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Effect of a Basketball-Specific Sportsmetrics Program on Neuromuscular Control in Female Athletes with Dynamic Knee Valgus

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Abstract

Background: In female high school basketball athletes, the most common site of injury is the knee, and the primary mechanism is increased DKV (Dynamic Knee Valgus) during landing .In this study, the effect of SMs basketball (Specifics-Sportsmetrics) on lower extremity control during landing in female basketball athletes with DKV was investigated.

Methods and Materials: The present quasi-experimental study included 30 high school basketball athletes with DKV in two groups of 15 participants. The Double-Leg Squat and LESS tests were used to assess DKV and LESS by Kinovea software version 2023.1 at a rate of 240 frames per second. The exercise group performed basketball SMs for 6 weeks. To analyze statistical data, SPSS and the ANCOVA statistical method were used at a significance level of 0.05.

Results: The results showed that performing six weeks of basketball SMs training significantly reduced the DKV angle (from 17.4 to 11.2 degrees,$p < 0.01$, $F=21$) and the LESS score (from 13.4 to 7.1,$p < 0.01$, $F=13$) in the exercise group, while in the control group, no significant change was observed in DKV and LESS score after 6 weeks of regular training.

Conclusion: Despite the small sample size and lack of long-term studies, due to adjustment, DKV, and poor landing technique, the use of SMS is recommended as a promising approach for basketball coaches and players with DKV.

Keywords: Basketball, LESS, Knee Valgus, Sports-Metrics, Injury Prevention

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1. Introduction

An evaluation of 130 basketball athletes from 12 high schools during the 2022-2023 season found that participation in annual tournaments and in basketball skills camps, compared to non-participation, increased the risk of injury by more than twice (1). Although the inequality in sports participation between boys and girls has decreased in the 21st century, this gap still exists, especially in contact sports such as basketball. One of the main reasons for this is the higher prevalence of injury in young girls and adolescents than in their boys counterparts (2). A review of injuries in basketball athletes over the past 35 years (1990-2024) showed that the lower extremity is the most common site of injury (men: ankle sprain, women: ACL sprain), the most common biomechanical mechanism is jumping, landing, and sudden changes in direction, and the most effective risk factor for knee injuries is DKV (Dynamic Knee Valgus) (3). A basketball player changes direction every 2 to 3 seconds and has 2 to 4 times more jumps and landings (35 to 46) during a match than a soccer player (4). The primary basketball ACL injury mechanism is an increase in knee valgus (5.1°–12.0°)and knee flexion (12.6°–32.6°) from the initial contact of the injured foot with the ground to 33 milliseconds thereafter (5). Increased knee flexion was observed in 73.7% of cases by at least 8 degrees, and in 47.4% of cases, more than 20 degrees, and increased knee valgus in 71.4% of cases was more than 4 degrees, and in 47.6% of cases, more than 9 degrees (5). For this reason, modifying DKV and preventing ACL injuries is the most essential intervention in adolescent girls' basketball athletes (6).

It is estimated that there are at least 450 million basketball players worldwide. In basketball, 65% of all injuries occur in the lower extremities, resulting in 72.3% of missed games(7). The return-to-play rate after ACL injury in WNBA players is 78%, and the average time to return to play ranges from approximately 10 to 14 months (7). The most significant risk factor for ACL injury is impaired neuromuscular control, which leads to increased knee abduction torque and angle, abnormal ground reaction forces, and asymmetric movement patterns, ultimately resulting in DKV during jump-landing in female athletes (8, 9). DKV, by increasing the tensile forces on the knee ligaments, causes chronic injuries (patellofemoral pain syndrome) and acute injuries (ACL rupture), especially during landing and jumping, and eventually leads to meniscal damage, knee instability, and osteoarthritis (8). For this reason, the DKV assessment during the squat test is used as a functional tool to screen athletes prone to knee injuries, especially ACL injuries, as well as to evaluate the rehabilitation process and prevent secondary ACL injuries during the return to sport (9). Due to the importance of knee injuries (especially ACL) in female basketball players, identifying female athletes prone to lower extremity injuries in basketball (with neuromuscular deficits, especially DKV) and

examining the effect of preventive interventions remains the goal of numerous studies, including the present study.

