

Effectiveness of exercise interventions for postural correction in upper crossed syndrome – meta-analysis

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Dictionary

IT – Information Technology

Upper Crossed Syndrome

– a postural imbalance characterized by tight chest and neck muscles and weak upper back stabilizers, often leading to forward head and rounded shoulders [68].

Chinese health-preserving exercises

– Chinese traditional practices combining movement, breathing and promote longevity, rooted in traditional Chinese medicine [69].

Comprehensive corrective exercises

– structured interventions aimed at improving posture, muscle imbalances, and functional movement to enhance alignment and reduce pain [70].

RCT – a randomized controlled trial is a form of scientific experiment used to control factors not under direct experimental control [71]

Abstract:

Background and Study Aim: Upper crossed syndrome (UCS) is a prevalent musculoskeletal disorder. Comprehensive corrective exercises (CCE) are the most commonly used conservative intervention for UCS, while Chinese health-preserving exercises (CHE) also demonstrate positive outcomes. This meta-analysis aims is knowledge about the effectiveness between CCE and CHE in addressing UCS-related postural symptoms, including forward head, round shoulders, and kyphosis.

Material and Methods: This meta-analysis included 24 studies comprising 995 participants, selected from six databases: EMBASE, EBSCO, Web of Science, Google Scholar, PubMed, and CNKI up to September 2024. In the qualified researches, the exercise interventions were primarily restricted and classified into CHE or CCE, and the primary outcome indicators included forward head angle (FHA), forward shoulder angle (FSA) or kyphosis angle (KPA).

Results: Both Chinese health-preserving exercises: standardized mean difference (SMD) = -2.32; 95% CI = -3.26 to -1.38; $p < 0.00001$) and comprehensive corrective exercises (SMD = -1.54; 95% CI = -1.95 to -1.12; $p < 0.00001$) significantly improve forward head angle, with no significant difference between them. Chinese health-preserving exercises significantly reduced forward shoulder angle (SMD = -0.88; 95% CI = -1.28 to -0.49; $p = 0.002$), while Comprehensive corrective exercises demonstrated significant reductions in both forward shoulder angle (SMD = -1.39; 95% CI = -1.84 to -0.94; $p < 0.00001$) and kyphosis angle (SMD = -2.25; 95% CI -3.15 to -1.35; $p < 0.0001$).

Conclusions: Chinese health-preserving exercises and comprehensive corrective exercises present effective strategies for enhancing postural alignment in upper crossed syndrome, including forward head and rounded shoulders. Comprehensive corrective exercises also show significant potential in improving thoracic kyphosis.

Keywords: Chinese health-preserving exercises, comprehensive corrective exercises, forward head, kyphosis, round shoulders

1. Introduction

Upper Crossed Syndrome (UCS) is a sub-health condition that lies between a normal posture and specific cervical pathologies [1]. It is characterized by hyperactivity of the neck and chest muscles, combined with hypoactivity of the upper back and core postural muscles [2,3]. In anthropometrics, UCS is primarily characterized by forward head posture, rounded shoulders, and upper thoracic kyphosis [4]. These abnormal postures are frequently associated with symptoms such as neck and shoulder pain, dizziness, numbness, and chest discomfort [5-7].

Increasing clerical workloads, growing dependence on electronic devices, and declining levels of physical activity have collectively contributed to the high prevalence and susceptibility to UCS [8]. Professionals such as IT personnel, office workers, and factory workers are particularly vulnerable to developing UCS [9-11]. Mujawar et al. [10] reported that the prevalence of UCS among laundry workers could exceed 28% based on random sampling. Among IT professionals, the prevalence of UCS has been reported to reach 67% based on the Neck Disability Index scale [11]. Furthermore, the incidence of UCS has been increasingly observed among younger populations in recent years [12]. In summary, individuals whose daily routines involve prolonged sitting and a lack of regular exercise are particularly susceptible to UCS.

Posture, flexibility, and spinal stability are key health indicators commonly used to assess the severity of UCS [13]. Posture analysis can provide a visual and intuitive indication of the extent of muscular imbalance in these individuals. Moreover, postural abnormalities such as forward head, rounded shoulders, and kyphosis are interconnected and can contribute to a negative chain reaction affecting overall health [14,15]. Therefore, posture analysis utilizing photogrammetric tools has emerged as one of the most widely adopted and reliable methods for quantifying the severity of UCS. Among the various indicators, forward head angle (FHA), forward shoulder angle (FSA), and kyphosis angle (KPA) are commonly evaluated in previous studies [16,17].

In the conservative exercise-based rehabilitation of UCS, comprehensive corrective exercises currently serve as the primary intervention worldwide and continue to be a major focus of research. However, in East Asia, traditional Chinese health-preserving exercises have also gained prominence as culturally significant and effective approaches for managing UCS. Chinese health-preserving exercises (CHE) are a collection of ancient physical and mental practices aimed at promoting health, longevity, and inner balance [18]. These exercises include various forms of movement, breathing techniques and mindfulness practices, such as *tai chi*, *Baduanjin* and *wu qin xi*, have demonstrated considerable efficacy in alleviating postural dysfunction and proprioception [19,20]. Goosheh et al. [21] demonstrated that tai chi exerts a significant therapeutic effect on forward head posture, particularly by enhancing cervical curve and function. Tang et al. [22] demonstrated that *tai chi* and *qigong* not only benefit the cervical vertebra but also significantly improve UCS symptoms by enhancing shoulder muscular strength and mobility, reducing chronic pain, and decreasing the round shoulder angle. In summary, CHE foster improvements in flexibility, strength, and balance, thereby effectively addressing the postural imbalances characteristic of UCS [23]. Comprehensive corrective exercises (CCE) are structured physical exercises designed to improve posture, enhance movement patterns, and reduce pain or discomfort caused by muscle imbalances or alignment issues [24]. CCE for UCS can be categorized into two primary components: those

aimed at strengthening the postural muscles surrounding the spine and scapula, and those designed to stretch the shortened musculature. Hajihosseini et al. [16] investigated the effects of three types of exercises (strengthening, stretching and comprehensive) on the forward shoulder angle in young females with forward shoulder posture. The study showed a significant reduction in the forward shoulder angle across all groups. In a panel study conducted by Ding and Ma [25], the regular comprehensive corrective exercise over a 24-week period was found to be effective in improving round shoulder posture and forward head posture in primary school students.

