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Functional Training and Proprioceptive Neuromuscular Facilitation for Upper Crossed Syndrome in College Students

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Abstract

This study aims to systematically review the effects, mechanisms, and current research status of functional training and proprioceptive neuromuscular facilitation (PNF) in treating upper crossed syndrome (UCS) among college students, thereby providing a theoretical reference for posture correction in this population. A narrative review method was adopted to summarize relevant domestic and international literature, with a focus on the principles, application outcomes, and limitations of the two intervention approaches. The results indicate that the core pathophysiology of UCS in college students is a crossed muscle imbalance in the neck, shoulder, and upper back regions: muscles such as the pectoralis major and upper trapezius become excessively tense and adaptively shortened, while muscles such as the rhomboids and middle/lower trapezius exhibit inhibition and weakness. Functional training can specifically strengthen these weak muscles, reconstruct kinetic chain function, and effectively improve abnormal postures such as forward head posture and rounded shoulders, but its effect on relaxing tense muscles is limited. PNF, by contrast, rapidly relaxes overactive muscles through neural reflex mechanisms, enhances flexibility and joint range of motion, and provides marked short-term symptomatic relief, yet it does not sufficiently strengthen weak muscles. Current studies commonly suffer from small sample sizes, inconsistent intervention protocols, and insufficient mechanistic exploration. In conclusion, functional training and PNF are effective interventions for UCS in college students, with the former suitable for strengthening weak muscles and the latter for relaxing tense muscles. Future research should optimize intervention protocols and deepen mechanistic investigations.

Keywords

College students; upper crossed syndrome; functional training; PNF; posture correction.

1. Introduction

With the widespread adoption of digital learning and lifestyles, college students are increasingly facing prolonged sitting, reliance on electronic devices, and poor sitting postures. As a result, upper crossed syndrome (UCS) has become a common postural health problem on university campuses. UCS is most frequently observed in individuals who work at desks or spend most of their day sitting with sustained poor posture. Epidemiological data show a wide prevalence range of 11%–60% across different populations and age groups, with college students at significantly higher risk due to prolonged computer use and sitting time [1]. Studies have found that maintaining poor postures and remaining in the same sitting position for extended periods can easily cause neck and shoulder muscle fatigue, and the incidence of cervical sub-health among college students has already exceeded 60% [2].

The core features of UCS include sustained tension and overactivity of the pectoralis major and upper trapezius, alongside weakness and underactivity of the rhomboids and middle/lower

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trapezius. These imbalances are often accompanied by typical postural abnormalities such as rounded shoulders and forward head posture. Long-term imbalance can further lead to chronic neck and shoulder pain, muscle stiffness, and restricted joint mobility, which not only directly affect the daily activity quality and athletic performance of college students but also pose potential threats to their long-term health and career development. Therefore, early prevention and scientifically based intervention for UCS in college students are of considerable practical importance. Functional training and PNF techniques, as mainstream interventions in the field of sports rehabilitation, have been widely applied to correct UCS. However, systematic reviews specifically focusing on college students and comprehensively comparing the value and research progress of these two approaches remain scarce. This paper aims to review the theoretical basis, application effects, and research progress of functional training and PNF in treating UCS in college students.

2. Overview of Upper Crossed Syndrome

2.1. Definition and Characteristics of UCS

Upper crossed syndrome (UCS) was first proposed by the Czech neurologist and pioneer of rehabilitation medicine, Dr. Vladimir Janda, and is also known as proximal or shoulder girdle crossed syndrome. UCS is a condition characterised by muscle tightness and weakness in the neck, shoulders, and upper back, with these states of tension and weakness distributed in a crossed pattern between the ventral and dorsal sides of the body [3].

The American College of Sports Medicine (ACSM) defines UCS as a syndrome of muscle strength imbalance caused by relative weakness of the rhomboids and middle/lower trapezius and excessive tension in the pectoralis major and upper trapezius, resulting in postural manifestations such as forward head posture, rounded shoulders, kyphosis, and winged scapulae [4].

