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The Effect of Corrective Exercises on Q Angle and Jump-Landing Mechanics

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ABSTRACT

BACKGROUND

Lower extremity alignment and faulty jump-landing patterns are significant risk factors for anterior cruciate ligament (ACL) injuries in young female athletes. Corrective exercise interventions aim to optimize biomechanical efficiency and neuromuscular control. This study aimed to examine the effects of a structured corrective exercise program on Q angle and jump-landing mechanics in competitive young female volleyball players during the in-season period.

METHODS

Twenty-three young female volleyball players were enrolled in this controlled intervention study and assigned to either an experimental group (n = 12, age: 15.33 ± 0.65 years) or a control group (n = 11, age: 15.27 ± 0.46 years). The experimental group participated in an 8-week corrective exercise program focused on body segment alignment and injury risk mitigation, while the control group continued their standard training. Pre- and post-intervention assessments included anthropometric measurements, static Q angle, the Landing Error Scoring System (LESS) for biomechanical analysis, and countermovement jump (CMJ) height for explosive power.

RESULTS

A significant multivariate effect was found following the 8-week intervention. In the experimental group, statistically significant improvements were observed in both Q angle and LESS scores ($p < 0.05$). The analysis revealed large effect sizes for the Q angle (partial $\eta^2 = 0.56$) and the LESS test (partial $\eta^2 = 0.62$). Regarding vertical jump performance, no statistically significant difference was found in CMJ measurements for the experimental group ($p > 0.05$), although a medium effect size was observed (partial $\eta^2 = 0.06$). In contrast, the control group showed no statistically significant differences between pre-test and post-test measures for any of the variables ($p > 0.05$).

CONCLUSIONS

An 8-week corrective exercise program effectively reduces the Q angle and improves jump-landing mechanics (LESS scores) in young female volleyball players. These findings suggest that integrating targeted biomechanical corrections into in-season training can optimize knee alignment and movement quality. Such interventions may play a critical role in athletic performance enhancement and long-term injury prevention by ensuring proper kinetic chain integration.

Trial registration: ClinicalTrials.gov, NCT07578701. Registered on 9 May 2026. Retrospectively registered.

Keywords: Volleyball, Q Angle, Landing, Corrective Exercises, Jump

INTRODUCTION

To achieve success in team sports, athletes must execute offensive and defensive actions in a coordinated manner. Volleyball is a dynamic sport that requires rapid transitions between attack and defense. Due to the nature of the sport, volleyball players frequently perform jumping and landing movements [1]. During a jump, athletes generate high force and power outputs, and it

is crucial that they maintain their performance while minimizing injury risk upon landing. To sustain and enhance performance, factors such as technique, strength, power, and speed must be developed. However, the repetitive execution of jump-landing movements in volleyball increases the risk of injuries [2]. Given that athletic performance is a priority, it is essential to address and mitigate these injury risk factors [3]. These demands are particularly pronounced in young female volleyball players, who often perform a high number of spike and block jumps during both training and competition, resulting in substantial cumulative loading of the knee joint [1, 2]. Therefore, reinforcing proper jump-landing technique and neuromuscular control is a key component of injury-prevention strategies in this population [4,5].

Deficiencies in landing mechanics or improper landing techniques play a significant role in athlete injuries. Incorrect landing mechanics prevent the body from effectively absorbing ground reaction forces, leading to excessive stress on joint structures [6]. Factors such as technique, muscular strength, balance, and muscle imbalances can influence landing mechanics. Suboptimal landing mechanics may result in excessive stress on the knee and spine, potentially affecting performance outcomes. In addition to these factors, structural abnormalities in individuals may also increase the risk of injury [7]. One such structural abnormality, an increased Q angle (i.e., an excessive lateral deviation of the quadriceps line of pull), is considered a risk factor for non-contact lower extremity injuries [8].

The Q angle is a parameter that can be easily measured in terms of time, cost, and equipment. It is defined as the angle formed between the anterior superior iliac spine and an imaginary line passing through the midpoint of the patella, as well as another imaginary line extending from the midpoint of the patella to the tibial tuberosity. A Q angle greater than 20 degrees in women has been identified as a risk factor for lower extremity injuries [9].

