterns. In the UCS population, the head-forward posture causes the neck to deviate from the neutral position in anterior extension, at which time the neck muscles such as the UT need to undergo continuous muscular contraction thereby maintaining the stability of the neck joints, resulting in prolonged fatigue for the UT (Yunqi, 2017). In addition, in the UCS population, the round-shouldered body posture causes both shoulders to close in, so that PM1 is forced to be in a shortened position, and the long-term activation state causes it to be in a fatigue state, whereas the reciprocal inhibition caused by antagonist muscle tension results in the LT being in a lengthened state for a long period of time, which leads to a decrease in muscle strength, and it belongs to the weak muscles (Meijing, 2023). In this research, the neck-pulling exercise, which was selected from the Pilates asanas, could retrain the subjects' awareness and control of neck movement, and maximise the activation and strengthening of the deep cervical flexor muscle groups during the exercise (Hagberg & Kvarnström, 1984); double legged upper kick, freestyle stroke and other asanas can effectively stretch the PM1 and exercise the back muscles, thus improving the fatigue of the PM1, and at the same time effectively Enhance the muscle strength and activation of weak muscle groups such as LT, and improve the muscle imbalance in UCS population.

At the same time, Pilates training, as a mind-body training that combines movement, breathing, and meditation, all exercises should be accompanied by complete, rhythmic breathing. Therefore, Pilates training may also alter breathing patterns and regulate nerve conduction through breathing training, thus improving muscle imbalances. S.W. Hsu et al.(Siwei, 2024) found that Yanda therapy combined with abdominal breathing training improved the neuromuscular function of UT, MT and PM1 better than Yanda therapy alone by performing Yanda therapy group and Yanda therapy combined with abdominal breathing training on 36 young people with UCS for 12 weeks, respectively. This is due to the fact that UT and PM1 act as auxiliary respiratory muscles, lifting the ribs to aid inspiration during breathing. Therefore, in this research, we cooperated with respiratory training at the arousal stage to help the UCS population to establish a correct breathing pattern, and the importance of respiratory exercise has been emphasised in the exercise thereafter, which effectively improved the function of the auxiliary respiratory muscles such as UT and PM1, and increased their fatigue resistance.

In addition, Pilates training may also improve muscle function by improving proprioception in people with UCS, where abnormal body postures result in the input of abnormal proprioceptive information, leading to inability of the neuromuscular control system to accurately control specific muscles, decreased muscle control, and impaired regulation of static and dynamic balance (Çabuk et al., 2017). The Pilates intervention programme designed for this research included the pelvic clock, which is the most basic asana of all movements, and was designed to correct abnormal proprioceptive inputs and improve neuromuscular control by re-educating subjects on their pelvic, spinal, head and neck postures, and developing their proprioception and awareness of their bodies (spine, pelvis, etc.).

Previous studies have confirmed that fascial massage can increase muscle extensibility and decrease muscle stickiness, thus improving muscle performance. Thomas W. Myers elaborated on the phenomenon of muscle imbalance caused by biomechanical factors from the fascial point of view, and believed that the muscles on both sides of the skeleton are in an antagonistic relationship with each other, and that the fascial units attached to the muscles on both sides are also in an antagonistic relationship. When one side of the muscle is shortened for a long time (centripetal shortening), i.e. fascial atresia shortening, the other side of the muscle will be stretched (centrifugal lengthening), i.e. fascial unit atresia lengthening. In this research, the use of a fascia gun and foam shaft to release the fascia of the PM2, UT, SCM and other muscles can effectively reduce their adhesion and increase muscle extensibility, so that the tense muscles can be relaxed and their fatigue-resistant ability can be improved. In addition, fascial massage can improve proprioceptive input. In this research, a foam shaft and a fascial gun were used to perform fascial massage on the muscles of the neck and the back of the shoulder, such as the rhomboid, SCM, and latissimus dorsi, and by releasing the tension on the overactive neurofascial tissues of these bodies, proprioception could be accurately transmitted to the nociceptors, thus improving muscle balance.

Following fascial muscle release, muscle tension is released, the muscle cross-sectional area widens at the microscopic level, muscle elasticity and toughness are restored over time, and the once restricted ROM is restored in the immediate aftermath of release. Pilates training at this point emphasise quality, precision and control of movement, activating the relevant muscles at an appropriate pace and in a specific sequence. As one's dynamic strength increases, the human cervical musculature begins to activate, and the fascially released cervical and back muscles reach a new equilibrium in the process of strength resistance (Chen Xixi, 2024), which may be the reason why Pilates interventions combined with fascial massage are effective.

4.1.4 Visual Analogue Score (VAS)

In this research, the pain levels of the two groups of subjects were assessed separately before and after the 12-week intervention using the VAS scale. The results of within-group comparisons showed that there was a significant difference between the pre- and post-intervention VAS in the experimental group, with the post-intervention VAS being significantly lower than the pre-intervention results, and there was also a significant difference between the pre- and post-intervention VAS in the control group, with the post-intervention VAS being significantly lower compared to the pre-intervention results. This suggests that both Pilates training alone and Pilates training combined with fascial massgae are effective in improving pain levels in the UCS population.

This is consistent with the results of the present study in which Yuqing (Yuqing,

2023) conducted a 6-week voluntary stretching combined with muscular endurance training for female undergraduate students and found that stretching combined with muscular strength training was effective in reducing the pain level of female undergraduate students. Muscle imbalance in UCS is usually accompanied by pain, which causes abnormal movement patterns, which in turn aggravates the muscle imbalance in UCS population, and the aggravation of muscle imbalance makes the level of pain more severe, which in turn affects the ability of daily living activities in UCS patients, forming a vicious circle (Jie, 2021). As one of the main symptoms of UCS population, the assessment and treatment of pain is important for improving the quality of life and work efficiency of patients. VAS is an internationally recognised method for assessing the degree of pain (Zhilv, 2018), which quantifies the pain perception of the patient and provides an important basis for clinical diagnosis and treatment. In addition, the VAS can be used to compare the differences in the efficacy of different treatments in population with UCS, providing a reference for clinical decision-making.