A review of the effects of neuromuscular exercise protocols on jump-landing biomechanics and risk of ACL injuries in 648 young female athletes showed that these exercises had small to moderate effects on maximum knee flexion angle and DKV during jump-landing (10). Therefore, it was recommended to conduct more research in this field, especially in young female athletes (10). One of the specific neuromuscular protocols successful in reducing the risk of knee injury and enhancing the athletic performance of female athletes in various sports (football, volleyball, basketball, and tennis) is the SMs exercise protocol(Sportsmetrics). The SMs protocols, which are performed in 18 sessions (six weeks, three sessions per week), include four separate comprehensive protocols, preventing knee injuries and enhancing athletic performance in soccer, volleyball, basketball, and tennis (11). One protocol includes the sports components of agility, reaction, speed, resistance, plyometrics, coordination, and strength. Which is designed for each of the above sports, based on its specific needs (11). In a review of the literature, improvements in knee neuromuscular control during landing and reductions in DKV have been reported after performing soccer SMs in male (12), and female (13) soccer players with DKV, after performing volleyball SMs in healthy female volleyball players (14), and with DKV (15), after performing tennis SMs in healthy male and female tennis players (16), after performing general SMs in healthy professional and amateur high school rowers (17), and after performing basketball SMs in healthy female high school players (18). However, due to the lack of evidence regarding the effect of basketball SMs on DKV and landing technique in high school girls players with DKV, the present study seemed necessary.

2. Methods and Materials

2.1. Participation (Study Design)

The present study was a quasi-experimental study with a pre-test and post-test design. After announcing the call for participation, applying for volunteers (162 people), introducing the research, and signing the consent form (Due to the age of the athletes, both athlete and parental consent forms were obtained), based on the results of the double-leg squat test, among the eligible volunteers (76 people), 30 athletes with DKV were randomly divided into two control and experimental groups (15 people in each group)The sample size (α=0.05, power ($1-\beta$)=0.80, effect size=0.50) was estimated based on G * Power 3.1 software as 30 subjects. Inclusion criteria included age range 14 to 17 years (high school), no history of serious lower extremity injury in the past year, having at least three years of regular basketball training three sessions per week, no postural abnormalities other than DKV, no history of knee injury or surgery (especially ACL), a score of more than

three in three repetitions of the double-leg squat test and a minimum dynamic valgus angle of 12 degrees (Using Kinovea software, 240 frames per second and landmarks of the middle of the patella, the middle of the two ankle malleoli, the middle of the greater trochanter and ASIS), and exclusion criteria included missing more than two sessions of training, injury during the study, and withdrawal from participation in the study. After coordinating the pre-test time and familiarizing the basketball players with the test, the LESS test was performed, then the subjects were randomly divided into two experimental and control groups (15 people). Then, the experimental group participated in SMs basketball training for 6 weeks (18 sessions). Because the SMs basketball training is performed as a full training session in pre-season training, the control group also performed pre-season training with the same volume and time as the experimental group (for 18 sessions and over 6 weeks, 3 sessions per week of 60 to 90 minutes with an RPE of 6 to 9). Although some of the control group's pre-season training sessions also included components of strength, agility, and plyometric training, the sessions and exercises were not the same as those in the experimental group. After completing the SMs basketball training, both groups participated in the post-test under the same conditions as the pre-test. To learn how to perform the exercises correctly, before the first session of each week, video exercises were sent to the athletes, and in the first session of the week, the exercises were taught in a real and practical way, so that the athlete can do the exercises regularly and correctly during the next two sessions a week.

2.2. Instrument (Assessment Tests)

Double Leg Squat (DLS): Used to diagnose DKV (ICC=0.76). The subject is in a standing position, feet shoulder-width apart, arms overhead, and elbows extended. Knees and toes straight forward, with knees flexed to 90 degrees (similar to sitting in a chair), into a DLS position at the bottom (Figure 1). Scoring was video-based and blind during five DLS repetitions. An athlete who scores between 3 and 5 (midpoint of the patella passes the inner part of the big toe) in at least 3 repetitions out of 5 consecutive repetitions has DKV (13, 19).

Landing Error Scoring System (LESS): Used to assess jump-landing errors. The athlete performs a forward and downward drop from a box (30 cm high) onto the target line, and then immediately performs the maximum possible vertical jump similar to a basketball rebound. LESS video was recorded in both frontal and sagittal views by two digital video cameras (model EXILIM EX-ZR1000; Casio, Japan). The cameras were mounted on a tripod at a height of 102.24 and a distance of 365.76 cm (Figure 1). A 3-point scoring method (0 = excellent, 1 = fair, 2 = poor) was then used to evaluate the recorded videos. The LESS test has a good intraclass correlation coefficient [ICC] = 0.82-0.99 (11, 12, 19).