Janda pointed out that UCS is primarily caused by muscle dysfunction: the pectoralis major, pectoralis minor, levator scapulae, and upper trapezius become chronically over-contracted and adaptively shortened, leading to persistent muscle tension; conversely, the rhomboids, middle trapezius, lower trapezius, and serratus anterior become weak due to disuse from prolonged passive stretching. This strength imbalance disrupts the normal mechanical balance of the neck, shoulder, and back regions. Muscle dysfunction also induces postural abnormalities and joint dysfunction [5]; in turn, abnormal postures such as forward head posture, rounded shoulders, kyphosis, and uneven shoulders further aggravate the muscle imbalance, creating a vicious cycle. Moreover, muscle dysfunction can cause musculoskeletal symptoms including headache, neck pain, chest pain, upper back pain, and tingling in the upper arms [6,7].

2.2. Aetiology of UCS

The aetiology of UCS is multifactorial, with prolonged poor posture being the most important trigger. College students spend long hours studying at desks, using computers, and looking down at mobile phones, which predisposes them to forward head posture and rounded shoulders, thus altering the mechanical loading of the neck and shoulder muscles. In addition, lack of physical exercise weakens the deep stabilising muscles (e.g., rhomboids, middle/lower trapezius, deep neck flexors), which cannot adequately maintain a neutral position; some students who do exercise may focus excessively on chest muscles while neglecting the back muscles, further exacerbating the anterior-posterior strength imbalance. Psychosocial factors (such as academic pressure, anxiety, and shyness) can also aggravate muscle tension via neural reflexes or lead to subconscious postures of chest-in and back-curved. In summary, poor posture, insufficient exercise, and psychological factors work together to disrupt the mechanical balance of the neck, shoulder, and back muscles, thereby inducing UCS.

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2.3. Pathogenesis of UCS

2.3.1. Muscle Imbalance

According to Janda's theory of proximal crossed syndrome, patients with UCS typically show overactivity and adaptive shortening of the anterior flexor muscles (e.g., sternocleidomastoid, pectoralis major, pectoralis minor, levator scapulae), while the posterior extensor muscles (e.g., deep neck flexors, rhomboids, middle/lower trapezius, serratus anterior) exhibit inhibition and reduced extensibility, forming a characteristic X-shaped tension imbalance in the sagittal plane [8]. This state of "persistent shortening of tight muscles and persistent weakness of weak muscles" directly leads to typical postural abnormalities such as forward head posture, rounded shoulders, and kyphosis, while also causing uneven loading on the articular surfaces of the neck, shoulder, and back, which lays the pathological foundation for subsequent functional abnormalities. Moreover, muscle imbalance reduces spinal stability and alters the physiological curvature of the spine, which in turn exacerbates the muscle imbalance (structure determines function, but function also acts back on structure). Over time, this creates a vicious cycle [9].

2.3.2. Abnormal Breathing Pattern

Normal breathing is dominated by the diaphragm and coordinated by the intercostal muscles, transversus abdominis, and other core muscles, all under neural control [10]. Postural abnormalities caused by UCS directly disrupt this normal breathing pattern, leading to a thoracic-dominant abnormal breathing pattern; the two interact and form a vicious cycle. Thoracic-dominant breathing essentially arises from inhibition of diaphragmatic function due to muscle imbalance in the cervicothoracic junction region [11]. Under this abnormal pattern, the pectoralis major, pectoralis minor, upper trapezius, and other neck-shoulder muscles must compensate to accomplish breathing, resulting in excessive tension in the chest muscles and reduced respiratory function of the core muscles and diaphragm, thereby decreasing breathing efficiency. Furthermore, when breathing becomes abnormal and respiratory function declines, the body may compensate by adopting a forward head posture, which in turn can contribute to UCS over the long term [12]. Similarly, a study on forward head posture and breathing patterns in adolescents showed that forward head extension is actually a maladaptive compensatory movement to enhance respiratory muscle function, and since forward head extension is also a typical manifestation of UCS and breathing is the body's longest-duration movement pattern, it is plausible that abnormal breathing patterns may be an important contributing factor to UCS [13].

2.3.3. Abnormal Kinetic Chain Pattern

Long-term incorrect exercise methods and specific movement patterns can lead to kinetic abnormalities, thereby causing faulty activation patterns of the muscles around joints [14]. For example, prolonged desk work restricts joint mobility, making it impossible to generate force through the normal kinetic chain, so the body relies on compensatory activation of already tense muscles. The concept of the postural chain further emphasises the importance of viewing the human body as an integrated whole. The structural chain affects joint alignment and position during static posture, while the functional chain influences muscle coordination patterns during dynamic movement [15]; both together affect posture and movement quality. Structural abnormalities lead to functional abnormalities, and functional compensation further aggravates structural imbalance.