A substantial amount of research has been conducted on the intervention effects of CHE and CCE in the treatment of UCS. Despite extensive prior research, the more effective type of exercise for UCS remains unclear. Given the long-term negative effects of UCS on health, it is essential to analyse studies involving individuals with UCS to compare the effectiveness of various exercise interventions on common postural indicators.

This meta-analysis aims to provide knowledge about the effectiveness between CCE and CHE in addressing UCS-related postural symptoms, including forward head, round shoulders, and kyphosis.

2. Materials and Methods

Search method

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive computer search of both English and Chinese databases was performed. Six databases were utilized: Web of Science, EMBASE, PubMed, EBSCO, Google Scholar, and China National Knowledge Infrastructure (CNKI). The following keywords were used for the search: ["Chinese health-preserving exercises" OR "corrective exercise" OR "exercise intervention" OR "Tai Chi" OR "Baduanjin" OR "Qigong" OR "Martial Art"] AND ["upper crossed syndrome" OR "upper cross syndrome" OR "hunchback" OR "kyphosis"]. The search strategy combined subject terms with keywords, covering the period from the inception up to September 2024.

Inclusion and exclusion criteria

Based on the PICOS principle, trials were considered eligible for inclusion if they met the criteria: 1) participants were diagnosed as UCS without clinical diseases; 2) the exercise interventions were classified and limited to CHE or CCE, all the RCT (see dictionary) research related to medical intervention or physical therapy are excluded, such as Muscle Energy Technology and McKenzie therapy; 3) the control group did not receive any exercise intervention during the same period as the experimental group; 4) the outcomes of included the common postural indices reflecting UCS: forward head angle (defined as the angle between the line connecting the tragus and the 7th cervical vertebra marker and the perpendicular line [26]), forward shoulder angle (defined as the angle between the acromion process and the perpendicular line [26]) and kyphosis angle (defined as the angle between the horizontal line and the diagonal connecting the bone markers of the 7th and 12th thoracic vertebrae spinous processes [27, 28]).

Exclusion criteria: Trials were deemed ineligible and excluded if they met any of the following exclusion criteria: 1) reviews, abstracts, observational studies, or non-peer-reviewed articles, such as dissertations or conference posters; 2) participants

diagnosed with cervical surgery, rheumatoid arthritis, severe spinal inflammation, or acute neck pain; 3) participants were professional athletes; 4) inability to identify the specific types of exercise interventions used; 5) experimental groups treated with manipulation, posture corrector or medication; 6) studies with incomplete data or insufficient descriptions of research methods.

Study selection

Based on the inclusion and exclusion criteria, 2 authors (A.X. and W.S.) independently extracted the following relevant data from each included study: first author, year of publication, country/region, participants' age, sample size, intervention (e.g., means, duration, frequency) and reported outcomes (e.g., FHA, FSA, KPA). In cases of disagreement, a third arbitrator (Z.H.) was consulted to reach a consensus.

Quality assessment and risk of bias

The quality of the included studies was evaluated by two independent authors using the Cochrane Collaboration tool, which assessed seven domains of bias: 1) random sequence generation (selection bias); 2) allocation concealment (selection bias); 3) blinding of participants and personnel (performance bias); 4) blinding of outcome assessment (detection bias); 5) incomplete outcome data (attrition bias); 6) selective reporting (reporting bias); and 7) other bias [29]. Each study was assigned a grade of high, low, or unclear bias. Any discrepancies were resolved through discussion or by consulting a third arbitrator.

Data analysis

To conduct this meta-analysis, the authors utilized the Review Manager 5.4 developed by The Nordic Cochrane Center. The meta-analysis evaluated the forward head angle (FHA), forward shoulder angle (FSA), and kyphosis angle (KPA) as primary outcomes. To calculate the summary statistic value, the Cochrane Handbook for Systematic Reviews [30] was followed, which allowed for the use of either post-intervention values (mean post-intervention SD post-intervention) or changes from baseline (mean of changes SD of changes). If studies reported cervical angle (CA, defined as the angle between the horizontal line through the C7 spinous process and the line connecting the C7 spinous process to the eardrum) instead of FHA, we would calculate FHA using the formula: $FHA = 90 - CA$. Besides, if studies reported shoulder angle (SHA, defined as the angle between the horizontal line through the acromion and the line connecting the C7 spinous process to the acromion) instead of FSA, we would calculate FSA using the formula: $FSA = 90 - SHA$ (Figure 1).

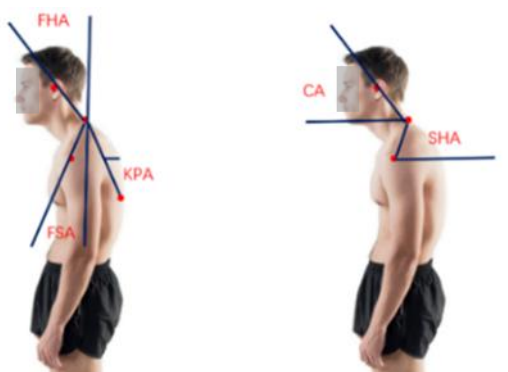


Figure 1. The diagrammatic sketch of FHA, FSA, KPA, CA and SHA

To evaluate the heterogeneity among studies, the I² index was employed. The level of heterogeneity was categorized as low, moderate, high, and very high when $I^2 \leq 25\%$, $25\% < I^2 \leq 50\%$ and $I^2 > 50\%$, $I^2 \leq 75\%$ and $I^2 > 75\%$, respectively [31]. If the level of heterogeneity was low or moderate, a fixed-effect model would be utilized. However, if the heterogeneity was high or very high, a random-effect model would be employed [32]. Considering that, in this meta-analysis, the measuring tool (e.g., UCS software application, Image J software and other photogrammetric tool) of postural indicators were different, we performed the standardized mean difference (SMD) to evaluate the compositive effects. Subgroup analysis was performed to evaluate the efficacy of two distinct exercise modalities (CHE and CCE) in enhancing posture among individuals diagnosed with UCS. The level of significance was set at $p < 0.05$.

