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Effect of Training Environment on Pain, Stability, Functional Disability, and Motor Control in Swimmers with Shoulder Impingement Syndrome

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ABSTRACT

Aims: Shoulder Impingement Syndrome (SIS) is a prevalent issue in swimmers, impacting pain, stability, and motor control. This study compares the effects of various training environments on these outcomes in swimmers with SIS.

Method and Materials: Thirty female swimmers with SIS were randomly assigned to Land-Based Training (LBT, n=15) or Water-Based Training (WBT, n=14) groups. Assessments included pain through Visual Analog Scale (VAS), stability (Upper Quarter Y-Balance Test), functional disability through Disabilities of the Arm, Shoulder, and Hand (DASH), and proprioception through Joint Position Sense (JPS error), measured pre- and post-intervention. The 24-session programs involved progressive stretching and resistance exercises, with intensity adjusted biweekly using the Borg scale (Ratings of Perceived Exertion (RPE) 9–11). Data were analyzed using ANCOVA followed by a Bonferroni post hoc test.

Findings: In this study, WBT led to greater improvements in pain ($\eta^2 = 0.94$), Y-Balance ($\eta^2 = 0.89$), and functional disability (DASH; $\eta^2 = 0.31$) compared to LBT (all $p < 0.01$). However, LBT showed superior proprioception with fewer joint position errors in internal rotation, external rotation, and abduction (all $p < 0.05$).

Conclusion: This study revealed that WBT effectively reduces pain and disability, while LBT improves proprioception; combining both approaches may optimize overall rehabilitation and functional recovery in SIS.

Keywords: Pain, Proprioception, Swimmers, Disability, Shoulder Impingement Syndrome

Introduction

The shoulder joint is a highly mobile joint that allows a wide range of motion, with this functionality facilitated by the coordinated contractions of the surrounding muscles, especially the rotator cuff muscles. Additionally, the scapular stabilizing muscles, in cooperation with the rotator cuff, maintain the position of the humeral head within the glenoid cavity, preventing subacromial impingement [1]. Since any disruption in this mechanism can lead to SIS, along with pain and injury, a significant number of professional swimmers encounter this issue at least once during their careers. This injury is considered one of the primary causes of disability, preventing continued training and causing absences from competitions [2].

SIS, the most common cause of shoulder pain, disrupts sensorimotor control and leads to functional disability in the region [3]. Following injury, dysfunction in mechanical receptors reduces sensory input to the joint, weakening neuromuscular stabilization and increasing the risk of recurrent injuries and joint dysfunction. Furthermore, deficits in upper limb stability may further highlight impairments in sensorimotor control and lead to functional instability in individuals with shoulder injuries [4].

Research has shown that proprioceptive mechanisms appear to play a critical role in glenohumeral stability, acting as an interface between static stabilizers and dynamic muscular restraints. Proprioception relies on afferent input from muscle, ligament, and joint receptors to the central nervous system, enabling precise motor control [4]. When proprioceptive function is compromised, as in SAIS, the activation patterns of the rotator cuff and scapular muscles are disrupted, which can lead to functional impairments. The body may respond by restricting the Range of Motion (ROM) to protect the joint [5]. Consequently, proprioceptive deficits reduce the accuracy of maintaining dynamic upper limb stability during multidirectional movements [4]. Nevertheless, some studies have reported that while specific proprioceptive mechanisms may be impaired, overall motor control through compensatory mechanisms may remain relatively intact [6]. Other research has found that individuals with chronic rotator cuff injuries demonstrate significantly reduced Joint Position Sense (JPS) at higher abduction angles (e.g., 100), especially when pain and impingement are present [7]. A review on shoulder proprioception further noted that, although deficits may be present in rotator cuff tendinopathy, responses to exercise interventions are often similar between individuals with and without proprioceptive impairments, suggesting that such deficits are not an absolute prerequisite for functional improvement [8]. Casadio et al. demonstrated that active exercises can enhance both upper limb functionality and proprioception by: [1] encouraging patients to concentrate more on joint positioning during active movements, and [2] boosting the sensitivity of the neuromuscular spindles [9]. Another study demonstrated that functional disability—defined as the reduced ability to perform daily activities involving the arm, shoulder, and hand—can be significantly improved through individualized exercise programs targeting movement errors, primarily due to pain reduction [10].