Pilates training are used to activate deep muscles in an orderly manner through regular and controlled movements, thus enhancing muscle control and balance, while Pilates asanas also include a lot of flexibility training, which may be one of the reasons why Pilates training can be effective in reducing pain. Parisa Nejati (Nejati, Lotfian, Moezy, & Nejati, 2015) quantified the postural changes in the head, neck, shoulders and thoracic spine of office workers while working on computers and found that office workers were more likely to experience pain when working with computers in a forward-facing posture than in a normal forward-facing sitting posture. It is well known that stretching can reduce pain, the stretching of muscles makes the stiff and shortened muscles of UCS people get loosened, increases the local blood flow of muscles, promotes the blood circulation of muscles, and the blood flow brings nutrients, and at the same time, the metabolites that cause pain locally are taken away and removed gradually from the muscles, so as to alleviate the pain (Yuqing, 2023). The Pilates training programme designed in this research stretches muscles that have been under prolonged spasmodic tension through asanas such as the neck-pulling exercise, which significantly reduces muscle stickiness and helps to alleviate muscle stiffness and contractures. When the muscles were stretched to their physiological limits in the stretched state, their normal physiological elasticity was restored, and at the same time the blood flow around the muscles was improved, accelerating the metabolism and improving the ischaemic state of the muscles, which resulted in an analgesic effect, leading to a significant reduction in the pain level of UCS population.

In addition, Pilates, as a mind-body exercise, places great importance on establishing correct breathing patterns. The breathing pattern training included in the Pilates training programme designed for this research may also contribute to making pain and neck dysfunction lower. Several previous studies have shown that the abnormal body posture caused by UCS decreases respiratory muscle strength and affects respiratory function (Mengyun, 2020; Yunqi, 2017). Wu Ying et al., (Wu Ying, 2020) found that inspiratory muscle strength was negatively correlated with the FHA through intergroup comparisons and correlation analyses of parameters such as deep cervical flexor endurance and the degree of thoracic expansion of people in the two groups of people who had chronic neck pain and those who did not have chronic neck pain. In this research, by establishing a correct breathing pattern during the arousal phase and strengthening the respiratory muscle function of the UCS population during training, the ischaemia of the auxiliary respiratory muscles, such as the UT and PM1, was directly improved, which in turn served to reduce pain.

Fascial massage techniques can accurately stimulate pain points and send out nerve impulses. When these nerve impulses reach the spinal dorsal horn, other nerves that innervate muscles and viscera converge accordingly, and the efferent nerve triggers a local convulsive response and disrupts the provocative point circuit, thus relieving local pain, distal entrapment pain, dyskinesia, and autonomic deficits. Similar to our findings, Lan Bowen (Bowen, 2021) also found that fascial training can effectively improve pain symptoms in the UCS population. 30 UCS students were divided into a fascial training group, a functional training group, and a combined group and underwent a 6-week exercise intervention. In this intervention, the fascial training group used foam shafts, tennis ball rolling, and massage. The results of this research showed that fascial training in the group was able to significantly improve pain and dysfunction by fascial massage of shortened and tense muscle groups. Therefore, the experimental group in this research used a fascial gun and a foam shaft for fascial massage prior to Pilates training, which can effectively reduce pain and allow for more accurate and controlled subsequent completion of Pilates movements, resulting in better therapeutic outcomes.

4.1.5 Neck Disability Index (NDI)

In this research, the subjects underwent 12 weeks of Pilates training and Pilates training combined with fascial massage interventions, and the NDIs of the two groups were assessed before and after the interventions, respectively, and the results of the within-group comparisons showed that there was a significant difference between the NDIs before and after the intervention in the experimental group, which was significantly lower than the pre-intervention one, and that there was also a significant difference between the NDIs before and after the intervention in the control group, which was significantly lower compared with the pre-intervention one. This indicates that either Pilates training alone or Pilates training combined with fascial massage intervention are effective in improving cervical spine dysfunction in the UCS population.

Muscle imbalances in the UCS usually lead to dysfunctions in the cervical joints, which in turn cause abnormal movement patterns, which in turn aggravate muscle imbalances in the UCS population, making cervical spine dysfunction even more severe, and thus creating a vicious circle (Jie, 2021). The NDI is a standardised tool commonly used in clinical practice to assess cervical spine dysfunction, providing researchers with an objective and quantifiable assessment standard (Collaborators, 2017)。

This is in line with the findings of Yu-Wei Kuo et al. who conducted a 1-month Pilates exercise intervention in patients with chronic non-specific neck pain and finally found that it was effective in lowering the patients' NDI scores.

Pilates training require muscle activation in a specific sequence at an appropriate rhythm, the best movements with the least amount of force, and activation of the right muscle groups at the right point in time, possibly through activation of the deeper muscle groups and changing the sequence of muscle activation to improve cervical spine dysfunction. Several studies have shown that neck dysfunction is caused by damage to the deep muscles. Petty et al., (Petty, 1998) noted that weakening of the deep flexor muscles leads to reduced activation of muscles such as the superficial muscles, SCM and anterior trapezius, and triggers hypermobility of the jaw and head which leads to hyperextension of the upper cervical bone and shortening of the cervical muscles by the posterior cervical bone, and reduces the stability of the neck; Lee et al (M. H. Lee, Park, & Kim, 2013) conducted 8-week deep cervical flexor training on UCS high school students and found that the strength and endurance of the deep flexors had significantly improved and could effectively reduce pain and cervical spine dysfunction in the UCS population; Yang Guo et al., (Yang Guo, 2023) conducted 8 weeks of resistance exercise on UCS college students and found that it could significantly reduce neck pain and increase cervical spine flexibility and improve neck dysfunction in UCS college students. The deep cervical flexor stabilisation exercises used in this research can well improve the endurance of deep cervical flexor muscle groups and inhibit the over-activation of muscles such as SCM and UT. With the gradual weakening of the recruitment of the tense muscle groups and the gradual strengthening of the recruitment of the weak muscle groups, the tense muscles and adherent fascia can be gradually restored to a balanced state, and the improvement of the muscle imbalance can help to restore the normal alignment of the vertebral joints and the normal physiological curvature. After the muscle imbalance, vertebral instability and abnormal physiological curvature of the spine are gradually restored to normal, the correction of postural abnormality can be further promoted (Zhilv, 2018), thus improving the level of cervical spine dysfunction in the UCS population.

