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The Effect of Six-Week Specific Injury Prevention Exercises on Performance in Female Volleyball Athletes with Neuromuscular Knee Valgus Defect: Quasi-Experimental Study

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Original Article

Abstract

Introduction: The key skills of volleyball require balance, agility, speed, and power in addition to core stability. Most volleyball injuries occur in the lower extremity during skilled performance. One of the reliable protocols in preventing sport injury and enhancing the performance is the “specific volleyball injury prevention exercise intervention”. In this study, the possible effect of the exercise intervention on core stability, balance, agility, speed, and power in female volleyball players with dynamic knee valgus (DKV) defect was investigated.

Materials and Methods: This quasi-experimental study included 30 female volleyball players. The assessments included double-leg squat (DLS) test, McGill core stability test, Y-Balance Test (YBT), 20-yard speed test, vertical jump test, and agility T-test. The training group participated in six weeks of the “injury prevention exercise intervention” and the control group participated in their usual routine at the same time. Analysis of covariance (ANCOVA) test was employed to analyze data in a significance level of $\alpha = 0.05$.

Results: The findings revealed significant improvement in core stability by 12.6% or 5.39 seconds ($P = 0.01$), speed by 1.64% or 0.07 seconds ($P = 0.03$), power by 11.84% or 3.6 cm ($P = 0.01$), and agility by 3.97% from 11.32 to 10.87 seconds, ($P = 0.01$) in the training group after 6 weeks of exercise intervention in comparison to control group. While the 3.68% increase in the balance record (76.3 cm) in the training group was not statistically significant ($P = 0.11$). The control group did not show significant change ($P = 0.05$). All the parameters improved significantly post-intervention in training group compared to pre-test measures ($P \leq 0.02$).

Conclusion: Some athletes believed that valid injury prevention exercise interventions had negative impact on performance and they did not use these interventions. However, the findings of the study showed that six weeks of exercise intervention significantly improved the core stability, speed, agility, and power of female volleyball athletes with DKV. Accordingly, performing this training intervention is recommended for female volleyball athletes with DKV defects and their coaches.

Keywords: Knee injury; Athletic performance; Volleyball; Neuromuscular exercise

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Introduction

Volleyball is a sport based on complex skills and ideal physical performance that requires quick change of direction and continual jumps (1, 2). Ability of performing high-level skills is a determining factor in volleyball match (3). Core stability plays an important role in movement, posture, flexibility, muscle endurance and stabilization, transmission of load and force to all body during performing volleyball abilities, and accordingly reduced risk of injury (3).

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Besides, balance affects stability of performing skills, technique, jump, and landing and it is an effective factor in performance (4). Dynamic balance leads to appropriate mechanics during landing for spiking and blocking in volleyball (5), and poor balance puts athletes in increasing risk of anterior cruciate ligament (ACL) injury (5). Effective factors in improving techniques and enhancing volleyball players' performance include ability of running speed, change of direction, and jumping (6). It is suggested that agility is combined with activities like zig-zag run, shuttle run, side step, and squat (7), because agility and speed are very important during receiving and blocking on the net (6). During volleyball match, 80% of points happen on the net; therefore, having taller players with higher jumping ability and better performance on the net is an advantage (8), so that increasing lower extremity explosive power can increase the likelihood of success of the team (8). In addition, there is a strong and positive correlation between success of spikes, defend, and height of vertical jump, and an excellent linear correlation (77%) between core stability and speed of spike (9). Overall, volleyball players' performance requires core stability, balance, agility, speed, and power (10).