In shoulder rehabilitation, programs have been designed to restore motor function and reduce the risk of re-injury, incorporating therapies such as physiotherapy, hydrotherapy, manual therapy, and dryland therapeutic exercises [11].

There is limited evidence on the effects of aquatic-based physiotherapy on shoulder proprioception following post-traumatic injury. Previous studies suggest that aquatic rehabilitation programs improve shoulder range of motion, strength, reduce pain, and restore functional movement patterns [2, 11-13]. One mechanical effect of water is the reduction in body weight due to Archimedes' principle and immersion depth. Other biomechanical effects, such as hydrostatic pressure and water viscosity, play a role in drainage, circulation, and sensory stimulation, enhancing proprioceptive, somesthetic, and kinesthetic feedback. Additionally, water's resistance increases sensory input and body awareness [14]. Warm water, when used in therapy, contributes to somatosensory stimulation, thereby improving proprioception, as demonstrated in studies on stroke patients. However, cold water immersion has shown no significant effect on JPS in healthy individuals [11].

Furthermore, studies have shown that performing resistance and stretching exercises, particularly those aimed at strengthening the rotator cuff muscles and correcting shoulder posture, can reduce pain and functional impairments associated with shoulder impingement syndrome in swimmers [15]. Wang et al. (2023), in a systematic review and meta-analysis of 32 randomized controlled trials with over 2,200 participants, found that aquatic exercise produced greater improvements in pain and physical function than land-based training in patients with chronic shoulder disorders, though it showed no significant effect on JPS in those with SIS [16]. While aquatic programs may reduce fatigue, pain, and muscle spasms through buoyancy, hydrodynamic resistance, and thermal effects, their impact on muscular strength is limited by the absence of gravitational loading [12].

Despite the widespread use of traditional land-based exercises for SIS, evidence comparing the effectiveness of resistance and stretching exercises in aquatic versus land environments remains limited, particularly in swimmers who impose high functional demands on their shoulders. Aquatic exercise offers unique advantages: buoyancy reduces joint stress, water resistance promotes strength, flexibility, and proprioception, and the low-impact environment may enhance rehabilitation without aggravating pain. While some studies suggest aquatic training benefits sensorimotor function more than land-based exercise, improvements in strength and overall performance are often greater on land. These mixed findings highlight the need for comprehensive research directly comparing resistance and stretching exercises in both environments on outcomes such as pain, stability, functional disability, and motor control in swimmers with SIS.

Method and Materials

This study employed a semi-experimental, applied design to examine the effects of exercise interventions in both aquatic and land-based environments. Two experimental groups were assigned to distinct training protocols. Participants were purposefully selected according to strict inclusion and exclusion criteria to ensure sample homogeneity and enhance the validity of the results. All participants were female swimmers with a minimum of three years of regular swimming experience and positive findings in shoulder impingement differential tests. Individuals with a history of hospitalization, surgery, neuromuscular disorders, the use of specific medications, or frequent absences from training were excluded from the study. Non-attendance at testing sessions or withdrawal from the exercise program also constituted grounds for exclusion.

The study population consisted of female swimmers aged 20 to 40 years in Qazvin diagnosed with shoulder impingement syndrome. The sample was chosen through a combination of accessibility and purposive sampling. Using G*Power 3.1.9.2 (University of Dusseldorf, Germany), the required sample size was calculated based on a covariance analysis with 80% statistical power and a significance level of 0.05, resulting in 28 participants. To account for potential dropouts, 30 participants were enrolled in the study.

Participants were randomly assigned to two equal groups: One group performed Land-Based Training (LBT, n = 15), and the other group performed similar stretching and resistance exercises in water-based training (WBT, n = 15). At the beginning of the study, the research procedures were thoroughly explained to all participants, and written informed consent, along with medical clearance for training in both environments, was obtained. One participant from the aquatic group withdrew due to unwillingness to continue. The study protocol was approved by the Ethics Committee of the University of Tehran under the code IR.UT.SPORT.REC.1404.075. This study was registered in the Iranian Registry of Clinical Trials (IRCT) with the registration number IRCT20250427065494N1.

