Research Paper:

# The Effect of Sportsmetrics on the Performance and Knee Valgus During Landing of Female Soccer Players

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## ABSTRACT

**Purpose:** Dynamic knee valgus and poor technique during landing are not only key risk factors for lower extremity injuries especially knee injury, but also can reduce the performance of athletes in the field. Sportsmetrics soccer training is one of the successful knee injury prevention and enhancement performance protocols for female soccer players. Because the effect of sportsmetrics soccer training has not been investigated on the performance and knee valgus during landing in female soccer players, we aimed to investigate this subject.

**Methods:** The current field-trial study was conducted on 24 female soccer players with dynamic knee valgus that were randomly divided into two groups: the training group (TG) and the control group (CG). The assessment tests were the agility t-test, 40-yard test, vertical jump test, double leg squat test, and valgus landing error scoring system test (LESS). The TG group participated in sportsmetrics soccer training regularly for 6 weeks, three 90-min sessions a week. Analysis of covariance was used to analyze the obtained data ($P<0.05$).

**Results:** Six weeks of sportsmetrics soccer training in the TG group not only reduced dynamic knee valgus during landing (51% reduction, $F=171.8$, $P=0.01$) but also improved performance factors significantly: agility (0.50 s reduction, $F=23.29$, $P=0.01$), power (2.50 cm increase, $F=13.20$, $P=0.01$) and speed (0.30 s reduction, $F=23.66$, $P=0.01$).

**Conclusion:** Sportsmetrics soccer training is strongly suggested for soccer players exposed to knee injuries due to dynamic knee valgus during landing.

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## Highlights

- The Sportsmetrics soccer training can be effective in improving performance (agility, power, and speed) in female soccer players with dynamic knee valgus during landing.

- Because of the correction of dynamic knee valgus during landing after 6 weeks of Sportsmetrics soccer training, this protocol in female soccer players can be effective in preventing lower extremity injuries, especially knee injuries.

- The Sportsmetrics soccer training is strictly recommended to soccer players with dynamic knee valgus during landing and their coaches to increase performance and prevent injury.

## Plain Language Summary

Soccer, the most popular sport in the world, is a contact sport with highly intense physical demands. Based on the epidemiological study in sports injury, the incidence of injuries in soccer is higher than in other sports (6.8 injuries per 1000 h of exposure) and the lower extremity (knee and thigh) is the most common site of injuries. The most important injury in female soccer players is anterior cruciate ligament rupture. In addition to high costs and losing competitions and training activity, it has irreparable consequences such as osteoarthritis in the long term. Accordingly, today most coaches use successful specialized injury prevention training like FIFA F11+ and sportsmetrics. However, there is no consensus on the effect of these exercises on sports performance. The main reason is that they do not separate athletes with key risk factors like neuromuscular defects (dynamic knee valgus) from athletes without no key risk factors. Consequently, in this study, we used sportsmetrics because it is special for knee injury prevention in female soccer players and helps them to be successful in improving performance. In this study, we selected soccer players exposed to knee injuries (having key risk factors such as dynamic knee valgus during landing). The research findings showed that sportsmetrics not only improves performance significantly but also is successful in modifying anterior cruciate ligament injury risk factors (51% reduction in dynamic knee valgus during landing). Therefore, this protocol is recommended for female athletes with dynamic knee valgus during landing.

## 1. Introduction

Soccer is a dynamic sport with high speed and intensity loading; therefore, having physical fitness is crucial to produce enough strength, speed, power, agility, balance, and endurance during exercise and competition [1]. In soccer, the factors such as acceleration, maximum speed, and agility can affect the outcome of the game [1]. Movements such as shooting, passing, kicking, dribbling, heading, jumping, short running, accelerating and decelerating, stopping, and pivoting require a high level of muscular functions which can increase the risk of injury [1, 2]. In other words, poor physical fitness increases the risk of injury and decreases success in performance in the field [2]. Most injuries of soccer players occur in the lower extremities in the knee and ankle joints [2]. The incidence of injury in soccer is 6.8 injuries per 1000 h of exposure, and the most commonly damaged structures are muscles and tendons [3]. In soccer players, the anterior cruciate ligament (ACL) injury is more common in women than men and often occurs during jumping, running, landing, cutting, acceleration, and deceleration [4]. In female soccer players, the most common sites of injury is knee joint, especially ACL injury which is about 8 times higher than men soccer players [4]. ACL rupture is the most important soccer injury [5]. In female athletes, dynamic knee valgus (DKV) is the main risk factor for ACL injury and occur during different tasks such as landing and cutting. The risk factors of DKV consist of hip internal rotation, tibia internal or external rotation, weakness of hip muscles, excessive Q angle, and poor body posture control [6]. DKV can increase shearing load to the ACL during the landing after jumping and therefore non-contact ACL injury [7]. Analyzing jump landing videos can illustrate and predict ACL injury. Also, there is a strong correlation between DKV neuromuscular defects and ACL injury and therefore in this study, the landing error scoring system (LESS) was used to assess DKV [8, 9].