2.3. Procedure (Intervention)

SMs Basketball Protocol: First introduced in 2012 by Noyes to prevent knee injuries and enhance performance in female basketball players (18). In addition to dynamic warm-up, cool-down, and strength exercises that were performed consistently throughout all sessions, SMs Basketball included jumping, agility, acceleration, and speed exercises with continuous feedback on jump-landing mechanics, which were specifically designed based on the needs of basketball players (Figure 2). The required equipment includes cones, training funnels, resistance bands, ladders, and Pilates bands, and can be performed on the basketball court and the school weight room. The exercises are performed three times a week for six weeks and for 60 to 90 minutes per session. The dynamic warm-up exercise included heel-toe walking, straight leg marching, leg cradle walking, dog and bush walking, and high-knee skipping for half a basketball court, high-knee and glute kicks, stride-out running, and all-out sprinting running in the full length of the basketball court. Strength exercises included hamstring, hip flexion/abduction, core, abdominal, and shoulder musculature, and flexibility exercise (cool-down) included hamstrings, quadriceps, iliotibial band, hip flexors, gastrocnemius/soleus, deltoid, triceps, pectoralis major, biceps, and low back (11, 18).

Table 1. SMs Basketball Protocol (11, 18).

Time session no	Jump	Agility	Acceleration, speed, and aerobic	Ladders, reaction, and dot jump drills
Week 1 no. 1-3	Wall jump (20 s) Tuck jump (20 s) Squat jump (10 s) Barrier jumps (20 s each) Side-to-side Forward-backward 180° Jump (20 s) Broad jump (5 repetitions) Bounding in place (20 s)	Shuttle drill Maze drill	Mountain climbers Sprint-back pedal Suicides	Ladder: high knees High knee ball toss over barrier Dot drill: double leg jumps
Week 2 no. 4-6	Same as in sessions 1-3, Add 5 s to each jump Add 5 repetitions to the broad jump	Tip drill Figure 4 drill	Mountain climbers Sprint-back pedal Suicides: forward/ backward	Ladders: up-up, back back Double high knee with ball toss, Dot drills: add split leg jumps
Week 3, no. 7-9	Wall jump (25 s) Tuck jump (25 s) Triple broad into vertical ump (5 repetitions) Squat jump (15 s) Barrier hops (25 s each) Side-to-side Forward-backward Single-leg hop (5 repetitions) Scissors jump (25 s)	Square drill 4 Dot drill Quarter eagle	Mountain climbers Quarter eagles sprints Suicides: defensive slides	Ladders: outside foot in Bleacher jumps Dot drills: add 180° split leg jump

	Bounding for distance (1 run)			
Week 4, no. 10-12	Same as in sessions 7-9, Add 5 s to each jump Add 3 repetitions to triple broad into a vertical jump	Defensive slides Shoot and sprint	Mountain climbers Sprint with ground touches Full court relay	Ladders: in-in,out-out Instructor pointing Dot drills: add single-leg hops
Week 5, no. 13-15	Wall jump (20 s) Step, jump up, down, vertical (30 s), Squat jump (25 s) Mattress jumps (30 s each) Side-to-side Forward-backward Triple single-leg hop, stick (5 repetitions each leg) Jump into bounding (3 runs)	Tip drill Irish "D"	Mountain climbers Sprint 180 Sprint, quick feet	Ladder: scissors Instructor pointing with quick feet up/down Dot drills: all jumps
Week 6, no. 16-18	Same as in sessions 13-15 Add 5 repetitions to the step, jump up, down, vertical Add 1 run to jump into bounding	T-drills: 5-10-5 Kill the grass	Mountain climbers Sprint 360 Power rebounds relay	Ladder: Icky shuffle Single-leg squat jumps and 180° scissor jumps Dot drills: all jumps

Figure 1. DLS (left) and LESS (right) tests

Table 2. Mean ± SD (Standard Deviation) variables, and Tests of Between-Subjects Effects (ANCOVA)

	ALL	Control Groups	Exercise Groups	Estimates Mean post Control groups	Estimates Mean post Exercise Groups	F	Sig.	Partial Eta Squared
Valgus Pr	16.8±3.1	16.3±3.1	17.4±3.1			21.32	0.01	0.45
ValgusPo	14.2±4.1	17.3±3.2	11.1±2.1	17.9±0.48	11.0±0.48			
LESS Pr	13.1±1.5	12.8±1.5	13.4±1.5			13.01	0.01	0.33
LESS Po	9.9±3.3	12.9±1.4	7.1±1.4	12.9±0.32	6.91±0.32			

