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The effect of sports-metrics volleyball training on the landing error scoring system in female volleyball players

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Abstract

Background: Excessive repetitions of the landing and jumping task are a key risk factor for lower extremity injury (specially ACL) in female volleyball players.

Aim: this study investigates the effect of Sports-Metrics Volleyball Training (SMVT) on landing technique in female volleyball players.

Materials and Methods: The participants of this study were 25 female young volleyball players and randomly divided into training (TG, n=13) and control groups (CG, n=12). The TG performed SMVT for 18 sessions, and the CG performed their regular training. Landing error scoring system (LESS) test were used for assessing landing errors. SPSS (version 25) was used to analyze the statistical data (P<0.05).

Results: The results of the data analysis showed a significant improvement (P=0.01) in LESS in TG (from 8.62 to 5.54), but no significant changes in CG the LESS (P=0.62, from 8.00 to 8.23). Eighteen sessions SMVT reduced the landing error by 35.73% in the TG.

Conclusion: Base on previous research the SMVT reduces lower extremity injuries and the results of this study showed that SMVT significant improvement the landing technique. Therefore, performing SMVT is recommended for female volleyball players because it is effective in both preventing injuries and improving landing technique.

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1. Introduction

Volleyball is a popular team sport that includes short-term explosive activities such as services, receiving passes, spikes, short spins, jumping, and high-speed, reversible movements [1]. In volleyball, successful performance depends on combination of proper implementation of skills, techniques, tactics and anthropometric, physiological, socio-psychological parameters [2]. The performance of a volleyball player is directly affected by the power generation capacity. Power is a combination of maximum strength and speed, and maximum power is obtained by the optimal relationship between these two variables [3]. Land-jumping task is an explosive sports activity that requires improvement power generation capacity [3]. In land-jumping task the knee segment has the most loading in lower limb human movement system, so that in jumping task 49% of loading in the knee joint, 28% of the hip joint, and 23% of the ankle joint will be applied [3].

Human movement system is a chain of motions, and injury to any human movement system segments affects its distal and proximal segments. In volleyball, the most common segments of injury is the lower extremity, because 77.8% injuries in the lower extremity, 18.5% in the upper extremity, and 3.7% in the trunk are located. The most common site of the injuries are ankle joints (51.9%) and knee joints (22.2%). Furthermore, the most common types of injury are sprain (55.6%) and strain (18.5%). The most common positions of injuries respectively included spiker position (55.6%), setter position (25.9%), and Libero position (18.5%).

In volleyball, jump-landing involves loading on the knee in three motion planes during training and competitions [4]. Knee injuries and reinjures are common in female volleyball players with history of anterior cruciate ligament (ACL) injury [5]. ACL injury risk factors consists environmental, anatomical, and biomechanical. Environmental risk factors are related to the shoes and sport surfaces. Anatomical risk factors include lower extremity abnormalities such as ACL size, joint laxity, and pelvic position. Biomechanical risk factors depend on neuromuscular control and joint stability. All of these risk factors lead to high stress and strain in the ligament.

During training and competitions, if the stretching on the ACL is greater than the level, it can withstand, the ACL will be ruptured [6]. The ACL injuries occur in 70% of cases with a non-contacts mechanism. The ACL injury, among female volleyball players, is 2 to 10 times higher than male players [5].

More than 80,000 ACL ligament ruptures are reported annually in the United States [6]. In 80% of the cases, ACL injury requires surgery, and a range of 60,000 to 300,000 reconstructions is done each year. 50% to 77% of cases return to the same level of activity 12 months after surgery; however, it is important to note that an alarming number of athletes (9.6% to 41%) have ACL rupture again [7]. Currently, each ACL surgery costs $ 38,000, and it takes about a year to healing [8]. The rate of return to play after ACL surgery and previous level of performance is lower among women than male athletes [9]. ACL injury can be debilitating and costly and requires a long course of exercise therapy. In addition, it is associated with an increased risk of developing osteoarthritis of the knee joint. Lower extremity movements are associated with ACL injury, and jump-landing tests are used to identify

lower extremity (specially ACL) risk of injury. The lower extremity movements include increased knee valgus, knee abduction angle, greater reaction force, shorter standing time, less tibialis anterior muscle activity, and increased external extensor muscle activity. When combination with valgus and knee flexion, the pelvic joint undergoes internal adaptation and rotation, the ACL becomes lengthening [10].