Literature screening results and process

The search process is depicted in the flowchart (Figure 2). Initially, a total of 5485 records were retrieved from the database search. After removing duplicates using EndNote X9, 2856 potentially relevant references were identified, out of which 2252 articles were excluded based on the screening of titles and abstracts. Ultimately, 604 studies were subjected to full-text review, and 580 of them were excluded due to low quality, risk of bias, or failure to meet the inclusion criteria for outcome standards. Eventually, 24 articles [33-56] with valid outcome data were found to meet the inclusion criteria. Figure 2 illustrates the PRISMA flow chart of the studies incorporated in this review.

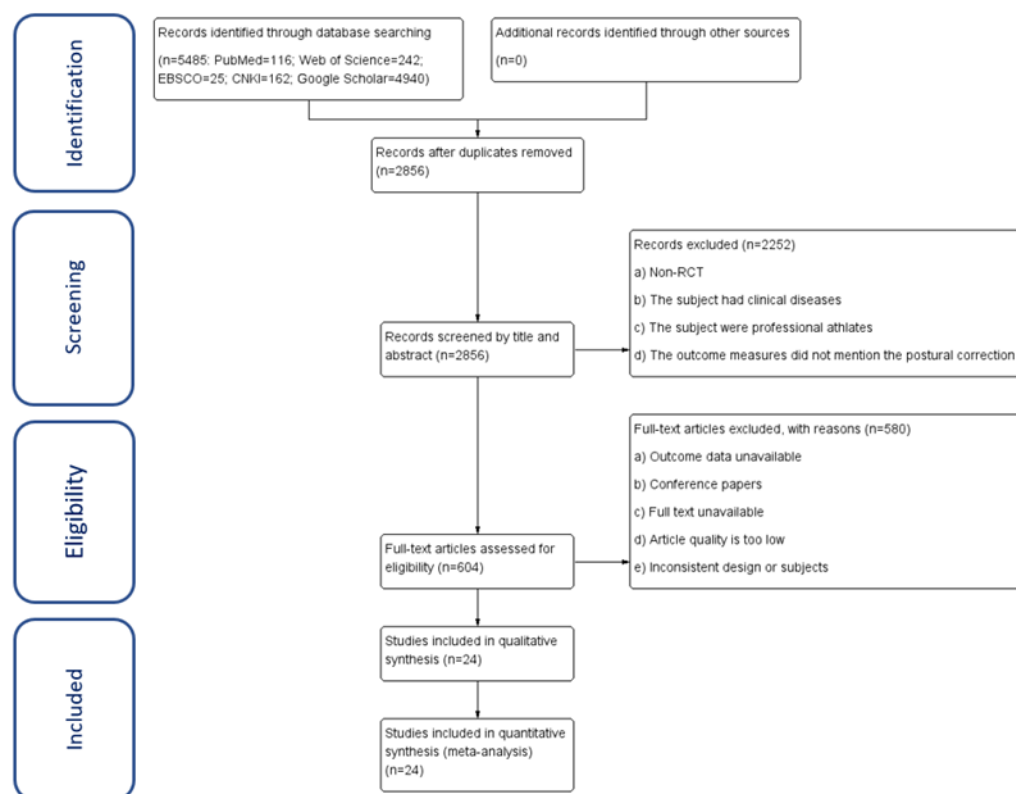


Figure 2. The flowchart of the literature screening procedure.

3. Results

Basic characteristics of included studies

Total 24 literatures were published between 2010 and 2024, from the United States, South Korea, Portugal, China, Iran and Thailand, with a total of 995 participants. In the randomized controlled trials from the included articles, the experimental group was Chinese health-preserving exercises (CHE) or Comprehensive corrective exercises (CCE), and the control group mostly had no intervention, or the intervention is maintaining the original physical education classes. The subjects include adolescents, young adults, and middle-aged individuals; the intervention time ranges from 4 to 32 weeks (Table 1).

Table 1. Basic characteristics of the included studies

| The first author | Country or region | Sample size | Age | Means of intervention | | Intervention does | | | Outcomes |
|----------------------------------|-------------------|-------------|--------------|--|-----------------|-------------------|------------------|-------------------------|---|
| | | | | IG | CG | weeks | weekly frequency | minutes / sets | |
| 2010 Lynch et al. [33] | America | T=14 | 19.29 ± 1.44 | CCE: Strengthening and stretching exercise | No intervention | 8 | 3 | 3 sets/d 10 reps/set | FHA; FST; TSD; Strength of selected muscles; ASES |
| | | C=14 | 19.29 ± 1.20 | | | | | | |
| 2014 Park et al. [34] | Korea | T=20 | 13.55 ± 2.21 | CCE: Strengthening and stretching exercise | No intervention | 25 | 3 | unclear | FHA; FSA; APA; Flexibility |
| | | C=20 | 13.75 ± 1.80 | | | | | | |
| 2016 Bae et al. [35] | Korea | T=15 | 22.70 | CCE: Strength training and self-stretching | No intervention | 4 | 3 | 10 sets/d 3 reps/set | FHT; Body temperature of posterior neck after CCE |
| | | C=15 | 24.33 | | | | | | |
| 2016 Ruivo et al. [36] | Portugal | T=42 | 15.5 ± 1.0 | CCE: Corrective exercise and PE Classes | PE Classes | 32 | 2 | unclear | Sagittal head tilt angle; CA; SHA; ASES |
| | | C=46 | 15.9 ± 1.1 | | | | | | |
| 2017 Cai et al. [37] | China | T=52 | 27 ± 5.96 | CHE: Chinese Martial Art "Baduanjin" | No intervention | 12 | 5 | 30-60 | FHT; FHA; FST |
| | | C=35 | 27 ± 5.48 | | | | | | |
| 2019 Abdollahzade et al. [38] | Iran | T=15 | 20.53 ± 1.55 | CCE: NASM-based corrective exercise | No intervention | 8 | 3 | 30-70 | FHA; FSA; KPA |
| | | C=15 | 20.00 ± 2.00 | | | | | | |
| 2019 Javazi et al. [39] | Iran | T=12 | 22.00 ± 1.53 | CCE: Corrective exercise with physioball | No intervention | 6 | 3 | 60 | FHA; FSA; KPA; Chest expansion |

