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# Comparing two corrective exercise approaches for body image and upper-quadrant posture in schoolgirls with hyperkyphosis

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**Proper posture is essential for healthy living. Maintaining an ideal upright posture is one of the most critical indicators of the health of the musculoskeletal and movement systems. The current study compared the effectiveness of 6 weeks of NASM-based exercise training and eccentric-based exercise programs on body image and upper-quarter posture in schoolgirls with hyperkyphosis. In this randomized, controlled study, two intervention groups that received 6 weeks of NASM and eccentric-based exercise were compared with a control group that did nothing but continue their daily activities. For the purpose of conducting the experiment, 14 subjects were assigned to two groups (eccentric-based and control), and 12 subjects were assigned to the NASM group by using a simple blocked randomization method. The body esteem scale questionnaire was used to assess participants' body image in the groups. Likewise, the photogrammetric technique and Kyphometer were used to gather data from all groups before and after six weeks of targeted corrective exercises. Differences in responses to workouts across groups were investigated using analysis of variance-covariance (ANCOVA) followed by post hoc Bonferroni tests. The results from the ANCOVA analysis indicated significant differences between the experimental and control groups regarding the effects of time*group on kyphosis ($P<0.001$), shoulder angle ($P<0.001$), and forward head posture ($P<0.001$). Nonetheless, there was no significant difference between the considered groups regarding body image ($P=0.617$). Based on the Bonferroni test, we found a significant difference between the control and eccentric-based groups for postural parameters measured during the study ($P<0.001$). Similarly, both the control and NASM groups demonstrated significant differences for all variables($P<0.001$), except the body image. However, we could not find any statistical difference between the NASM training group and the eccentric-based exercise group concerning the upper quarter postural variables that were mentioned before. This study demonstrates that compared with a control group, schoolgirls with hyper-kyphosis who received a six-week intervention of eccentric-based and NASM- based exercises had significantly improved postural parameters but not body image. Despite these advantages, the improved kyphosis, shoulder angle, and forward head posture did not differ significantly between the NASM-based and eccentric-based exercise groups.**

**Keywords** Eccentric-based, NASM, Kyphosis, Posture, Body image

Proper posture is essential for healthy human living. It has been suggested that maintaining an ideal upright posture is one of the most critical indicators of the musculoskeletal and movement systems' health[1]. Thus, it makes sense that a person's posture deformity could harm their health. It has been reported that postural alterations are caused by adaptations to soft tissue structure and muscle length brought about by maintaining static postures. These changes can cause muscular imbalance and spinal column misalignment[2]. It has been shown that maintaining proper posture requires less energy expenditure and activates the body's postural muscles[3]. In addition to the physical effects, poor posture seems to be linked to psychological factors in people[1,4]. According to previous studies, maintaining incorrect posture throughout adolescence increases the risk of developing

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serious postural malalignment in adults[5]. Consequently, especially for younger individuals, correcting postural malalignment is considered a health-promoting strategy[6].

Many lifelong experiences with pain and disorders may have originated in the thoracic spine region[7]. An excessive anterior concavity of the thoracic spine is referred to as hyperkyphosis[8]. The incidence of hyperkyphosis is 15.3% in 11-year-old children[9]. This is one of the most common abnormalities and an etiological factor of considerable impairment in the upper quarter, ranging from shoulder pain to spinal compression fractures[10]. This situation is further exacerbated by the fact that research suggests that poor posture can negatively impact the physical and psychological well-being of adolescents[11]. School type may alter posture and psychological state, with public school students showing more coronal postural shifts and higher stress and anxiety levels than private school students[12]. In addition, in comparison to slumped posture, upright posture has been linked to stronger self-esteem, better mood, and less fear[13]. Hyperkyphosis is also a slumped postural abnormality that leads to mental health problems, physical difficulties, and a negative body image for individuals[14]. Body image is linked to an individual's unique relationship with their body, including their beliefs, thoughts, perceptions, feelings, and behaviors surrounding their physical appearance[15]. People who judge their bodies can develop positive or negative body image. This occurs by evaluating one's body against others, which can lead to a positive or negative body image[16]. For women, physical attractiveness and appearance are significantly more vital than for men; all the same, research indicates that young women's personalities are more influenced by gender norms and social influences[17]. As a consequence, it may seem logical to assume that hyperkyphosis adversely affects the body image of young women; however, little is currently known about the role of corrective exercises in diminishing this effect. Postural treatment has been shown to have favorable effects on mental health and school adjustment in students with a history of school refusal[11]. However, some studies have suggested that posture does not affect stable characteristics like intelligence or life satisfaction[18].

Increased forward bending at work and thoracic kyphosis may lead to a flexed posture[19]. Some exercise training protocols are suggested to restore these postural changes. One exercise training method is eccentric-based training. The muscle's eccentric exercise increases the number of serial sarcomeres and strengthens them by reaching the optimal sarcomere length[20]. Extending the pull of the shortened fascia may also activate the cervical region's craniocervical flexion movement, which may help to decrease thoracic kyphosis and increase spinal stabilization[19,20]. According to recent studies, a girl with thoracic kyphosis who participated in a 9-week exercise program that included rectus abdominis muscle eccentric strengthening exercise had a decrease in her thoracic kyphosis angle[21]. Similarly, a recent meta-analysis demonstrated that short- and long-term improvements can be achieved with stretching and strengthening exercises in individuals with hyperkyphosis[22].

