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RESEARCH

Effects of aquatic versus land-based core strengthening exercise programs on thoracic kyphosis angle and scapular position in young and middle-aged women with hyperkyphosis

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Abstract
Background Previous studies have shown that the aquatic and land-based exercise programs are effective on thoracic kyphosis angle and scapular position. However, little is known to compare these exercises on middle-aged women with kyphosis.
Purpose This study aimed to compare the impact of aquatic versus land-based core strengthening exercise programs on the thoracic kyphosis angle and scapular position in young and middle-aged women with hyperkyphosis.
Methods Thirty women aged 25 to 45 years, with thoracic kyphosis angles ranging between 42 and 50 degrees, participated in an 8-week exercise program comprising either aquatic or land-based core strengthening (15 participants per group). Each group attended three supervised sessions per week, lasting 60 min per session. Thoracic kyphosis angle and scapular position was measured using an inclinometer, and a tape measure respectively. Data were analyzed utilizing repeated measures analysis of variance (ANOVA), with significance level at $P \leq 0.05$.
Results No significant differences were observed between aquatic and land-based core strengthening exercises regarding the thoracic kyphosis angle and scapular position ($P > 0.05$). However, both exercise groups exhibited significant within-group improvements in these measurements.
Conclusions The findings indicate that aquatic and land-based core strengthening exercise programs contributed to decreased thoracic kyphosis angle and improved scapular position in young and middle-aged women with hyperkyphosis. These findings highlight the efficacy of tailored both aquatic and land-based core strengthening exercise interventions in managing hyperkyphosis, emphasizing the importance of considering these exercise modalities when designing therapeutic strategies for this specific population.

Keywords Land-based exercises · Hunchback · Hydro training · Trunk-exercise training · Shoulder

Introduction

Hyperkyphosis, defined as excessive thoracic spinal curvature exceeding 40°–45°, represents a progressive spinal deformity demonstrating greater severity and accelerated progression in female populations compared to males [1]. Epidemiological studies indicate a 38% prevalence among adults aged 20–50 years [2], with clinical manifestations encompassing musculoskeletal impairments (thoracic back pain, reduced strength, respiratory compromise), functional limitations (diminished balance, restricted activities of daily living), and systemic complications (increased fall risk, mortality) [3, 4]. The deformity's biomechanical consequences extend to upper extremity dysfunction through scapular malpositioning characterized by protraction, elevation, and anterior tilt [5], alterations that reduce subacromial space dimensions and elevate impingement syndrome susceptibility [6], ultimately restricting functional range of motion essential for personal care activities [7, 8].

Current management strategies employ multimodal approaches including therapeutic exercise, orthotic intervention, and manual therapies, with exercise therapy demonstrating particular efficacy in spinal deformity correction [9,

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10]. While existing research substantiates corrective exercise benefits for hyperkyphosis severity and scapular alignment [1], evidence remains limited regarding core strengthening interventions'specific effects on thoracic kyphosis angle and scapulothoracic mechanics. The core musculature system, conceptualized as a three-dimensional myofascial structure bounded by abdominal walls, paraspinal/gluteal complexes, diaphragmatic roof, and pelvic floor foundation [11], coordinates 29 muscle pairs to maintain spinal stability during functional movements [12, 13]. Contemporary rehabilitation paradigms emphasize core strengthening programs targeting postural control through trunk stabilization during static and dynamic activities [14], with evidence suggesting superior efficacy over alternative exercise modalities in enhancing spinal protection and neuromuscular control [15, 16].

Emerging aquatic-based rehabilitation approaches leverage hydrostatic properties and buoyancy effects to facilitate exercise execution in populations with musculoskeletal limitations [17, 18]. Despite theoretical advantages of water environments for impaired populations, comparative effectiveness data remain scarce regarding aquatic versus land-based core strengthening programs for hyperkyphosis management. This study therefore investigates the differential impacts of aquatic and terrestrial core strengthening interventions on thoracic kyphosis angle and scapular positioning in young and middle-aged women with hyperkyphosis, addressing critical evidence gaps in optimal exercise modality selection for this population. We hypothesize that both interventions will reduce kyphosis angle, with aquatic exercise producing greater improvements in scapular position and function due to enhanced muscle activation and postural control facilitated by water properties.