Jump-landing task is a key risk factor, which increasing knee and ankle joints sprain in the athletes. Jump-landing task is usually assessed in order to identification athletes which predisposed to lower extremity injuries; Because, this task is an activity that involves sudden stopping, decelerating and accelerating. In sports such as basketball, volleyball, handball and soccer, which require a sudden stopping or change direction, injuries in the landing phase are especially greater than jumping phase. Athletes who land with poor posture are more at the risk of lower extremity injuries such as fractures, knee pain, ACL injury, and ankle sprains [11]. Lower extremity injuries are most common in short-term physical activity, and approximately 20% of injuries in competitions and 37% of injuries in training occurred whit non-contact mechanism. Also athletes with poor abduction and external hip rotation are more likely to have lower extremity injuries during the season [12].

The main muscles responsible in controlling the dynamic knee valgus consist of Gluteus medius and maximus, and Tensor fasciae latae, as abductor muscles have an important role in gait and landing mechanics. Lack of sufficient strength in these muscles result in increased knee movements in the frontal plane, especially knee abduction, which makes the athlete predisposed to ACL injury [13]. In addition, hip external rotator muscles are responsible for its protection from excessive internal rotation on the transverse plane in sports tasks [13]. At 0 to 30 degrees of knee flexion, quadriceps contraction creates a large shear force in the upper anterior part that increases ACL sprain [14]. Investigation of knee injury and its relationship with ACL injury are essential in injury prevention studies, especially among female volleyball athletes.

It seems that improvement neuromuscular weaknesses could prevention injuries and improve performance. Therefore, in this study we decided to use a specialized volleyball neuromuscular training warm-ups program which is called Sports-Metrics Volleyball Training (SMVT) [15]. SMVT can compensate neuromuscular weakness, and consist of strength, endurance, balance, core stability, speed and agility component [16]. SMVT is one of the success ACL injury prevention programs which introduced by the American Academy of Pediatrics (pediatric orthopedic surgeons who work with schools and sports organizations) and developed by Dr. Frank Noise, the Sports Rescue Team, physiotherapists, and researchers about 20 years ago [17].

The results of previous study showed that SMVT can prevention ACL injury in volleyball players [15]. But the effect of this protocol on correction landing technique in female athletes has not been studied. Therefore, in this study, the effect of SMVT on LESS in healthy female volleyball players was studied.

2. Materials and Methods

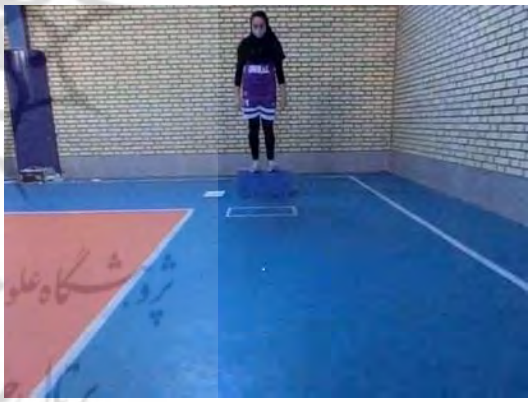
The design of this study was a randomized

controlled trial with pre- and post-tests in training group (TG) and control group (CG). The subjects of this study included 25 female young volleyball players and randomly divided into TG (n=13, age=15.92±1.18, height=1.67±6.2, weight=57.15±7.87, and BMI=20.37±3.18) and CG (n=12, age=17.75±2.63, height=1.67±4.8, weight=58.25±7.41, and BMI=21.18±2.74). The subjects in the TG performed about 35-40 min SMVT for 3 sessions per week in a period of 6 weeks. The CG does regular volleyball exercises during these 6 weeks. The number of statistical samples was determined using past studies and research. All of the subjects completed a personal information questionnaire and injury registration form before the test. Before to performing the test on the subjects, individuals with one of the following conditions in the course of the last 12 months were excluded from the study:

- History of ACL injury,
- History of surgery in the trunk and lower extremities,
- History of serious lower extremity injuries,
- Pain in the lower extremities.

2.1. LESS test

To evaluate subjects' jump-landing technique, LESS test (ICC=0.82-0.99) was used. The test was performed by the athlete jumping forward from a 30 cm high box and landing in front of the platform at distance that placed at half of participant's height (Figure 1). After contact whit surface, she would immediately perform a maximum vertical jump. During the test, no instruction feedback was given to the athlete. Each subject performed three jump-landings and the most correct jump was selected. If the person had not reached the specified horizontal distance, this trail would have been deleted. Two digital video cameras (model EXILIM EX-ZR1000; Casio, Corporation of Japan) whit 240 frame in a second, were placed 345 cm in front of (Figure 2) and to the side of (Figure 3) the participants to record frontal and sagittal images. Then by examining the recorded videos, both lower extremities were analyzed in Kinova software according to the 17 items and the final scores of the subjects was calculated**.** LESS scores were divided into 3 categories: a score less than 4 was excellent, a score of 4 to 6 was average, and a score of more than 6 was weak indicating more errors [10]. The final score for each landing-jump was calculated from the sum of the scores of all items (0-17), and the higher scores indicated more landing technique errors [10].