In addition, the correction of abnormal breathing patterns in Pilates training programmes may also contribute to the reduction of neck dysfunction. Prolonged hunched sitting posture causes an increase in the pressure in the human abdominal cavity, which has an effect on the contraction of the diaphragm to decline, an increase in the ROM of the ribcage, and instability of the thoracolumbar joints, which affects lung function; secondly, the forward head posture common in UCS population leads to the dilation of the upper thoracic contour and the constriction of the lower thoracic contour, which results in the decline of the body's respiratory function, with a greater degree of anterior displacement of the upper chest, and an anterior displacement of the lower chest accompanied by internal rotation. Professor Koseki et al., (Koseki, Kakizaki, Hayashi, Nishida, & Itoh, 2019) compared the chest shape and respiratory function in forward head posture with those in normal neutral posture and found that the chest shape was altered and respiratory function was reduced in the same subject in forward head posture. They believe that it is the deformation of the thorax caused by the forward tilt posture that leads to the restriction of thoracic movement, and the reduced mobility of the lower thorax during the entire respiratory process, resulting in the formation of an erroneous respiratory pattern commonly seen in the clinic - the upper thoracic segment. breathing pattern (Koseki et al., 2019). Prolonged forward head posture also leads to fatigue and ischaemia of both respiratory and locomotor muscles, and there is competition for blood flow between respiratory and locomotor muscles (Fulton et al., 2020). In this research, we improved the function of auxiliary respiratory muscles such as UT and PM1 in the UCS population by correcting the breathing pattern to improve their cervical spine dysfunction on the one hand, and on the other hand, we improved local blood circulation and metabolism through the training of respiratory muscles to improve physiological performance of the soft tissues around the cervical spine and to reduce the degree of cervical spine dysfunction.

Similar to Pilates training, previous studies have found that fascial training may work through multiple mechanisms to reduce neck dysfunction (Chun'e Hu, 2024). Firstly, fascial massage can help to restore biomechanical balance. By relieving muscle fatigue and reducing muscle tension, it improves the force pattern of neighbouring muscles and reduces pain levels and dysfunction. Secondly, fascial massage can also improve local blood circulation. Heat is transferred to the soft tissues through friction, increasing blood circulation. In addition, fascial massage stimulates pain points, sending nerve impulses that relieve pain by crushing the excitation point circuit. Pilates training produces a superimposed effect with fascial massage; therefore, the experimental group that combined fascial massage showed better improvement in NDI in this research.

4.2 Compare the effects of Pilates training combined with fascial massage with Pilates training alone on UCS in office workers

The results of the trial suggest that fascial massage combined with Pilates is more effective than Pilates alone in the treatment of UCS, as evidenced by the fact that Fascial Relaxation combined with Pilates is more effective in improving various indicators compared to Pilates alone. The details are as follows:

4.2.1 Forward Head Angle (FHA) and Forward Shoulder Angle (FSA)

In this research, population with UCS whose FHA exceeded 46 degrees and FSA exceeded 52 degrees were treated with Pilates training alone and Pilates combined with fascial massage. The result of between-group comparison before the intervention revealed that there was no significant difference between the FHA and FSA values of the two groups. But after the intervention, between-group comparison result indicated that the FHA and FSA values of the experimental group were significantly lower than those of the control group. And the subjects in both groups showed a decrease in their FHA and FSA values compared to pre-intervention. This suggested that both interventions resulted in a significant improvement in FSA, and that Pilates combined with fascial massage was significantly better than Pilates training alone.

Previous research has found that the main postural abnormalities associated with UCS include excessive forward head extension and shoulder pronation (Chang et al., 2023). These postural abnormalities put constant stress on the joints, and when exposed to constant stress, degenerative changes in the joints can progress rapidly, leading to muscle imbalances and pain. If the muscle imbalance persists and progresses, this can lead to altered movement patterns and joint damage, which can cause further dysfunction. Good body posture is a measure of good health. Cervical spondylosis pathogenesis (Wang Qingfu, 2013). that the cervical spine maintains its stability in a neutral position through a combination of static and dynamic forces. Optimal head and neck posture is important to minimise the need for muscular activity and the stress exerted on neck tissues (Yip, Chiu, & Poon, 2008). Therefore, therapists emphasise the importance of assessing head, shoulder and spinal position, as misalignment of these areas can affect a number of biomechanical variables, motor control and performance (Claus, Hides, Moseley, & Hodges, 2016).

The shoulder and neck muscles in the UCS population are characterised by tightness in one group of muscles (PM1, UT, levator scapulae) and weakness in the other (DNF, MT, LT and SA) （Izraelski, J, 2012). Tight muscle groups become shortened and overactivated, while weak muscle groups become elongated and inhibited, resulting in neither group being able to function effectively (Muscolino, 2015). Long-term muscular imbalance makes the joints have abnormal lines of force and the cervical spine cannot be in the correct position; this misalignment increases the pressure on the back of the neck, affects the length-tension relationship of the neck muscles, raises the level of muscular activity, restricts neck movement and impairs the proprioception of the cervical spine (Yip et al., 2008). In turn, abnormal joint force lines exacerbate this muscular imbalance, thus creating a vicious circle. Therefore adjusting and maintaining the correct position of the head is important to improve symptoms in patients with upper cross syndrome.

FHA is one of the most important indicators for assessing the degree of postural abnormality in patients with UCS, and its magnitude directly reflects the severity of the patient's head forward extension, which is an important reference value for the diagnosis of UCS. Prolonged forward head tilt may lead to increased cervical lordosis, straightening of cervical curvature or even retroversion, which in turn may trigger symptoms such as cervical spine pain, stiffness, and limitation of movement. In addition, forward head tilt may also cause excessive strain on the shoulder and neck muscles, leading to muscle tension, fatigue and pain. FSA is also an important indicator for assessing the degree of shoulder postural abnormality in patients with UCS, and its size directly reflects the severity of shoulder internal rotation in patients, which is also an important reference value for diagnosing UCS. Rounded shoulders can seriously affect the body's respiratory movement, leading to loss of appetite and lung capacity, while the wrong body shape can seriously affect the body's circulatory system. Studies have linked these postural deficiencies to alterations in scapular kinematics and muscle activity position (Fathollahnejad, Letafatkar, & Hadadnezhad, 2019). Some studies have observed that upper cervical hyperextension is associated with shortening of the UT, cervical extensors (e.g., suboccipital, semispinalis, and splenius), SCM, and levator scapulae (Shadi, Khalaghi, & Seyedahmadi, 2024; G. P. Szeto et al., 2002).Maintaining a contracted muscle state for a long time can lead to tension on blood vessels and nerve endings, causing pain and other symptoms. The latissimus dorsi and rhomboid muscles, which act as antagonist muscles, are passively stretched and unable to contract, resulting in incorrect body postures such as kyphosis.