| | | | | | | | | | | | | | |
|------|-----------------------------------|------------------|--------------------|---|----------------------------------|-----------------|----|-------------------------|---|---|--|--|--|
| | | C=12 | 21.58 ±1.88 | | | | | | | | | | |
| 2019 | Iran Karimian et al. [40] | T=11 | 45.2 ± 8.1 | CCE: NASM corrective exercise | No intervention | 12 | 4 | 45-60 | FHA; FSA; KPA | | | | |
| | | C=12 | 44.1 ± 7.8 | | | | | | | | | | |
| 2017 | | China Qi [41] | T ₁ =12 | 22.6 ±2.6 | CHE1: Fitness Qigong Ba Duan Jin | No intervention | 10 | 3 | 60-70 | FHA; FSA; Bilateral acromion distances; VAS | | | |
| | T ₂ =12 | | 22.6 ±2.6 | CHE2: Fitness Qigong Ba Duan Jin | | | | | | | | | |
| | C=12 | | 22.7 ±1.6 | | | | | | | | | | |
| 2019 | China Wang [42] | T=16 | 20.65 ±1.6 | CHE: Health qigong exercise | No intervention | 12 | 3 | 40 | NPAD; FHA; FSA; Cervical ROM | | | | |
| | | C=16 | 20.75 ±1.5 | | | | | | | | | | |
| 2021 | Iran Hajizadeh et al. [43] | T=15 | 24.20 ±4.12 | CCE: General corrective exercise | No intervention | 10 | 3 | 20-60 | FHA; FSA; KPA | | | | |
| | | C=15 | 24.66 ±3.56 | | | | | | | | | | |
| 2021 | Thailand Nitayarak et al. [44] | T=20 | 20.26 ±1.20 | CCE: Scapular stabilization exercises utilizing elastic bands | No intervention | 4 | 3 | 3 sets/d 10 reps/set | CA; SHA; Mid-thoracic curve; Length and strength of related muscles | | | | |
| | | C=20 | 20.15 ±1.27 | | | | | | | | | | |
| 2021 | Iran Piri et al. [45] | T=20 | 33.40 ±2.30 | CCE: Dynamic training, stretching, and myofascial release | No intervention | 12 | 3 | 60 | FHA; FSA; KPA | | | | |
| | | C=20 | 31.95 ±1.47 | | | | | | | | | | |
| 2022 | Iran Ahmadi et al. [46] | T=17 | 23 ±0.80 | CCE: Corrective exercises in water | No intervention | 8 | 3 | 50-70 | FHA; FSA; KPA | | | | |

Quality of included studies

We assessed the quality of the 24 included articles based on the guidelines proposed by Chandler et al. [30]. The studies included in our analysis were prone to bias, primarily due to the blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), and incomplete outcome data (attrition bias). The evaluation of quality and bias about the included literatures were presented in Figure 3 and Figure 4.

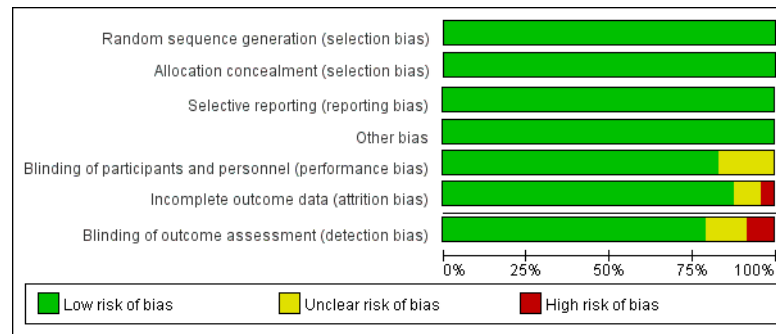


Figure 3. Percentage of text bias items

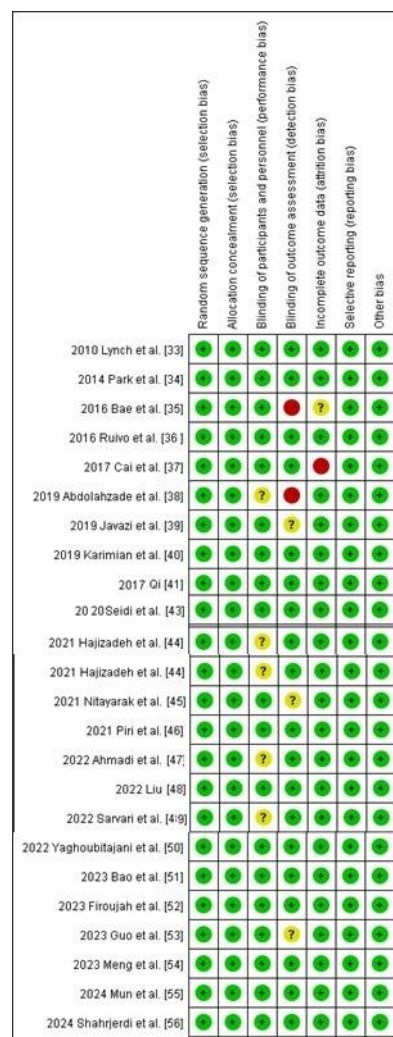


Figure 4. Visualization of the data presented in Table 1 and Figure 3

Meta analysis

Many studies have shown [12-14] that Upper Crossed Syndrome is a common musculoskeletal imbalance affecting the head, neck and shoulder regions, characterized by forward head posture, rounded shoulders and kyphosis. The forward head angle (FHA), forward shoulder angle (FSA) and kyphosis angle (KPA) are commonly used to quantify the severity and intervention effect of UCS-related postural symptoms.