2.3.4. Neuromuscular Control Dysfunction

The neuromuscular control system is central to maintaining postural stability and coordinating muscle contraction. Muscle imbalance and postural abnormalities directly cause disordered neuromuscular control in the neck, shoulder, and back regions, leading to abnormal muscle

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activation timing and impaired regulation of contraction intensity, which are key factors in the persistence of UCS. From the perspective of central-peripheral neural regulation, patients with UCS have difficulty adjusting their posture independently because the central nervous system's ability to perceive and regulate abnormal postures is reduced [16]. One study found that chronic neck pain impairs the proprioceptive acuity and spatial orientation of the cervical spine, thereby affecting postural control and balance [17]. In UCS patients, the proprioceptors around the cervical spine and scapula are continuously stimulated by abnormal posture, resulting in distorted signals of position and movement. Consequently, the central nervous system cannot accurately perceive body posture and struggles to make timely postural adjustments, leading to compensatory muscle contractions.

In summary, the pathogenesis of UCS is a multi-factor, systemic pathological process. Muscle imbalance serves as the core foundation, directly triggering postural abnormalities, which in turn lead to sequential abnormalities in breathing pattern, neuromuscular control, and kinetic chain function. Each component interacts with the others, forming a vicious cycle that progressively worsens the dysfunction of the neck, shoulder, and back regions. For college students, long-term static studying and poor posture simultaneously induce abnormalities in multiple links of this process, which explains why UCS is highly prevalent in this group and tends to become chronic. These mechanisms also provide clear targets for subsequent intervention combining functional training and PNF.

3. Functional Training for Upper Crossed Syndrome in College Students

3.1. Definition of Functional Training

Functional training originated in rehabilitation as an active self-treatment in which patients use their own efforts to correct various functional deficits left by injury or disease, thereby improving or restoring their ability to return to work and social life [18]. It later extended into fitness, sports training, and posture correction, moving away from the traditional model of isolated single-joint exercises and instead emphasising the whole-body movement synergy. There is no universally accepted definition of functional training. Gary, known as the "father of functional training", argued from an anatomical perspective that functional training should be based on the body's anatomical structures, combining complex technical movements with body structure to achieve efficient and coordinated movement. He emphasised the acceleration of movement transitions, functional balance, and multi-dimensional characteristics, providing theoretical support for functional training [19]. Mike Boyle, a strength and conditioning coach for the US national team, focuses on neural control of muscles, believing that functional training uses enhanced movement stimuli to achieve specific training goals, highlighting the role of the nervous system in precisely controlling muscle contraction and relaxation, including balance exercises and proprioceptive training [20]. Li Danyang et al. consider functional training as a comprehensive training approach that improves the overall function of the body's motor system to achieve better athletic performance [21].

3.2. Mechanisms of Functional Training

As a core intervention for UCS in college students, functional training is not simply a set of movements; it is built on multidisciplinary theories including human movement science, neuromuscular control, kinetic chain theory, and kinesiology. It aligns with the pathological mechanism of UCS ("muscle imbalance – neural control abnormality – kinetic chain dysfunction") and forms a scientific, systematic theoretical support system that makes the training movements highly consistent with the body's physiological functions and the needs of UCS correction.

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Kinetic chain theory is the central theoretical foundation of functional training. This theory holds that human movement is not an isolated action of a single joint or muscle but an overall movement process completed by the coordination of open and closed kinetic chains composed of bones, joints, and muscles [22]. The core pathological problem of UCS is precisely an upper-body kinetic chain dysfunction involving the neck, shoulders, back, thoracic spine, core, and upper extremities, which interrupts force transmission and leads to compensatory muscle activation [23]. Guided by kinetic chain theory, functional training abandons traditional isolated muscle training [24] and instead trains the neck-shoulder-back muscles, core muscles, and upper limb muscles as an integrated unit. It focuses on strengthening the weak links in the kinetic chain (e.g., middle trapezius, serratus anterior, deep neck flexors), restoring normal force transmission for scapular stability, thoracic extension, cervical neutral alignment, and upper limb movement, correcting the compensatory patterns of UCS patients, and allowing the upper-body kinetic chain to return to a synergistic physiological state [25], thereby fundamentally addressing postural abnormalities and functional impairment.

