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Dual Task Reduces Balance Score but not Joint Repositioning Error in Female Athletes with Dynamic Knee Valgus

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SUMMARY

Background. Dynamic knee valgus (DKV) refers to an improper movement strategy of the lower limbs involving multiple planes.

Objective. The present study aimed to examine the impact of dual task conditions on joint repositioning sense in female athletes with DKV.

Methods. This controlled laboratory investigation involved 31 volunteered female athletes who met specific criteria for inclusion and exclusion (17 with DKV, and 14 without DKV). The assessment of DKV was carried out through the Single-Leg Stance (SLS) test. Knee repositioning sense and dynamic balance were measured by using photogrammetric method and y-balance test, respectively. The tests were done on two conditions with and without dual task. Paired samples t-test was used to analyze data t confidence level of 95% ($p < 0.05$).

Results. The knee JPS in the frontal ($p = 0.008$) planes improved while the Y-balance scores in anterior ($p = 0.001$), Posteromedial ($p = 0.003$), and composite score ($p = 0.003$) decreased significantly while perform dual task in female athletes with DKV.

Conclusions. Our results showed that dual task training could improve joint position sense in the frontal plane, but it does not have a clear effect on the joint position sense in the sagittal plane. Moreover, dual task may impair dynamic stability in individuals with DKV.

KEY WORDS

Balance; athletes; knee; proprioception; dual task.

INTRODUCTION

Maintaining proper body posture has always been of interest to health professionals for the preservation of musculoskeletal health (1). Dynamic knee valgus (DKV) refers to an improper movement strategy of the lower limbs involving multiple planes. This pattern includes external rotation of the tibia, inward rotation of the femur, knee abduction, and inward movement of the hip joint (2). DKV is more prevalent in females compared to males, and the likelihood of developing it increases as individuals progress through childhood (3). The dynamic form of knee valgus is considered a risk factor for various lower extremity injuries, including anterior knee pain, anterior cruciate ligament (ACL) sprain, osteoarthrosis, and runner's knee (4-6). The main factors contributing to knee arthritis, in the elderly are the accumulated knee traumas experienced over their lifetime (7). Additionally, knee valgus can be a secondary condition resulting from various factors, such as weak hip abductor muscles, excessive femur antetorsion, internal tibial torsion, an increased quadriceps angle, and inadequate control of hip muscles (8). A dysfunctional sensorimotor system can disrupt the functioning of the neuromuscular system (9). This neuromuscular alteration can result in flawed movement patterns, like DKV, while performing functional tasks (10).

Disruption of joint position sense (JPS), which is a component of proprioception, can contribute to the development of

inaccurate movement patterns. Proprioception is a comprehensive concept that involves perceiving motion in the body and limbs, as well as a sense of body movement and location (11). It constitutes a fundamental aspect of neuromuscular performance (12). Proprioception plays a paramount role in maintaining balance, joint stability, coordination, and preventing injuries (11). Proprioceptive dysfunction in the knee is linked to injuries such as anterior knee pain and ACL injuries (13). Excessive medial knee displacement during dynamic movements due to neuromuscular inefficiency has been identified as a central risk factor for ACL injuries in high-risk sports such as handball, volleyball, basketball, and soccer (14). It seems that DKV is controllable and preventable, and activation of core muscles, strength of hip external rotators and abductors, and neuromuscular control play a major role in this regard (15, 16).

A dual task often entails performing a primary activity while doing a secondary task (17). It includes activities including executive functioning, working memory, attention, and others that can all overtax the brain's cognitive abilities (18). Adult cognitive function decreases with dual tasks (19). Therefore, dual tasks, especially single leg squat (SLS), are impressive for adults.