Although an increased Q angle has traditionally been regarded as a static anatomical risk factor, some authors have suggested that the Q angle also reflects dynamic lower-limb alignment

during functional tasks [10,11]. Excessive femoral internal rotation, hip adduction, and pelvic drop can increase the frontal-plane projection of the Q angle and contribute to dynamic knee valgus during landing [12]. Corrective exercise programs that focus on trunk, hip, and knee alignment, as well as strengthening of the hip abductors and external rotators, may therefore reduce excessive Q angle values by improving neuromuscular control and lower-limb alignment in weight-bearing positions. In this context, changes in Q angle following corrective exercises may represent a modifiable indicator of improved movement quality rather than a purely fixed structural characteristic.

The Q angle is closely associated with knee valgus. Knee valgus, which may result from improper landing mechanics or an excessively high Q angle, can have detrimental effects on the knee structures and more proximal segments, particularly the pelvis and trunk segments. Misalignment of these segments disrupts load transfer, thereby impairing force and power generation [13,14].

Individuals with an increased Q angle experience greater stress on the anterior cruciate ligament (ACL) during dynamic knee movements. Repeated stress on the ACL over time can lead to stretching, partial tears, or complete rupture [12,15]. Additionally, knee valgus may induce excessive tension in the lumbar region muscles, potentially leading to lateral deviations in the spine and pelvis [16].

Corrective exercises are commonly used to address muscle imbalances, improve alignment, and reduce injury risk in athletes [4,5].

In volleyball, fundamental movements such as spikes and serves are performed repeatedly, which may lead to asymmetries and functional imbalances between the limbs. Corrective exercises targeting the knee, hip, and core muscles in volleyball players can contribute positively to body segment alignment and overall performance. Given the high frequency of jump-landing tasks and the elevated risk of knee valgus-related injuries in young female

volleyball players, examining the effects of corrective exercise interventions is particularly relevant. This study aimed to examine the effects of corrective exercises on Q angle and jump-landing mechanics.

METHOD

Research Group

Twenty-three young female volleyball players participated in the study. Participants were randomly assigned to the experimental (n = 12) or control (n = 11) group using a simple randomization procedure. The participants were divided into experimental (n= 12, age 15.33 ± 0.65 years, body mass 63.19 ± 10.50 kg, height 167.83 ± 6.19 cm) and control (n= 11, age 15.27 ± 0.46 years, body mass 53.78 ± 7.83 kg, height 160.81 ± 3.21 cm) groups. Female athletes with no previous history of sports injuries were recruited voluntarily. Written informed consent was obtained from all participants and their parents or legal guardians prior to participation. Before starting the study, ethical approval was obtained from the Kocaeli University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Approval No: GOKAEK-2022/21.16).

Research Design

Participants were informed about the purpose of the study, the methodological protocol, the study duration, and potential risks. Written informed consent and parental consent forms were obtained prior to participation. As all participants were minors, written informed consent for publication of clinical details and/or images was obtained from their parents or legal guardians. The study was conducted during the in-season period to prevent any impact on the athletes' adaptation process.

To ensure the reliability of the collected data, all participants were instructed to abstain from alcohol, caffeine, and ergogenic aids on the day of testing and the preceding day.

Anthropometric measurements, Q angle, Landing Error Scoring System (LESS) scores, and countermovement jump (CMJ) scores were recorded for all participants in both the experimental and control groups.

Following the initial assessments, the experimental group participated in an 8-week corrective exercise program designed by a specialist physical therapist in addition to their regular volleyball training (**Table 1**). This study adheres to the CONSORT (Consolidated Standards of Reporting Trials) guidelines for reporting randomized controlled trials. Meanwhile, the control group continued with volleyball training alone. After the 8-week intervention, all measurements were repeated, and comparisons were made between the experimental and control groups. Biological maturation (e.g., peak height velocity) was not assessed, which should be considered when interpreting the findings in this adolescent sample.