In addition, a comprehensive systematic review found that modest improvements in clinical measurements of kyphosis were obtained from programs of exercise that targeted back extensor muscle strength[23]. In addition, corrective exercise improves patients' mental health and satisfaction while reducing periodic back pain[24]. Strengthening exercises are considered a component of corrective exercise that can help children and adolescents achieve greater muscle strength than what is typically achieved via regular growth and development[25]. After 8 weeks of corrective exercise, there was a significant decrease in the degree of back curvature and an increase in the strength, endurance, and flexibility of the abdominal and hamstring muscles[26]. In other words, corrective exercises can be effective for individuals suffering from kyphosis and lordosis can be considered an effective strategy[24].

Furthermore, a new corrective exercise protocol involving four stages of inhibiting, lengthening, activating, and integrating approaches was recently proposed by the National Academy of Sports Medicine (NASM)[27]. In this protocol, it is preferable to use inhibitory exercises first, followed by lengthening, activating, and integrating exercises on the muscle, rather than only lengthening the shortened or stiff muscle[28]. It might appear rational to infer that using a four-step NASM-based corrective protocol can lead to improvements in postural abnormalities, such as kyphosis[29]. For instance, teachers with upper-crossed syndrome may benefit from a rehabilitation program that combines NASM exercises with ergonomic interventions to reduce their kyphosis angles[28]. The recommended NASM-based training exercises are also recommended for people with spinal cord injuries who spend a lot of time in wheelchairs to prevent muscular imbalance and the development of abnormalities in the upper quadrant of the body[30]. Likewise, occupational therapists should consider the advantages of NASM corrective exercises as a novel technique for correcting the forward head angle, as these exercises have been demonstrated to be more effective than the traditional training method in improving the pain scale and head angle[31].

The comparison of NASM-based and eccentric-based exercise programs has important implications for clinical practice and rehabilitation. NASM exercises are well-known for their systematic approach to addressing muscular imbalances[32], whereas eccentric activities have been shown to improve muscle strength and length[33]. Understanding the relative effectiveness of these protocols can help clinicians customize treatments to the specific needs of adolescents with hyperkyphosis, perhaps lowering the incidence of postural abnormalities and health-related problems later in life. Furthermore, this study encourages the establishment of school-based corrective programs that provide accessible, evidence-based options for improving posture and general quality of life in young people. Thus, It is crucial to conduct research to assess the efficacy of novel training methods like eccentric-based or NASM exercises. On the other hand, because of increased social pressure and gender-specific standards of physical appearance, teenage schoolgirls are especially at risk[34]. Our hypothesis is that corrective exercises that improve posture may also improve body image through psychological and physical mechanisms, such as improved self-perception and less social stigma. To the best of our knowledge, no study has compared the efficiency of eccentric-based corrective exercises and NASM-based training for deformities in the upper quarter of the body of schoolgirls with hyperkyphosis. In addition, there are some connections between postural abnormalities and the body image of women[14]. Thus, the current study aimed to compare the effectiveness of

6 weeks of NASM-based and eccentric-based exercise programs on schoolgirl body image and upper quarter posture with hyper-kyphosis.

## Materials and methods
### Study design
In this randomized, controlled study, two intervention groups that received 6 weeks of NASM and eccentric-based exercise were compared with a control group that did nothing but continue their daily activities. The study was conducted among schoolgirls at the Iranian Middle Schools in Mashhad. The subjects first participated in the baseline assessment procedure. After that, they received the interventions for six weeks; every measurement was performed again after completing the intervention phase. The Research Committee at Allameh Tabataba'i University in Tehran provided ethics approval for this study (Ethic code: IR.ATU.REC.1402.022, date: 2023/06/28). Moreover, this study has a clinical trial registry code of IRCT20180626040244N5 (Date: 2024-10-04). All legal guardians of the participants read and signed informed consent forms before the trial. All procedures were carried out in agreement with the Helsinki Declaration's ethical guidelines. The study is entirely voluntary, and data confidentiality was maintained. The participants were made clear regarding their ability to leave the study at any moment without explanation.

### Participants and eligibility criteria
Using an intended power of 80%, alpha of 0.05, and effect size of 0.5, the G*Power software estimated a sample size of 40 participants; thus, we assumed 40 schoolgirls aged 12 to 18 years old. The medium effect size is consistent with previous interventional studies on corrective exercises in adolescents, ensuring sufficient power to detect meaningful group differences[35,36]. For the purpose of conducting the experiment, 14 subjects were assigned to two groups (eccentric-based and control), and 12 subjects were assigned to the NASM group by using a simple blocked randomization method (using random digit tables and blocked by a maximum number of 14 participants in two groups and 12 participants into one group) (Fig. 1). Through advertisements on bulletin boards inside the schools they attended, schoolgirls were selected from among those in attendance at several middle schools in Mashhad, Iran.