Previous research has indicated that dual task situations can impair the motor and cognitive function of younger adults and lead to a decline in working memory and executive performance among older adults (20-23). Various methods have been proposed to prevent and improve dynamic knee valgus. For example, research results show that the implementation of comprehensive corrective exercises has a significant effect on improving the sense of proprioception of people with dynamic valgus (24, 25). Also, a study investigated the effects of a neuromuscular training session on the balance and position sense of the knee joint in female athletes with DKV. The results of this study indicated that these exercises could enhance proprioception, suggesting that both strength and proprioception are crucial factors in promoting joint stability and equilibrium (26). Moreover, alterations in position sense during dual task conditions have been studied in individuals with various musculoskeletal conditions, including anterior cruciate ligament injury, low back pain, and chronic ankle sprain (27, 28). It suggests that musculoskeletal injuries may increase the cognitive demands for joint position sense (29).

As mentioned, it's worth noting that many female athletes experience a condition known as DKV. What is concerning is that this condition has been linked to a higher risk of suffering an ACL injury. Furthermore, studies have shown that changes in joint alignment, like DKV, might affect an athlete. These alterations in proprioception appear to influence a person's balance, making them more susceptible to injuries. Additionally, it has been observed that when athletes have to handle cognitive tasks while performing a sports activity, it can affect their accuracy and precision. However, there hasn't been any research paper that has closely examined how these cognitive tasks impact a person's sense of joint positioning and dynamic balance during sport-specific tasks, especially in athletes dealing with DKV. Given the high prevalence of DKV and its potential adverse effects on performance of female athletes, the present research aimed to examine the impact of dual task conditions on joint repositioning sense of female athletes with DKV.

MATERIALS AND METHODS

Participants

In this controlled laboratory study, 31 volunteered female athletes who met specific criteria for inclusion and exclusion (17 with DKV, and 14 without DKV) were recruited. The participants were recruited based on the convenience sampling method. The inclusion criteria were female athletes with an age of 18 to 25 years, demonstrating DKV according to the single-leg squat test (SLS) (30), and athletes who had history of participating in regular exercises for at least 3 years and 3 days a week. Also, the exclusionary criteria were: a history of any type of fracture, surgery and joint diseases in the lower limb or spine in the last five years, having participated in a sports competition at least two days before the test, the presence of significant malalignment in the lower limb based on the New York test (31), the inability to implement the protocol, the presence of pain in any part of the body during the test so that the subject was unable to continue the test, and body mass index (BMI) less than eighteen or more than twenty five. The review board of the research ethics committee of Allameh Tabataba'i University (Code: IR.ATU.REC.1400.032 – Date of approval: August 15, 2021), approved the protocol of the present study. The participants provided written informed consent during a familiarization session and had their height, weight, and BMI measured. The participants were given the assurance that their personal information would be kept confidential and that they could opt-out of the study at any point.

Protocols

The entire data collection process took place in the corrective exercises laboratory at Allameh Tabataba'i University in Tehran, Iran. Participants were required to attend the laboratory on one day. On this day, kinematic data were initially recorded as pre-test measurements. After that, participants followed a predetermined protocol, and immediately after-

ward, photogrammetric data and dynamic balance were measured as post-test measurements.

DKV assessment

The assessment of DKV was carried out through the Single-Leg Stance (SLS) test. During this test, participants' feet were in sagittal plane, and their arms were folded in front of the body, while standing. Each participant performed five repetitions of the SLS test using their dominant leg, which was determined as the leg used to kick the ball (32). Participants underwent training to execute a SLS with a sixty degrees of flexion in the knee joint and then return to the start position. The tempo of SLS was 2-0-2. The time allocated to eccentric and concentric phases was 2 seconds. Having more than three abnormal responses out of the five trials considered as positive SLS. To ensure proper technique, all participants performed the task two to three times. The validity and reliability of SLS test has been reported in a previous study (33). The SLS test has been suggested as a suitable method for evaluating DKV (34).