Methods

Design

This is a randomized controlled trial without control group, to investigate the effects of the interventions on thoracic kyphosis angle and scapular position. A priori power analysis revealed that 30 participants (15 per group) would be required to detect a small-moderate effect between the two groups ($f = 0.3$; type I error = 0.05; type II error = 0.80). The effect size was determined from changes in the thoracic kyphosis angle following an exercise training intervention [19].

All participants were informed of the study procedures, and provided their written informed consent prior to the commencement of the study. The present research was approved by the Biomedical Research at Ferdowsi University of Mashhad, Iran (Ethics Code: IR.UM.REC.1397.050).

Participants

Thirty participants (mean ± SD; age: 37.6 ± 7.42 years, height: 162.36 ± 4.63 cm, weight: 68.16 ± 9.3 kg, BMI: 25.55 ± 3.2) were recruited from the university campus and local community through posted and emailed flyers, as well as announcements in university and local news outlets. They were randomly assigned into two equal groups (15 individuals each): land-based and water-based exercise. For randomization, a computer-generated random number list (using SPSS software, version 25) was used. Each participant was assigned a unique random number, and then they were divided into two groups based on the median value (participants with numbers below the median were assigned to the land-based group, while those with numbers equal to or above the median were placed in the water-based group). This method ensured an equal number of participants ($n = 15$) in each group.

Inclusion criteria for thoracic kyphosis were angles greater than 42 and less than 50 degrees and being within the age range of 25–45 years. Individuals were excluded if they (i) had attended community exercise classes in the last 6 months, had a history of spinal surgery, (ii) had any medical condition(s), were pregnant, or were taking prescribed medication that might have hindered safe participation in an exercise program, absence for more than three sessions, and inability to perform exercises in more than three sessions.

Procedures

The principal investigator supervised all training sessions at Ferdowsi University of Mashhad's Corrective Movements Laboratory, where participants from both intervention groups completed three weekly 60-min sessions over 8 weeks. Each session comprised a 10-min warm up (walking, stretching, calisthenics), 45 min of core strengthening exercises, and a 5-min cool-down (stretching/relaxation) [20]. Both groups progressively increased exercise intensity from 10 to 15 repetitions per exercise by week 8, with specific environmental adaptations: the aquatic group (Table 1) performed Halliwick Aquatic Therapy in 28 °C water (110 cm depth) using both stable (feet-on-floor) and dynamic (feet-off-floor with noodles/kickboards) exercises, progressing through modified support surfaces and increased resistance every 2 weeks [21]. The land-based group (Table 2) executed multidirectional exercises (bridging, trunk curls, quadrupedal patterns) across various positions, advancing difficulty through postural modifications and elastic resistance implementation on the same biweekly schedule [20].

Supervision protocols included direct researcher oversight, environmental safety measures (lifeguards, medical

Table 1 Detailed exercise protocol for aquatic group

Exercise (aquatic)	Set	Frequency
Warm up	1	10 min
Posture check	2–3	10–30 s
Breathing	2–3	10–15 rep
Seated balance (on noodle)	2–3	10–30 s
Posture push	2–3	10–20 rep
Abdominal leg sweep	2–3	10–15 rep
Bent leg twists	2–3	10–20 rep
L-sit float and row	2–3	10–20 rep
Leg sweeps through side to side	2–3	10–15 rep
Lateral trunk Flexion	2–3	10–20 rep
Stationary plank	2–3	10–30 s
Side noodle plank	2–3	10–30 s
Deep-water seated core	2–3	10–20 s
Cool down	1	5 min