Figuer 1. The subject stands on the platform and jumps down into landing frame (sagittal view)

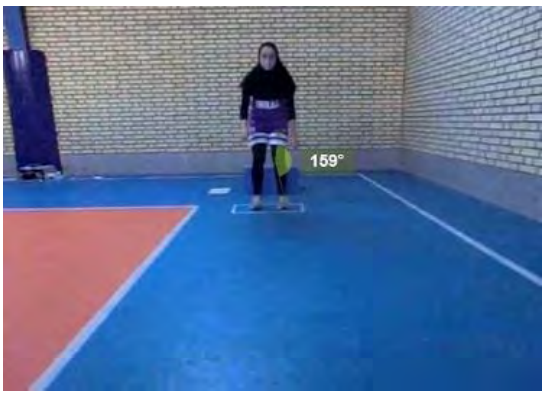


Figure 2. The subject lands in the landing area

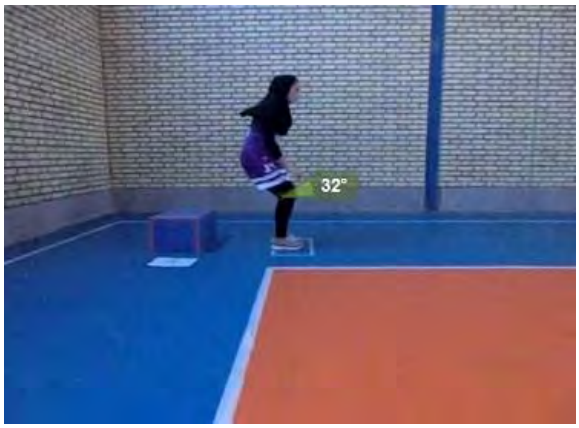


Figure 3. After the jumping down and landing, the subject jumps immediately (frontal view)

The collected data were analyzed by $SPSS_{25}$, and descriptive and inferential statistics were used to analyze the data. The normality of demographic data was assessed by the Shapiro-Wilk test. Due to the non-normality of the data, U-Man-Whitney test was used to compare the mean data between two groups; in addition, Wilcoxon test was used to compare the pretest and posttest for each group. The significance level of (P<0.05) was used for descriptive analysis of subjects' data.

3. Results

As shown in Table 1, the Shapiro Wilk Test, for demographic characteristics (age, height, weight, BMI, pre-test landing error score, post-test landing error score) is at a significance level of 95% for age and landing error score. As the test is significant, we use the nonparametric analysis test for statistical information.

According to Table 2, Wilcoxon statistical results showed that there is a significant difference between pre-test and post-test scores at a significant level (P <0.05) in the TG., because in the TG a significant level is 0.01. Therefore, SMVT significantly reduced the score of LESS, and has improved landing technique in healthy female volleyball players.

According to Table 3, there is no significant difference between the two groups in the pre-test comparison, but there is a significant difference in the post-test comparison between two groups (P=0.01). According to these results, it can be said that SMVT significantly reduced the score of LESS, and has improved landing technique in healthy female volleyball players.

Table 1. The result of Shapiro-Wilk test for checking the normality of demographic data

Demographic characteristics	Number	Variable	Mean±SD	Sig
CG	12	Age	17.75±2.63	0.09
		Height	1.65±0.048	0.57
		Weight	58.25±7.41	0.64
		BMI	21.18±2.74	0.95
		Pre-test LESS score	8±2.33	0.19
		Post-test LESS score	8.25±1.54	0.54
TG	13	Age	15.92±1.18	0.03
		Height	1.67±0.06	0.71
		Weight	57.15±7.87	0.99
		BMI	20.37±3.18	0.28
		Pre-test LESS score	8.62±1.92	0.10
		Post-test LESS score	5.54±1.33	0.01

Table 2. Comparison of LESS in CG and TG in pre and post tests using non-parametric Wilcoxon

Test	Variable	Levels LESS score		Z	Sig
		Pre test M±SD	Post test M±SD		
Less test	CG	8±2.33	8.25±1.54	-3.095	0.63
	TG	8.62±1.19	5.54±1.33	-0.419	0.01