Neuromuscular control theory emphasises that posture maintenance and movement execution depend on the central nervous system's precise control of muscles, feedback from proprioceptors, and appropriate regulation of muscle activation timing. In UCS patients, long-term poor posture leads to disordered neuromuscular control in the neck, shoulder, and back regions: on one hand, the tense muscles develop an overly active neuromuscular memory, while the weak muscles show reduced neural activation signals; on the other hand, proprioceptors around the cervical spine and scapula send distorted signals due to abnormal posture [26], preventing the central nervous system from accurately sensing body posture and leading to compensatory movements. Functional training uses precise movement control and proprioceptive stimulation to activate proprioceptors (e.g., muscle spindles, Golgi tendon organs) in the neck-shoulder-back region, enhancing the central nervous system's ability to regulate the timing and intensity of muscle activation. It reconstructs correct neuromuscular control, enabling patients to voluntarily activate the weak muscles and inhibit excessive compensation from the tense muscles [27], achieving precise coordination of posture perception, muscle activation, and movement execution, thereby resolving the neuromuscular control abnormalities of UCS.

3.3. Intervention Effects of Functional Training

Given its core advantages of correcting muscle imbalance, rebuilding neuromuscular control, and aligning with daily functional needs, functional training has become a mainstream intervention for UCS. In recent years, domestic and international researchers have conducted numerous empirical studies on the intervention models, implementation effects, and mechanisms of functional training, providing a scientific basis for clinical intervention and practical application.

A study targeting muscle-specific intervention in female college students with UCS showed that 12 weeks of functional training effectively improved forward head posture and reduced the difference in integrated electromyography (IEMG) of the left and right pectoralis major [28]. Mai Quanan et al. found that functional training was more effective than intensive strength training in improving UCS in primary school children, suggesting that early intervention is beneficial [29]. Wang Binghan et al. showed that both 12-week functional training and machine-based training effectively improved UCS in fitness populations of different ages, with functional training being more effective in improving the forward head angle in the 20-year-old age group [30]. Jiang Weifen et al. applied functional training to obese male college students with postural kyphosis for three months and found a significant improvement in their posture, indicating that functional training can be used not only in medical rehabilitation and sports training but also for body posture correction [31]. A three-month intervention on a young

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woman showed that shoulder-back functional training greatly improved her rounded shoulders; the distance between the scapulae decreased from 16 cm to 8 cm, and the angle between a splint attached to the scapula and the body decreased from 5 cm to 2 cm [32]. Yi Haiyan et al. demonstrated that functional posture exercises were very effective in correcting backward head tilt, lateral head tilt, excessive cervical flexion, rounded shoulders, and posterior pelvic tilt in female college students [33]. An international study found that after four weeks of diaphragmatic breathing re-education combined with scapular stabilisation training in young men with UCS, significant improvements were observed in upper trapezius pain threshold, craniovertebral angle, rounded shoulder posture, shoulder inclination, neck disability index, and closed kinetic chain upper extremity stability test results [34]. Similarly, Nemati et al. conducted a randomised controlled trial on adolescent girls (12–15 years old) with UCS, using exercises such as wall angels and resistance band adduction three times per week for eight weeks. They found effective improvement in abnormal scapular movement, reduction in forward head angle, and increased electromyographic activity of the middle trapezius [35].

In summary, numerous studies both in China and abroad have confirmed the effectiveness of functional training for UCS. Regardless of whether the population is adolescents, students, or fitness enthusiasts, several weeks of targeted training can effectively correct abnormal postures of the head, shoulders, and spine, optimise the functional status of related muscles, regulate inter-muscular coordination, and improve cervical movement function and pain tolerance. In some populations, functional training has shown better results than traditional single-modality training, providing substantial practical support for the clinical correction and daily postural management of UCS.

4. PNF for Upper Crossed Syndrome in College Students

4.1. Definition of PNF

Proprioceptive neuromuscular facilitation was first proposed by Herman Kabat and Margaret Knott and was originally used in rehabilitation for cerebral palsy and other neurological disorders [36]. Through patterns such as contract-relax, hold-relax, and contraction of antagonists, PNF improves muscle flexibility and neuromuscular control. As the theoretical framework matured, PNF extended to musculoskeletal rehabilitation and sports performance enhancement. Its stretching branch, which combines immediate effects with long-term adaptability, has been widely applied in posture correction, injury rehabilitation, and athletic training. PNF uses concentric, eccentric, and isometric contraction patterns to promote muscle contraction, while the stretched muscle (target muscle) contracts and is combined with appropriate resistance and facilitation procedures, which are adjusted to individual needs, with the contracting and antagonistic muscles alternating contraction [37]. The principle of PNF stretching is to use sensory stimulation to increase flexibility, enhance joint range of motion, improve muscle tolerance, increase muscle strength and endurance, strengthen neuromuscular coordination and control, and enhance the sensitivity of reflex activity during rest and movement.