Forward head angle

A total of 23 literatures [33,34,36-56] were included. The meta-analysis revealed a high level of heterogeneity (I2 = 88%). Consequently, the random-effects model was employed. There is a significant difference between the experimental group and control group (SMD = -1.80; 95% CI = -2.22 to -1.38; p<0.00001), which indicates that exercise interventions had a significant effect on improving the forward head posture for upper crossed syndrome (Figure 5).

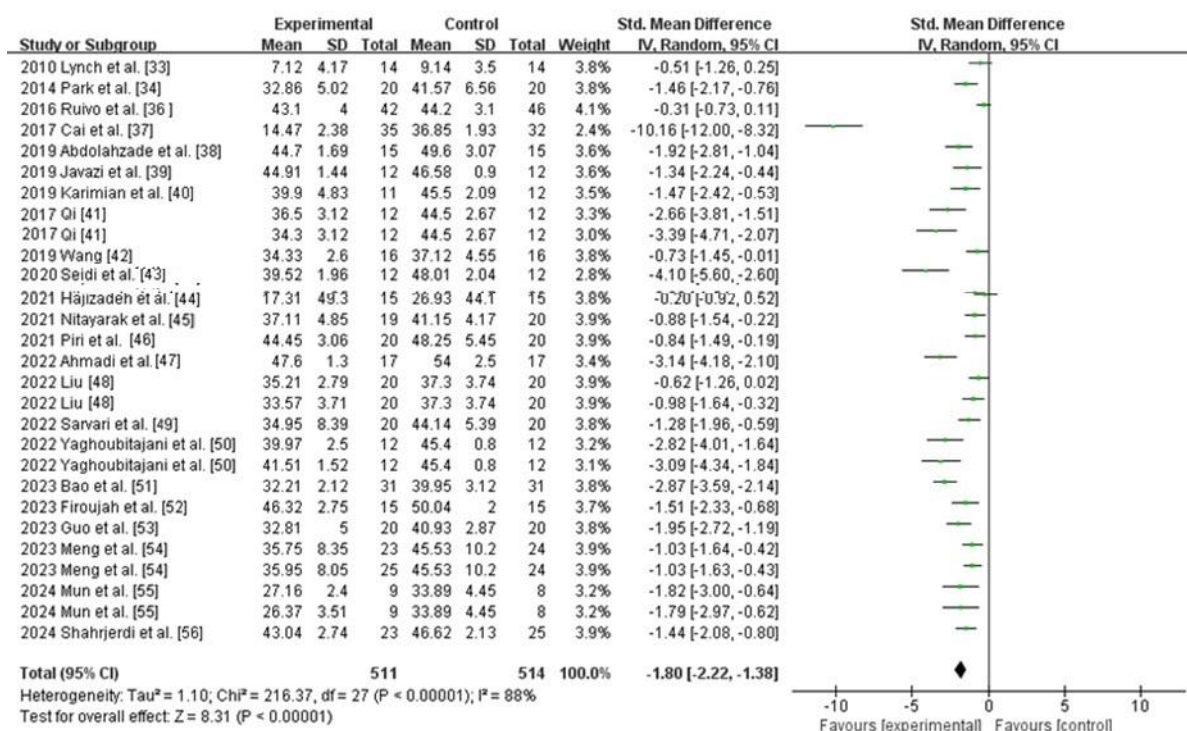


Figure 5. The forest plot of meta-analysis of FHA in exercise group and control group

In order to evaluate the impact of various exercise interventions on the reduction of FHA, we conducted a subgroup analysis based on the types of exercise (i.e., CHE, CCE). Seven studies [37, 41, 42, 48, 51, 53, 54] with ten data points were included in the analysis, which demonstrated the effectiveness of CHE in reducing FHA among UCS participants. There is a significant difference between the CHE and control groups (SMD = -2.32; 95% CI = -3.26 to -1.38; p<0.00001). The results suggest that CHE is an effective intervention for improving forward head posture in UCS participants (Figure 6, point 1.1.1).

Regarding CCE, sixteen studies [33,34,36,38-40,43-47,49,50,52,55,56] with eighteen data points were included in the analysis to assess its impact on FHA among UCS participants. There is a significant difference between the CCE and control groups (SMD = -1.54; 95% CI = -1.95 to -1.12; $p < 0.00001$), which implied that CCE was significantly effective for people with upper crossed syndrome to improve bad head forward posture. Through subgroup analysis, the comparison showed the lack of statistical significance ($p = 0.13$), indicated no significant difference in effectiveness between the CHE and CCE subgroups (Figure 6, point 1.1.2).