Table 2 Detailed exercise protocol for land-based group

Exercise (land-based)	Set	Frequency
Warm up	1	10 min
Breathing in supine position	2–3	10–15 rep
Superman	2–3	10–30 s
Cross limb superman	2–3	10–20 rep
Cat & camel	2–3	10–20 rep
V-raise supine	2–3	10–15 rep
Breathing supine on foam roller	2–3	10–15 rep
V-raise on physio ball	2–3	10–15 rep
Trunk extension on physio ball	2–3	10–15 rep
V-raise prone	2–3	10–15 rep
Chest opener	2–3	10–30 s
Side lying thoracic mobility	2–3	10–15 rep
Bicycles crunch	2–3	10–15 rep
Cool down	1	5 min

supplies, temperature control), and adherence monitoring allowing ≤ 3 absences. Motivational strategies incorporated real-time feedback, postural corrections, group dynamics, and routine variations. Thoracic kyphosis and scapular positioning were reassessed at 4-week intervals using standardized measurement protocols, with no exclusionary events reported during the study period. The structured progression system and environmental adaptations ensured equivalent exercise intensity between groups while accommodating their distinct training modalities.

Measurements

Baseline demographic and anthropometric characteristics were systematically documented alongside initial measurements of primary outcome parameters. Thoracic kyphosis angle, quantified using a digital inclinometer following standardized spinal curvature assessment protocols, and scapular positional alignment, evaluated through validated tape measure techniques assessing medial border-to-spine distances, constituted the principal outcome measures. Post-interventional reassessments of all parameters were conducted under identical measurement conditions 8 weeks following training initiation. A single trained investigator (SR) performed all evaluations at the Corrective Movements Laboratory of Ferdowsi University of Mashhad to ensure measurement consistency, utilizing established protocols for instrument calibration and anatomical landmark identification to enhance reliability.

Thoracic kyphosis angle measurement

Thoracic kyphosis angle quantification employed a bubble inclinometer following established spinal assessment protocols [22]. Through manual anatomical landmark identification, spinous processes of T1–T2 and T12-L1 were localized via palpatory techniques. Participants assumed a standardized upright stance with weight evenly distributed across both lower extremities, performing three cyclical arm elevations in the sagittal plane followed by cervical spine flexion–extension maneuvers and three controlled respiratory cycles to establish neutral postural alignment [22, 23].

Following skin marking at identified vertebral levels, the inclinometer bases were calibrated to inter-spinous process distances (T1–T2 and T12-L1 segments) for optimal device positioning. Angular measurements (α = upper thoracic segment, β = thoracolumbar junction) were recorded triplicate using the dual-inclinometer technique, with final kyphosis angle derivation through trigonometric summation of $\alpha + \beta$ values as per validated computational methods (Fig. 1) [23].

Scapular position

Measurements were taken with the participants standing. To achieve a natural posture, participants were asked to gently swing their arms backward and forward three times by their sides and then stop in a position that felt natural and comfortable to them. They were also instructed to flex and extend their head three times gently and stop in a position that felt natural and comfortable, as well as to take three breaths and adopt a position that felt natural and comfortable. These instructions were given to each subject before each data collection period. Once the participant's natural posture was achieved, self-adhesive markers, six millimeters in diameter, were placed directly on the skin over specific landmarks bilaterally. These included the posterior aspect of the acromion (tubercle at the lateral end of the scapular spine), the root of the scapular spine, the thoracic spinous

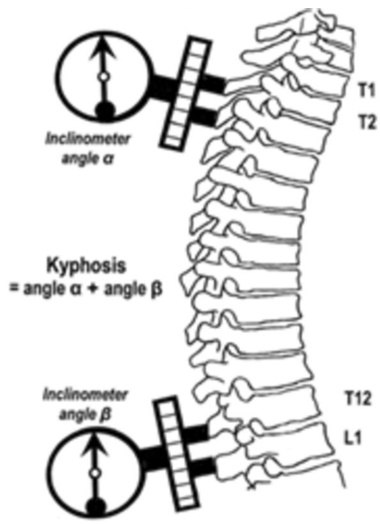

Fig. 1 The thoracic kyphosis angles. Thoracic kyphosis angle calculated by the summation of the angle recorded by the inclinometer placed over T_1 and T_2 (angle α) and the angle recorded by the inclinometer placed over T_{12} and T_1 (angle β)