Performance is the ability of an athlete to perform specific tasks and activities [10]. Enhancing performance is very important for all players and coaches, because it may lead to success in competitions [11]. The most important physical fitness factors in soccer performance

include jumping (power), speed running (speed), cardiorespiratory endurance, and change of direction (agility) [11]. During important competitions, speed (45%) and power (vertical jump 16%) are two necessary factors for professional players [11]. For example, jumping to head the ball in attacking and defending situations need power [12]. The vertical jump height test is the most reported test for evaluating power in athletes [13]. Another predictor of success is speed [14]. One of the most common tests for evaluating soccer players' ability is the 40-yard speed test and used to determine players' potential in national soccer teams [15, 16]. Also, professional soccer players have better scores on this test than amateurs [17]. Acceleration, deceleration, and change of direction and speed are very common in soccer, and most goal situations require a sudden change in speed and direction. So another factor of success in soccer is agility [18]. Agility is the ability to stable body position in good condition at high speed by changing directions suddenly and quickly without loss of balance and is composed of coordination, balance, strength, and speed [19]. Agility is one of the most important functional factors in soccer [18, 19]. Agile athletes have more endurance and balance during quick movements, and this ability can reduce the risk of injury or re-injury [19].

Unfortunately, players tend to participate in exercises that lead to enhanced performance and increase the chance of success, and often they refuse to participate in injury prevention training due to no impact on performance. Few studies have investigated the effect of injury prevention training on the modification of neuromuscular defects (such as DKV) and performance. Also, most players do not tend to participate in injury prevention programs despite the success in reducing injuries, because of a lack of effect on improving performance [5]. However, a few comprehensive neuromuscular injury prevention programs have been proven successful in improving performance and preventing injury [20]. The most common ACL injury prevention programs in female soccer players include sportsmetrics, prevent injury enhance performance (PEP), Frappier acceleration training program, knee ligament injury prevention (KLIP), FIFA11+, SODERMAN, Harmoknee preventive training (HPT), and WALDEN. Of these programs, PEP, HPT, and WALDEN have had significant effects on ACL injury prevention, but FIFA11+, KLIP, and SODERMAN have not [20]. Also, the effect of some training programs on increasing speed, strength, endurance, power, and agility was significant [11]. Sportsmetrics soccer training (SMST) includes agility, strength (resistance), endurance, speed, plyometric and balance exercises. SMST has been designed specifically for female soccer players to prevent ACL injury and increase performance [21]. SMST was used in different exercises such as fast and resistance training to increase the initial acceleration and speed, strength and plyometric exercises to increase power, plyometric and jump training to correct neuromuscular defects, and agility exercises to increase agility and reaction time [21, 22]. Generally, SMST can prevent ACL injury and increase the performance of soccer players, which indicates that SMST is a comprehensive protocol [22]. It seems that the effects of SMST on performance and neuromuscular defect modification such as DKV have not been investigated. So, we aimed to study this topic.

## 2. Materials and Methods

### Research design

The current field-trial study includes one control group (CG) and one training group (TG) with a pre-test and post-test. Among 86 volunteer female soccer players with DKV, based on the inclusion criteria, a pilot study, and the sample size formula, 12 athletes were selected for each group by systematic random sampling. The TG participated in SMST and the CG participated in their usual exercises with the same duration as the TG.