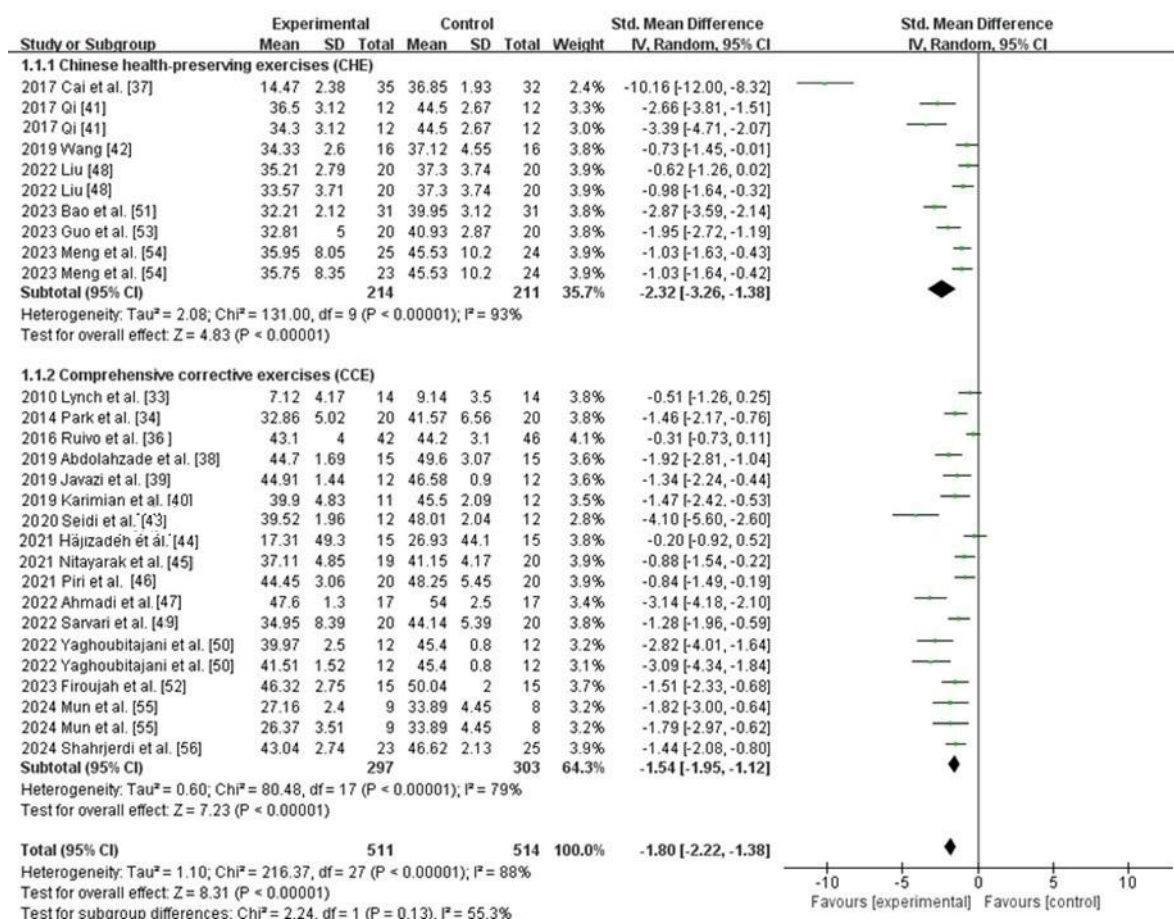


Figure 6. Subgroup analysis of effectiveness of different exercise interventions on FHA

Forward shoulder angle

A total of 20 literatures [34,36,38-48,50-56] were included. Since the heterogeneity was obtained to be ($I^2 = 77%$) on the analysis of effects of exercise intervention on forward shoulder angle, the random effects model was chosen to combine these studies to derive the final outcome as well (Figure 7). There is a significant difference between the experimental group and control groups based on random-effect model (SMD = -1.18; 95% CI = -1.50 to -0.87; $p < 0.00001$), which indicates that exercise intervention also had a significant effect on declining FSA for people suffering from Upper Crossed Syndrome (Figure 7).

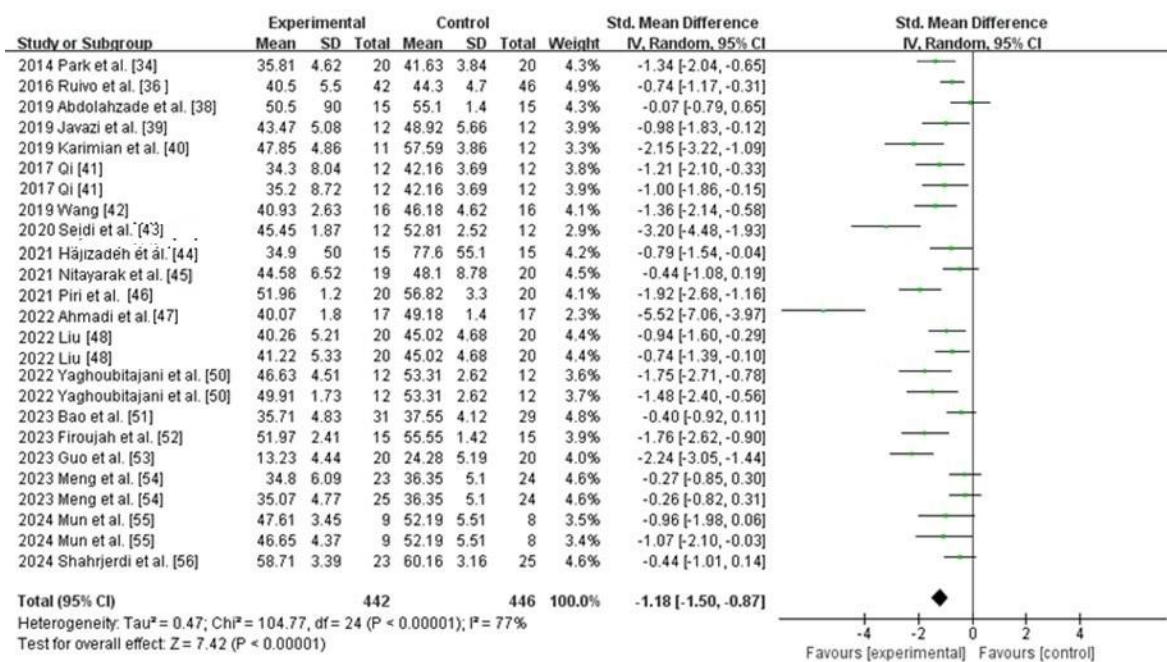


Figure 7. The forest plot of meta-analysis of FSA in exercise group and control group

To compare the effects of two different exercise interventions on FAS, we made a subgroup analysis based on the exercise types. Nine data points from six studies [41,42,47,51,53,54] evaluated the effectiveness of CHE on FSA of individuals with UCS, figure 8 shows a significant difference between the CHE and control groups (SMD = -0.88 ; 95% CI = -1.28 to -0.49 ; $p=0.002$), which proposed that CHE is an effective intervention for improving forward shoulder posture in UCS participants. For the effect of CCE intervention, sixteen data points from fourteen studies [34,36,38-40,43-46,49,50,52,55,56] were pooled in our meta-analysis. There is a significant difference between CCE groups and control groups based on a random-effect model (SMD = -1.39 ; 95% CI = -1.84 to -0.94 ; $p<0.00001$). It indicated that corrective exercise interventions were conducive to decreasing FSA in participants with upper crossed syndrome. Through subgroup analysis, the lack of statistical significance ($p = 0.09$), which indicated there was no significant difference in effect between the CHE and CCE subgroups (Figure 8).