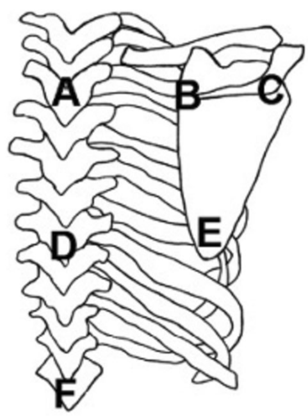

Fig. 2 Anatomic reference points. **A** Spinous process corresponding with the root of the spine of the scapular; **B** root of the spine of the scapular; **C** lateral end of the spine of the scapular; **D** spinous process corresponding with the inferior angel of the scapular; **E** inferior angle of scapular; **F** T_{12} spinous process [23]

process at the level corresponding with the root of the scapular spine, the inferior angle of the scapula, the spinous process corresponding with the inferior angle of the scapula, and the spinous process corresponding with the level of the iliac crests. Two sets of differently colored markers were used, one for the landmarks on the left side of the body and one for the right side (Fig. 2) [24].

Statistical analyses

The sample was assessed for normality using the Shapiro–Wilk test ($P > 0.05$), indicating that it follows a normal distribution. The Leven test revealed no significant difference between the two groups at baseline. Data analysis involved employing analysis of variance with repeated measures to examine the results. The analysis of variance with repeated measures was used to evaluate both within-group and between-group changes in thoracic kyphosis angle and scapular position following 8 weeks of the exercise program. Statistical analysis was performed using SPSS software version 21, with statistical significance defined as $P < 0.05$.

In addition to statistical significance, effect sizes were calculated to evaluate the magnitude and practical importance of the observed effects. For group comparisons, Cohen's d was used as the measure of effect size. Cohen's d was calculated as the difference between the means of two groups divided by the pooled standard deviation.

Results

Figure 3 illustrates the recruitment and study flow process. All participants in both aquatic-based and land-based exercise groups completed 24 training sessions without any dropouts, training or test-related injuries, or other adverse events. Baseline measurements did not show significant differences between the two groups (Table 3).

The between-group differences in thoracic kyphosis angle and scapular position were no significant ($P \geq 0.05$) (Table 4). However, There were significant within-group improvements (adjusted mean difference [95% CI] or percentage %) in the thoracic kyphosis angle ([3.73 (95% CI 3.03 to 4.46), 8.7%]), in scapular position (scapular protraction [0.35 (95% CI 0.14 to 0.58), 19.15%], and scapular rotation [5.05 (95% CI 3.23 to 6.88), 8.38%]) in the aquatic-based core strengthening exercise group (Table 4).

The results also showed within-group significant improvements in the thoracic kyphosis angle ([9.8 (95% CI 9.07 to 10.53), 23.3%]) and in scapular position (scapular protraction [0.51 (95% CI 0.73 to 0.3), 26.06%] and scapular rotation [7.04 (95% CI 5.22 to 8.86), 10.97%]) in land-based core strengthening exercise group (Table 4).

Discussion

This study examined the impact of an 8-week supervised aquatic core strengthening exercise program compared to a land-based program on the thoracic kyphosis angle and scapular position in young and middle-aged women with hyperkyphosis. The results revealed that both the aquatic and land-based core strengthening exercise programs led to a significant reduction (with-in group) in thoracic kyphosis angle (3.7° and 9.8°, respectively), with no significant differences observed between the two exercise