Pilates is a type of exercise that works deep muscles through regular, controlled movements with breathing to enhance muscle control and balance (Patti et al., 2015). An umbrella review suggests that Pilates is associated with a variety of health outcomes, particularly for the musculoskeletal system or connective tissues (e.g., low back pain, neck pain, and scoliosis) as well as physical conditions in older adults (e.g., balance, strength, and risk of falls) (Xu et al., 2023). Previously, the Pilates method has been proposed as a useful form of exercise for people suffering from neck pain, and clinical experts have recommended Pilates as a therapeutic exercise method to repair spinal disorders such as back pain and scoliosis. Yamato et al. suggested that the basic principle of using the Pilates method to treat patients with neck pain is to improve motor control of the neck muscles (Yamato et al., 2015). In a review, Fangyi Li suggested that Pilates integrates the upper and lower limbs with the trunk, rather than training specific muscle groups separately. Through proper selection of exercises and controlled dosage, muscle strength and control can be enhanced to correct spinal deformities and improve posture. The results suggest that Pilates can be used to benefit a variety of populations of different ages, including children, junior high school students, high school students, college students, and people with UCS (Li, Omar Dev, Soh, Wang, & Yuan, 2024). Pilates training such as plank support and roll up can significantly improve the strength and stability of the muscles of the abdomen, back, pelvic floor and hips. Chest Lift mainly exercises the upper abdominal muscles, enhances the strength of the abdomen and improves the line of the abdomen. Roll Up starts from the abdominal area to contract and gradually rolls up the whole body, mainly exercising the muscles around the upper abdominal area and spine, and improving the flexibility of the spine. The Quadruped Kneeling Stretch works the muscles of the back, hips and back of the thighs through arm and leg extensions to strengthen the posterior chain of the body.

The Pilates training programme used in this research consisted of a series of asanas that promote core stability, muscle strength and flexibility with attention to muscle control, posture and breathing (de Oliveira Francisco, de Almeida Fagundes, & Gorges, 2015). The training programme focuses on body alignment, developing a strong core area and enhancing coordination and balance, and involves flexibility exercises as well as strength and stability exercises for the deep abdominal muscles, which allow for better control of movement. Deep cervical flexor stabilization is effective in strengthening the DNF; Seated rhomboid training can effectively train the back muscles, such as obliques, etc.; single-legged pullback, double legged upper kick, and freestyle stroke, and other asanas can effectively exercise the core muscles, such as the waist, abdomen and hip muscles. The Pilates training improves muscle imbalances by enhancing the activation of weak muscle groups, decreasing the recruitment of tense muscle groups, and thereby decreasing the head-forward tilt angle and rounded shoulder angle to improve poor body posture in the UCS population.

In addition, Pilates training may also improve body posture in the UCS population by improving breathing patterns. Previously, it has been confirmed that enhancing the strength of the respiratory muscles through scientific methods can help to strengthen the respiratory system and improve respiratory efficiency (Yuting, 2023). A large portion of the UCS population will use oral respiration, which is due to the fact that the breathing resistance of the oral cavity is less than that of nasal passages, and the oral respiratory passages can be further opened up through the head-forward stretching posture. When the respiratory muscles and ventilation are improved, the symptoms of respiratory weakness will also be reduced to a certain extent, reducing the compensatory situation. Following the Pilates training principle of “concentration, breathing, neutrality, control, precision, and fluidity”, the exercise programme designed in this research started with breathing exercises at the beginning of the arousal training, using nasal inhalation and oral exhalation. During inhalation, the thorax was actively expanded to both sides (feeling the ribs open to both sides), and during exhalation, the mouth exhaled evenly and actively sank the shoulders and lowered the ribs, actively tightening the abdomen. At the same time, during the exercise, the abdominal muscles are effectively activated through a Pilates breathing pattern integrated with the movement, while enhancing core stability. By changing the abnormal breathing pattern of UCS people, it can improve their abnormal body postures such as forward head tilt and rounded shoulders.

Performing fascial massage improves sliding between soft tissue layers, reduces pain, increases flexibility and improves functional performance (Beardsley & Škarabot, 2015). The fascial system provides tension support to the human body and is crucial for complex motor control mechanisms. It penetrates and surrounds all organs, muscles, bones, and nerve fibers, giving the body a functional structure and providing an environment that allows all body systems to operate in an integrated manner (Martínez-Aranda, Sanz-Matesanz, García-Mantilla, & González-Fernández, 2024). Trauma, inflammation or infection as well as structural imbalances in the body can cause the fascia to tighten with strain. If this occurs over a long period of time, the loss of physiologic adaptations can lead to lack of mobility, pain, and limited movement. Fascial coagulation occurs at the structural level where collagen becomes dense and fibrous and elastin loses its elasticity, affecting physiological and biomechanical processes and activating injury receptors. The conditioning and restoration of the fascial chain is done through targeted stretching, relaxation and strengthening exercises to adjust the state of tension of the fascial chain and restore its balance and stability. This helps to improve the postural problems of rounded shoulders and hunched back and reduces all the resulting discomfort. Therefore, combining the fascial massage with Pilates training can provide a more effective improvement in the posture of patients with UCS, and can have additional benefits over Pilates training alone.

4.2.2 Cervical Spine Range of Motion (ROM)

In this research, the ROM of the cervical spine in all directions was measured before and after the intervention. The results of intergroup comparison showed that before the intervention, there was no significant difference in the mobility of flexion, extension, left lateral flexion, right lateral flexion, left rotation, and right rotation between the two groups of subjects; after the intervention, compared with the control group, there was no significant difference in the ROM of forward flexion, left lateral flexion, and right lateral flexion in the experimental group, and there was a significant difference in the ROM of extension, left rotation, and right rotation, which was significantly higher than that of the control group. This suggests that compared with Pilates training alone, Pilates training combined with massage is more effective in improving joint mobility.