In this study, we defined hyperkyphosis as a thoracic curvature exceeding the usual range. The diagnostic criteria included a thoracic kyphosis angle > 32°, measured using a kyphometer, which was in line with known clinical thresholds for adolescents. Female middle school students with thoracic kyphosis greater than 32° were required for study inclusion. Individuals with a history of spinal fractures or surgeries, psychological issues, structural kyphosis, neuromuscular diseases, abnormalities in the spine, or physical disorders were not allowed to participate in the study. A history of chronic pain in the cervical and lumbopelvic regions, a history of postural control disorders, participation in professional or regular sports, severe visual impairments, and any medical condition that would prevent participation in physical training programs were among the other

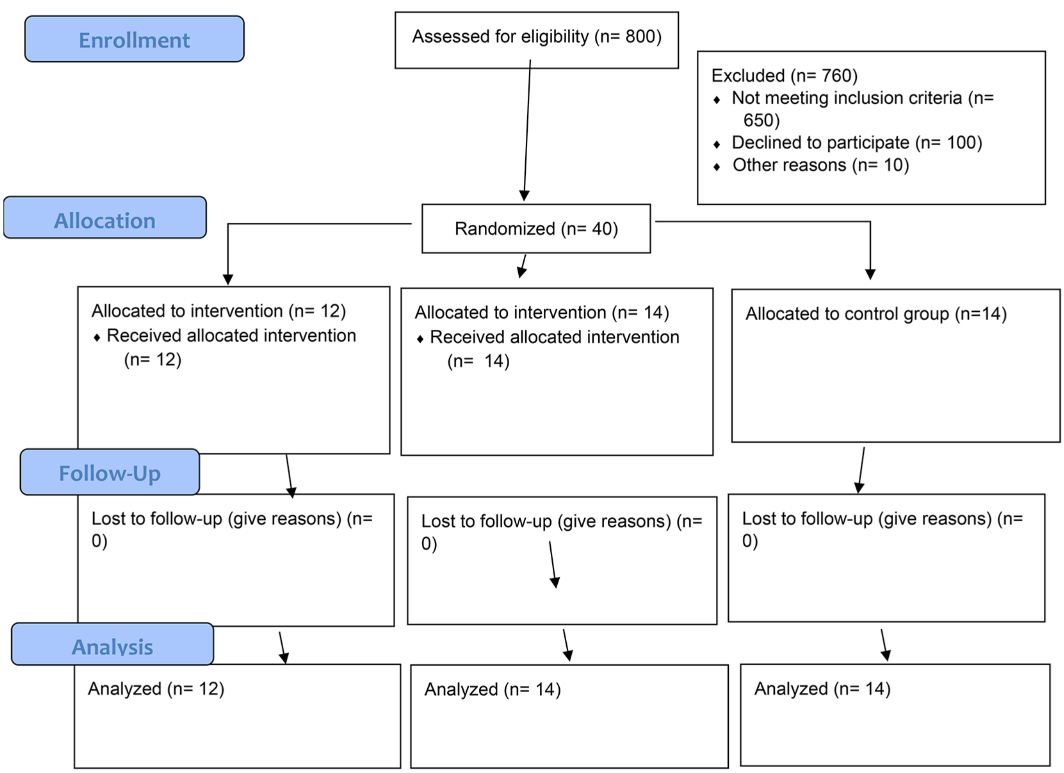



**Fig. 1**. Randomization.

exclusion criteria. In addition, participants were eliminated from the study if they missed practice for three non-consecutive sessions or two consecutive sessions.

## Procedure and randomization

Using a random number table, subjects with kyphosis greater than 32° were randomly divided into experimental and control groups at random (simple randomization method). The numbers in the table ranged from 0 to 14 for the control group, 15 to 28 for the group performing eccentric-based exercises, and 29 to 40 for the group performing NASM exercises. A random number table was used for the randomization process. The participants were instructed to touch a numeral with their fingers by moving it certainly while closing their eyes. After that, the SM records the number and uses it to place the participants in appropriate groups. For six weeks, the experimental group engaged in three targeted corrective exercises per week. As previously stated, during the study phase, the control group did not participate in posture correction. During the assessment, participants were not informed about their group assignments. Although participants were randomly assigned to groups and were not explicitly informed of their group assignment throughout assessments, due to the nature of the interventions, total blinding was not feasible. The NASM and eccentric-based groups participated in visible, structured exercise routines, whereas the control group did not receive any interventions. To reduce potential bias, all outcome assessments were conducted by a blinded assessor who was uninformed about group allocations. Participants were told not to discuss their exercise during assessments to reduce the risk of inadvertent bias.