Fig. 3 Study flow diagram

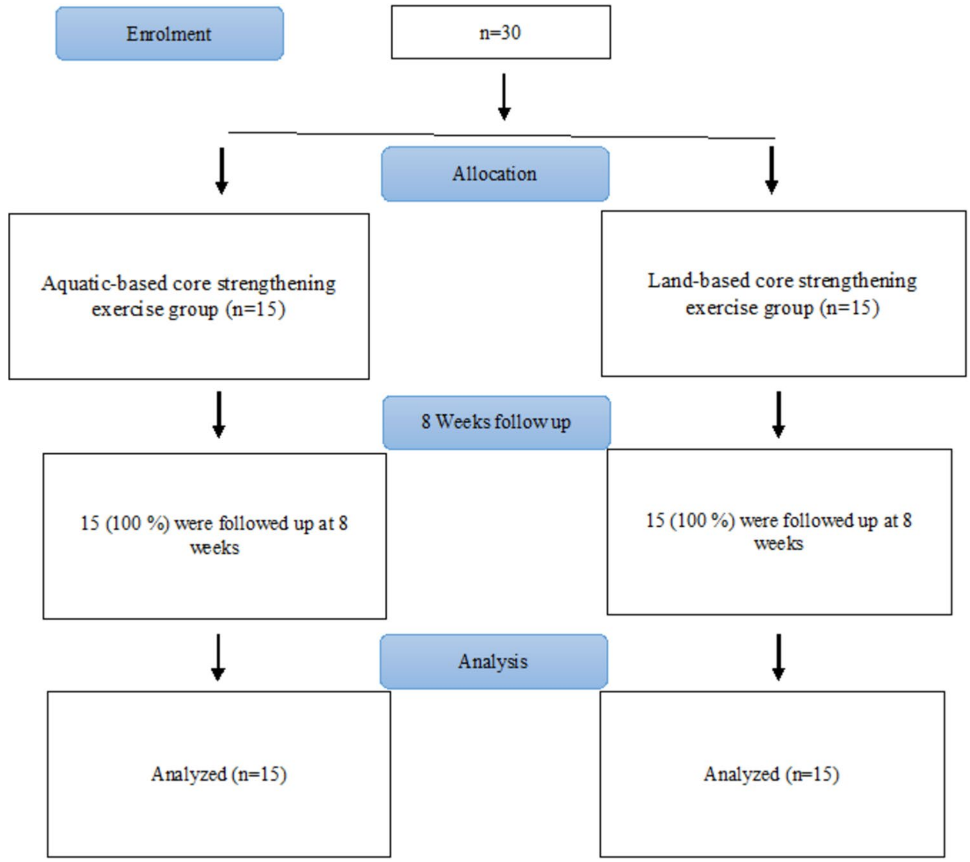

Table 3 Participants' characteristics at the baseline ($n = 30$)

Characteristics	Aquatic-based core strengthening exercise group ($n = 15$)	Land-based core strengthening exercise ($n = 15$)	*P value*
Gender	Female ($n = 15$)	Female ($n = 15$)	
Age, y[a]	32.8 ± 7.65	30.4 ± 4.28	0.41
Height, cm[a]	162.46 ± 4.42	156.66 ± 21.92	0.32
Weight, kg[a]	71.16 ± 7.17	64.16 ± 9.68	0.28
BMI, kg.m^{-2} [a]	27.33 ± 2.59	26.45 ± 10.08	0.74

[a]Values are presented as mean ± SD

programs. This outcome aligns with a previous study by Azizi et.al, which also noted a substantial decrease in thoracic kyphosis angle following an 8-week specific corrective exercise program conducted in both aquatic and land settings [23].

Similar findings, indicating an improvement in thoracic kyphosis angle following corrective exercise programs, were also observed by WoN-GYU Yoo and colleagues in 2013 [24]. However, it is important to note that direct comparisons between these studies and our own are challenging due to differences in methodologies, including variations in the duration of training programs, frequency of workouts, participant demographics such as age and gender, and the specific types of exercise programs utilized.