### Study participants

After describing the objectives and process of the research and providing the consent form, the research subjects were selected from volunteer female soccer players aged 18-25 years based on inclusion criteria. The criteria were as follows: no serious lower extremity injuries over the last year, no history of a serious knee injury, defects, or knee ligament surgery, having at least three years of continuous participation in soccer club teams, and no history of participation in injury prevention protocols. Based on the results of the double leg squat (DLS) test (ICC=0.76) [23], 24 players with DKV were selected by systematic random sampling. Then, the subjects were randomly divided into TG (n=12) and CG (n=12) groups. Also, the subjects were asked to attend training sessions regularly with maximum effort. Since the present study was conducted during the COVID-19 pandemic, observing health protocols (using masks and observing legal distance) during exercises was necessary. Also, all athletes had at least two shots of the COVID-19 vaccination before the start of training and the situation of the city was also blue during the study. The subjects were excluded from the study in case of absence of more than two sessions in training, athletes unwilling to con-

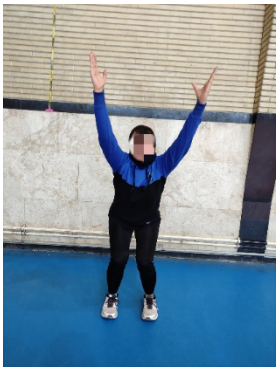


**Figure 1.** Double leg squat test

tinue training, coronavirus infection, or non-compliance with health protocols.

## Research procedure

In the pre-test session, the athletes' demographic and anthropometric characteristics were collected and measured, and after specialized warm-up, agility t-test (ICC=0.98) [19], 40-yd speed test (ICCs=0.98) [16], vertical jump power test (very high reliability) [11], and also LESS test (ICC=0.92) [24] were performed to assess knee valgus angle. Then, the TG participated in SMST for 18 sessions, while the CG participated in their routine exercises for the same period. Exercises were performed for 6 weeks, 3 sessions per week for approximately 90 minutes per session. The protocol included specialized warm-up (Table 1), balance, agility, endurance, speed, and plyometric training (Table 2), strength training (Table 3), and cool-down (Table 1) [20]. After 18 sessions of training, TG and CG participated in the post-test and all assessments were performed again in the same conditions as the pre-test.

## Double leg squat test (DLS)

DLS test was used for diagnosing DKV (ICC=0.76 reliability) [23]. To perform the test, subjects raise their arms above their head and open the legs to hip-width apart and the knees and toes pointing straight ahead. Then, they squat down as if sitting in a chair on comfortable knee flexion. The DLS was scored by a single observer in real-time. Each subject repeated five times the DLS test in a row. To diagnose DKV, knee conditioning was evaluated and observed in frontal view. If the knee has internal displacement higher than the standard level so that, knee alignment crossed over the internal part of the thumb, the subject has DKV (Figure 1).

## Landing error scoring system test (LESS)

LESS is one of the valid clinical tests for diagnosing neuromuscular defects in the trunk and lower extremity during jump landing task, which has intragroup reliability of 0.82 (out of 0.99) and intergroup reliability of 0.83 (out of 0.92) [24]. To prepare for the present test, a box with a height of 30 cm was placed in one part of the field. Then, a line equal to half of the participant's height was drawn ahead of the box and finally, two cameras were used for two-dimensional analysis of motion in anterior and lateral directions with a height of 120 cm from the ground and a distance of 3 m from the box. To perform the test, the subject went on the box and opened her legs the size of the hip-width apart. first, she did a forward jump on the target line and after the forward jump immediately did a vertical jump at the same site. The subjects were not given any feedback to prevent bias and move in a controlled way (Figure 2). There is an 88% correlation between DKV and ACL injury and having DKV during performing the LESS test. The test can predict the risk of ACL injury to around 67% with a sensitivity of 78%. In the present study, this test was used to evaluate the risk of ACL injury because study subjects had DKV [25, 26].

## Vertical jump test (power)

The vertical jump test was used to assess power. The subject stood next to the graded wall and placed her hand