Knee proprioception measures

Before conducting the tests, each participant's dominant leg was marked with a 10 mm diameter reflective adhesive tape. Then, they were asked to sit upright. To measure the frontal plane knee angle, reflective markers were attached to specific points, including the anterior superior iliac spine (ASIS), the midpoint between ASIS and the middle of the patella (mid-thigh), the midpoint between two malleoli (ankle), and the midpoint between the medial malleolus and the middle of the patella (mid shank). The position of markers was carefully chosen to minimize the potential impact of patellar movement on the valgus angle measurement. The valgus angle was calculated as an angle formed by the intersection of the line connecting the ASIS to the midpoint of the thigh with the line connecting the ankles and the midpoint of the shank markers.

The knee flexion angle in the sagittal plane was assessed using markers positioned on the greater trochanter, the lateral femoral epicondyle, and the lateral malleolus. The angle between two lines, the line connecting lateral femoral epicondyle to greater trochanter and the line connecting the lateral femoral epicondyle to lateral malleolus, is considered as knee angle. All of the reflexive markers were attached to bony landmarks by the same assessor.

A test angle of 60 degrees of flexion in the knee joint was selected because muscles tend to operate most efficiently in the mid-range of movement. In the literature, test angles of 40 degrees and 80 degrees of knee flexion are also commonly used (35). Assessing the accuracy of reproducing a target angle and calculating the discrepancy between the target angle and estimated locations as the output is a valid approach for measuring knee position sensing (36). In this approach, JPS is characterized as the absolute error between the target position and the estimated position (35). Photogrammetric method was used for JPS assessment (**figure 1**). Closed chain assessment of knee JPS was executed, while the target angle was drawn on the wall. The participants executed a SLS on dominant leg with open eyes. When the participants estimated a knee flexion of sixty degrees, images were taken using cameras prepositioned in sagittal and frontal planes (Canon EOS 2000D, Canon, Ōta, Tokyo, Japan). Both cameras situated one hundred and eighty-five centimeters away from the participants and at the height of their knees. The camera height for each participant was adjusted according to their own height, but the distance from the camera to the location of individuals was the same for everyone.

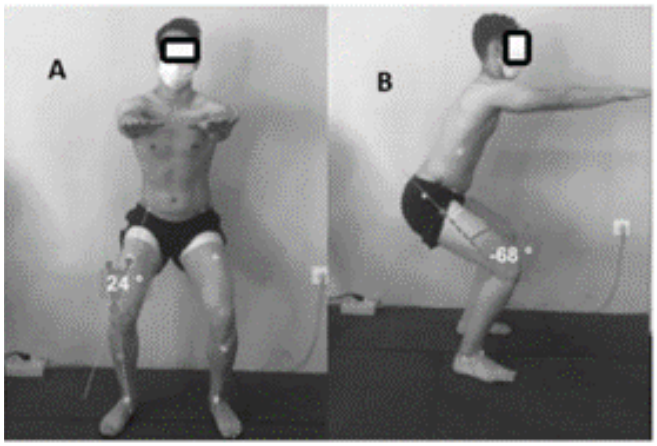

Figure 1. Calculation of knee angle in frontal **(A)** and sagittal **(B)** planes.

After completing three trials, the participant's eyes were bound shut with a band to exclude visual feedback from the assessment. The next step was for each participant to imitate the 60 degrees of knee flexion, hold it for 5 seconds, and then recall this angle. The rest time between trials was 7 seconds. The repositioning error was then determined by subtracting the angles of closed-eye photographs from open-eye photos and determining the absolute values. The average repositioning error obtained from three measurements was utilized for subsequent analysis. The changes in repositioning error were calculated by deducting the repositioning error of the post-intervention from the pre-intervention in each session, and by this way the influence of a specific protocol on the repositioning error was assessed.

Dynamic balance measure

The Y-balance test (YBT) was used for dynamic balance assessment, as used in previous studies. The Y-balance test's validity and reliability have been reported in a previous research, with an ICC (intraclass correlation coefficient) of 0.987 and a 95% confidence interval (37).