Mazloum, V et al. (Mazloum, V et al., 2018) also found that a selective Pilates and stretching-type exercise intervention in patients with chronic nonspecific low back pain was effective in improving pain, limb disability, flexion ROM, and lumbar curvature.One of the main functions of the cervical spine is to facilitate and control head movement in a three-dimensional manner. ROM can be characterised as the general mobility of the entire spinal segment or between two consecutive vertebrae (Lindenmann, Tsagkaris, Farshad, & Widmer, 2022). During different movements of the cervical spine, each joint does not contribute the same amount, resulting in differences in joint mobility. In cervical spine motion experiments, it was found that the forward flexion and backward extension motion curve resembles a parabola, from which C4/C5 and C5/C6 are the main contributors to the motion. In lateral flexion motion, C3/C4 and C6/C7 had the highest contribution. In rotational motion, the atlanto-occipital joints contributed the highest in the motion (Gu Jiangpeng, 2024).

The effect of abnormal body posture on the atlanto-occipital joints and the C4-C5 segments is particularly obvious when the head is located above the shoulders, when the atlanto-occipital joints are less stressed and the neck muscle forces are in a balanced state. In the lateral flexion of the cervical spine, the UT, levator scapulae, SCM, and rhomboid all play a crucial role. Weakness of the DNF makes it more difficult for the cervical spine to maintain a normal posture and perform activities. It has been shown that the cervical spine has significant axial rotation when completing lateral flexion activities, and the lower cervical spine has a smaller axial rotation angle compared to the upper cervical spine. In other words, the lower cervical spine tends to be more stable in lateral flexion compared to the upper cervical spine. The starting point of the rhomboid is located in the transverse process of the C3-C6 transverse process.

Pilates training can be used to enhance spinal stability, improve posture, and promote an overall healthy workout system by training deep muscles. Vahid Mazloum et al., (Mazloum et al., 2018) intervened with selective Pilates and extension-based exercises in patients with chronic non-specific low back pain, and found that a 6-week programme of selective Pilates and extension-based exercises was effective in improving pain, physical disability, flexion ROM, and lumbar curvature in patients. In addition, the Selective Pilates asanas was significantly more effective post-intervention and at subsequent assessment intervals, suggesting that Pilates training can be effective in improving ROM. The seated rhomboid used in this research worked the rhomboids, the MT; the double legged upper kick works the back muscle groups and the cervical flexor stabilization works the DNF to improve muscle imbalances and promote improved ROM in the cervical spine.

In addition, the fascial massage technique used in this research restored the shoulder to a neutral position while performing chest extensions to further elongate the shortened fascial chest wall tissue. Once a more neutral shoulder position is established, asymmetric fascial loading of the cervical spine is reduced (Morris et al., 2015). This has resulted in the release of muscle adhesions and normalisation of muscle tone in the UCS population, thus restoring normal muscle performance and helping to maintain joint ROM.

4.2.3 Surface Electromyography (sEMG) frequency domain indexes

In this research, a 12-week Pilates training and Pilates training combined with fascial massage training were performed on a UCS population, and the sEMG indices of the right and left UT, the LT, and the PM1 were collected before and after the intervention, and analysed to obtain the MPF and MF values, respectively.

For the MPF values, the results of between-group comparison showed that before the intervention, there was no significant difference in the MPF values of the UT, LT and PM1 of the left and right sides in the experimental and control groups. And after the intervention, the LT of the left and right sides in the experimental and control groups did not have any significant difference, but the MPF values of the UT and the PM1 of the left and right sides in the experimental and control groups were significantly higher, and the experimental group had a significantly higher MPF value when compared with the control group.

For the MF values, the results of between-group comparison showed that before the intervention, there was no significant difference in the MF values of the UT, the LT and the PM1 on the right and left sides between the experimental and control groups. And after the intervention, there was no significant difference in the MF values of the left PM1 of the experimental and control groups. But about the MF values of the UT, the LT on the left and right sides and the right PM1 there were significant differences between the experimental group and control group.

Significantly higher MF values were found for the right and left UT and right PM1, but significantly lower MF values were found for the bilateral LT. These results suggest that Pilates training combined with fascial massage is more effective than Pilates training alone.The decrease in MPF and MF values of the LT may be due to the fact that it is a weaker muscle group in the upper cross syndrome population, and the presence of fatigue suggests that the LT has increased recruitment after getting adequate exercise.

Previously, it was also found in a research (Jie, 2021) that the MPF and MF of the left and right LT showed a decreasing trend after simple Pilates training, indicating that fatigue appeared in the LT, and the emergence of fatigue indicated that the LT had an increased degree of recruitment after sufficient exercise, which suggests that Pilates training can increase the activation of weak muscle groups such as the LT. Therefore, the results of this research demonstrated that both Pilates training alone and Pilates training combined with relaxation exercise are effective in improving muscle fatigue resistance.

The main frequency domain analysis of sEMG is the analysis of EMG signals in the frequency dimension, which can reflect the changing state of neuromuscular fatigue. The MPF and MF are frequency domain indicators of sEMG signals. MPF is a frequency parameter describing the centre position of the energy distribution of sEMG signals. It calculates the frequency point corresponding to the average value of the energy distribution through spectral analysis of sEMG signals, revealing the concentration of energy in different frequency bands of the sEMG signals. MF represents the frequency value of the cut-off point that divides the power spectrum of a signal into two equal energy parts, which reflects the position of the midpoint of the energy distribution of the signal. MPF and MF are commonly used to determine muscle fatigue when it occurs during dynamic or static exercise, and a decrease in MPF and MF is often seen as an early sign of muscle fatigue.

Pilates, as a sport that emphasises the quality, precision and control of movements, can be trained to change muscle activation patterns, enhance proprioceptive input, relax tense muscle groups, and exercise weak muscle groups, thus improving muscle imbalances and helping to restore normal muscle performance.

Vladimir et al. (V. Janda, 2002) believe that muscle imbalance is a form of damage to the neuromuscular system, and that incorrect joint positions or movements can lead to deviations in proprioceptive input signals, which can result in local stabilising muscle imbalances. Over time, this imbalance allows the nerve centre to establish a new pattern of movement, creating a vicious cycle of pain and disorders. For example, one research found that when performing a typing test in front of a computer, UT activation was significantly increased in people with severe neck pain compared to healthy people (Szeto, Straker, & O'Sullivan, 2005), suggesting that people with neck pain experience different patterns of muscle activation, resulting in different movement patterns. Only when the DNF are fully activated and strengthened, the proportion of superficial neck muscles (e.g., UT, etc.) involved in the activity can be reduced, which in turn delays the generation of physiological fatigue of shoulder and neck muscle groups and improves the degree of UT fatigue. The cervical flexor stabilization used in this research can effectively train the deep neck flexor muscles, while the seated rhomboid training can effectively train the rhomboid muscles and other back muscles. By adjusting the muscle activation sequence of the UCS population, it aims to improve muscle imbalance, help the UT and PM1 muscles that are chronically in a tense state regain normal muscle tone, and simultaneously enhance the muscle strength of the LT muscle group that is chronically in a lengthened state. This, in turn, improves the fatigue resistance of these muscle groups.