Lower extremity is the most common segment, knee joint (10% to 25% of total injury) is the most common joint, and ACL is the most common injured structure in sports (11). In female volleyball players, 50% of lower extremity injuries occur in knee joint (12). Most of the ACL injuries (70%) occur in non-contact mechanism due to poor neuromuscular control (13). Most of the sport maneuvers such as running, jumping, and cutting movements for maintaining balance and sufficient performance require enough neuromuscular control (14). Better performance in volleyball task requires enhancement of neuromuscular control (15). Poor neuromuscular control increases load on lower extremity joints during activities and accordingly increases the risk of non-contact injury (12). More prevalence of ACL injury among female (vs. male) is due to neuromuscular difference (16). Hewett and Johnson introduced four neuromuscular defects as more important ACL injury mechanism (17). Analyzing female and male students aged 18-25 and active in basketball, volleyball, soccer, tennis, and badminton in a study showed that prevalence of ligament dominance in women (81%) was two times more than in men (40%) (12). Quadriceps dominance leads to landing with knee extended (5), and trunk dominance occurs due to lateral flexion during landing and it leads to increased displacement of center of gravity to the outside of knee joint and increased dynamic knee valgus (DKV) (18, 19). In athletes with ligament dominance, DKV occurs when muscles are not able to absorb ground reaction force and most forces are loaded into knee ligaments during activities like jump landing (12). Increasing DKV around 5º causes forces on knee ligaments to increase six times higher and accordingly leads to ACL rupture (18).

The most common injury in prevention protocols is included Prevent Injury and Enhance Performance (PEP), comprehensive FIFA 11+ exercise (FIFA 11+), and Sportsmetrics protocol (5). Although PEP protocol is designed for various sports, the FIFA 11+ is designed for soccer and specific injury prevention exercises (Sportsmetrics) are designed for knee injuries in female volleyball players (20). PEP exercise with the same logic but, Sportsmetrics protocol and specific injury prevention exercise were designed for soccer, volleyball, and basketball separately. Specific injury prevention exercise is more effective in enhancing landing technique and performance compared to static and dynamic warm-up (11). In previous studies, the specific soccer injury prevention exercise was conducted on risk of injury in soccer players, for example, performing six-week specific injury prevention exercises, in addition to modification of knee valgus angle around 51%, led to significant improvement in core stability (8%) and balance (11%) (21). Although a combination of core stability, neuromuscular control, strength, coordination, and proprioception trainings resulted in 77%-90% decrease in knee injury (22), performing neuromuscular trainings led to 41% decrease of injury in players aged 14-19 years (23). The comprehensive neuromuscular training which includes plyometric, core stability, balance, strength, speed, and agility in addition to preventing injury can be effective in enhancing performance (24), and performing interventional trainings in female soccer athletes leads to lower extremity alignment improvement (25). On the one hand, although this comprehensive training was successful in injury prevention, some coaches and athletes believed that these trainings had negative effect on performance and avoided performing these trainings (12, 24). Necessity of analyzing this interventional exercise in female athletes with neuromuscular defects is recommended (12). Accordingly, the prevalence of knee injuries is 4-6 times more common in female athletes than male athletes and this difference is more prominent in volleyball, basketball, and soccer. In present study, the effect of specific volleyball injury prevention exercise was investigated on performance factors of female volleyball players with DKV as the most common neuromuscular defect, and also volleyball specific performance, core stability, and dynamic balance were reported.

Materials and Methods

This semi-experimental study was conducted on female volleyball athletes in league 2 with knee valgus defect. After getting ethical code, the researcher presented the research introduction form to the Isfahan volleyball committee, Isfahan, Iran, and explained the aims of the research process to the coaches and athletes. The participant volunteers were referred to the researcher through the publication of a call by Isfahan volleyball committee in summer 1400. After presenting the consent form and demographic form, the personal information and medical background form of the athletes were collected by questionnaires and interviews in fall 2021. To evaluate the valgus defect, a double-leg squat (DLS) test was used. Further, inclusion criteria were age of 18-25 years (considering the age of starting professional volleyball in adulthood), participating in volleyball teams for at least three years, three sessions a week, not participating in injury prevention protocols, having no history of lower extremity injuries, no ankle and knee injury in the past year, and no history of serious defects or injury in the knee joint, observing health problems such as using mask and transfusing two doses of coronavirus disease 2019 (COVID-19) vaccine before starting the research. Moreover, in terms of COVID-19 coloring about country situation, the city situation was blue. At first, initial screening was done using DLS test. Squat analysis was performed using Kinovea software (Kinovea-0.9.5-x64, Freeware) only if athlete' score was higher than 3 in three out of five squats. Then, the exact amount of valgus was measured; the minimum dynamic valgus angle of 12 degrees was considered.