The six-week intervention's exercise progression was determined by established criteria, such as participant tolerance and the supervising researcher's feedback. Tolerance was assessed through participant-reported discomfort and observed ability to complete the exercises without excessive strain.Initial workloads (e.g., duration, repetitions, and resistance) were progressively increased every two weeks for both NASM- and eccentric-based protocols to ensure consistent adaptation. Although the programs had a planned progression, small adjustments were made in response to each participant's distinct response. To maintain safety and adherence without reducing efficacy, participants who had trouble with particular exercises were given adjustments, such as lowering their intensity or moving in different directions. To ensure consistency in the delivery of the programme, these modifications were recorded and examined weekly.

The body esteem scale was used to assess the body image of the participants in each group. Likewise, the photogrammetric technique and kyphometer were used to gather data from all groups before and after six weeks of targeted corrective exercises. In fact, during the final exercise session after 6 weeks, each student was photographed by a blind photographer.

## Interventions

Targeted exercise programs were set up for the intervention groups; as a matter of fact, we told every student in the intervention groups to complete the exercises three times a week for six weeks. The participants were given comprehensive exercise instructions in groups by the principal investigator (SM) during the first week to ensure that they performed the exercises well. To ensure consistently good exercise performance during the six weeks of the program, personalized advice was provided.

## National academy of sports medicine (NASM)

The NASM corrective exercises comprise the inhibiting, lengthening, activation, and integration phases. A stiff foam roller was used to apply more pressure to the soft tissue structures for inhibition and release. Using this method, the participants covered the desired area with foam for 30 s. In addition, stretching was continued for 30 s at the initial point of discomfort. Retraining or increasing the activity of less active tissues was another use of activation techniques. Using progressive functional motions, the integration technique was used to retrain and coordinate neuromuscular function[37,38] (Table 1). For the progression of the protocol, we increased the duration of the foam rolling and static stretching phases, as well as the number of repetitions for activation and integration exercises (e.g., progressing from two sets of 10 reps to three sets of 12 reps).

## Eccentric-based exercises

The regulation of muscle lengthening under tension is the main objective of eccentric-based exercises. Eccentric-based exercises include intentional lengthening of movements, in contrast to concentric (shortening) muscular contractions, which are the focus of traditional NASM exercises. By treating muscular imbalances and improving muscle control over the complete range of motion, eccentric-based exercises can improve athletic performance, increase muscle adaptation, and lower the risk of injury when incorporated into a training program[39]. Therefore, the eccentric-based approach improved muscular imbalances and postural deformities through functional motions Table 2. For the progression, we gradually increased the resistance and the eccentric loading phase duration (e.g., from 3 to 5 s per repetition).

We designed the eccentric-based exercises that most overlapped with each phase of the NASM training from the eccentric training book[31]; this intervention was designed under the supervision of 2 to 3 biomechanical experts.

A blinded examiner who was unaware of the participant groups performed all outcome assessments at baseline (both before and after interventions). Before the intervention, the following demographic data were measured: weight, height, age, and body mass index.

## Thoracic kyphosis angle

A kyphometer was used to measure each participant's degree of thoracic kyphosis. The kyphometer is a valid and reliable tool that is frequently used to measure the angle of kyphosis without invasive procedures[40]. To measure the kyphotic curve accurately, participants were required to stand relaxed while the kyphometer was

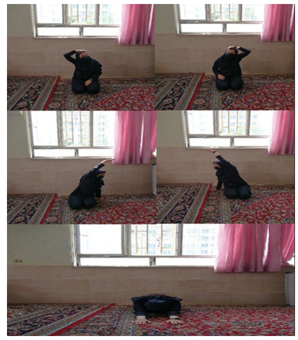
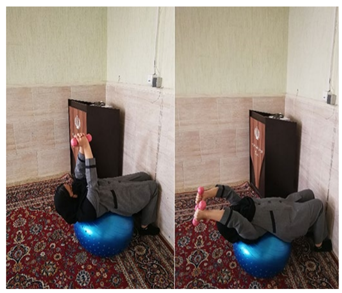
| Techniques | Involved muscles | Exercise training | Illustration | Work Load |
|---|---|---|---|---|
| Inhibiting | Levator scapula, pectoralis muscles, erector spinae, latissimus dorsi, upper trapezius, Sternocleidomastoid | The muscles were released using a foam roller massage ball and manual massage. |  | Five repetitions in a set, with 30 s to hold each repetition and 20 s of recovery before increasing to 40 s |
| Lengthening | Upper Trapezius- Pectoralis Major- Levator Scapula- Latissimus Dorsi- Sternocleidomastoid | Practice standing or sitting stretch in the wall's corner. | Sitting  | Perform four repetitions, hold for 20 s, and then rest for 20 s (increasing to 30 s progressively) |
| | | | Standing  | |
| Activating | Erector Spinae, Neck extensors, Rhomboid, Deep Neck Flexor, Trapezius, Lower Trapezius | Chin tuck, Y and W perform a chin tuck exercise, Scaption exercise, and Kobra exercise. |   | Begin with two sets of ten repetitions, followed by a 60-s rest period (sets were subsequently increased to three, and repetitions to twelve) |
| Integrating | Using all of the muscles required to complete the task, each muscle is activated in the ideal order and at the right time. | Step and lunge exercises and external rotation of the shoulders: press above the head while squatting with both legs. |  | Three sets of eight repetitions with a sixty-second break in between (repetitions gradually raised to 12). |