Meanwhile, unlike other exercise therapies, Pilates training emphasise the training of breathing patterns, which may also be a potential mechanism for Pilates to improve muscle performance. Previously, S. W. Hsu et al. (Siwei, 2024) found that Yanda therapy combined with abdominal breathing training improved the neuromuscular function of the UT, MT, and PM1 better than Yanda therapy alone. However, some studies have given different results, He Baoxiong et al., (Baoxiong, 2019) used thoracic and abdominal respiratory training for a UCS population and found that there was no significant difference in neuromuscular function of the PM1 when compared to the pre-intervention period. This may be due to the difference in training modalities, where breathing pattern training focuses on correcting the abnormal activation sequence of the muscles, whereas inspiratory muscle resistance training focuses more on the functional training of the inspiratory muscles.

Like Pilates, fascial massage may improve muscle imbalances by improving proprioception in people with UCS. Previous studies have demonstrated that balance information is mainly obtained through proprioception, vision, and the vestibular nervous system, and transmitted through the central nervous system to the hip and ankle joints to maintain balance.

The shortened side of the fascia in people with UCS shows a decrease in muscle elasticity and contractile function, while the lengthened side often shows discomfort such as pain, due to the prolonged stretching of the myofascia. Jung-Ho Kang et al., (Kang et al., 2012) demonstrated that the forward head posture shifted the centre of gravity forward, reduced balance and postural control. and postural control.

This is consistent with our findings. In this research, we used a foam shaft and a fascial gun to release the fascia of the shoulder and neck muscles, such as the rhomboid and SCM, prior to the Pilates training intervention, so that proprioception could be accurately transmitted to the nerve centre, and then we added the Pilates training intervention at this time, which emphasised the quality, precision and control of the exercise and activated the relevant muscles in a specific sequence. And the neck and back muscles after fascial massage reached a new state of equilibrium in the process of strength resistance (Chen Xixi, 2024), which will better improve the muscle performance of the UCS population.

4.2.4 Visual Analogue Score (VAS)

In this research, a 12-week Pilates training and Pilates training combined with fascial massage training were performed on a UCS population, and the sEMG indices of the right and left UT, the LT, and the PM1 were collected before and after the intervention, and analysed to obtain the MPF and MF values, respectively.

For the MPF values, the results of between-group comparison showed that before the intervention, there was no significant difference in the MPF values of the UT, LT and PM1 of the left and right sides in the experimental and control groups. And after the intervention, the LT of the left and right sides in the experimental and control groups did not have any significant difference, but the MPF values of the UT and the PM1 of the left and right sides in the experimental and control groups were significantly higher, and the experimental group had a significantly higher MPF value when compared with the control group.

For the MF values, the results of between-group comparison showed that before the intervention, there was no significant difference in the MF values of the UT, the LT and the PM1 on the right and left sides between the experimental and control groups. And after the intervention, there was no significant difference in the MF values of the left PM1 of the experimental and control groups. But about the MF values of the UT, the LT on the left and right sides and the right PM1 there were significant differences between the experimental group and control group. Significantly higher MF values were found for the right and left UT and right PM1, but significantly lower MF values were found for the bilateral LT. These results suggest that Pilates training combined with fascial massage is more effective than Pilates training alone.The decrease in MPF and MF values of the LT may be due to the fact that it is a weaker muscle group in the upper cross syndrome population, and the presence of fatigue suggests that the LT has increased recruitment after getting adequate exercise.

Previously, it was also found in a research (Jie, Z. R., 2021) that the MPF and MF of the left and right LT showed a decreasing trend after simple Pilates training, indicating that fatigue appeared in the LT, and the emergence of fatigue indicated that the LT had an increased degree of recruitment after sufficient exercise, which suggests that Pilates training can increase the activation of weak muscle groups such as the LT. Therefore, the results of this research demonstrated that both Pilates training alone and Pilates training combined with relaxation exercise are effective in improving muscle fatigue resistance.

VAS, as an internationally recognized and important method for quantifying pain, is widely used in various pain assessments due to its simplicity, intuitiveness, ease of understanding, and ease of operation. For the sedentary office workers, prolonged head bowing will lead to cervical spine soreness, the body's nerves as well as blood vessels are subjected to long-term compression, and the muscles, tendons, and surrounding tissues of the neck and shoulder produce persistent mechanical stress, resulting in muscle strain and insufficient local blood supply, which is an important cause of idiopathic headache in the UCS population (M. H. Lee et al., 2013; Luo

Yongjun, 2017). Heo JG et al., (허진강, 2005) observed that patients with chronic neck pain often have deep flexor muscle damage, which severely weakens muscle endurance and triggers pain. At the same time, the pain further weakens static muscle strength, creating a vicious cycle. Therefore, pain, as one of the most common symptoms in the UCS population, is a key indicator for assessing the severity of the condition, formulating a treatment plan, monitoring the effectiveness of the treatment, and improving the compliance of the subjects.

Pilates training can help the UCS population to regain normal body posture and reduce pain by training to change muscle activation patterns, improve muscle imbalances, and help muscles return to normal performance. When the UCS population deviates from the ideal body posture, the daily load on the spine increases, and overloading of the spine can also cause pain in the body (Jaromi, Nemeth, Kranicz, Laczko, & Betlehem, 2012). In the UCS population, maintaining a posture for a long period of time can cause spasms in the UT and other muscle groups, and prolonged spasms in these muscle groups can lead to muscle ischaemia, which prevents the effective metabolism of nutrients and inflammatory substances, and also contributes to the development of pain in the organism.