The participants were excluded because of being absent for more than two sessions, history of injury within last six weeks, having COVID-19 symptoms (positive test required), and not willing to continue participation. To evaluate core stability, McGill's test, Y-Balance Test (YBT), Sargent's power test, 20-yard speed test, and agility T-test were used. Subjects were selected randomly and systematically. The athletes included 30 players with valgus defect who were randomly divided into the training group (n = 15) and the control group (n = 15).

In this study, first, to determine the sample size, 64 athletes with DKV were selected from among 112 female volleyball players. Then, 10 of them were randomly selected by draw to determine sample size and their knee valgus angle was analyzed in pilot study (in formula, 10 was placed instead of N). The sample size was calculated with a confidence level of 95%, measurement error of 10%, and probability of falling of 0.25 (because of COVID-19 pandemic). 15 athletes were randomly selected in each group from among 64 female volleyball players in league 2 of Isfahan.

In the assessment session, the assessments (Table 1) were performed after familiarizing athletes with how perform the tests and 10-minute warm-up. Then training group participated in specific injury prevention exercise for six weeks (18 sessions) three sessions per week around 60-90 minutes in even days and control group performed their routine exercise with the same time as training group. After completing the protocol, post-test assessments were performed in both groups in the pre-test situation.

DLS

To evaluate knee valgus defect, the athlete opened her feet hip-width apart, so that the toes were placed straight in line with knees; her arms were opened shoulder-width apart placed overhead in extension position. Then, a squat was performed similar to the pattern of sitting in a chair, by bending the knees at a comfortable angle of flexion (about 90°), and DLS was repeated five times without interruption. The middle point of patella was checked from the anterior view. Patellae crossing over the internal part of the thumb indicated valgus neuromuscular defect (Figure 1A). The validity and reliability of this test are 73% and 78%, respectively (26).

McGill Core Stability

McGill's assessment includes four tests (flexor, extensor, and left and right plank) with five-minute rest intervals (27) (Figure 1B). Each test was repeated three times with the best record as the athlete's score.

Flexor: Seated on the mat, trunk angle with the ground surface was 60° (leaning back on a box), with the hip and knee at 90° flexion, their legs fixed by a partner, and their arms crosswise on the chest. When the athlete was ready, the box moved back 10 cm and they were requested to maintain the position (27). The test intraclass correlation coefficient (ICC) was 0.97 (28).

Extensor: In a prone position on the examination table, anterior superior iliac spine (ASIS) was placed on the edge of the table and the trunk was hung. Then, the athlete placed her hands on the chair while her legs were fixed by the partner. The athlete was requested to take the hands from the chair and keep the trunk parallel to the surface of the table as long as possible; the duration was the athlete's record (27). The test ICC was 0.97 (28).

Lateral Plank: Laid on lateral side, the elbow was right underneath the shoulder bearing the weight on the forearm. The athlete was asked to raise her trunk and pelvis, so that the legs, trunk, and head were aligned. Maintaining duration was recorded (27). The test ICC was 0.99 (28).