4.2. Mechanisms of PNF

The theoretical basis of PNF lies at the intersection of neurophysiology and biomechanics. Neurologically, it relies on four mechanisms: autogenic inhibition, reciprocal inhibition, stress relaxation, and the gate control theory. Current evidence indicates that these four mechanisms work together to increase joint range of motion [38]. Sherrington’s theory of neural reflexes proposes that muscle contraction and relaxation are regulated by reflex arcs at the spinal level, and that stimulating proprioceptors can modulate the excitability of motor nerves [39]. PNF promotes connectivity between the primary motor cortex and the supplementary motor area

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and enhances information transmission efficiency. At the same time, PNF facilitates inter-muscular coordination through antagonistic movements, using reciprocal inhibition to improve movement precision [40]. Moreover, during isometric contraction, a very strong stimulus is applied to the muscle; the Golgi tendon organs at the muscle-tendon junctions send signals via afferent nerves to the central nervous system, which then via efferent nerves elicits a reverse stretch reflex that reflexively relaxes the muscle. This use of the reverse stretch reflex is the ultimate means of achieving muscle relaxation [41]. Biomechanically, PNF increases joint range of motion through traction, reduces joint friction, stabilises joints through compression, enhances axial pressure, and, combined with verbal instructions from the therapist, achieves motor control, thereby accelerating recovery.

4.3. Intervention Effects of PNF

Numerous studies both in China and abroad have shown that PNF, owing to its unique mechanism of action, has significant advantages in improving UCS and has accumulated abundant empirical support.

In athletes, UCS not only affects postural aesthetics but may also reduce movement efficiency, alter movement patterns due to muscle imbalance, and increase the risk of sports injury. Qian Jinghua et al. selected 20 high-level table tennis players with UCS, analysed their muscle tightness and weakness using a multi-function muscle strength diagnostic system, and applied PNF. The results showed that PNF had a prominent effect on improving their body posture [42]. Similarly, Zhang Qin et al. performed five weeks of PNF training on 20 high-level athletes with UCS and found that PNF not only improved the symptoms of UCS but also significantly increased the players' forehand and backhand stroke speeds, notably increased peak power in the backhand pattern, and enabled proper muscle activation in three postures [14].

For college students and office workers, UCS caused by prolonged sitting and looking down at screens is often accompanied by chronic muscle fatigue and pain, with the muscle imbalance tending to create a vicious cycle of tighter tight muscles and weaker weak muscles. Zhao Mengmeng conducted a six-week intervention on college students with UCS and reported that proprioceptive training (PNF) enhanced proprioceptor function, facilitated proprioceptive recovery, improved neck-shoulder muscle imbalance, alleviated pain, restored muscle function, and consequently corrected poor body posture [43]. Ji Xueying performed an eight-week intervention on female college students with UCS using neck-shoulder muscle release exercises, strengthening exercises, and proprioceptive exercises. She found that corrective exercises improved abnormal postures such as forward head posture, rounded shoulders, and kyphosis, and also improved the FHA (forward head angle) and FSA (forward shoulder angle) of the subjects [44]. Zhang Zhongnan compared Pilates and PNF training in 40 college students with UCS; after six weeks, the PNF group showed greater improvement in cervical joint range of motion than the Pilates group [45]. Zhu Mengyun conducted an eight-week intervention on 60 male college students with UCS using PNF stretching combined with strength training, and found that the intervention strategy effectively reduced shoulder-neck pain and improved the poor postures of forward head and rounded shoulders [46]. Dai Zhepíng conducted an experiment on office workers with UCS, involving 81 UCS patients who were assigned to three groups: PNF stretching alone, strength training alone, and PNF stretching combined with strength training, with a healthy control group. The results confirmed that stretching and relaxing the tense muscles while strengthening the weak muscles effectively improved UCS-related symptoms [47].