During the initial session, participants underwent anthropometric assessments, including measurements of height, weight, and Body Mass Index (BMI), using a Body Composition Analyzer (model ioi353, JAWON, South Korea). All outcome measures were reassessed two days after the conclusion of the final training session, following the same protocols as the baseline assessment. Participant recruitment was coordinated with the provincial Aquatic Sports and Sports Medicine Federations, focusing on swimmers who had been diagnosed with SIS within the preceding two months.

Diagnosis was verified by an orthopedic specialist using clinical evaluations, including Neer’s test and the Hawkins–Kennedy test, in addition to the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. In Neer’s test, pain elicited during passive forward flexion of the arm with internal rotation, particularly between 70° and 120°, is indicative of potential subacromial impingement. The Hawkins–Kennedy test involves flexing the arm and elbow to 90°, followed by passive internal rotation of the humerus; the presence of pain suggests rotator cuff tendon impingement. The DASH questionnaire, consisting of 30 items, quantifies upper limb disability, with higher scores reflecting greater functional limitations [17].

The dependent variables in this study included pain (measured using the Visual Analog Scale (VAS), upper limb stability (assessed by the Y-Balance Test), functional disability (evaluated using the DASH questionnaire), and motor control (measured by the Restoration of JPS).

Pain intensity was measured using the VAS, a 10-cm horizontal line anchored with "no pain" at one end and "worst pain imaginable" at the other. Participants indicated their perceived pain during activities related to SIS. Measurements were collected both before and after the intervention. The VAS has been shown to possess high reliability (ICC = 0.94–0.99) and established construct validity for assessing pain severity [14].

Upper limb stability was assessed using the Y-Balance Test, which evaluates active reach in three directions: medial, superolateral, and inferolateral. Reach distances were normalized to arm length, measured from the spinous process of C7 to the fingertip with the shoulder abducted to 90°, and the final score was reported as a percentage. This test has demonstrated excellent reliability (ICC = 0.92) and validity for assessing stability and functional reach of the upper extremity [18].

The DASH questionnaire was used to assess upper limb functional disability. This 30-item instrument evaluates pain intensity (21 items), joint stiffness (5 items), and the impact of upper limb function on social and work-related activities (4 items). Each item is rated on a 5-point scale (1–5), and the total score is calculated by averaging the responses, subtracting one, and multiplying by 25, yielding a score from 0 to 100. Higher scores indicate greater disability. The DASH questionnaire has demonstrated good construct validity (r = 0.70–0.80) and excellent reliability (ICC = 0.96) [19].

To evaluate motor control (Restoration of JPS), participants were seated in a quiet room with eyes closed and their trunk stabilized against the chair back. A flex meter was attached to the mid-outer forearm to measure shoulder internal and external rotation. Target angles were calculated as 10% of the total active range of motion, and the examiner passively moved the participant's arm to the target for 5 seconds. Participants then actively restored the angle, signaling when they believed they reached it, and the absolute error between the target and reproduced angles was recorded over three trials per movement. Shoulder abduction was assessed using a goniometer in the frontal plane, with the arm initially positioned at 0° and moved through the full range. The angle relative to an external fixed reference point was recorded to ensure accuracy and minimize compensatory movements. This procedure provided reliable, precise measurements of shoulder joint position sense and abduction range. The reliability of shoulder joint position sense assessments is generally good, with ICC reported between 0.77 and 0.86 in healthy individuals, though it may be lower in patients with shoulder disorders [20].

The intervention consisted of 24 sessions (Table 1) with predefined intensity, sets, and repetitions, progressing biweekly according to the Borg Ratings of Perceived Exertion (RPE) scale (9–11). Exercises were performed pain-free (≤3 on VAS) with proper technique. ROM, pain, and function were assessed at baseline, week 4, and week 8. Aquatic training took place in a pool at 30–32°C and a depth of 1.0–1.3 m, using resistance bands, kickboards, and water dumbbells.