**Table 1**. Protocol for NASM training used in a 6-week intervention exercise program.

| Techniques | Involved muscles | Exercise training | Illustration | Work load |
|---|---|---|---|---|
| Eccentric-based | Levator scapula, upper trapezius | Shoulder Shrug |  | A sequence of sets (beginning at 3 and ending at 5), repetitions (beginning at 8 and ending at 12), and rest (beginning at 10 s and ending at 1 min). |
| | Pectoralis major: Pectoralis minor | Push-Up |  | |
| | Sternocleidomastoid | Resistance Band Exercise Training |  | |
| | Latissimus Dorsi- Teres Major | Pull-Over |  | |
| | Rectus Abdominis- Abdominal Oblique | Half Sit-Up |  | |
| Continued | | | | |

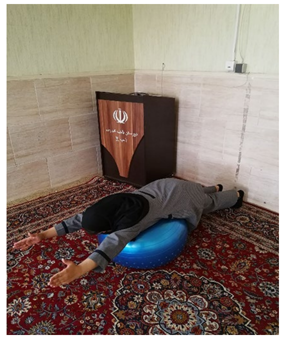
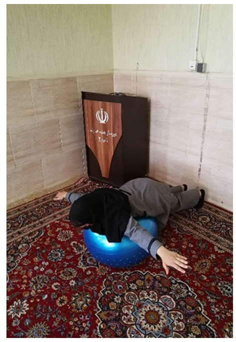
| Techniques | Involved muscles | Exercise training | Illustration | Work load |
|---|---|---|---|---|
| | Lower Trapezius to Middle Trapezius | Y-Exercise |  | |
| | Rhomboid | T-Exercise |  | |

**Table 2**. Protocol for 6-week eccentric-based trainings.

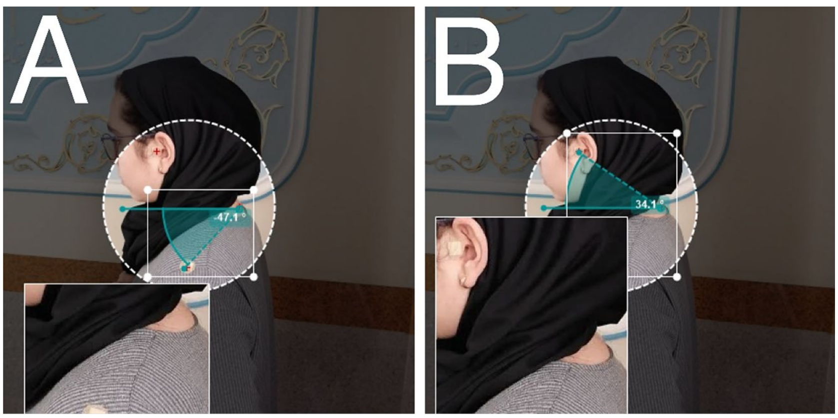



**Fig. 2**. (**A**) Assessing shoulder angle. (**B**) Assess the craniovertebral angle.

positioned along the thoracic spine. The kyphometer was used to quantify each participant's thoracic kyphosis before the intervention. With their feet shoulder-width apart, arms at their sides, and heads in a neutral posture, the participants stood straight. The thoracic kyphosis angle was measured by placing the kyphometer on the spinous processes of the T1 and T12 vertebrae[40,41]. The same method was used to reassess the kyphosis angle after the six-week intervention to detect any modifications in thoracic kyphosis.

## Craniovertebral angle (CVA) and shoulder angle (SA)

The established photogrammetric technique was used to evaluate head and neck posture. Excellent intrarater (95% ICC of 0.98 to 0.99) and interrater (95% ICC, 0.91–0.99) reliability were obtained when using photogrammetric methods to quantify head position[42]. A digital camera was positioned in lateral view at an 80-cm distance from each subject at the height of their acromion on an adjustable camera stand. By placing special markers located on the tragus of the ear, C7 vertebra of the neck, and acromion of participants, photos were taken to calculate CVA and SA. Using Kinovea software, shoulder and craniovertebral angles were determined (Fig. 2). To assess SA, the angle between the horizontal line passing through the spinal process of the seventh vertebra of the cervical spine and a line drawn from the midpoint of the shoulder joint to the spinal process of C7 was measured.

| Variables | NASM ($N$ = 12) (mean ± SD) | Eccentric-based ($N$ = 14) (mean ± SD) | Control ($N$ = 14) (mean ± SD) |
|---|---|---|---|
| Age (years) | 13.92 ± 0.9 | 13.36 ± 0.49 | 15.71 ± 0.72 |
| Height (cm) | 162.25 ± 8.97 | 158.64 ± 5.32 | 164.86 ± 4.88 |
| Weight (kg) | 51.33 ± 9.80 | 50.00 ± 11.83 | 62.00 ± 8.89 |
| BMI | 19.36 ± 2.77 | 19.84 ± 4.46 | 20.84 ± 3.42 |