**Figure 2.** Landing error scoring system test

**Figure 3.** Vertical jump test PHYSICAL TREATMENTS

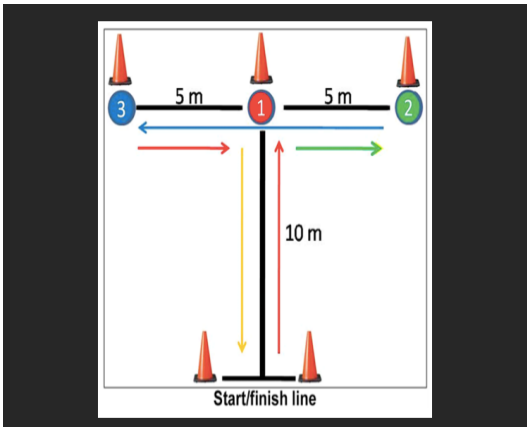


**Figure 4.** t-test PHYSICAL TREATMENTS

on the wall, the subject's middle finger was placed on the point of the meter and was recorded. Then she did a vertical jump as high as possible and hit her hand on the meter and this point was recorded. Finally, the difference between the two points was calculated as the vertical jump height. Based on the previous studies, the present test has a very high reliability of the re-test [11] (Figure 3).

## 40-yard test (speed)

In this study, a 40-yard speed test was used to measure the speed of subjects. The test has high reliability (ICC=0.97). Two cones were placed at a distance of 40 yards (37.58 m) from each other on the field and the start and the finish line were determined. The subjects were given verbal feedback to run at their maximum speed to pass the end cones and not slow down their speed near the finish line. Two examiners were used to perform the test, one was placed at the start line and the other one was at the finish line. Each subject performed the present test twice and the speed was taken using a chronometer and the best record was recorded as the subject's record [16].

## Agility t-test

Agility t-test was used in the present study to measure agility that has very high reliability and intragroup reliability of 0.98 [19]. To perform the test, a scale of 10 by 10 m using 4 cones was used that was placed in the form of T. The subject was placed at the starting point and started running fast to the middle, right, and left and came back to the middle cons respectively and finally came back to the starting point. Time was recorded in seconds using the chronometer (Figure 4).

## Sportsmetrics soccer training (SMST)

SMST was designed for female soccer players, to prevent injury and enhance performance. These exercises include specialized warm-up, strength, speed, agility, balance, plyometric and specialized cool-down exercises. The training was regularly divided separately for each week and three 90-min sessions of training each week. At the beginning of the training session, 10 types of warm-up exercises were performed (Table 1) that took about 10 minutes, then 7 types of SMST (Table 2) and 10 types of strength exercises (in the first and second weeks for 30 s, in the third and fourth weeks for 45 s and in the fifth and sixth weeks for 60 s) (Figure 5). Finally, 10 types of stretching exercises (Table 1) that took about 10 minutes were performed [21].

## Agility and reaction training

To increase the speed of reaction and agility, two different types of exercises were used each week, which were repeated in each session. So, the subject was asked to perform the following exercises: serpentine running, three repetitions (reps) and wheel drill, two reps in the first week of training; modified shuttle, three reps and sprint-stop feet listen, two reps in the second week of training; square drill, two reps and running and joking by coach command, two reps in the third week of training; Nebraska agility, four reps and a reactive running by coach command, two reps in the fourh week of training; Illinois agility, four reps, and reaction mirror drill with training companion, two reps in the fifth week of training; and finally T drill, four reps and advanced wheel drill, two reps in the sixth week of training [21] (Table 2).

**Table 1.** Warm-up and cool-down exercises

| Dynamic Warm-up | Cool-down (Stretching) |
|---|---|
| Toe walk | Hamstring |
| Heel walk | Iliotibial band |
| Straight leg march | Quadriceps |
| Leg cradle | Hip flexor |
| Hip rotator walk | Gastrocnemius |
| High knee skip | Soleus |
| High knees | Deltoid |
| Glut kicks | Triceps, latissimus Doris |
| Stride out | Pectoralis, biceps |
| All-out sprint | Low back |

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### Acceleration, endurance, and speed training

To improve the speed and initial acceleration, each week three different types of exercises that were repeated in each session were used in acceleration, endurance, and speed training groups. So, the subject was asked to perform these exercises as follows: partner push-offs hold 5 s with five reps, sprint-backpedal, five reps, and 1170 m Jog in the first week of training; acceleration with band 10-yd, sprint with ground touches, five reps, and a 100-yd shuttle, four reps in the second week of training; partner push-off hold 10 s, five reps, eagle into sprint six reps, and 50-yd shuttle, four reps in the third week of training; acceleration with band 20-yd, box drill three reps, and 50-yd shuttle, four reps in the fourth week of training; partner push-offs hold 15 s five reps, sprint-180º-backpedal, seven reps, and Jingle Jangle 10-yd, five reps in the fifth week of training; and acceleration with band 30-yd, sprint-360º-sprint, seven reps, and Jingle Jangle 20-yd, five reps in the final week of training [21] (Table 2).