Table 1) Eight-Week Stretching-Resistance Protocol

Week	Sessions	Stretching (Land / Aquatic)	Resistance Training (Land / Aquatic)	Notes / Equipment
1	1–3	Internal & external rotation, cross-body arm stretch (30 s × 3) / Same in poolside	Rotator cuff bands, full-can, rowing 3×12 / Push-pull against water, light dumbbells 3×15	Warm-up 10 min, cool-down 10 min
2	4–6	Add side-lying stretch / Add diagonal PNF stretch (35 s × 3)	Increase band resistance, dumbbell 1.5 kg / Medium water resistance, aquatic dumbbell 3×15	Progress intensity per RPE
3	7–9	Hold stretches 35–40 s / Same, 40 s	Full can & rowing 2 kg, horizontal abduction / Arm flexion push/pull 3×1 min, increase water resistance.	Monitor ROM, pain, and function

4	10–12	Add capsular stretch / PNF with higher reps	Modified push-ups 3×10 / Increase sets & duration arm flexion	Warm-up/cool-down maintained
5	13–15	Hold 40 s, combined stretches / Medium depth, higher resistance	Dumbbells 3 kg, blue band / Medium-heavy aquatic dumbbell, horizontal arm swing 3×15	Focus on form & pain-free execution
6	16–18	4 reps each stretch / Hold 45 s	Scaption 3 kg ×12 / Wall push-up in water 3×12, increase intensity	Controlled technique emphasized
7	19–21	Hold 45 s, controlled breathing / Controlled breathing	Increase reps to 15 / Increase reps to 20	Gradual load progression
8	22–24	Focus on high stability, 45s / Same, 4 reps	Max intensity: dumbbell 4 kg, push-up 3×15 / Heavy dumbbell, modified push-up, deeper water	Maintain pain-free, monitor ROM.

RPE: Ratings of Perceived Exertion, PNF: Proprioceptive Neuromuscular Facilitation

Data were analyzed using SPSS version 22 with both descriptive and inferential statistics. The Shapiro–Wilk test was first applied to assess the normality of data distribution. For normally distributed variables, analysis of covariance (ANCOVA) was conducted, followed by the Bonferroni post-hoc test, with a significance threshold set at $\alpha \leq 0.05$.

Findings

The Shapiro–Wilk test confirmed normal data distribution. A pre-intervention one-way ANOVA revealed no significant differences between groups ($p<0.05$), indicating participant homogeneity. Participants' characteristics and ANOVA results are summarized in Table 2.

Table 2) Participants' Demographic and Physical Characteristics

Groups/ Variables	n	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	History (years)
LBT	15	28.40 ± 5.12	169.13 ± 4.13	64.54 ± 4.01	22.54 ± 0.53	7.29 ± 0.07
WBT	14	29.85 ± 4.34	170.57 ± 4.57	66.52 ± 4.11	22.84 ± 0.21	7.12 ± 0.71
P-value	-	0.195	0.116	0.213	0.226	0.578

LBT: Land-based training, WBT: Water-based training.

Table 3) Adjusted Means and ANCOVA Results

Outcome	LBT Mean ± SD	WBT Mean ± SD	F (df)	P_ value	η^2	Post-hoc (MD)
Pain (VAS, score)	4.13 ± 0.04	2.68 ± 0.05	434.8 (1)	< .001	0.94	1.45
Y-Balance Test (score)	107.14 ± 0.27	112.85 ± 0.28	212.96 (1)	< .001	0.89	- 5.72
Functional disability (score)	24.41 ± 0.33	22.78 ± 0.34	11.51 (1)	0.002	0.31	1.64
Proprioception (degree)						
Internal rotation	5.60 0.32	4.40 ± 0.33	6.73 (1)	0.015	0.21	1.21
External rotation	4.54 ± 0.39	3.53 ± 0.30	5.99 (1)	0.021	0.18	1.01
Abduction	4.50 ± 0.22	3.65 ± 0.23	6.83 (1)	0.015	0.21	0.85

To control for pre-test effects, ANCOVA was employed, with all assumptions (no high correlations, normality of residuals, and homogeneity of variances) satisfied. Results revealed a significant reduction in pain in the WBT compared to the LBT group ($F(1,26) = 434.8$, $p < 0.001$, $\eta^2 = 0.94$; MD = -1.45, Bonferroni post hoc). Similarly, the Y-Balance Test showed greater improvement in the WBT group ($F(1,26) = 212.96$, $p < 0.001$, $\eta^2 = 0.89$; MD = 5.72). Functional disability (DASH) showed greater improvement in the WBT group ($F(1,26) = 212.96$, $p = 0.002$, $\eta^2 = 0.31$; MD = -1.64). Proprioception, measured as absolute error, indicated more minor mistakes in the LBT group for internal rotation (F(1,26) = 6.73, p = 0.015), external rotation (F(1,26) = 5.99, p = 0.021), and abduction (F(1,26) = 6.83, p = 0.015), with MDs of 1.21, 1.01, and 0.85, respectively (Table 3).