Table 1. Injury prevention protocol for volleyball

Week	Training	Repeats	Week	Training	Repeats
First (1-3)	1. Volleyball shuttle 2. Partner push-off, hold 5 seconds 3. Sprint, backpedal 4. Ladder: high knees 5. Wheel drill-listen to instructor 6. Suicides-volleyball court × 2 7. Dot drill: double-leg jumps	1. 3 reps 2. 5 reps 3. 5 reps 4. 4-6 reps 5. 30 seconds, 2 reps 6. 2 reps 7. 5 reps × 3	Second (4-6)	1. Volleyball tip drill 2. Acceleration sprint with band, hold 5 seconds 3. Sprint, backpedal 4. Ladder: up-up/back-back 5. Sprint/stop feet/listen to instructor 6. Suicides/forward/backward, volleyball court × 2 7. Dot drill: add spilt-leg jump	1. 2 reps 2. 5 reps 3. 7 reps 4. 4-6 reps 5. 30 seconds, 2 reps 6. 2 reps 7. 5 reps × 3 (session 5-6)
Third (7-9)	1. Square drill 2. Mountain climbers 3. Quarter-eagle into sprints: listen to instructor 4. Ladder: outside foot in 5. Sprint/quick feet/listen to instructor 6. Suicides/lateral shuffle, volleyball court × 2 7. Dot drill: add 180º split leg jump 8. Dot drill: add spilt-leg jump	1. 3 reps 2. 6 reps 3. 6 reps 4. 4-6 reps 5. 30 seconds, 2 reps 6. 2 reps 7. 5 reps × 3 8. 5 reps × 3 (session 7)	Fourth (10-12)	1. Nebraska drill 2. Partner push-offs, hold 5 seconds 3. Forward sprints with ground touches 4. Ladder: in-in/out-out 5. Reaction drill/watch instructor point 6. Jingle-jangle 7. Dot drill: add single-leg hops	1. 4 reps 2. 6 reps 3. 5-7 reps 4. 4-6 reps 5. 45 seconds, 2 reps 6. 10-yard, 4-6 reps 7. 5 reps × 3
Fifth (13-15)	1. Illinois drill 2. Shuffle pass with partner 3.Acceleration sprints with band 4. Sprint-180º-backpedal 5. Ladder: scissors 6. Reaction mirror drill/partner pressing 7. Jingle-jangle	1. 5 reps 2. 1 set 3. 15 seconds, 5 reps 4. 7 reps 5. 4-6 reps 6. 45 seconds, 1 rep 7. 20-yard, 4-6 reps	Sixth (16-18)	1. Agility test:5-10-5 2. Shuffle set with partner 3. Mountain climbers 4. Sprint-360º-sprint 5. Ladder icy shuffle 6. Reaction instructor pointing/quick feet + up/down with push up 7. Power rounds relay	1. 4 reps 2. 1 set 3. 5-7 reps 4. 5-7 reps 5. 4-6 reps 6. 45 seconds, 2 reps 7. 1 set
Strength training	1. Squats with resistance band 2. Power lunges (pulsating) 3. Single-leg heel raise 4. Supine hamstring bridge, single leg 5. Seated scapular retraction 6. Seated latissimus pull with resistance band	30 seconds all exercise (sessions 1-6) 45 seconds all exercise (sessions 7-12)	Strength training	7. Seated scapular protraction with resistance band 8. Abdominals of choice 9. Hip flexor resistance band kicking with partner 10. Steamboats (hip flexor) 11. Hip abductor resistance band kicking with partner 12. Lateral walking with resistance band	60 seconds all exercise (sessions 13-18)
Warm-up: 20 to 30 seconds of muscle stretching	1. Toe walk 2. Heel walk 3. Straight leg march 4. Leg cradle 5. Hip rotator walk 6. High knee skip 7. High knees 8. Glut kicks 9. Stride out 10. All-out sprint 20 to 30 seconds of walking	-	Cool-down: 20 to 30 seconds of muscle stretching	1. Hamstring 2. Iliotibial band 3. Quadriceps 4. Hip flexor 5. Hip flexor 6. Soleus 7. Deltoid 8. Triceps, latissimus dors 9. Pectoralis, biceps 10.	-

Figure 1. A) Double-leg squat (DLS) test; B) McGill test

YBT

The athlete performed three attempts in all three directions: anterior, posteromedial, and posterolateral, and rested for 30 seconds between each test. The athlete should keep her foot in the maximum reaching distance for 2 seconds for evaluating the reaching distance in each direction and the athlete's score was recorded (5). Leg length was used to normalize the reaching distance. The validity and reliability of the test were 0.91 and 0.99, respectively (5).

20-yard Speed Test

The athletes were placed behind the service line at the starting point and, when hearing start, they ran at maximum speed to cross the second service line (the length of the volleyball court). The duration was recorded. The validity of the test was 0.90 (20).

Agility T-Test

Four cones, placed T-shaped, were assigned like this: the first in the middle of the service line, the second in the middle of the line under the net, and the third and fourth in the right and left corners of the line under the net. The athlete stood behind the first cone and sprinted toward the other cones one-to-one. After touching the fourth cone, they returned to the second cone and after touching it, they ran on maximum speed toward the starting point. The duration was recorded. The validity of test was 0.90 (20).

Sargent Power Test

This test evaluates the difference between the athlete's height with the hand extended upwards and the highest height touched by the hand during a vertical jump (29, 30). The test was taken three times and between each attempt, 45 seconds of rest was included. The best record was athlete's score (8). The reliability of the test was 0.94 (31).