The YBT assesses the balance on a single foot and the dynamic neuromuscular control of the lower limbs. It involves a Y-shaped pattern marked on the ground by means of tape, and the participant stands at its center. During the test, the individual stands on one leg, with the fixed foot placed at the center of the Y, while attempting to reach as far as possible in three directions (front, back, and sides) using the tip of the other foot's great toe. Lightly touching the floor during the reach is allowed, but the participant must return to the initial position without completely removing the weight from the fixed foot. A practice phase consisting of six repetitions is permitted to become familiar with the test. If the fixed foot is lifted from the start position, or if the non-supportive foot is used to regain balance, that particular trial is omitted. The YBT is conducted on both legs, starting with the dominant leg as the supportive foot. In each direction, three repetitions were completed, and the maximum distance reached in each direction was recorded as the final score.

To ensure a fair comparison among individuals, the true length of the limb is measured and used to normalize the values obtained during the test. Then for each direction the mean and standard deviation were calculated. Normalization is crucial to account for variations in limb length among athletes. The normalized value is obtained by summing the three range values and dividing the result by 3 times the lower extremity length, which is then multiplied by 100. A difference equal or less than 4 cm between the dominant and non-dominant lower extremity is considered as normal, but larger discrepancies are suggestive of a higher risk of injury.

Dual task

After conducting initial measurements of JPS and dynamic balance, the athletes were given a twenty-minute break. Following the break, they were asked to participate in two study tests involving a cognitive task, specifically a dual task that included backward digit counting. The examiner provided the participants with a verbal calculation just before the start of the tests. Each participant then carefully considered the answer and provided their response to the examiner after completing the study tests. For the addition task, the starting numbers ranged from 50 to 99, and they were presented in a random order using digits generated from a mobile calculator. Additionally, during the study tests, the participants were asked to perform 3-digit subtractions. They had to subtract three digits from the initial number and communicate the results audibly so that the examiner could hear their responses. All tests were instructed by the same examiner and data analyses was run by a statistician who was unaware about the grouping names and desired outcomes.

Statistical methods

The data were analyzed using SPSS (Version 19; IBM, Armonk, NY, USA). Descriptive statistics were used to calculate the mean and standard deviation of the study variables. The normality of the data was assessed using Shapiro-Wilk test. To compare the effect of dual task, the dependent t-test was used. All statistical analyses were done by considering the level of significance at 95% ($\alpha < 0.05$).

RESULTS

In **table I**, the demographic data of the participants are summarized. There were no significant differences between two groups regards to the demographics.

The Shapiro-Wilk test was run to examine the data distribution. The data for all research variables exhibited a normal distribution ($p > 0.05$). Due to the reduction in knee repositioning error angles, the results of paired samples t-test showed that the knee JPS in the frontal ($p = 0.008$) planes improved by dual task. Moreover, the Y-balance scores in anterior ($p = 0.001$), posteromedial ($p = 0.003$), and composite score ($p = 0.003$) decreased significantly while perform dual task in female athletes with DKV, showing the ability to maintaining dynamic balance may decrease with cognitive loads. More information presented in the **table II**.

DISCUSSION

The purpose of the present study was to investigate the Effect of dual task on joint repositioning sense in female athletes with dynamic knee valgus. According to results of the present study, in female athletes with the DKV the dual task program can improve the knee joint reposition sense in

Table I. Demographic data of participants with (n = 17) and without (n = 14) DKV.

Variable	DKV	Without DKV	P-value
Height (cm)	166.59 ± 5.18	164.86 ± 6.55	0.24
Weight (kg)	62.00 ± 4.92	60.36 ± 4.78	0.54
Age (years)	22.24 ± 1.67	22.21 ± 1.67	0.972
BMI (kg/m^2)	22.32 ± 0.96	22.15 ± 1.12	0.67

DKV: Dynamic Knee Valgus; BMI: Body Mass Index.