Discussion

The present study aimed to examine the comparative effects of WBT and LBT on pain, stability, functional disability, and proprioception in individuals with SIS. The results highlight environment-specific benefits that can guide targeted rehabilitation programming.

In practical terms, WBT led to a significant reduction in pain and disability, as well as greater improvements in stability (as measured by the Y-Balance) compared to LBT, highlighting its rehabilitative benefits. In contrast, LBT produced greater improvements in proprioceptive accuracy, especially in shoulder rotation and abduction. These patterns suggest that while aquatic training is more effective for pain relief, enhanced stability, and functional recovery, land-based exercises may be better suited to improve neuromuscular control.

This finding indicates that WBT exerts a greater effect in reducing pain symptoms associated with SIS compared to LBT (a score of 1.45 on the VAS scale). The findings of this study are consistent with previous evidence, indicating that WBT plays a significant role in alleviating pain associated with SIS [16, 21, 22]. Prior research has highlighted that dysfunction of the dynamic and static shoulder stabilizers can reduce the sub acromial space, thereby increasing pressure on soft tissues and leading to inflammation and pain [16, 23]. Since this condition commonly arises from repetitive use of the upper limb—particularly in athletes who frequently perform overhead movements—corrective exercises appear to restore the functional balance of the stabilizing muscles, maintain the subacromial space, and prevent soft tissue entrapment. Consequently, this mechanism contributes to a reduction in pain and inflammation in affected individuals [4, 5, 10]. As previously mentioned, SIS often involves inflammation and reduced sub acromial space, leading to pain, limited ROM, and altered muscle activation. Furthermore, WBT, which includes both stretching and resistance components, provides a low-load, supportive environment that reduces joint stress, facilitates pain-free movement, and enables the gradual re-engagement of weak or inhibited muscles [21, 22]. Additionally, hydrostatic pressure, buoyancy, and adjustable water resistance promote neuromuscular re-education, serving as a practical foundation for early rehabilitation and motor pattern correction [14].

The findings of this study indicate that WBT led to greater improvements in stability compared to LBT, suggesting that aquatic environments may be particularly effective in enhancing stability in individuals with SIS. Some research, such as previous study which found no significant differences between WBT and LBT, possibly because water's buoyancy and reduced weight-bearing decrease postural demands, while its viscosity slows movements, limiting repetition intensity and balancing overall training effects [24]. This discrepancy may stem from previous studies focusing on lower-limb stability in individuals with chronic ankle instability, a population whose responses differ from those observed in our shoulder-focused sample. Nevertheless, Aquatic environments offer unique characteristics that support improvements in balance and stability. Buoyancy in water reduces joint loading and imparts a sense of lightness to muscles and tendons, while water viscosity slows movements and neuromuscular responses [14, 16]. These properties facilitate controlled and stable motions, providing a safe and effective setting for individuals with balance deficits or joint instability. In shoulder impingement syndrome, joint stress and muscle activity in land-based settings can exacerbate inflammation and pain [25]. Conversely, aquatic exercise reduces joint load and friction, allowing shoulder joint mobility, enhancing functional performance, and alleviating discomfort [14]. A significant barrier in the rehabilitation of individuals with shoulder pain is kinesiophobia, or fear of movement [25]. Exercising in a water-based environment diminishes pain and promotes a sense of safety, encouraging active participation and supporting the restoration of healthy movement patterns, ultimately accelerating overall functional recovery [21, 23].