Fascial massgae improves local blood circulation, which may be one of the reasons why it can reduce pain. In fascial massage, friction generates heat transfer to soft tissues and increases blood circulation, thus improving local blood supply and metabolism, which is conducive to nutrients reaching the soft tissues, and at the same time increasing the discharge of inflammatory substances and reducing pain. Previously, Lan Bowen (Bowen, 2021) found that pain and dysfunction in higher education students could be significantly improved by fascial massage of shortened and tense muscle groups, which is consistent with the results of this research. In this research, the experimental group performed fascial massage of tight muscle groups by fascial gun and foam shaft, which can effectively improve their blood circulation and promote the elimination of inflammatory factors, thus reducing pain, and then combined with the stretching movements of Pilates training and the training to improve muscle imbalance, which can better improve the pain symptoms of the UCS population.

4.2.5 Neck Disability Index (NDI)

In this research, the NDI scale was assessed in the experimental and control groups before and after the intervention, allowing for a comparison of the effectiveness of the two interventions. The results showed that there was no significant difference between the NDI results of the experimental and control groups before the intervention, and there was a significant difference between the NDI of the two groups of subjects after the intervention, with the NDI of the experimental group significantly lower than that of the control group. This suggests that Pilates training combined with fascial massage has better efficacy in improving cervical spine dysfunction in the UCS population than Pilates training alone.

Previous studies have concluded that pain and cervical spine dysfunction in the UCS population is primarily due to long-term abnormal body posture. Incorrect head posture increases the pressure on the posterior cervical muscle groups, which affects the length-tension relationship of the neck muscles, leading to reduced atlanto-occipital as well as atlantoaxial joint space, increased posterior lateral pressure, and compression of the small joints, which in turn leads to shortening of the suboccipital muscles and increased stress on the posterior longitudinal ligaments, resulting in neurological deficits that limit neck movement (Shan, 2023).The NDI is a commonly used clinical questionnaire for assessing neck function (Wang Xueqiang, W. Y.，2020), which allows for the quantitative assessment of cervical spine dysfunction and serves as an important indicator for monitoring the effectiveness of treatment.

Pilates training require the practitioner to consciously control the body in a neutral position, using Pilates style breathing, so that the body is in the correct muscle recruitment sequence and bone alignment to perform the exercises accurately, whilst maintaining fluidity of movement and even breathing during the exercise. Therefore, following the principles of Pilates training ensures that we complete the movements with high quality and achieve the workout results, which in turn strengthens the recruitment of weak muscle groups and weakens the recruitment of tense muscle groups, and improves muscle imbalances. This may be one of the mechanisms by which Pilates training improves cervical spine dysfunction. It has been found that long-term bowing of the head can lead to compression of the nerves and blood vessels around the cervical spine, causing continuous mechanical stress on the muscles, tendons, and surrounding tissues of the neck and shoulders. This can result in cervical instability and induce cervical dysfunction (M. H. Lee et al., 2013; Luo Yongjun, 2017). Bullo (Bullo et al., 2015) found that Pilates training can lead to a decrease in NDI in elderly patients with chronic neck pain, which is similar to the results of the present research. The asanas selected for this research, such as double legged upper kick, and freestyle stroke, included strength training of weak muscle groups such as the DNF and the LT, by enabling subjects to train the correct sequence of muscle recruitment on the basis of a neutral position of the pelvis and spine (Jie, Z. R., 2021), inhibiting the over-activation of muscles such as SCM and UT. By improving the muscle imbalance, restoring the normal alignment and normal physiological curvature of the spinal joints, further promoting the correction of postural abnormalities, and restoring the blood circulation of spastic muscle groups (Zhilv, 2018), we can improve the level of cervical spine dysfunction in the UCS population and enhance the quality of life.

Similar to the mechanism of action of Pilates training, fascial massgae can also improve neck dysfunction by relaxing tense muscle groups, improving local blood circulation, and raising pain threshold. Previously, Wang Yanwen (Wang Yanwen, 2023) randomly divided 40 patients with chronic non-specific low back pain into a fascial massage group and a fascial massage combined exercise group, and found that after two weeks of treatment the combined group had a significantly higher improvement in neck NDI than the fascial massage group. Wang Jiasen (Jiasen, 2024) divided patients with chronic non-specific neck pain into, functional training group, fascial release group and combined intervention group, after a period of 6 weeks, found that the NDI of the three groups of subjects were significantly improved after the intervention, and the degree of improvement of NDI in the combination of the intervention group was higher than that of the functional training and the fascial release group. These are consistent with the results of the present research, which found that although both interventions were effective, the programme which combined with fascial training was more effective in improving neck dysfunction in the UCS population than the Pilates training intervention alone. This may be due to the fact that the two interventions were able to simultaneously reduce the level of pain, increase the strength of the weak shoulder and neck muscle groups, and at the same time relax the tense muscle groups to restore the muscles' normal physiological properties, thus reducing the level of neck dysfunction.

5. Suggestions

5.1 Practical Implications

(1) Established the validity of the comprehensive intervention program: Through a rigorous experimental design, this research systematically verified that Pilates reaining combined with fascial massage, as a non-invasive and comprehensive means of rehabilitation, has a significant improvement effect on the UCS population. This finding not only enriches the theoretical basis of UCS treatment, but also provides a scientific basis for clinical practice and community health promotion.

(2) Constructed a multidimensional assessment system: This research constructed a multidimensional assessment framework including joint mobility and surface electromyographic characteristics, which provides a new method for comprehensively and accurately assessing the physiological status of UCS patients. This not only helps accurate diagnosis, but also establishes a unified standard for the evaluation of subsequent intervention effects.

(3) Developed a standardized intervention protocol: Based on the experimental results, this research successfully developed an effective intervention protocol for UCS patients, i.e., the integrated therapy of Pilates training combined with fascial massage. The program is highly operable and easy to be extended to medical institutions, gyms and family self-rehabilitation, which is of great significance in improving the quality of life of UCS patients.

5.2 Shortcomings of this research and prospects for further research

(1) Lack of age stratification: although this research broadly included UCS patients of different ages, it did not delve into the differences in intervention effects among different age-stratified groups. Future studies should refine the grouping of subjects and clarify the specific influence of age factors on the intervention effect through comparative analyses in order to develop a more individualized treatment plan.

(2) Limitations of surface EMG signal analysis: In this research, only frequency-domain analysis was performed on surface EMG, which failed to comprehensively reveal the time-domain characteristics of muscle activity in UCS patients. In the future, the time domain analysis technique should be combined to deeply explore the abnormal muscle activation pattern of UCS patients and its relationship with the intervention effect in order to further optimize the treatment plan.