Data Collection Tools

Anthropometric measurements, Q angle, Landing Error Scoring System (LESS), and countermovement jump (CMJ) tests were conducted on the female volleyball athletes participating in this study.

Collection of Data

The study was conducted during the in-season period of the 2023–2024 season. The athletes' assessments were carried out in the sports halls of their respective clubs. To minimize potential confounding factors, measurements were not conducted on the day following a match or during the athletes' menstrual cycle to prevent any negative impact on the results.

Anthropometric Measurements: Height and body mass measurements were taken while the athletes were barefoot and wearing shorts and a t-shirt. A stadiometer was used for height measurement, and body mass was measured using a Tanita-brand scale.

For leg length measurements, the athletes were instructed to lie supine on a mat with their ankles in the plantar flexion position. In this position, the distance between the anterior superior iliac spine and the tip of the toe was measured using a sliding caliper and recorded in the My Jump 2 mobile application.

Sitting height was measured while the athletes maintained 90 degrees of knee flexion. Additionally, in a squatting position with the knee flexed at 90 degrees, the distance between the anterior superior iliac spine and the ground was measured using a sliding caliper, with knee angles confirmed by a goniometer.

Q Angle Measurements: Prior to measuring the Q angle, anatomical landmarks were marked on the athletes, including the anterior superior iliac spine, the midpoint of the patella, and the tibial tuberosity. Participants were instructed to stand barefoot with their feet shoulder-width apart, arms relaxed at their sides, and eyes looking straight ahead, and to maintain this position during image capture. Subsequently, photographs were taken using an iPhone 13 Pro camera while the athletes maintained a natural, upright, and motionless standing position [17]. The smartphone camera was mounted on a tripod at a height of approximately 90 cm and at a distance of 3 m in front of the participant, with the lens aligned perpendicular to the frontal plane. The captured images were then transferred to the Kinovea software for Q angle calculation. In Kinovea, the Q angle was calculated by marking the anterior superior iliac spine, the center of the patella, and the tibial tuberosity, and then measuring the angle formed by the line from the ASIS to the patella and the line from the patella to the tibial tuberosity. All images were analyzed by the same evaluator, and anatomical landmarks were identified manually within Kinovea to draw reference lines and calculate the angle. The procedure followed standard clinical measurement principles to ensure consistency across participants.

Landing Error Scoring System (LESS) : For the Landing Error Scoring System (LESS) test, a 30 cm-high box was used. Each athlete performed a drop jump from a distance equal to half

of their height, followed by a maximal vertical jump. The test was repeated three times. The jumps were recorded from both the front and side views using an iPhone 13 Pro camera, set to a 60 fps frame rate with HD video recording. The recorded videos were analyzed using Kinovea software, and slow-motion playback was used to evaluate landing mechanics. The recordings were reviewed multiple times, and scoring was performed according to the standardized LESS criteria by an evaluator experienced in movement analysis to ensure accurate identification of observable landing errors.

The camera lens was positioned at a height of 122 cm from the ground using a tripod and placed 345 cm from the landing area in both the front and side views. No verbal motivation or commands were provided during the test. The LESS has been shown to be a valid and reliable clinical tool for assessing jump-landing mechanics and identifying movement patterns associated with an increased risk of lower extremity injury [18].

Countermovement Jump (CMJ) Test:

Athletes positioned their feet at a self-selected stance on a flat, non-slippery surface and performed a maximal vertical jump from a stationary position without taking a forward step. A rest period of 10 seconds was provided between each attempt. Arm swing was allowed to reflect the athletes' typical volleyball jumping technique and to maximize ecological validity. The jumps were recorded using an iPhone 13 Pro camera set to a 60 fps frame rate with HD video resolution. The recorded videos were analyzed using the My Jump 2 mobile application, and the athletes jump heights were calculated. The My Jump 2 application has demonstrated good validity and reliability for estimating vertical jump height when compared with force-platform measurements in athletic populations [19].

Corrective Exercise Protocol

Prior to the implementation of the corrective exercise program, participants were introduced to all movements and provided with detailed instructions on key technical points (Fig. 1). The corrective exercises administered to the experimental group were performed over an eight-week period, three days per week.