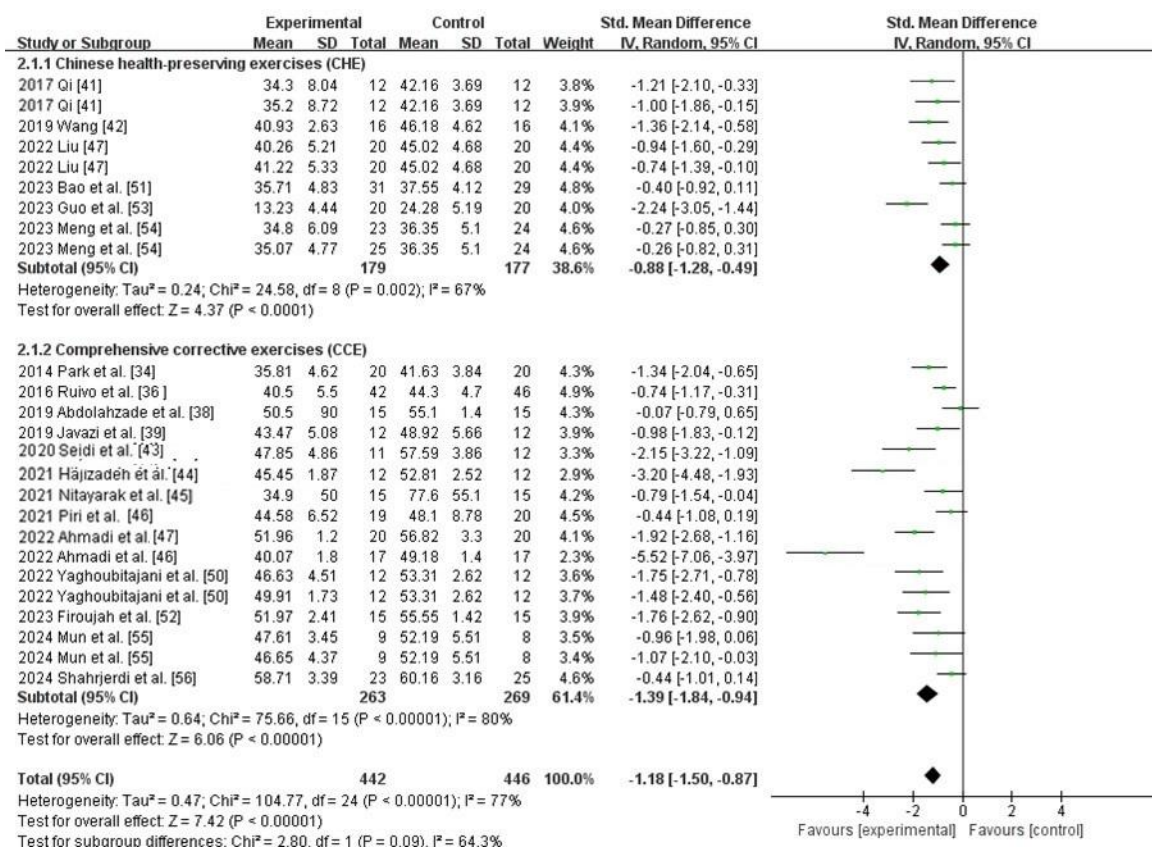


Figure 8. Subgroup analysis of effectiveness of different exercise interventions on FSA

Kyphotic angle

Since there was no qualified study research about the intervention of CHE on participants with UCS in this meta-analysis, 10 literatures [38,40,43-46,48,52,55,56] were included to analyse the effectiveness of CCE interventions solely. The result of heterogeneity analysis showed: $I^2 = 90\%$, using random effect model. There was significant difference between the CCE group and control groups based on the random-effect model (SMD = -2.25 ; 95% CI = -3.15 to -1.35 ; $p < 0.00001$), which indicated that CCE intervention had a significant impact on declining kyphotic angle for participants with UCS (Figure 9).

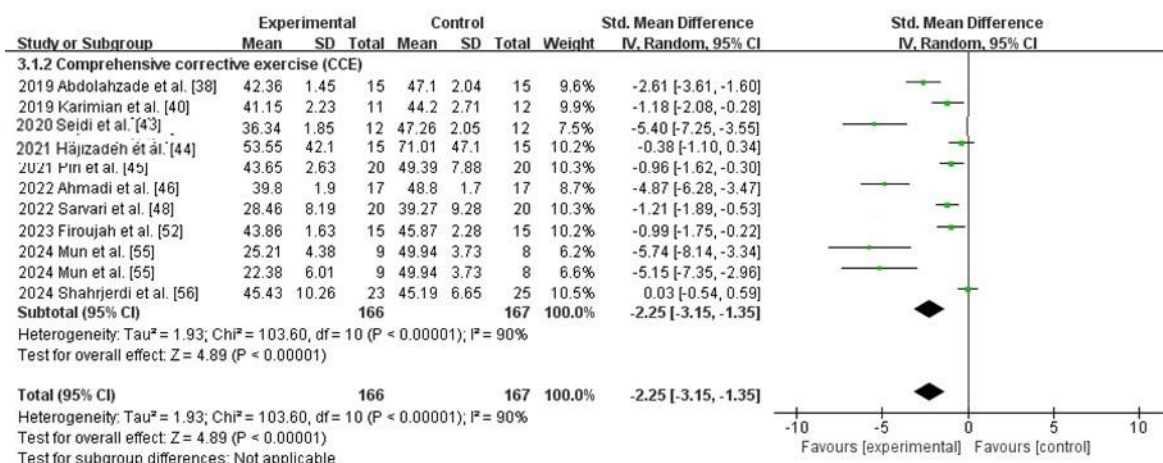


Figure 9. The forest plot of the meta-analysis of KPA in CCE group and control group