### Plyometric training

To improve power and jump, two different types of exercises which were repeated in each session were used each week by the plyometric TG. So, the subject was asked to perform these exercises as follows: ladder up-up and back-back, two reps and dot drill double-leg jump, 3×5 reps in the first week of training; ladder toe touches, two reps and dot drill add split leg jumps, 3×5 reps in the second week of training; ladder outside foot, two reps and dot drill add 180º split leg jump, 3×5 reps in the third week of training; ladder in-in_out-out, two reps and dot drill add single-leg hops, 3×5 reps in the 4th week of training; ladder up-up and back-back, two reps and dot drill combo all jumps, 3×5 reps in the fifth week of training; and ladder one foot forward, one foot backward, two reps and dot drill combo all jumps, 3×5 reps in the final week of training [21] (Table 2).

### Statistical analyses

The obtained data were analyzed in SPSS software, version 25. The normality of data distribution was checked by the Shapiro-Wilk test. The equality of intergroup variances was checked by Levene's test. Finally, the analysis of covariance (ANCOVA) was performed to investigate intergroup changes. This test can neutralize the effect of the group and only investigate the effect of time. In this study, the significance level was set at 0.05.

## 3. Results

The subjects of the research included 24 female soccer players which were semi-professional with at least three years of regular participation in soccer club teams. They were randomly divided into TG and CG. Subjects' demographic characteristics are presented in Table 3. The results of covariance analysis, taking into account the pre-test values as the control, showed significant differences between the TG and CG regarding the research variables. Applying 6 weeks of SMST, significantly (P=0.01) improved agility, power, speed, and DKV in the TG. The speed record in the TG decreased by about 0.30 s (from 7.36±0.45 to 7.07±0.44, Eta=0.54, F=23.66), the agility record decreased by about 0.50 s (from 11.55±0.89 to 11.09±0.83, Eta=0.53, F=23.29), the power record increased about 2.50 cm (from 28.01±4.68 to 30.583±4.36, Eta=0.40, F=13.20), and also the DKV decreased about 13º (from 25.30±4.74 to 12.45±2.62, Eta=0.90, F=171.8) (Table 4).

**Table 2.** Sportsmetrics soccer training

| Component | Session | Exercise | Duration |
|---|---|---|---|
| Ladder, quick feet, additional jumps (power exercise) | 1-3 | Ladder: up-up and back-back | 2 reps |
| | 1-3 | Dot drill: double-leg jumps | 5 reps×3 |
| | 4-6 | Ladder: toe touches | 2 reps |
| | 4-6 | Dot drill: add split leg jumps | 5 reps×3 |
| | 7-9 | Ladder: outside foot in | 2 reps |
| | 7-9 | Dot drill: add 180º split leg jump | 5 reps×3 |
| | 10-12 | Ladder: in-in, out-out | 2 reps |
| | 10-12 | Dot drill: add single-leg hopes | 5 reps×3 |
| | 13-15 | Ladder: up-up and back-back | 2 reps |
| | 13-15 | Dot drill: combo all jumps | 5 reps×3 |
| | 16-18 | Ladder: 1 foot forward, 1 foot backward | 2 reps |
| | 16-18 | Dot drill: combo all jumps | 5 reps×3 |
| Agility and reaction (agility exercise) | 1-3 | Serpentine run | 3 reps |
| | 1-3 | Wheel drill: listen to the instructor | 30 s, 2 reps |
| | 4-6 | Modified shuttle | 3 reps |
| | 4-6 | Sprint-stop feet-listen | 45 s, 2 reps |
| | 7-9 | Square drill | 2 reps |
| | 7-9 | Sprint-quick feet-listen | 45 s, 2 reps |
| | 10-12 | Nebraska drill | 4 reps |
| | 10-12 | Reaction drill-watch instructor point | 45 s, 2 reps |
| | 13-15 | Illinois drill | 4 reps |
| | 13-15 | Reaction mirror drill, pressing | 60 s, 2 reps |
| | 16-18 | T-drill: 5-10-5 | 4 reps |
| | 16-18 | Advanced wheel drill: listen to the instructor | 60 s, 2 reps |
| Acceleration, speed, endurance (speed exercise) | 1-3 | Partner push-offs, hold 5s | 5 reps |
| | 1-3 | Sprint-backpedal | 50-yd 5s |
| | 1-3 | Jog | 1170m |
| | 4-6 | Acceleration with bond | 10-yd |
| | 4-6 | Sprint with ground touches-backpedal | 50-yd |
| | 4-6 | 100-yd shuttle | 4 reps |
| | 7-9 | Partner push-offs, 10-s hold | 5 reps |
| | 7-9 | Eagle into the sprint, jog back | 50-yd, 6 reps |
| | 7-9 | 50-yd shuttle | 4 reps |
| | 10-12 | Acceleration with bond | 20-yd |
| | 10-12 | Box drill, sprint-90º-backpedal | 3 reps |
| | 10-12 | 50-yd cone drill | 4 reps |
| | 13-15 | Partner push-offs, hold 15 s | 5 reps |
| | 13-15 | Sprint-180º-backpedal | 50-yd, 7reps |
| | 13-15 | Jingle jangle, 20-yd | 5 reps |
| | 16-18 | Acceleration with band | 30-yd |
| | 16-18 | Sprint-360º-sprint | 50-yd, 7 reps |
| | 16-18 | Jingle jangle, 10-yd | 6 reps |