The corrective exercise sessions were typically performed at the beginning of regular volleyball practice and lasted approximately 25–30 minutes. Each session included the eight exercises listed in Table 1 (plank, side-lying hip abduction, squat, side bridge, heel touches, lunge, glute bridge, and single-leg glute bridge), targeting hip-dominant strengthening, trunk and lumbopelvic stabilization, and jump-landing technique. Depending on the exercise, athletes generally performed 2 sets of 8–16 repetitions or 15–40-second isometric holds, with 30–60 seconds of rest between sets, as detailed in Table 1. From week to week, the number of repetitions or the duration of the holds was progressively increased, and mini-bands were introduced in later weeks to further increase the load while maintaining proper technique and pain-free execution.

Elastic resistance during selected exercises was provided using commercially available mini-bands of light to moderate resistance levels. Although the specific brand and exact resistance values were not recorded, resistance was individually adjusted based on each athlete's ability to perform the movements with proper technique and without pain. Resistance progression was achieved by increasing band tension or exercise complexity when participants were able to complete the prescribed repetitions while maintaining correct movement quality. The mini-bands were positioned around the distal thigh or ankle depending on the exercise.

This approach reflects common clinical practice in corrective exercise interventions where resistance is tailored to individual capacity to ensure safe and effective movement execution.

All corrective exercise sessions in the experimental group were supervised by a licensed physical therapist and the team strength and conditioning coach to ensure correct execution and adherence to the program.