Children and adolescents have an immature musculoskeletal system, making them prone to UCS due to long-term poor sitting postures and improper backpack loading. If not addressed in time, UCS may affect spinal development. A study on upper elementary school students with UCS compared three different intervention methods over five cycles and found that the

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strength-training group, stretching group, and PNF-based physical therapy group all improved UCS symptoms, with PNF being significantly more effective in improving upward shoulder contraction [48]. Tang Jing et al. conducted an intervention on 180 adolescents with UCS and found that PNF combined with musculoskeletal manipulation effectively relieved muscle fatigue, improved the imbalance of neck-shoulder muscles, increased cervical range of motion, and achieved significant improvements in body posture in adolescents with UCS [49]. Xu Yangjing's experimental study on PNF stretching for children and adolescents with UCS showed that after eight weeks of intervention, both PNF stretching and combined strength and stretching training improved forward head and rounded shoulder symptoms in fifth- and sixth-grade students. However, for the specific problems of rounded shoulder and scapular deviation angle, PNF stretching was more effective than combined strength and stretching training [50].

Furthermore, Wang Lu noted that a decrease in the craniovertebral angle (CVA) affects the position of forward head displacement, leading to forward head posture, rounded shoulders, and other incorrect postures, which progressively worsen UCS symptoms. PNF can fully stretch the neck-shoulder muscles, reduce blood lactate levels, and relax continuously contracted muscle groups, especially the upper trapezius and levator scapulae. Post-exercise stretching with PNF enables better muscle recovery and improves the balance and stability of the neck muscles. At the same time, PNF is more effective for improving shoulder joint range of motion and alleviating pain. It uses stretching techniques to promote proprioceptive recovery and increase joint range of motion, employs maximal resistance to enhance neuromuscular mechanisms, and improves joint stability and muscle coordination through alternating contraction of flexor and extensor groups, thereby achieving better limb control during movement [51,52]. An international study comparing static stretching, PNF contract-relax, and contract-relax-antagonist-contract techniques on hip flexion and shoulder extension range of motion in men and women found that all experimental groups showed significant improvements in joint range of motion, and for both hip flexion and shoulder extension, both PNF techniques were superior to static stretching [53].

In summary, PNF has demonstrated significant intervention effects across various populations at high risk for UCS, including athletes, office workers, adolescents, and primary school students. For athletes, it improves body posture and enhances sports performance; for office workers and students, it effectively relieves pain and corrects posture, with even better results when combined with strength training. PNF is superior to stretching or strength training alone in improving specific symptoms, increasing joint range of motion, and reducing recurrence rates. Its core mechanism involves neural-muscle-joint synergistic regulation, relaxing tense muscles and strengthening weak ones without requiring complex equipment, making it a safe and efficient intervention for UCS. Moreover, PNF incorporates multiple aspects such as flexibility enhancement, strength balance, and proprioceptive improvement, representing a comprehensive intervention approach well-suited for college students who have both muscle tightness and weakness, especially for moderate-to-severe patients with muscle imbalance.

5. Limitations and Future Directions

Although existing literature has confirmed the positive effects of functional training and PNF on UCS in college students, research is still at an exploratory stage. There are notable limitations in study design, intervention protocols, mechanistic investigation, and practical application, and future efforts should address these issues from multiple perspectives.

The main limitations of current research include the following. First, most studies have small sample sizes and short intervention periods; large-sample, long-term follow-up randomised controlled trials are lacking. Second, intervention protocols are not standardised. The

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frequency, duration, exercise selection, and intensity of functional training and PNF vary considerably across studies, making cross-study comparisons difficult. Third, mechanistic explanations are relatively superficial. Existing research focuses largely on external indicators such as posture, pain, and joint range of motion, with insufficient investigation of internal mechanisms such as neuromuscular control, electromyographic activity, and kinetic chain repair.

Future research should pursue the following directions. First, expand sample sizes and extend intervention and follow-up periods. Second, develop standardised intervention protocols by determining optimal parameters for functional training and PNF, thereby creating replicable and scalable programmes suitable for university settings. Third, deepen mechanistic research by incorporating techniques such as surface electromyography and three-dimensional motion capture to reveal the neuromuscular regulatory principles underlying the interventions.

6. Conclusions

(1) Functional training can strengthen weak muscles and reconstruct the kinetic chain, providing clear benefits for long-term postural correction and functional improvement.

(2) PNF can rapidly relax tense muscles, enhance flexibility and joint range of motion, and has a distinct advantage in symptom relief.

(3) Current research suffers from limitations such as small sample sizes, inconsistent protocols, and insufficient mechanistic studies, which need to be addressed in future investigations.

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