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3. Single-leg heel raise

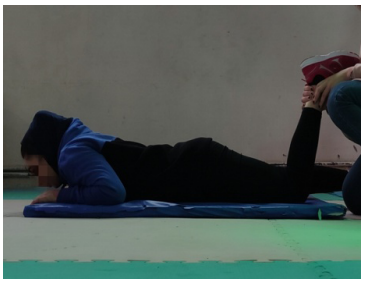
2. Resistance band: lunges

1. Resistance band: squats

6. Wall sits

5. Supine hamstring bridge

4. Prone hamstring: with partner



9. Arm swing: resistance band

8. Hip abductor: resistance band

7. Hip flexion: resistance band

3-10. Abdominal of choice

2-10. Abdominal of choice

1-10. Abdominal of choice

**Figure 5**. Strength training

**Table 3.** Demographic characteristics of players (age, weight, height, body mass index, and sports experiment)

| Group | Mean±SD | | | | |
|---|---|---|---|---|---|
| | Age (y) | Sports Background (y) | BMI (kg/m²) | Weight (kg) | Height (cm) |
| TG | 20.2±8.02 | 5.16±1.99 | 20.88±1.89 | 56.17±4.86 | 164.1±7.34 |
| CG | 19.75±1.71 | 5.41±2.06 | 20.30±1.81 | 53.50±5.35 | 162.3±5.35 |

TG: Training group; CG: Control group; BMI: Body mass index.



**Table 4.** Effect of SMST on performance (speed, agility, and power) and DKV during landing

| Variables | Mean±SD | | | | Eta | P | F |
|---|---|---|---|---|---|---|---|
| | TG | | CG | | | | |
| | Pre-test | Post-test | Pre-test | Post-test | | | |
| Power (cm) | 28.01±4.69 | 30.59±4.36 | 28.81±5.97 | 28.76±4.82 | 0.39 | 0.01 | 13.2 |
| Speed (s) | 7.37±0.46 | 7.07±0.44 | 7.36±0.49 | 7.36±0.45 | 0.52 | 0.01 | 3.23 |
| Agility (s) | 11.56±0.89 | 11.10±0.83 | 11.19±0.64 | 11.23±0.60 | 0.54 | 0.01 | 23.6 |
| DKV (degree) | 25.30±4.74 | 12.45±2.62 | 27.45±5.09 | 27.10±5.39 | 0.89 | 0.01 | 171.8 |



Abbreviations: TG Training group; CG: Control group; DKV: Dynamic knee valgus; SMST: Sportsmetrics soccer training.