4. Discussion

The effectiveness of exercise interventions for forward head posture

Forward head posture (FHP) is a prevalent postural abnormality that contributes to a variety of musculoskeletal disorders, including neck and shoulder pain, tension headaches, diminished respiratory function in severe cases [57,58]. In China, traditional health-preserving exercises (CHE), such as *tai chi* and *qigong*, have been shown to improve posture by enhancing flexibility, promoting body alignment awareness and fostering overall musculoskeletal health [59]. Comprehensive corrective exercises (CCE) represent a more contemporary approach, utilizing targeted exercises that focus on strengthening weakened muscles, particularly in the upper back and neck, while stretching the tight muscles of the chest and shoulders [60]. This targeted approach addresses the muscle imbalances that underlie FHP, promoting more balanced musculoskeletal function.

The present meta-analysis indicates that both CHE and CCE significantly reduce forward head angle (FHA) in UCS patients. Subgroup analysis based on exercise type, however, revealed no statistically significant difference between the effectiveness of CHE and CCE in reducing FHA. While both approaches aim to address the root causes of FHP, they differ in their underlying methodologies. CHE incorporates elements of traditional Chinese exercises that emphasize gentle, flowing movements and an overall focus on body wellness, while CCE adopts a more targeted, muscle-specific approach that emphasizes corrective exercises and strength training. The absence of significant differences between the two approaches suggests that each has distinct advantages, and when combined, they may offer a more comprehensive solution to the management of FHP and UCS. Further research is warranted to explore the potential synergistic effects of integrating both CHE and CCE in the treatment of head and neck postural abnormalities caused by UCS.

The effect of exercise interventions on rounded shoulder and kyphosis

Rounded shoulder posture (RSP) and thoracic kyphosis, collectively referred to as 'hunchback', are interrelated postural abnormalities that frequently coexist [61]. Both CHE and CCE have been shown to significantly reduce the rounded shoulder angle in patients with UCS, with no statistically significant difference observed in their effectiveness for this outcome. However, evidence from four studies indicates that CCE interventions result in statistically significant improvements in the kyphotic posture

angle (KPA), highlighting the potential efficacy of CCE in addressing thoracic kyphotic abnormalities. In contrast, this meta-analysis found no conclusive evidence to support the effectiveness of CHE in improving thoracic kyphosis. Considering the primary causes of 'hunchback' include prolonged sitting or standing, muscle strength imbalance in the thoracic and back muscle groups, spinal structural or postural abnormalities [62], the effect mechanism of CHE or CCE intervention on these two postural symptom of UCS should play a different role.

Research indicates that individuals with sedentary lifestyles are at higher risk for 'hunchback', and CHE are widely embraced in Asia for their benefits in improving cardiovascular health, managing weight, reducing chronic disease risk, and enhancing mood and mental well-being [59,63]. These exercises effectively promote muscle flexibility while addressing imbalances associated with 'hunchback'. The slow, controlled movements facilitate neuromuscular re-education and improve proprioception, contributing to overall postural stability. Additionally, the stress-reducing aspects of these exercises help alleviate muscle tension that can exacerbate postural dysfunction [64]. By integrating physical, mental, and emotional dimensions, CHE provide a functional approach to addressing both the structural and functional aspects of "hunchback", ultimately promoting better postural alignment.

The mechanisms through which CCE enhances 'hunchback' are multifaceted. Primarily, CCE counters the detrimental effects of a sedentary lifestyle by promoting increased daily physical activity. Moreover, it directly addresses critical factors contributing to postural dysfunction, such as muscular imbalances, limitations in joint mobility, and deficiencies in neuromuscular control that are often associated with poor posture [65]. CCE protocols specifically target these imbalances by incorporating exercises that strengthen underactive muscles, including the rhomboids, lower trapezius, and deep cervical flexors, while simultaneously lengthening overactive muscles such as the pectoralis major and upper trapezius [66]. Additionally, CCE incorporates thoracic spine and scapular mobilization exercises to enhance joint range of motion, which may partly explain that, in our meta-analysis, only CCE was proved to be helpful for people to improve the kyphosis symptom of UCS. It also emphasizes neuromuscular re-education, which is essential for improving proprioception and reinforcing postural awareness in daily activities [67]. Collectively, these mechanisms indicate that CCE offers a comprehensive strategy for postural correction in 'hunchback' by addressing both structural and neuromuscular factors contributing to postural dysfunction.

While this study showcased the remarkable impact of CHE and CCE on posture improvement among individuals with UCS, there are some limitations to consider. First, the findings of this meta-analysis are specific to the effects of these two exercise types on postural alignment in UCS and cannot be extrapolated to other potential benefits, such as relief from fatigue or chronic pain. Additionally, the effects of exercise interventions on UCS may vary with factors such as race, age, or gender. Yet, several studies in our meta-analysis included heterogeneous participant samples, making it challenging to analyse these variables independently. Furthermore, our meta-analysis focused on comparing CHE and CCE without examining the influence of exercise volume and frequency, factors that could potentially interact with UCS outcomes. Future research might benefit from investigating these interactions in greater depth.

Finally, the relatively limited number of studies included in this review ($n = 24$) may have influenced the findings. Despite the systematic and rigorous nature of our

methodology, the exclusion of unpublished studies and research not available in English or Chinese might have affected the comprehensiveness of our analysis.

5. Conclusions

The results of this meta-analysis show that both Chinese Health-Preserving Exercises (CHE) and Comprehensive Corrective Exercise (CCE) can effectively improve the postural symptoms of Upper Crossed Syndrome (UCS), including forward head posture and rounded shoulders, with nearly equivalent effectiveness. CCE interventions have already demonstrated significant potential in improving thoracic kyphosis. In recommendations for individuals with UCS, exercise interventions should be encouraged, with the specific type of intervention tailored to the patient's primary postural symptoms.

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