(3) Neglect of the mental health dimension: this research focused on the improvement of physiological function and body shape in UCS patients and did not address the mental health dimension. Given the strong association between mental health and physical health, future studies should incorporate mental health assessment indicators, such as anxiety and depression levels, in order to comprehensively assess the health status of UCS patients and explore the potential benefits of Pilates training combined with fascial massage on mental health.

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APPENDIX

Appendix A Fascial relaxation equipment

Fascia Gun

Fascia gun brands	WEI YE
Model number	PRO
Point	★★★★★
Stability (lower is better)	41.2
Thrust (kg)	25
Amplitude (mm)	13
Frequency range (rpm)	1500-3600
gear level (i.e. first gear, high gear etc)	8
Types of Massage Heads	6
Noise (DB)	56.7
accreditation	National 3C certification U.S. FCC certification European Union CE certification
Weight (g)	700

Foam Shaft

Foam shaft brands	JOINFIT
brand name	PRO Series Foam Shafts
Specification	Length 55cm, Diameter 14.5cm
Weight	1.68KG
Material	EVA , PVC
Colors	Black/Gray/Green

Appendix B Cervical Spine Dysfunction Index Evaluation Questionnaire

Cervical Dysfunction Index (NDI) Questionnaire

Please read the questions in the questionnaire carefully. The answers to these questions will help us understand how neck pain affects your daily life. Please read the result items for each question and check the box for the item that best matches your current situation.

Name: Sex: Age: File number:

1. Pain intensity

☐ Mouth I have no pain at the moment.

☐ I have very mild pain at the moment.

☐ I have moderate pain at the moment.

☐ The pain is quite severe at the moment.

☐ The pain is very severe at the moment.

☐ The pain is unimaginable at the moment.

2. Personal care (washing, dressing, etc.)

☐ Mouth I can take care of myself normally without causing additional pain.

☐ Mouth I can take care of myself normally without causing additional pain.

☐ Mouth I experience pain when taking care of myself and I have to do it slowly and carefully.

☐ Mouth I need some help with activities of daily living.

☐ Mouth I need daily care for most activities of daily living.

☐ Mouth I can't get dressed and have difficulty washing and have to stay in bed.

3. Lifting heavy objects

☐ I can lift heavy objects without causing any additional pain.

☐ I can lift heavy objects, but it causes any additional pain.

☐ The pain in my mouth prevents me from lifting heavy objects from the floor, but I can manage to lift them if they are in the right place on the table.

☐ Mouth pain prevents me from lifting heavy objects, but I can lift medium weight objects.

☐ Mouth I can lift light objects.

☐ Mouth I cannot lift or move any objects.

4. Reading

☐ Mouth I can read as much as I want without causing neck pain.

☐ Mouth I can read as much as I want, but it can cause mild neck pain.

☐ I can read as much as I want, but it causes moderate neck pain.

☐ I can't read as much as I want because of moderate neck pain.

☐ I have severe neck pain that makes it difficult for me to read. I cannot read at all.

5. Headaches

☐ Mouth I don't have headaches at all.

☐ Mouth I have mild headaches, but they occur infrequently.

☐ I have moderate headaches that occur infrequently.

☐ I have moderate headaches that occur frequently.

☐ I have severe headaches that occur frequently.

☐ I have headaches almost all the time.

6. Concentration

☐ Mouth I can concentrate fully and without any difficulty.

☐ I can concentrate my attention completely, but with a slight degree of difficulty.

☐ I have some difficulty when I want to concentrate fully.

☐ I have more difficulty concentrating when I want to.

☐ Mouth When I want to concentrate completely, there is a great deal of difficulty.

☐ Mouth I can't concentrate at all.

7. Work

☐ Mouth I can do as much work as I want.

☐ I can do most of the daily work, but not too much. I can only do part of my daily work.

☐ I can't do my daily work.

☐ I can hardly work.

☐ I can't do any of my work.

8. Sleep

☐ Mouth I have no problem sleeping.

☐ Mouth My sleep is slightly affected, insomnia less than 1 hour.

☐ My sleep is mildly disturbed, insomnia 1-2 hours.

☐ My sleep is moderately disturbed, insomnia 2-3 hours.

☐ My sleep is severely affected, insomnia 3-5 hours.

☐ My sleep is completely affected, insomnia 5-7 hours.

9. Driving

☐ I can drive without any neck pain.

☐ I can drive if I want to, but have only mild neck pain.

☐ I can drive if I want to, but have moderate neck pain.

☐ I can drive if I want to, but cannot due to moderate neck pain.

☐ I can barely drive due to severe neck pain.

☐ I cannot drive at all due to neck pain.

10. Recreation

☐ Mouth I am able to engage in all my recreational activities without neck pain.

☐ I can do all my recreational activities but have some neck pain.

☐ I can only do most of my recreational activities because of my neck pain. I can only engage in a small amount of recreational activities due to neck pain.

☐ I can hardly participate in any recreational activities due to neck pain.

☐ I cannot participate in any recreational activities.

Each question has 6 options with a maximum score of 5 points, the first item scores 0 points, and the last item chosen in order scores 5 points. If all 10 questions are answered, the scoring method is: actual score/50 (highest possible score) × 100%, and if one question is not answered, the scoring method is: actual score/45 (highest possible score) × 100%, with higher scores indicating more severe dysfunction.

Date: Cervical Spine Dysfunction Index (total score): Recorded by:

Appendix C Ethics Certificate

MAHASARAKHAM UNIVERSITY ETHICS COMMITTEE FOR RESEARCH INVOLVING HUMAN SUBJECTS

Certificate of Approval

Approval number: 184-038/2024

Title : Kids' Athletics Program Development and Intervention for Physical Activity, Fundamental Movement Skills, and Social-emotional of Chinese Children.

Principal Investigator : Mr. Chenhua Huang
Responsible Department : Faculty of Education
Research site : Nanning, Guangxi Zhuang Autonomous Region, China

Review Method : Expedited Review

Date of Manufacture : 28 March 2024 expire : 27 March 2025

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
....

(Assistant Professor Ratree Sawangjit)
Chairman

Approval is granted subject to the following conditions: (see back of this Certificate)

BIOGRAPHY

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