## 4. Discussion

In the last decade, participation in sports injury prevention and performance enhancement protocols has increased continuously among athletes and coaches. One of these protocols which has been designed for preventing knee injuries and enhancing performance in female soccer players is SMST. In this study, the effect of this training protocol on performance and DKV during landing in female soccer players was investigated. The results of the present study showed that performing 6 weeks of SMST improved performance such as a reduction in speed and agility records, an increase in vertical jump height, and a reduction in DKV by 51%. Accordingly, SMST can be effective in enhancing performance and preventing knee injuries, especially ACL injuries. In previous studies, the effect of neuromuscular exercise protocol on injury prevention and performance was investigated only in players without neuromuscular defects. The SMST is one of these protocols which can prevent injury and enhance performance in female soccer players with neuromuscular defects [22]. The results of the present study also indicated that performing SMST not only enhanced performance but also modified DKV during landing significantly. Athletes and coaches prefer to participate in interventional exercises that, besides injury prevention, improve performance [27]. Two common methods of injury prevention training in soccer include the training interventions at the start of a training session as a warm-up, with a maximum of 20 minutes (such as FIFA11+), and preparing or bodybuilding in the preseason as a complete training session with at least 60 minutes (such as SMST) [22]. The second method seems to have a greater impact on reducing injury, improving neuromuscular defects, and increasing performance than the first method [22]. A review of previous studies shows that FIFA11+ has different effects in different societies, some research indicates a significant increase in performance (speed, jump, and agility), and others report no effect on performance [28]. Most neuromuscular injury prevention programs are performed to improve neuromuscular control, strength, coordination, and proprioception [29]. For example, injury prevention programs (IPP) which are a combination of plyometric, dynamic flexibility, and balance, is one of the successful programs in the field of reducing injury and enhancing performance, which is done in the first method, i.e. warm-up [27]. The effect of plyometric and strength training on female soccer players showed that the effect of plyometric training on improving speed, power, and reaction is more than strength training. In SMST, a combination of strength and plyometric training is performed in each session, and accordingly, it seems that the effect of SMST on performance is more than other training methods [30]. Although neuromuscular injury prevention training programs have been successful in improving landing error, their effects on power (vertical jump, long jump) and speed (shuttle running) were not

statistically significant [27]. Investigating the effect of SMST on performance in male soccer players without neuromuscular defects showed that performing these exercises leads to improvement in performance (7% speed, 18% power, and 12% agility), which is consistent with the findings of the present study. It seems that agility, speed, strength, and plyometric exercises in each session of SMST are the main causes [31]. Also, SMST can lead to a decrease (57%) in landing error and improve balance significantly in healthy male soccer players [32]. Based on the previous studies, SMST in players without neuromuscular defects by correcting landing error seems to be effective in improving lower extremity alignment and reducing the risk of knee injuries, especially ACL, and improving performance that aligns with the results of the present study which reduces DKV during landing [31, 32]. On the other hand, the results of another study indicate that performing 6 weeks of plyometric training in soccer players significantly improves the record of the speed and jump furthermore; plyometric exercises are one of the key components of SMST [33]. A review on the effect of plyometric training in soccer players shows that performing these exercises can lead to a significant improvement in the records of types of jumping and speed in short distances and accordingly, plyometric training in soccer players programs is necessary [34]. The effect of plyometric training in females with DKV shows that these exercises significantly improve balance, power, and agility [35]. Evaluation of plyometric training methods of load plyometric-jump training and unload plyometric-jump training presented that, load plyometric-jump training exercises have a greater impact on improving agility, reaction, speed, and power, as well as this training method leads to single leg jumping performance improvement and maximum shooting distance improvement in healthy male soccer players [36].

Power is a combination of two factors: speed and strength. By increasing speed and strength, power increases as well. Speed and strength training are other key components of SMST and perhaps because of this, the present protocol has led to an increase in power [31]. The effect of SMST on female players in soccer, basketball, and volleyball showed that in addition to reducing the risk of injury, these exercises have significantly improved power in 57% of players and also have a significant effect on the agility and strength of lower extremity muscles. However, it had no significant effect on speed [37]. In this study, about 80% of players had DKV in landing and after participating in exercises, a significant improvement in the lower extremity and an improvement in landing alignment technique were reported in 60% of participants; the results of the study are consistent with the present study [37]. The results of another study also exhibit that performing 6 weeks of SMST in female soccer players improves the agility record by about 87%, also, it enhances speed, jump, and overall strength significantly [22]. However, SMST and other injury prevention protocols have had conflicting results on performance.