Specific Injury Prevention Protocol

Specific knee injury prevention protocol in female volleyball players with neuromuscular defects was introduced for first time in 2011 by Noyes et al. (31), then was revised in 2015 (22), and in 2019. In the present study, the last version of volleyball specific injury prevention protocol (Sportsmetrics) was used (Table 1). This protocol has been designed to prevent knee injuries, especially for ACL, and improve performance in female volleyball players; the protocol includes exercises such as plyometrics, agility, endurance, power, strength trainings, and cool-down and warm-up (22, 31, 32).

Data analysis

The data were analyzed using SPSS software (version 25, IBM Corporation, Armonk, NY, USA). The normality of data distribution was investigated by Shapiro-Wilk test and homogeneity of variance was determined using Levene's test. Analysis of covariance (ANCOVA) test was used to examine the changes between groups and to evaluate the effect of training at a significance level of 0.05.

Results

In the present study, all athletes completed all stages of study and the rate of loss was zero (Figure 2).

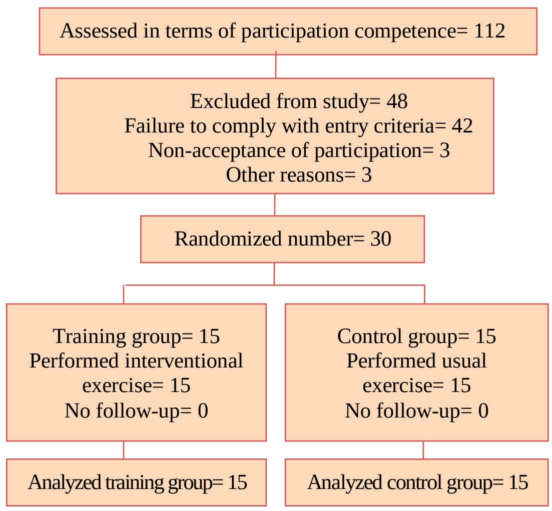

Figure 2. Study process and athletes' loss in different stages

Table 2. Demographic characteristics of the athletes

Group	Age (year)	History (year)	BMI (kg/m2)	Height (cm)	Weight (kg)
Training	20.40 ± 1.90	5.40 ± 1.90	20.69 ± 1.62	166.46 ± 6.34	57.46 ± 6.73
Control	21.30 ± 2.50	5.50 ± 1.70	20.98 ± 1.46	169.86 ± 6.35	60.80 ± 7.89
P value	0.29	0.84	0.22	0.15	0.61

Data are presented as mean ± standard deviation (SD)
BMI: Body mass index

Considering data being normal (Shapiro-Wilk test) and homogeneity of variance (Levene's test), to evaluate between-group changes and the effect of training, ANCOVA test was used. The demographic characteristics of groups are shown in table 2.

After performing six-week volleyball specific injury prevention exercise in training group, the average of core stability was increased by 12.6% (P = 0.01). Besides, improvement of balance was not statically significant (P = 0.11). Speed was decreased by 1.64% and significant improvement (P = 0.03). The average of agility also was decreased by 3.97% and significant improvement (P = 0.01). In addition, power was increased by 11.48% and significant improvement (P = 0.01). No significant changes during study period were found in control group (P ≥ 0.05) and all the studied indices in training group showed significant improvement compared to pre-test (P ≤ 0.02) (Table 3).

Discussion

Core stability and dynamic balance are bases of performance, and power, speed, and agility are the key factors of performing volleyball skills. In this study, the effect of volleyball specific injury prevention exercise on core stability, dynamic balance, and performance (power, speed, and agility) was investigated in female volleyball players with the most common neuromuscular defect related to lower extremity injuries, especially knee injury (DKV). The result showed that six weeks of interventional exercise could improve core stability and performance.