Table II. The comparison of changes in mean scores using dependent t-test in both groups.

Variable	Group	Pretest mean ± SD	With dual task mean ± SD	t	P-value
JPS Knee abduction	DKV	2.98 ± 1.89	2.02 ± 1.25	3.06	0.008*
	Without DKV	1.64 ± 0.94	2.10 ± 1.76	-1.21	0.248
JPS Knee flexion	DKV	2.38 ± 0.97	2.44 ± 1.13	-0.23	0.823
	Without DKV	3.23 ± 1.74	2.67 ± 1.85	0.912	0.380
JPS Knee abduction	DKV	2.98 ± 1.89	2.02 ± 1.25	3.06	0.008*
	Without DKV	1.64 ± 0.94	2.10 ± 1.76	-1.21	0.248
Y-balance Anterior	DKV	67.48 ± 6.86	65.95 ± 7.02	3.86	0.001*
	Without DKV	68.31 ± 6.93	69.54 ± 7.38	-1.35	0.201
Y-balance Posterolateral	DKV	89.77 ± 7.34	88.21 ± 9.91	1.87	0.080
	Without DKV	94.99 ± 11.44	95.85 ± 11.14	-0.70	0.495
Y-balance Posteromedial	DKV	95.64 ± 10.89	93.10 ± 11.17	3.54	0.003*
	Without DKV	99.58 ± 11.15	100.40 ± 11.57	-0.78	0.452
Y-balance Composite	DKV	84.29 ± 7.86	82.42 ± 8.53	3.55	0.003*
	Without DKV	87.63 ± 8.91	88.60 ± 8.94	-1.04	0.318

DKV: Dynamic Knee Valgus; JPS: Joint Position Sense; *Statistically significant differences were observed.

the frontal plane, but it has no effect on the joint reposition sense of the knee in the sagittal plane. Similar research to the present study was not found, but several researches have been conducted in line with this study (21, 38).

Regards to this study results, some explanations may explain the better knee repositioning sense while performing dual task. Dual task activities could potentially enhance the sensitivity of the intrafusal muscle fibers, leading to an improvement in knee position sense (39). As a result, dual tasking reduces the level of error observed during the measurement of dual task performance. Apart from the peripheral changes in receptors, there might also be some central nervous system changes, such as the central facilitation of neural information and an expanded somatosensory field of proprioception in the sensory cortex, which could be a consequence of engaging in dual task activities (40). According to systems theory, the function of the sensory system in controlling balance depends on the purpose and environmental conditions, and each sensory system can be more important under certain conditions; That is, the superior sensory system at any moment outputs more accurate information about the current environmental situation (41). On the other hand, improper function of the muscles around the knee joint can affect its dynamic stability and put it at risk of injury. It seems that DKV with associated improper muscle function is a risk factor for acute and chronic lower limb injuries (42). But we should keep in mind that our results demonstrated that interestingly, the improved JPS did not associate with better ability of maintaining dynamic balance.

On the other hand, our results showed that the dual task resulted in decreased dynamic balance scores in athletes with DKV. Some explanations are exist to explain this finding. In Kahneman theory of attention, it is suggested that attention is limited and has a fixed central source that cannot be changed, and all activities compete for this source (43). According to this model, also known as the theory of the central source of attention, when performing two tasks simultaneously, attention demands exceed this central capacity (43). For this reason, it seems that the cognitive load may disrupt the performance of other concurrent tasks. The dual task method is developed using the notions of Kahneman's theory, in which the attentional needs of an action or a part of a task are assessed (44). The level of interference in a special task (primary) is evaluated when the person simultaneously executes another task (secondary). The results often reveal that 1) the processing of different tasks is different and 2) the simultaneous execution of tasks can cause an overload on the limited capacity of the attention system (45). In a special type of dual task, the exploration method is also popular. If the exploring phase of the main task is perceived to require the total capacity for attention, the response to the secondary task will be longer than when the person has to only respond to the secondary task. This method has been long used to determine the attention needs of sports skills (46).