Pr: Pre-test, PO: Post-test

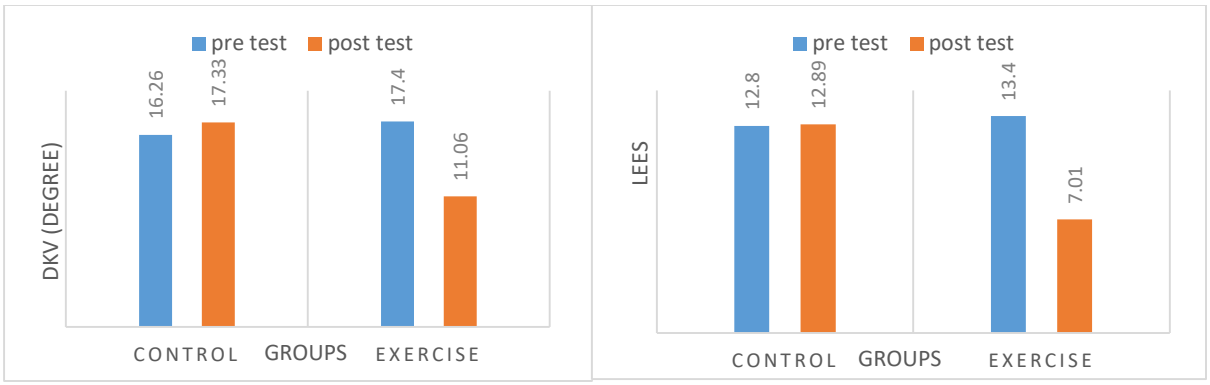

Figure 2. Comparison of the mean LESS score(right) and DKV angle (left) in the pre-test and post-test

3. Results

The results of the ANCOVA, by removing the possible effect of the pre-test, to examine the changes in DKV and LESS of the training group (age: 15.40±1.24 years; height: 161.67±5.98 cm; weight: 54.53±5.54 kg; basketball experience: 4.27±1.03 years and body mass index: 20.82±1.23) and the control group (age: 16.06±1.27 years; height: 162.60±4.13 cm; weight: 56.66±4.77 kg; basketball experience: 4.67±1.04 years and body mass index: 21.39±0.98) in the post-test compared to the pre-test are presented in Table 2. The results showed that six weeks of SMs basketball protocol modified both risk factors for knee injury in high school female basketball players with DKV, as in the training group, a significant improvement ($p < 0.01$), and an 35% decrease in DKV angle (from 17.4 to 11.2 degrees), and a 47% decrease in LESS score (from 13.4 to 7.1) were observed in the post-test compared to the pre-test (Figure 2).

4. Discussion

In the present study, performing 18 sessions of the basketball SMs protocol resulted in a significant decrease($p < 0.01$), and about 6.3 points in the LESS test of high school basketball girls with DKV. The results of athlete screening help identify key risk factors for potential injuries, identify athletes who are prone to injury, and introduce beneficial preventive interventions (19-21). The LESS is a standardized and validated tool for detecting DKV, and has excellent intra-rater reliability (ICC = 0.95, 95% confidence interval (CI), 0.90–0.97) (20). In young individuals (132 newly entered army soldiers aged 18 to 25 years), the LESS test can predict injury risk better than other functional tests, such as the FMS, with poorer LESS scores predicting up to 77% of lower extremities injury risk (22). Also, in adolescent athletes, motor competence explains approximately 50% of the variance in LESS scores (23). The LESS score provides an overview of an athlete's landing technique. Athletes who score more than five or six (based on age, sex, sport) on the LESS have a high-risk landing performance, and values less than 5 or 6 indicate a safer landing mechanism with a lower risk of injury (20). Athletes in the training group of the present study had high-risk