For instance, the FIFA 11+ comprehensive injury prevention program had no significant effect on agility and core stability, but its effect on speed and power was significant [38]. One of the most common injury prevention programs in soccer is the FIFA11+ comprehensive program, many studies have investigated the effect of these exercises. In investigating the effect of these exercises on the speed, agility, power, and reaction of male soccer players, only a significant improvement in power was seen. Nonetheless, in the present study, the effect of SMST on the improvement of all three indicators of performance was significant [38]. However, in another study, a significant effect of these exercises on the performance of adolescent soccer players was reported in the components of agility, power, and speed [39]. Investigating the effect of 72 sessions of PEP showed that doing these exercises improved DKV by 5%, while in this study, performing 18 sessions of SMST resulted in an improvement in DKV landing by about 51% [40]. Also, in previous research on the effect of PEP on power, contrary to the present study, no significant change in power has been reported [38]. Furthermore, in other research studies about the effect of PEP on agility, speed, and power, only a significant effect on speed has been reported [38].

Plyometric training in female players seems to be able to improve lower extremity biomechanics and reduce DKV [35]. FIFA 11+ comprehensive training can be effective in preventing injury and improving the biomechanics of the lower extremity by increasing the strength of the hip muscles [37]. Adding strength and balance exercises to the FIFA+11 comprehensive training has been suggested because it can reduce the incidence of injury in soccer players. However, in SMST, the strength exercises are one of the key components of the training protocol and this protocol seems to be more comprehensive than other injury prevention protocols [28]. A study illustrates that ACL-injury prevention protocol training can reduce DKV in soccer players significantly. Although the performance was not studied, its finding in the field of DKV was consistent with the present study result (51% reduction in DKV during landing) [41]. However, in this study, in terms of soccer-specific fatigue protocol application, a DKV increase was observed in players without DKV

[41]. Investigating the effect of injury prevention protocol training on landing mechanism and neuromuscular defects shows that hip and knee flexion during landing increases and knee abduction reduces, although an improvement of landing technique and reduction in the risk of ACL injury was reported which was consistent with the present study results [42]. Yet, some other studies have reported no effect of injury prevention protocol training on DKV reduction and landing technique improvement [42]. A review of the effect of neuromuscular training on injury prevention shows that neuromuscular training could decrease landing forces in stop and jump activities, also, it could reduce knee and hip abduction, adduction, and flexion during landing and reduce knee valgus and varus during jump landing and vertical jump tests [43]. By the way, investigating the effect of neuromuscular injury prevention training in female athletes shows that this training in addition to improving the landing mechanism in jumping activities and increasing the knee range of motion positively affects performance and improves speed and power records [44]. Also, players had an excessive angle of knee varus and knee valgus during landing, which occurred a significant improvement after training [44]. Altogether, previous research has investigated the effect of SMST on athletes without neuromuscular defects. So, it seems that investigating the effect of SMST on female soccer players at risk of knee injuries, especially ACL (with DKV during landing) and its effect on performance is necessary and accordingly, the present study was conducted [22, 32].

The present study subjects were female soccer players with DKV, so it was impossible to compare the effect of SMST in females with males and also different neuromuscular defects such as trunk dominant, leg dominant, and quadriceps dominant. So, it is suggested that more research be conducted on the effect of SMST in females and males with different neuromuscular defects. Sportsmetrics is a successful protocol in athletes without neuromuscular defects. However, studies about the effect of sportsmetrics on athletes with neuromuscular defects were indistinct and very limited.

## 5. Conclusion

Most previous researchers have investigated the effect of injury prevention training only on reducing the risk of injury or enhancing performance in athletes without neuromuscular defects and it seemed that concurrent investigation of the effect of SMST on performance and DKV modification during landing is necessary. Because DKV during landing is a key risk factor for lower extremity injury in female soccer players, we studied the effect of SMST on performance in female soccer players with DKV during landing. The data analysis showed that not only performance improved significantly (power, speed, and agility) but also DKV decreased during landing (51%). Consequently, using SMST is strongly recommended to coaches and athletes with DKV during landing to enhance performance and prevent injury.

## Ethical Considerations

### Compliance with ethical guidelines

This study was approved by the Ethics Committee of the University of Kurdistan (Code: IR.UOK.REC.1400.030).

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The paper was extracted from the MSc thesis of the second author, Department of physical education and sport science, Faculty of humanity science, University of Kurdistan.

### Authors' contributions

All authors equally contributed to preparing this article.

### Conflict of interest

The authors declared no conflict of interest.

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