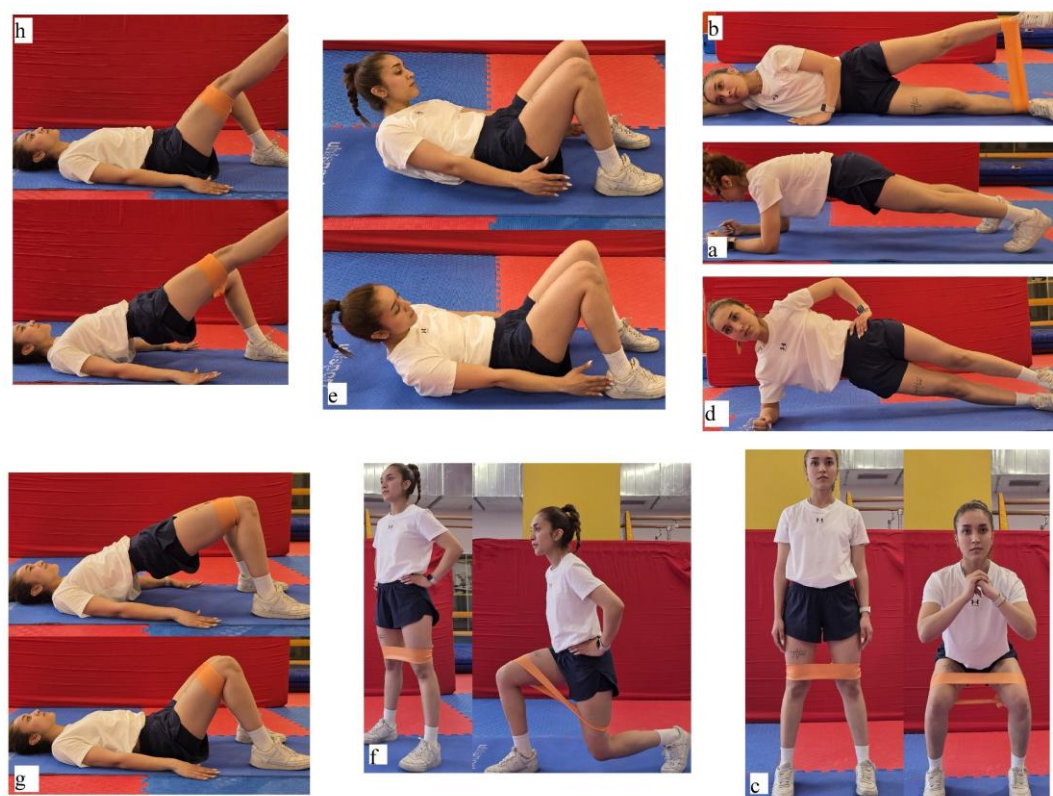


Figure 1. Corrective Exercise Movements

Table 1. Corrective Exercise Program

Exercise	First Week	Second Week	Third Week	Fourth Week	Fifth Week	Sixth Week	Seven Week	Eight Week
a)Plank	2x15sec	2x20sec	2x25sec	2x30sec	2x35sec	2x40sec	2x40sec	2x40sec
b)Side Lying Hip Abuction	2x10	2x15	3x10	315r	2x15 + wb	3x10 + wb	3x12 + wb	3x15 + wb
c)Squat	2x10	2x15	2x12+ wb	2x15 + wb	3x12 + wb	3x15 + wb	3x20 + wb	3x20 + wb
d)Side Bridge	2x8	2x10	2x12	2x15	3x10	3x12	3x15	3x20
e)Heel Touches	2x16	2x20	2x24	2x30	3x16	3x20	3x24	3x30
f)Lunge	2x16	2x20	2x24	3x16	3x20 + wb	3x20 + wb	3x24 + wb	3x30 + wb
g)Glute Bridge	2x15	2x20	3x15	3x20	2x15 + wb	3x12 + wb	3x15 + wb	3x20 + wb
h)Single Leg Glute Bridge	2x8	2x10	2x10	2x15	2x10 + wb	2x12 + wb	3x10 + wb	3x12 + wb

sec: second, wb: with mini band

Type of exercises, loading, intensity, and complexity of the protocol increased gradually, numbers indicate sets×repetitions of each exercise

Statistical Analysis

The IBM SPSS Statistics 25 software was used for data analysis. The Shapiro-Wilk test was conducted to assess the normality of data distribution. A repeated-measures analysis of variance (ANOVA) was performed to evaluate within-group and between-group differences. In addition, independent samples t-tests were used to compare baseline anthropometric and performance variables between the experimental and control groups. Partial eta squared (η^2) values were considered for effect size estimation. The statistical significance level was set at $p < 0.05$.

RESULTS

Table 2. Comparison of the Pre-Test and Post-Test of the Participants

		Pre-Test		Post-Test		Within Subjects	Between Subjects	
		N	Mean±SD	Mean±SD	F	P	P	η^2
Q Angle	Experiment	12	22,80±4,85	20,38±4,47	14,27	,003*	,000*	0.56
	Control	11	23,01±4,60	22,11±4,11	1,36	,270		
LESS	Experiment	12	5,83±1,29	4,41±1,26	18,34	,001*	,000*	0.62
	Control	11	5,29±1,07	5,17±0,99	2,22	,167		
CMJ	Experiment	12	34,18±5,49	34,94±6,24	,812	,387	,000*	0.06
	Control	11	24,73±3,49	24,48±3,08	,207	,659		

* $p < 0,05$, Abbreviations: SD, standard deviation; LESS, landing error scoring system; CMJ, vertical jump.

Table 2 presents the pre-test and post-test results for Q Angle, LESS, and CMJ in both the experimental and control groups. At baseline, the experimental group was significantly taller and heavier than the control group, whereas no significant differences were observed between groups for Q angle, LESS, or vertical jump performance. The repeated measures ANOVA (rmANOVA) analysis revealed a significant Time $\times$ Group interaction for Q Angle ($F(1,11) =$

14.27, $p = .003$, $\eta^2 = .56$) and LESS ($F(1,11) = 18.34$, $p = .001$, $\eta^2 = .62$), indicating notable changes over time in the experimental group.

Further analysis showed that Q Angle significantly decreased in the experimental group compared to the pre-test values. Similarly, LESS scores improved over time, supporting the effectiveness of the applied intervention. However, no significant Time $\times$ Group interaction was found for CMJ ($F(1,11) = 0.812$, $p = .387$, $\eta^2 = .06$), suggesting that the intervention did not lead to a meaningful improvement in vertical jump performance. As a result, no additional post-hoc tests were conducted for this variable.