Enhancing core stability in sports is necessary for body stabilization and force transfer to extremities (33). Furthermore, assessing core stability is necessary to predict risk of injury and assess performance and it should be added to young player's screening assessments (33). Core stability is a reflector of trunk control and its movement on pelvic and leg which is able to transfer the force to the extremity correctly and acts like synchronic and harmonic human movement system chain. Core stability is like a dynamic control which can be effective in force production, transfer, control, and moving in the distal part of chain movement (33, 34). Core stability weakness leads to weakness in dynamic control of lower extremity during movement and sports maneuver with high speed which increases risk of lower extremity injuries (34). Performing six weeks (18 sessions) of core stability exercises seems to increase core muscle strength significantly in volleyball players (3). Moreover, performing neuromuscular exercises leads to improvement in core stability and hip and pelvic muscle strength of athletes with ACL reconstruction in soccer, futsal, basketball, handball, and volleyball (19), and a combination of neuromuscular exercises, core stability exercises, and plyometric exercises can decrease risk of lower extremity injury (34). Core stability muscles start to move before lower extremity muscles during movement, so that the central nervous system (CNS) makes a stable base for lower extremity movements by performing the transverse abdominal muscle and the multifidus muscle (35). Therefore, core stability is effective on body's ability of maintaining or resuming balance during activity. Participating in neuromuscular protocols which include core stability exercises can decrease the risk of ACL injury around 72% in collegiate athletes (35). In present study, neuromuscular exercise was used which included core stability exercises and a part of core stability enhancement can be due to performing this training.

Table 3. The results of analysis of covariance (ANCOVA)

Variable	Training group			Control group			Covariance		
	Pre-test (mean ± SD)	Post-test (mean ± SD)	P value	Pre-test (mean ± SD)	Post-test (mean ± SD)	P value	Eta	P value	F
Core stability (second)	42.75 ± 3.48	48.14 ± 3.34	0.98	43.89 ± 4.81	43.87 ± 5.10	0.01	0.51	0.01	26.69
Balance (cm)	98.17 ± 7.53	101.93 ± 6.31	0.35	99.16 ± 6.66	100.26 ± 5.21	0.01	0.09	0.11	2.76
Speed (second)	4.25 ± 0.27	4.18 ± 0.27	0.25	4.18 ± 0.25	4.23 ± 0.29	0.02	0.17	0.03	5.39
Agility (second)	11.32 ± 0.77	10.87 ± 0.90	0.69	11.42 ± 0.61	11.46 ± 0.58	0.01	0.40	0.01	17.63
Power (cm)	30.40 ± 3.56	34.00 ± 3.85	0.72	30.86 ± 4.92	31.06 ± 4.47	0.01	0.36	0.01	14.42

SD: Standard deviation

It seems that the athletes with core stability weakness due to changing trunk position and the force direction to lower extremity are at the risk of knee injuries (35).

Performing 4-6 weeks of balance exercises leads to enhancement of dynamic balance and performance in basketball, soccer, and cricket significantly (4). However, performing a nine-week program showed no significant improvement in dynamic balance of volleyball players (36). A study was conducted on 19 professional volleyball players which showed that performing interventional trainings did not result in a significant improvement in dynamic balance (37). However, it seems that a combination of plyometric exercise and core stability exercise can improve dynamic balance (38), and Sportsmetrics also includes both of these factors, but performing this protocol did not have a significant effect on dynamic Y-balance in amateur and collegiate rower athletes (5). In this study, performing six weeks of volleyball specific injury prevention exercises which is a Sportsmetrics protocol did not result in a significant improvement in dynamic balance. Perhaps the reason for this finding is the short duration of exercise in the present study. Volleyball specific injury prevention exercises have less balance factors than specific protocols for soccer or basketball (31), and based on history of studies, performing eight weeks of reactive neuromuscular training (RNT) resulted in a significant enhancement in dynamic balance of female athletes with valgus defect (39). Therefore, it is suggested that progressive balance exercises are designed and added for this factor in volleyball specific injury prevention protocol like other performance factors (power, speed, and agility).

Ability of performing quick stop and a quick restart movement during concentrating on competitor or ball can affect athlete's performance (35). This ability includes understanding and decision (cognitive factor), muscle strength, quick change of direction (kinetic factor), and also extremity movements (technique factor) (35). Although previously agility was expressive of advanced schedule quick change, nowadays the new agility assessments include both of factors such as cognitive factor (prediction and recognition of pattern) and kinetic factor (quick change of direction), and both of factors are effective in performing agility (33). The relation between agility time and movement time was decreased by increasing distance (33). Although assessing agility is associated with sprint, sprint with change of direction (agility) has substantial difference with direct speed (sprint) (35), so that a study showed that correlation of speed and agility was highly low in professional athletes (35). Accordingly, it is suggested that specific assessments in agility test and speed test are used (35). Based on history of study, the comprehensive FIFA 11+ warm-up program seems to enhance Illinois agility and power in male volleyball players (40). Further, specific injury prevention exercise could improve agility by 12% in male soccer players (41).