landings and an average LESS score of about 13.4 in the pre-test, but after six weeks of SMs basketball training, their average score decreased to about 7.1, and their score became very close to safe landings (score less than 6 or 5 based on age, sex, sport). Therefore, it is suggested to increase the duration of basketball SMs exercises in high school girls with DKV to more than six weeks for a safer landing. In female volleyball players with DKV, six weeks of SMs volleyball training resulted in a significant decrease of 9.86 LESS points, but the LESS score was 7.6 at the post-test (15). A review of LESS test results by gender and sport indicated that further field studies are needed to determine reference LESS scores, particularly in women and basketball players (24). The hypothesis that a score of 7 in the less test can be the threshold for predicting the risk of injury in teenage girls' basketball players with DKV (based on differences in sports, age, and gender) exists and needs to be investigated in future studies. A reduction in LESS scores after six weeks of training has been reported for soccer SMs (12, 13), and volleyball SMs (14, 15). A significant reduction in LESS scores in healthy adolescent male soccer players from 9.17 to 5.73 after eight weeks of a Prevent Injury and Enhance Performance (PEP) program (25), and in injury-prone female volleyball players from 8.2 to 4.1 after six weeks of TRX-Based Movement Pattern Correction Exercises (26), has also been reported. One of the main reasons for the reduction in the LESS score of about 50% (47%) after performing the SMs basketball training is the comprehensiveness and multi-component nature of this training protocol. The SMs basketball is designed to prevent knee injuries and enhance performance in female basketball players, and is performed as a complete training session(18). The SMs basketball includes warm-up, cool-down, and dynamic strength exercises, and basketball-specific exercises such as jumping, agility, acceleration, and speed exercises, which are accompanied by continuous feedback on jump-landing technique and are specifically designed based on the physical needs of basketball players (11, 18).

Also in the present study, performing 18 sessions of the basketball SMs protocol resulted in a significant decrease of DKV ($p < 0.01$), and about 35% (from 17.4 to 11.1) during landing, in high school basketball players with DKV. A reduction in DKV has been reported after soccer SMs protocol for female soccer players with DKV (from 25.30 to 12.45) (13), and after volleyball SMs protocol for female volleyball players with DKV (from 23.4 to 7.86) (15).In adolescent male soccer players, a significant decrease in DKV (from 20.133 to 11.04) has also been reported after eight weeks of PEP training (25). Also, a combination of feedback and neuromuscular training for 6 weeks resulted in a 6-7 degree decrease in DKV in recreational volleyball and basketball players (27). A review of ACL injury prevention training interventions in young female athletes showed that SMs, PEP, and KIP (Knee Injury Prevention) protocols were successful in preventing non-contact knee and ACL injuries

(28). Whereas single-dimensional ACL injury prevention training programs were unsuccessful in young female athletes (29). Overall, the most effective strategy for ACL injury prevention is to perform comprehensive multicomponent protocols (e.g., SMs) and simultaneously assess the relative risk of injury using neuromuscular screening assessments (e.g., DKV) (30). The present study was also conducted by this strategy, and performing a comprehensive multicomponent protocol (basketball SMs) significantly improved neuromuscular deficit (DKV) and landing technique (LESS score) in athletes prone to ACL injuries (high school basketball girls with DKV).

5. Conclusion

In female basketball athletes, the most common site of injury is the knee, the most common injury is an ACL tear, the most common mechanism is jumping and landing, and the most effective risk factor is DKV. An analysis of the mechanism of injury to the ACL in basketball athletes from 2006 to 2022 showed that the primary mechanism of injury is an increase in DKV (in 71.4% of cases, more than 4 degrees, and in 47.6% of cases, more than 9 degrees) at the time of initial foot contact with the ground until 33 milliseconds later. The results of the present study showed that six weeks of SMs basketball protocol reduced DKV by 35% and landing errors by 47%. Despite the small sample size (30 subjects) and the lack of a long-term follow-up study (6 or 12 months) in the present study, and the need for further studies, due to the promising initial findings, it can be somewhat suggested that SMs basketball is recommended for high school female basketball players with DKV and their coaches. It is recommended to researchers in future research to better understand the kinetics and forces during jump-landing, to evaluate using a force plate. Also, to investigate the long-term effects of basketball SMs on other factors, such as athletic performance and skill, in addition to DKV and landing technique, in other age groups, and basketball players with other neuromuscular impairments.

Limitations

The present study was conducted on high school female basketball athletes with DKV and investigated the short-term effects of basketball SMs on landing technique and DKV. Therefore, its results cannot be generalized to other age groups, semi-professional and elite levels, and male basketball players because landing technique and types of neuromuscular impairments vary across populations.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

Both authors contributed to the initial idea and design of the present study.

Ethical considerations

The guidelines of the Declaration of Helsinki were followed in the present study. Also, ethical approval for this study was obtained from the Research Ethics Committee of the University of Kurdistan with code IR.UOK.REC.1400.037.

The responsible author has fully considered ethical issues, including informed consent, plagiarism, data falsification, infringement and/or distortion, republishing 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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