In the control group, none of the measured variables showed statistically significant changes over time ($p > .05$). This indicates that the observed improvements in Q Angle and LESS scores were likely due to the intervention applied in the experimental group. Meanwhile, the lack of change in CMJ scores suggests that the intervention did not significantly influence this parameter.

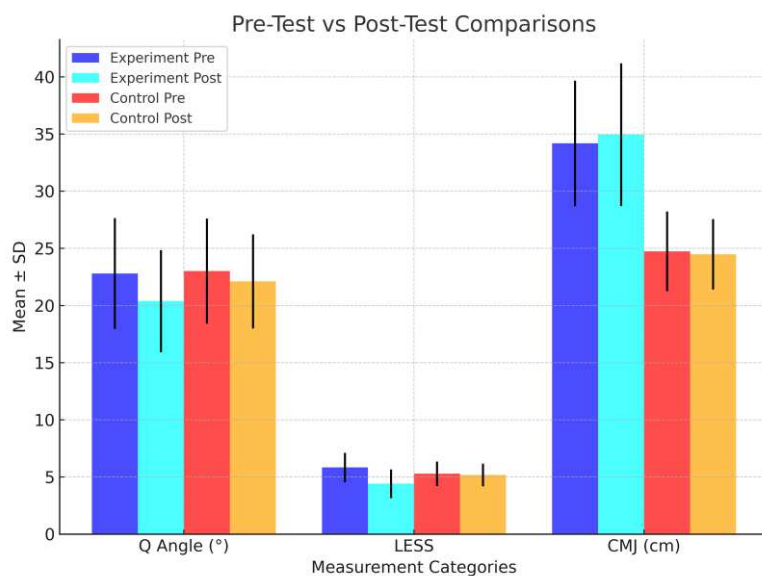


Figure 2. Comparison of scores between groups

DISCUSSION

Athletes are expected to perform at their highest level during the competitive season. To achieve this, they must be physically well-prepared. Injuries occurring during the season can be detrimental to both the athlete and the team. Therefore, minimizing potential risk factors associated with sports injuries is essential for maintaining optimal performance and reducing injury-related setbacks.

This study examined the effects of an eight-week corrective exercise program on Q angle and jump-landing mechanics in female volleyball players. The findings revealed a statistically significant reduction in Q angles and an improvement in LESS scores within the experimental group ($p < 0.05$, $\eta^2 = \text{large effect}$), while no significant changes were observed in the control group. However, no statistically significant improvement was found in countermovement jump (CMJ) performance ($p > 0.05$, $\eta^2 = 0.06$), despite a medium effect size.

Several studies have reported similar reductions in Q angle following corrective exercise interventions. A 12-week theraband-based program and an eight-week exercise protocol in female participants led to significant improvements in Q angles [20,21]. Additionally, a study involving young girls (aged 9–13) demonstrated positive changes in Q angle following an eight-week exercise plan [22]. These findings suggest that corrective exercises targeting the knee and pelvis are effective in modifying Q angle.

In the present study, the experimental group showed an average reduction in Q angle of approximately 2.4° (from 22.8° to 20.4°). Some authors have suggested that Q angles of 20° or higher may be associated with an increased risk of knee problems in female athletes [9]. However, it remains unclear whether small changes of a few degrees are clinically meaningful. Our findings therefore indicate a favorable shift in knee alignment, but the clinical relevance of this magnitude of change should be interpreted with caution until it is linked to prospective injury outcomes.