Vertical jump is under the effect of physiological and biomechanical parameters and the size of jumping depends on various factors such as ability of generating moment and external forces (8). As regards, explosion force is expressive of maximum force in minimum time but is one of the key factors of volleyball performance (8). Some researchers believe that the most important difference between female professional and semi-professional volleyball players is because of more explosion force or, on the other words, ability of producing force in movements of acceleration and explosion (42). Because of direct relationship between force and acceleration, increasing muscle strength can lead to force production increase in muscles and as a result, is able to improve performance in acceleration and explosion movements (43). There is a significant correlation between explosion force and muscle strength, so that increasing muscle strength leads to more force production against static and dynamic resistance in female volleyball players (8). In present study, in each session, 12 strength exercises (Table 1) were performed and it seems that the considerable part of power improvement is because of performing these exercises. One of the essential approaches to enhance the performance (power, agility, and speed) is volleyball specific injury prevention exercise components, because in each session, exercises related to power, agility, and speed components were performed and had a progressive process, so that type and number of exercises, intensity, or loads of exercises were changed. For example, in the first week of exercise, double-leg dot drill and high knee ladder for power, partner push-offs hold 5 seconds and sprint-backpedal for speed, and volleyball shuttle for agility were performed, and every week, there was a progressive process, and in the six weeks, exercises were changed to skiing ladder and powerful rebound for power, mountain climbers and sprint-360º-sprint backpedal for speed, ans agility test: 5-10-5 and shuffle set with partner for agility.

Limitations

In this study, the short-term effect of volleyball specific injury prevention exercise on performance was investigated and its long-term effect on injury rate was not investigated. Besides, athletes had valgus defect and its effect on other three defects (trunk dominance, leg dominance, and quadriceps dominance) was not assessed.

Recommendations

Although present protocol is effective in preventing injury, its effect on performance was positive in athletes with neuromuscular defect. Thus, performing this exercise is suggested to female volleyball athletes with valgus defect, and it is recommended that other researchers analyze the effect of these exercises on other neuromuscular defects (trunk dominance, leg dominance, and quadriceps dominance) in the long term. Besides, determining the effect of this interventional exercise on permanence can be valuable for determining when to return to exercise and at what level athlete should start her activities and trainings, especially when athlete is forced to keep away from trainings because of physical injuries.

Conclusion

The result of present study showed that performing volleyball specific injury prevention exercise in female athletes with the most common neuromuscular defect could improve core stability and performance (power, agility, and speed). On the one hand, core stability is one of the most important bases of performance and also power, agility, and speed are key factors of performing tasks successfully in volleyball. On the other hand, the athletes with neuromuscular defects are more at risk of non-contact lower extremity injuries. Therefore, it is suggested that female volleyball players with valgus defect and their coaches use volleyball specific injury prevention protocol, because these exercises not only do not lead to performance dysfunction, but also improve performance.

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Authors' Contribution

Study design and ideation: Hemn Mohammadi, Masoumeh Khosravani
Getting finical resources for the study: Hemn Mohammadi
Data collection: Masoumeh Khosravani
Analysis and interpretation of the results: Hemn Mohammadi
Specialized statistics services: Hemn Mohammadi
Manuscript preparation: Hemn Mohammadi, Masoumeh Khosravani
Specialized scientific evaluation of the manuscript: Hemn Mohammadi, Masoumeh Khosravani
Confirming the final manuscript to be submitted to the journal website: Hemn Mohammadi, Masoumeh Khosravani
Maintaining the integrity of the study process from the beginning to the publication and responding to the referees' comments: Hemn Mohammadi, Masoumeh Khosravani

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Conflict of Interest

The authors have no conflict of interest. Dr. Hemn Mohammadi is the assistant professor of corrective exercise and sports injury at University of Kurdistan, Sanandaj, Iran. Masumeh Khosravani has been studying at University of Kurdistan since 2020 as MSc student in corrective exercise and sports injury.

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