Nonetheless, the results of our study support the notion that both approaches yield positive outcomes for thoracic kyphosis angle, while suggesting that core strengthening exercise programs may be significantly more effective than corrective exercise in reducing thoracic kyphosis angle. This could be attributed to the ability of core exercises to address spinal misalignment through enhancements in neuromuscular control, as well as improvements in the strength and endurance of various muscles in the trunk and pelvic floor, which are vital for spinal stability and alignment [25, 26].

Additionally, exercises such as yoga and Tai Chi have demonstrated effectiveness in reducing the severity of functional scoliosis and improving posture [27]. Core strengthening exercises, such as bridging, prone plank, squat, and

Table 4 Changes in kyphosis angle and scapular position in response to the aquatic and land-based core strengthening exercise groups

Outcome measures, unit (Group X Time Interaction: *P* values)	Aquatic-based core strengthening exercise group (*n* = 15)	Land-based core strengthening exercise (*n* = 15)	Mean between-group difference (95% CI): Aquatic versus Land-based core strengthening exercise group	*P* values	Effect size
Kyphosis angle (degree)					
Baseline	42.86 ± 5.93	42.06 ± 3.30	0.8 (− 2.79 to 4.39)	0.65	
8 Weeks	39.13 ± 5.66	32.26 ± 2.98	6.86 (3.47 to 10.25)	0.08	0.81
P values, Mean difference (95% CI): Baseline versus week 8	0.001, 3.73 (3 to 4.46)	0.001, 9.8 (9.07 to 10.5)			
Protraction (cm)					
Baseline	1.85 ± 0.33	1.98 ± 0.35	0.13 (− 0.38 to 0.13)	0.33	
8 Weeks	1.5 ± 0.18	1.46 ± 0.26	0.04 (− 0.13 to 0.2)	0.66	0.17
P values, Mean difference (95% CI): Baseline versus week 8	0.002, 0.35 (0.14 to 0.5)	0.001, 0.51 (0.3 to 0.73)			
Rotation (cm)					
Baseline	60.35 ± 3.45	64.13 ± 4.66	3.78 (0.7 to 6.85)	0.07	
8 Weeks	55.29 ± 3.43	57.09 ± 5.87	1.79 (− 1.8 to 5.39)	0.31	0.37
P values, Mean difference (95% CI): Baseline versus week 8	0.001, 5.05 (3.2 to 6.88)	0.001, 7.04 (5.2 to 8.86)			

rocking horse exercises, can contribute to the improvement of hyperkyphosis. Core stability, defined as the capacity to control the position and movement of the trunk over the pelvic and lower extremities, allows the core to generate, transfer, and manage force and motion to the distal segments [26]. The dynamic stability of the spine pertains to the functional use of muscular strength and endurance to control the spine during activities [28].

In relation to scapular position, no significant differences were found between the two groups, while there were significant within-group improvements in scapular position in both exercise groups. Several studies have reported similar outcomes regarding enhanced scapular position. For instance, Man-Ying Wang and colleagues implemented a 24-week yoga intervention in older adults with hyperkyphosis, demonstrating notable improvements in scapular posturing following the intervention [29]. However, our study exhibited greater improvements in a shorter timeframe. In addition, Ji-hyun Lee and colleagues achieved comparable results in scapular position among young men with round-shoulder posture, despite differences in intervention type and participant demographics compared to our study [30]. Although all these exercise programs resulted in improved scapular position, the core strengthening exercises utilized in our study proved to be slightly effective. This heightened effectiveness may be attributable to several underlying mechanisms.

One potential mechanism involves the thoracolumbar fascia, which envelops the trunk like a band [26] and serves to integrate the upper and lower extremities in the kinetic chain by connecting the superior/inferior and right/left segments [26]. Comprising anterior, middle, and posterior layers, the superficial lamina of the posterior layer originates from the latissimus dorsi muscle, while the transvers abdominis exhibits extensive attachments to the middle and posterior layers. This fascial cover encompasses various muscle groups, including pectoralis major and minor, rhomboids major and minor, trapezius, and serratus anterior, before extending toward the latissimus dorsi and gluteus maximus [31]. These layers play a crucial role in mediating load and energy transfer between the upper and lower extremities, as well as the abdominal wall and lumbopelvic region, while also contributing to spinal stabilization through their connection to the internal obliques and transverse abdominis muscles [26]. In addition, the diaphragm, contracting prior to limb movement and independently of respiration, has been shown to assist with spinal stability [26].