For instance, Castiello *et al.* (46) employed dual tasking to identify the temporal differences in attention in several sports tasks, including receiving a volleyball serve, 100-meter run, 110-meter hurdle run, and receiving a tennis serve, the results of which revealed that in tennis and volleyball serve, all stages require attention, but not in equal proportions. Jafarzadeh *et al.* (47) investigated the effect of quadriceps muscle fatigue on knee joint position sense in healthy men. The participants in this study were 34 healthy young people who did not have any problems in muscle strength and joint flexibility at the knee joint. The subjects actively restored the 45-degree flexion angle (target angle) in the knee joint by concentric contraction of the quadriceps muscle. The results showed that fatigue of the quadriceps muscle decreases the accuracy and increases the absolute and constant error of knee joint angle reconstruction in healthy people (47). Also, Shahrjerdi and colleagues investigated the effect of proprioception training on the knee joint position sense of athletes with genu varum. The findings revealed that knee joint proprioception exercises effectively decreased the reconstruction error, indicating an enhancement in proprioception among athletes with genu varum (48). Mirzaee *et al.* reported improvement in balance and joint position sense in participants with DKV as a result of one session of reactive neuromuscular training. The outcomes of this study offer valuable insights for developing injury prevention and rehabilitation strategies targeted at athletes with DKV (26). A dual task condition is a technique used in neuropsychology, where a participant is required to accomplish two tasks concurrently to compare their function with single-task situations. If the scores on one or both tasks are lesser when done simultaneously compared to when done separately, it suggests that the two tasks interfere with each other. This interference implies that both tasks compete for the similar class of information processing resources in the central nervous system (49). Engaging in dual task activities can enhance knee position sense by promoting the restoration of muscle firing patterns' synergy and synchrony needed for dynamic joint stability and precise motor control (50). Another reason for the beneficial impact of dual task exercises on knee position sense is their inherent capacity to enhance cognitive awareness of position and movement of the joint (51).

Therefore, it seems that paying attention to cognitive and sensory-motor characteristics, training with dual task in designing an effective course on the risk factors of dynamic valgus has a positive effect on improving balance and sense of joint position, and also reduces the injury rate. In other words, according to the results of this research, by taking advantage of the characteristic of exercise and consequently challenging the sensory-motor system involved in proprioception, balance, and most importantly, the low cost and availability of the cognitive task reduces the incidence of injuries caused by reducing the balance and sense of joint position, with the design of combined protocols, it has a positive effect on the sense of joint reconstruction and with the aim of improving the reduction of body dynamics and balance.

To investigate the generalizability of the data in this research, it is necessary to consider its limitations more closely. One limitation of this study is its case-study nature, thus leaving the long-term effects of cognitive loads on knee balance and proprioception largely unexplored. Moreover, it is essential to acknowledge that this study was conducted under laboratory conditions, and therefore, caution must be paid when extrapolating its findings to real-world sports settings. Furthermore, it should be noted that there is no consensus among different researchers regarding the likelihood of a relationship between changes in proprioception and the occurrence of lower limb injuries and sports performance. Consequently, it would be unwise to simply correlate alterations in proprioception with an increased likelihood of lower limb injuries in sports.

CONCLUSIONS

The present study aimed to examine the impact of dual task conditions on joint repositioning sense in female athletes with DKV. Our results showed that dual task training could improve knee joint sense of position in the frontal plane, but it does not have a clear effect on the joint position sense in the sagittal plane. Moreover, dual task may reduce dynamic balance in individuals with DKV. It appears that being in competitive conditions and dealing with cognitive loads may potentially impact both sports performance and the likelihood of sports-related injuries. Therefore, it is recommended to consider these findings when providing exercises to athletes with dynamic knee valgus.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

All authors: conceptualization, writing – original draft, writing – review & editing, project administration, data curation.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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