**Table 3**. Participants' characteristics. *SD* standard deviation, *BMI* body mass index, *Cm* centimeters, *Kg* kilograms.

| Variable | | NASM ($N$ = 12) (mean ± SD) | Eccentric-based ($N$ = 14) (mean ± SD) | Control ($N$ = 14) (mean ± SD) | F | $P$-value | ES |
|---|---|---|---|---|---|---|---|
| Kyphosis | Pre | 37.20 ± 1.08 | 34.50 ± 1.09 | 35.35 ± 0.87 | 114.389 | 0.001 | 0.864 |
| | Post | 19.83 ± 1.27 | 20.42 ± 0.73 | 35.67 ± 1.77 | | | |
| Shoulder angle | Pre | 56.22 ± 1.53 | 58.65 ± 2.30 | 56.44 ± 2.08 | 26.061 | 0.001 | 0.591 |
| | Post | 66.75 ± 2.44 | 70.37 ± 2.11 | 56.09 ± 2.05 | | | |
| Forward head posture | Pre | 35.07 ± 1.50 | 32.82 ± 1.29 | 38.83 ± 1.63 | 28.780 | 0.001 | 0.615 |
| | Post | 41.55 ± 1.63 | 39.86 ± 1.63 | 38.40 ± 1.59 | | | |
| Body image | Pre | 52 ± 1.18 | 49.41 ± 1.49 | 47.4 ± 1.77 | 0.489 | 0.617 | 0.026 |
| | Post | 64.1 ± 1.56 | 60.00 ± 1.54 | 49.00 ± 2.36 | | | |

**Table 4**. ANCOVA results comparing the mean average of post-test measures by eliminating possible effects of pretest measures of kyphosis, shoulder angle, forward head posture, and body image for the NASM group ($n$ = 12), eccentric-based group ($n$ = 14), and control group ($n$ = 14).

The CVA angle was determined as the angle resulting from a horizontal line passing through the C7 vertebra's spinous process and a line passing from the spinous process through the ear tragus[43].

## Body image

The body esteem scale was used to evaluate the thoughts of adults and adolescents about their bodies. The questionnaire is administered to people aged above 12 years, and the questions have an 88% reliability rate and 89% internal consistency[44]. The 23 items in the questionnaire were divided into three subscales: weight, appearance, and other people's attitudes. The Likert scale runs from zero (never) to four (always)[31]. In this study, we used the Persian version of the questionnaire, and its reliability in the study sample was 0.83[14].

## Statistical analysis

Version 26 of SPSS software was used for statistical analysis. The Shapiro-Wilk test was used to investigate the data's normal distribution. Using the analysis of variance-covariance (ANCOVA) followed by the posthoc Bonferroni test, differences in responses to workouts across groups were investigated. To mitigate the potential impact of inter-individual differences, the pre-test measurements were included as covariates. p 0.05 was considered statistically significant. In this study, the effect size (ES) was measured using Partial Eta Squared. No adjustments were required because the assumptions for ANCOVA were satisfied.

## Results

The participants' characteristics and demographics are presented in Table 3. We could not find any significant difference among these three groups. It is worth noting that no dropouts occurred during the project.

The results from the ANCOVA analysis indicated significant differences between the experimental and control groups regarding the effects of time*group on kyphosis ($P < 0.001$), shoulder angle ($P < 0.001$), and forward head posture ($P < 0.001$). Nonetheless, there was no significant difference between the considered groups regarding body image ($P = 0.617$). A detailed summary of these results is presented in Table 4; Fig. 3.

Based on the Bonferroni test, we found a significant difference between the control and eccentric-based groups for postural parameters measured during the study ($P < 0.001$). Similarly, both the control and NASM groups demonstrated significant differences for all variables($P < 0.001$) except body image. However, we found no statistical difference between the NASM and eccentric-based exercise groups regarding the upper quarter postural variables mentioned before (Table 5).

## Discussion

The results of the current study indicated that six weeks of NASM-based and eccentric-based exercise training could greatly improve postural parameters but not the body image of schoolgirls with hyperkyphosis compared with the control group. However, we did not observe any significant differences between the two experimental groups in terms of the enhancement of participants' kyphosis, shoulder angle, and forward head posture.