The mechanism by which water exercises improve thoracic kyphosis angle involves several key aspects related to the physical properties of water and targeted corrective exercise benefits. Aquatic exercise mitigates gravitational forces through buoyancy, significantly reducing axial loading on spinal structures and peripheral joints. This biomechanical advantage enables kyphotic patients to execute movement patterns with diminished pain perception and enhanced kinematic efficiency, thereby improving exercise adherence and potentiating postural realignment. The hydrostatic pressure inherent to aquatic environments creates progressive respiratory resistance during thoracic expansion, inducing adaptive strengthening of inspiratory musculature. This physiological adaptation enhances thoracic stabilization mechanisms critical for postural correction in kyphotic deformities.

Another significant mechanism is the "serape effect," which underscores the interconnectedness between the body and extremities [28]. This mechanism relies on the crisscross arrangement of muscles, facilitating force production between the shoulders and contralateral hips. The diagonal tension generated during rotation of the shoulders and hips in opposite directions creates the "serape effect," involving the interaction of the rhomboid major, rhomboid minor, serratus anterior, and oblique abdominal muscles [28]. According to Gracovetsky's spinal machine theorem, the oblique abdominal muscles collaborate with other core muscles to generate rotator torque, enabling kinetic and functional movements such as walking, throwing, and similar activities, which are based on core muscles and integrated with power from the body and lower extremities via the thoracolumbar fascia to achieve maximum power production. These mechanisms elucidate the biomechanical integration of body and extremity segments within the kinetic chain approach [28].

Study limitations

The study has a number of limitations. First, this study was not blinded and none of the researchers were blinded to the study protocol. Secondly, this study did not incorporate any long term (> 8 weeks) of the effect of aquatic and land-based core strengthening exercise programs on thoracic kyphosis angle and scapular position thus the impact of these programs over longer periods is unknown. Furthermore, there is a limitation to the generalizability of the present study. We recruited only young and middle-aged adults. Therefore, the results of this study cannot be generalized to older, individuals of > 45 years with hyperkyphosis. Moreover, the lack of a control group to compare with the two exercise program groups.

Future directions

Future studies should thus focus on the long term (> 8 weeks) of the effect of aquatic and land-based core strengthening exercise program on different physical and functional performance variables in young and middle-aged male and female using randomized controlled trials. In addition, the benefits of the aquatic and land-based core strengthening exercise in other populations (e.g., males, kids, elderly) or other deformities (round shoulder, forward head, scoliosis, sway back) can be investigated. Owing to the small number of participants in this study, it is evident that a significantly larger sample size is required to effectively demonstrate differences between the aquatic and land-based core strengthening exercise groups.

Conclusion

Based on the findings of the current study, it was observed that an 8-week aquatic and land-based core strengthening exercise regimen (comprising three sessions per week) led to a significant reduction in thoracic kyphosis angle and improvement in scapular position among young and middle-aged women with hyperkyphosis. However, there was no significant difference between two exercise programs.

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Author contributions SR was involved in conceptualization, methodology, data collection as well as writing-original draft preparation and approval of the final manuscript. AEA was involved in the conceptualization, methodology, critical manuscript revision and final approval. NKY was involved in the conceptualization and methodology and final approval. BSH was involved in writing-reviewing and editing, software and final approval. RBF was involved in the data collection, conceptualization and methodology and final approval. All authors read and approved the final manuscript.

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Data availability No datasets were generated or analyzed during the current study.

Declarations

Conflict of interests The authors declare no competing interests.

Ethical approval and Informed consent The present research was approved by the Biomedical Research at Ferdowsi University of Mashhad, Iran (Ethics Code: IR.UM.REC.1397.050).

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