The findings indicated that WBT was more effective than LBT in improving functional disability. The DASH questionnaire assesses functional disability of the upper extremity, capturing limitations in daily activities, work, and social or recreational tasks. It also evaluates pain, weakness, stiffness, and other symptoms affecting arm, shoulder, and hand function [19]. The study found that both WBT and LBT programs improved pain and shoulder functional disability in patients with SIS, but the WBT program produced greater improvements over time. These findings suggest that aquatic exercises may be more effective in enhancing shoulder function and reducing disability [22]. WBT offers significant advantages over LBT in improving functional disability in patients with SIS. A key factor is the reduced joint load in water due to buoyancy, which decreases intra-articular friction and allows greater freedom of movement [11, 13, 16]. This reduces stress, particularly during stretching exercises, facilitating mobility in multiple planes and enhancing daily functional performance [13]. Additionally, the warm aquatic environment can increase blood flow, aiding in the reduction of pain and inflammation, and promoting the recovery of the injured shoulder [12]. Consequently, aquatic training effectively improves functional capacity while simultaneously alleviating pain [3]. Kinesiophobia, or fear of movement due to pain, is a significant barrier in shoulder rehabilitation. The aquatic environment reduces pain and provides a sense of safety and psychological comfort, enabling patients to engage actively in exercises and restore healthy movement patterns, thereby accelerating overall functional recovery [21, 23].

Overall, the results indicated that LBT was more effective than WBT in improving shoulder proprioception, particularly in internal and external rotation as well as abduction. Stretching and resistance exercises can improve joint stability and reduce pain by enhancing proprioceptive receptor function and sensory awareness. In SIS, where neuromuscular control is often impaired, these exercises help restore precise movement regulation and JPS [8, 21]. Various studies have shown that resistance and stretching exercises in a land-based environment can improve shoulder JPS and the accuracy of joint angle reconstruction in patients with SIS [4, 5, 7, 21]. This improvement arises from several mechanisms: direct mechanical loading of the joint and surrounding tissues, which stimulates proprioceptive receptors [21]; strengthening of stabilizing muscles such as the rotator cuff and scapular muscles, which maintain the humeral head in the center of the glenoid cavity [2]; exercising through a complete and multi-directional range of motion to enhance joint angle reconstruction [25]; and activation of neural pathways associated with joint position sense, promoting neural adaptation and cortical plasticity. Studies have indicated that proprioceptive exercises initially heighten the brain's conscious attention to proprioceptive cues and subsequently enhance automatic processing, while the training-induced activation of neural connections in the relevant sensory areas further contributes to improved proprioception [21]. Additionally, pain can impair JPS, but with exercise and pain reduction, joint position sense improves, ultimately enhancing motor control and shoulder function [13, 21, 25]. In summary, LBT allows precise load control and targeted strengthening of weak muscles, enhancing neuromuscular coordination and facilitating faster recovery of normal function. In contrast, WBT, while reducing joint load, may be limited in developing strength in specific movement directions [10, 22].

Aquatic exercise can offer superior rehabilitation benefits for swimmers with SIS, particularly during the early stages of recovery, by reducing pain, improving stability, and function. While LBT provides controlled mechanical loading that benefits shoulder JPS and motor control, combining active and resistance stretches in water with land-based proprioceptive training and instruction on proper overhead technique, under continuous monitoring of pain and ROM, can optimize functional recovery, accelerate improvement in SIS, and reduce the risk of reinjury.

The present study had several limitations. Its single-center design and small sample size may limit the generalizability of the findings. Additionally, only female participants were enrolled, which restricts the applicability to male populations. Long-term follow-up to assess the durability of improvements was not performed, and the investigation focused solely on chronic SIS cases without distinguishing between underlying etiologies. Future research should include larger, more diverse samples and evaluate both short- and long-term outcomes across different SIS subtypes. Small sample size is another limitation maigh influence on the results.

Conclusion

WBT is particularly effective for reducing pain, improving functional disability, and enhancing stability in individuals with SIS Conversely, land-based resistance and stretching training more effectively improve shoulder proprioception and neuromuscular control. Combining water- and land-based interventions, with careful monitoring of pain and ROM, may provide an optimal rehabilitation strategy, accelerating functional recovery, restoring healthy movement patterns, and reducing the risk of reinjury.

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Authors' Contribution

All authors participated in the design and conduct of the research. The manuscript was written and confirmed by all authors.

Conflicts of Interest

The researchers claim no conflicts of interest.

Ethical Permissions

The study protocol was approved by the Ethics Committee of the University of Tehran under the code IR.UT.SPORT.REC.1404.075. This study was registered in the Iranian Registry of Clinical Trials (IRCT) with the registration number IRCT20250427065494N1.

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