Clinicians consider it crucial to evaluate head, shoulder, scapula, and spinal posture behavior because these can be affected by numerous motor control, biomechanical, and performance variables[45]. As a result, exercise can be thought to correct postural deformities[46], but an initial review observed little evidence to assess the

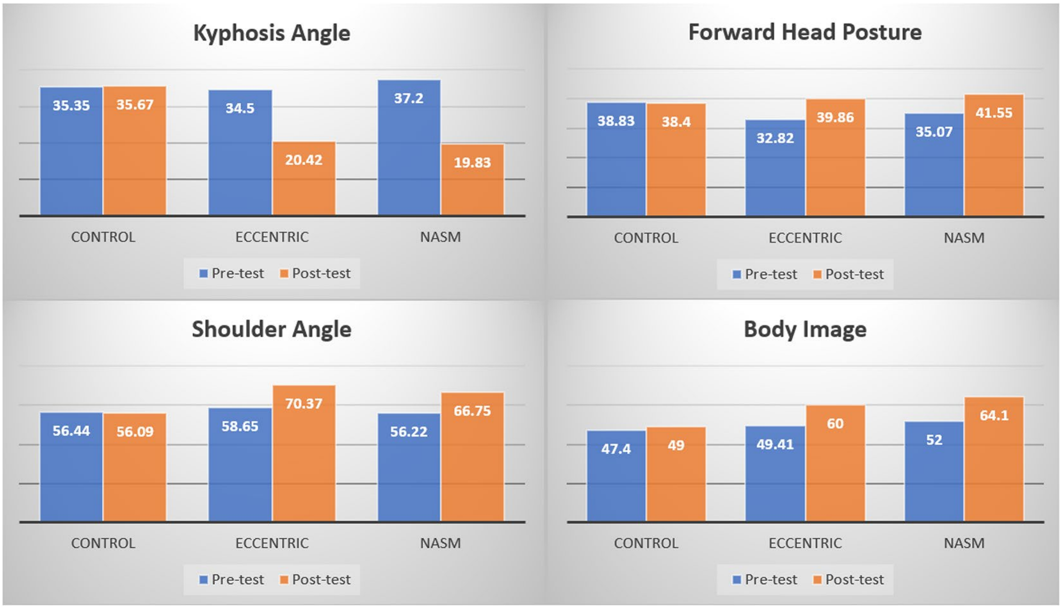



**Fig. 3**. Comparative analysis of pre- and post-test results for selected variables across three groups.

| Variable | (I) Group | (J)Group | Mean difference (I-J) | *P*-value |
|---|---|---|---|---|
| Kyphosis | Control | Eccentric-based | 14.901 | 0.001 |
| | | NASM | 16.598 | 0.001 |
| | NASM | Eccentric-based | − 1.697 | 0.587 |
| Shoulder angle | Control | Eccentric-based | − 12.391 | 0.001 |
| | | NASM | − 10.848 | 0.001 |
| | NASM | Eccentric-based | − 1.543 | 1.00 |
| Forward head posture | Control | Eccentric-based | − 7.389 | 0.001 |
| | | NASM | − 6.862 | 0.001 |
| | NASM | Eccentric-based | − 0.527 | 1.00 |

**Table 5**. Comparison of outcomes among the different groups analyzed using the Bonferroni test.

efficacy of NASM-based training and comparison of eccentric-based training. Although there are widespread postural corrections in different exercise training interventions, there is limited empirical data to support NASM and eccentric-based training efficacy[47].

The observed enhancement in postural variables, such as reducing hyper-kyphosis or improving the angle of the shoulder, is in line with previous research highlighting the advantages of exercise interventions in addressing postural deformities[17,18,24]. This improvement can be a result of exercises that focus on the back to maximize the activation of the lower trapezius and to minimize the activation of the upper trapezius[48]. Thus, the NASM-based and eccentric-biased exercise training protocols seem to have effectively targeted the underlying musculoskeletal imbalances contributing to hyper-kyphosis, resulting in improvements in postural deviations. For instance, a previous study demonstrated the effectiveness of the NASM-based approach in improving postural deformities and reducing upper-crossed syndrome[49]. In addition, research has determined that 9 weeks of eccentric training can be a feasible strategy for lowering the thoracic kyphosis angle and cervical lordosis[21]. In the same manner, studies have indicated that an 8-week exercise routine, including stretching for the limbs and strengthening exercises for both the trunk and limbs, can create a wonderful chance to decrease the thoracic kyphosis angle of boys diagnosed as hyperkyphosis[50,51].

Furthermore, considering the results obtained in this study, it can be concluded that we could combine the studied training protocols, and, in turn, better results could be achieved. For instance, it has been observed that four-stage exercises based on NASM training, which focused on the three malalignment involved in upper crossed syndrome (including kyphosis, forward head posture, and round shoulder), significantly affected these deformities[30]. In addition, it was shown that chin-tuck exercises lead to an increase in the length of the shortened neck muscles in the posterior region, as well as an increase in the strength of the anterior neck muscles, which corrects the head angle by creating a balance between the upper muscle groups[52]. Likewise, the 8-week Iyengar yoga exercise, which is performed three times a week and focused on the spine and shoulder, had a significant effect on the cervical, shoulder, and thoracic flexion angles in middle-aged women with upper crossed syndrome[53]. Additionally, stretching and strengthening training of the periscapular muscles and cervical neck flexors can significantly improve the rounded shoulder and forward head posture of elite swimmers[54].

However, our findings are inconsistent with those of previous studies showing the effectiveness of exercise therapy on body image. In fact, a previous study found that the body image of female students can be significantly improved by undergoing 8-week corrective exercises and, in turn, their personal satisfaction with regard to their appearance is enhanced[14].