Table 3. Mann-Whitney test compares pre-test between CG and TG and post-test between CG and TG

Group	Test	Mean±SD LESS score	Mann-Whitney	Z	Sig
CG & TG	Pre test	8.32±1.819	63.5	-0.802	0.44
CG & TG	Post test	6.84±1.972	14	-3.56	0.01

4. Discussion

The purpose of the present study is to investigate the effect of SMVT on landing technique in healthy female volleyball players. The SMVT protocol is a specialized volleyball neuromuscular exercise designed to prevent lower injuries in female volleyball players. The results of the hypothesis showed that 6 weeks of SMVT (3 times a week for 18 sessions, 35-40 min) can significantly reduce the score of LESS in TG. Therefore, SMVT significantly improved the landing technique in female volleyball players, and this improvement could be a possible reason to reduce the risk of the lower extremity injuries.

Padua et al. (2015) used the LESS test as a screening tool for an ACL injury among elite young soccer players. The results of the study indicate that LESS assesses the potential for ACL injury among athletes [18]. The results of Padua's study are consistent with the present study because the SMVT is an ACL injury prevention program which reduced the score of LESS, which, in turn, help prevents ACL injury.

In a review study, Voskanian (2013) reported that the rate of non-contact ACL injury among females was 3.5 times higher than in males. He examined the effectiveness of the ACL Injury Prevention Program, which showed a significant effect on ACL injury prevention [19]. His survey are consistent with this study.

Soltandoost, Ebrahimi and Khoshraftar (2017) implemented FIFA 11+ injury prevention program on the anterior knee shear force in 30 teenage male soccer players. The results showed that the program significantly reduced the injury caused by reduction anterior shear force on the knee joint and ACL [20]. Their results also consistent with the present study in the sense that the SMVT program, as a comprehensive protocol, includes strength training, endurance, agility, speed, reaction; in addition, and it reduced the score of LESS that prediction can effectively reduce ACL injuries.

Hadzovic, Ilic and Lilic (2020) conducted a review study on effect of a knee injury-prevention program on young female basketball players from 2003 to 2018. The results showed that knee injury prevention program effectively balanced and enhanced biomechanical abilities in knee joint and injury prevention ACL [21]. Their results are consistent with the present study.

Sadoghi, von Keudell and Vavken (2012) conducted a study examining the effectiveness of ACL and knee injury prevention exercises. They used online sites such as *pubmed*, *medline*, *embase*, *cinahl*.

According to their study, injury prevention programs had positive effects on the performance of the athletes and caused 52% reduction in ACL injury among female athletes and 85% reduction in ACL injury among male athletes [22].

Root et al. (2015) conducted a study on the landing technique and performance of young athletes after a session of injury prevention exercise. The exercises in their study were classified according to age and sex among 29 female athletes and 60 male athletes from various disciplines. The program included three methods of warm-up consist of, injury prevention program, static warm-up, and dynamic warm-up. The injury prevention program, included dynamic, stretching, plyometric, and balance flexibility. Static warm-up was comprised of running, static lower extremity stretching, and dynamic warm-up focused on flexibility. Each jump-landing was measured using LESS, and finally, the average of all jump-landings were calculated. The results showed no difference between measuring the performance of the groups; however, the score of LESS in group that performed injury prevention program exercises was reduced [23].

The most of lower extremity injury mechanism (specially ACL) in volleyball athlete are non-contact and caused by unsafe landing. Usually, neuromuscular training intervention in order to injury prevention should be performed to improve the performance of athletes landing [15]. Due to the different consequences of injury for athletes, various articles study the injury prevention protocols. Neuromuscular training has been reported to significantly reduce the risks of lower limb injuries [15]. SMVT focuses on decreasing landing forces and improving lower limb alignment by teaching lower limb neuromuscular control [16, 17]. Numerous studies have investigated the effect of plyometric training on landing performance. The results indicated that individuals who perform plyometric training have better motor control [15, 16, 17, 24].

5. Conclusion

The SMVT protocol is a specialized volleyball neuromuscular exercise designed to prevent lower extremity injuries (specially ACL injury) in female volleyball players. The results of previous research show that SMVT is successful in preventing injury. The results of the data analysis in present study showed that 6 weeks of SMVT reduced the landing error by 35.73% (from 8.62 to 5.54) in the TG, and SMVT significant improvement the landing technique (P=0.01). This improvement could be a possible reason for reducing the risk of the lower extremity injuries. Therefore, performing SMVT is recommended for healthy female volleyball players because it is effective in both preventing injuries and improving landing technique. These two factors improve the performance of healthy female volleyball players.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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