In contrast, our study did not find a significant improvement in CMJ height. The corrective exercise program in the present study was primarily designed to improve alignment, neuromuscular control, and landing mechanics rather than to provide a high-intensity strength or power stimulus. Therefore, the overall training load and intensity of the corrective exercises may have been insufficient to elicit substantial gains in jump height. In addition, the intervention was implemented during the competitive season, when ongoing volleyball training and match demands may have increased neuromuscular fatigue and limited the potential for improvements in CMJ performance. This result aligns with previous findings by Dallam et al. [23], who reported that corrective exercise interventions had no significant impact on vertical jump performance. A possible explanation is that our study was conducted during the competitive season, potentially limiting the athletes' adaptation to the intervention. Additionally, the intensity of the applied exercises and potential neuromuscular fatigue from in-season training may have influenced the results. Moreover, the absence of high-intensity gluteal strengthening exercises in the corrective exercise protocol may have affected jump performance (**Fig. 2**). Gluteal muscle activation plays a crucial role in stabilizing the pelvis and generating force for vertical jumps, as suggested by Gallego-Izquierdo et al. [24]. Future studies should explore the integration of high-intensity gluteal strengthening exercises into corrective training protocols.

When examining landing mechanics, our findings align with previous studies reporting improvements in LESS scores following corrective exercise interventions. A study on basketball players demonstrated enhanced landing mechanics after an injury prevention program [25]. Similarly, a large-scale study involving 1,104 participants in the United States found that a holistic injury prevention training protocol led to reduced LESS scores, indicating improved landing mechanics [26]. Additionally, a four-week core exercise intervention in young female athletes contributed to better landing mechanics [27]. LESS was chosen

specifically due to its high validity in assessing dynamic knee stability and its widespread use in injury prevention studies.

From a practical standpoint, incorporating corrective exercises targeting the knee, pelvis, and core segments into training programs may contribute to improved body alignment and reduced injury risk in female athletes. Coaches and sports practitioners should consider integrating such interventions alongside strength training regimens to maximize performance benefits.

Conclusion

In conclusion, this study demonstrated that an eight-week corrective exercise program significantly improved Q angle and landing mechanics in female volleyball players. However, no significant improvement was observed in vertical jump performance. This growing interest in corrective exercises is due to their ability to enhance stability, reduce ACL injury risk, and improve neuromuscular coordination. Future studies should explore the long-term effects of such interventions and their role in optimizing athletic performance.

Limitations

This study has some limitations. First, the camera frame rate used for the LESS and CMJ analyses was limited to 60 fps. Higher frame rates (e.g., ≥ 120 fps) may provide more precise temporal resolution and allow a more detailed analysis of rapid joint angle changes during the landing phase. Therefore, small and fast kinematic changes in jump-landing mechanics may not have been fully captured in the present study. Second, biological maturation (e.g., maturity offset) was not assessed. Given that maturation status can influence both movement kinematics and jump performance in adolescent athletes, future studies should control for or report maturation when examining the effects of corrective exercise interventions.

Third, the sample size was relatively small and no a priori power analysis was performed, which may limit the generalizability of the findings and the ability to detect small effects, particularly

for CMJ outcomes. Fourth, although baseline differences in height and body mass between groups were accounted for in the statistical analyses, these anthropometric characteristics may still have influenced the responses to the corrective exercise program. Fifth, playing position and years of volleyball experience were not controlled for or reported, which may have contributed to variability in jump-landing mechanics. Finally, session attendance, perceived exertion, and overall training load during both the corrective exercise sessions and regular volleyball practice were not systematically monitored, so the actual dose of the intervention received by each athlete could not be precisely quantified.

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Authors contributions

B T and BM B were responsible for supervision and investigation of the research; O was responsible for conceptualization; B T and Ö A were responsible for writing of the manuscript; B T were responsible for the processing of the original data; and B T, Ö A , T G and BM B were responsible for Review and editing. All authors read and approved the final manuscript.

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Data accessibility

The data generated and analyzed in this study pertain to young female volleyball players and are not publicly available due to confidentiality restrictions and ethical considerations regarding the participants. However, with the approval of the relevant athletic club and the ethics committee, anonymized data can be obtained upon reasonable request from the corresponding author of the article.

Declarations

Ethics approval and consent to participate

Informed consent and parental assent forms were obtained from participants and their legal guardians for participation in the study. The study was conducted in accordance with the principles of the Declaration of Helsinki (revised in 2013) and approved by the Kocaeli University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Approval No: GOKAEK-2022/21.16).

Trial registration: ClinicalTrials.gov, NCT07578701. Registered on 9 May 2026. Retrospectively registered.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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