The body image is not only related to what a person really looks like. Rather, it is related to a person's special relationship with their body, especially to their beliefs, feelings, and emotions. The presence of health problems or the occurrence of disorders (mentally or physically) is effective in another dimension of satisfaction[11,47]. Nevertheless, investigating the association between physical and postural abnormalities and mental problems is essential. In the current study, we did not observe any difference between the efficacy of NASM training and eccentric-based exercises on the body image of schoolgirls ($P = 0.001$). The severity of postural abnormality before the intervention did not reach a threshold at which participants perceived significant esthetic or functional benefits from the changes. However, the severity of abnormality and deformity cannot always predict body image[56]. In most cases, a person who has an abnormality is aware of the feedback of other people and probably has accepted his abnormality, or it is possible that he has learned ways to cope with his abnormality so that his body image cannot be affected by deformity[14]. In addition, it is crucial to consider that body image is a multifaceted construct influenced by psychological, social, and cultural factors that extend beyond physical posture[57]. Thus, societal pressures and peer comparisons may have a greater impact on schoolgirls' body image judgments than physical improvements alone.

Clinicians can consider using these exercises in routine rehabilitation or physical therapy settings, concentrating on the structured progression of the inhibition, activation, and integration phases. Educators can also adapt simplified versions of these protocols for application during physical education classes, focusing on proper form and gradual progression to ensure safety and efficacy. In addition, involving trained instructors or physical therapists in schools may improve the accessibility and effectiveness of these interventions.

The current study has a few limitations. First, because the study's participants were exclusively female students, its findings could not be generalized to other demographics. Gender-specific factors, such as differences in musculoskeletal development and sociocultural influences on body image, may influence the outcomes of identical therapies in different populations. Future research should examine whether the reported advantages apply to other demographics, considering the physiological and psychosocial differences. The results should be interpreted as applicable primarily to adolescent girls within the studied age range. Second, no follow-up was conducted; the purpose of this study was to examine the effects of a 6-week selected corrective exercise program on the kyphosis angle, CVA, and SA. It is preferable to conduct research to determine the long-term benefits of corrective exercises for the kyphosis angle, CVA, and SA. In the same manner, while this study showed that NASM-based and eccentric-based corrective exercise programs improved postural parameters in schoolgirls with hyperkyphosis, outcomes were only evaluated at the end of a six-week intervention. The lack of interim assessments restricts the ability to follow progress and comprehend the trajectory of improvement over time. Future studies should incorporate numerous evaluation points during the intervention period to better measure the rate and pattern of change. Furthermore, readers should be aware that while recommending various medical treatments or alternative corrective exercise treatments, the minimum clinically important difference (MCID) values obtained in this study may differ. Therefore, further research should be conducted to determine the MCIDs for additional exercise interventions and treatments. In addition, although the biomechanical aspects of postural correction were the main emphasis of this study, the depth of the biomechanical analysis may have been constrained by the lack of direct collaboration with a biomechanics specialist. Collaborations like this should be considered in future studies to improve the methodological rigor and interpretative depth. Likewise, although this study sheds light on the effects of corrective exercise regimens based on NASM and eccentric principles, it failed to take into consideration potential confounding variables, including individuals' levels of physical activity, dietary practices, or other underlying medical issues. These factors may have affected the results, especially regarding changes in body image and postural improvements. To obtain more reliable and broadly applicable results, future studies should evaluate these aspects and consider controlling for them. Finally, our study only described the effects of corrective exercises on the static posture of the thoracic, head, and shoulder joints; therefore, the findings could not be generalized to dynamic posture.

## Conclusion

This study indicates that schoolgirls with hyperkyphosis who attended a six-week intervention of eccentric-based exercise training and a NASM-based program experienced significant improvements in postural parameters compared with the control group. Despite these benefits, no significant difference was observed between the NASM- and eccentric-based exercise groups in terms of decreased kyphosis, shoulder angle, and forward head posture. These findings suggest that both exercise modalities may help improve hyperkyphosis, making them beneficial options for intervention in healthcare and educational settings.

## Data availability

All data generated or analyzed during this study are presented in Supplementary Information File 1.

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## Author contributions

SM, RS, HP, and MS contributed to the study design and data collection. HP and RS drafted the manuscript and provided critical revisions. All authors have read and approved the final manuscript.

## Declarations

## Competing interests

The authors declare no competing interests.

## Ethics approval

**and participation**.

The Biomedical Research Ethics Committee of Allameh Tabatab'i University approved this study (Ethic code: IR.ATU.REC.1402.022). Moreover, this study has a clinical trial registry code of IRCT20180626040244N5 (Date: 2024-10-04). Informed written consent was obtained from the legal guardians of all participants. Additionally, consent was obtained for the publication of identification images for online open-access publication. The authors affirm that all methods were conducted in accordance with relevant guidelines and regulations, and further consent was obtained from all legal guardians for the publication of identifying images in an online, open-access publication.

## Consent to publish the study
Consent was obtained for the publication of identification images for online open-access publication.

## Additional information
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