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The impact of lumbar hyperlordosis on dynamic knee valgus during single-leg jump landing and squat in male college football players

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Abstract

Study aim: Dynamic knee valgus is one of the most common reasons for knee instability during functional activities in sports. Lumbar hyperlordosis, as an abnormal posture, is associated with decreased knee stability due to altered neuromuscular function of the lower limb muscles. This study aimed to investigate the impact of lumbar hyperlordosis on dynamic knee valgus during single-leg jump landing and squat in male college football players.
Materials and methods: Thirty male college athletes (15 with and 15 without lumbar hyperlordosis) participated in this study. Dynamic knee valgus was measured using a motion analysis system during single-leg jump landing and squat (descending phase). The independent samples t-test was used to compare the means between the groups (α=0.05).
Results: Athletes with lumbar hyperlordosis exhibited significantly greater knee valgus during both tasks.
Conclusions: Increased dynamic knee valgus angle in athletes with lumbar hyperlordosis may contribute to decreased knee stability and increased injury risk. Coaches and athletes should implement corrective strategies and exercises to prevent injuries associated with dynamic knee valgus in athletes with lumbar hyperlordosis.

Keywords: Lumbar hyperlordosis – Dynamic knee valgus – Landing – Squat

Introduction

The knee joint, being the largest synovial joint, is susceptible to injury due to its complex structure and exposure to significant forces during weight-bearing activities, especially in sports. Knee injuries, particularly non-contact injuries such as ACL tears, are prevalent among athletes (Motififard et al., 2024). The causes of such non-contact and overuse injuries are multifactorial. Abnormal lower limb alignment during exercise is a significant risk factor for these injuries (Beynnon et al., 2023). Alterations in hip, knee and ankle joint dynamics can lead to dynamic knee valgus and instability, increasing the risk of knee injury.

Researchers have suggested that an increase in hip internal rotation and adduction may be associated with dynamic knee valgus and may lead to knee injuries (Chuter & Janse de Jonge, 2012; Powers, 2003). In addition, changes in the tibial rotation during dynamic activities may be associated with knee instability (Chuter & Janse de Jonge, 2012). Furthermore, foot pronation and decreased foot longitudinal arch height can contribute to tibial internal rotation and increased knee valgus during continuous dynamic activities (Yoo et al., 2022).

On the other hand, the trunk posture and movements are contributing factors to knee joint stability and dynamic knee valgus (Leetun et al., 2004). Increased lumbar lordosis is associated with spinal instability, but its consequences are not specific to the local areas. It can progress to the anterior pelvic tilt, which may alter the alignment of the lower extremities as well (Been & Kalichman, 2014). This relationship between the pelvic angle in the sagittal plane knee alignment is due to the functional anatomy of the hip joint (Khamis & Yizhar, 2007). The hip internal rotation may move the hip anatomical axis, which adducts the femur and abducts the tibia, leading to knee abduction (Khamis & Yizhar, 2007). Many studies have shown a higher incidence of lumbar hyperlordosis in athletes (Franz et al., 2009; López-Miñarro et al., 2010; Wojtys et al., 2000).

Considering the kinetic and kinematic chain reaction in the joints, changes and deviations in one joint may cause changes and deviations in the adjacent joints and ultimately lead to injury. While an association between lumbar hyperlordosis and knee valgus has been suggested, direct evidence is limited. Therefore, this study aimed to investigate the impact of lumbar hyperlordosis on dynamic

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knee valgus during single-leg jump landing and single-leg squat.

Materials and methods

Thirty male college football players (15 subjects with lumbar hyperlordosis and 15 with normal lumbar lordosis) were recruited. This study was in compliance with the Declaration of Helsinki and obtained ethics committee approval. All the participant signed the written informed consent prior to the tests. Male participants were included if they were collegiate team members with 3–5 training sessions per week, between 20 and 25 years old, with no history of lower limb, spine, or knee injury within the past six months, lower extremity malalignments or reported pain in these regions and excluded if they were unable to perform the tests or experiencing pain in the lower extremity on the test day or if they did not consent to continue participation in any phase of the study.

Lumbar hyperlordosis was measured using a 30 cm flexible ruler (flexicurve) according to the Youdas method (Youdas et al., 2006). The validity and reliability of the device were ICC = 0.91 and ICC = 0.81, respectively (Seidi et al., 2009). According to the Youdas method, the T12 and S2 spinous processes were located by palpation. Afterward, a flexible ruler was molded gently to the lumbar spinal curvature in a natural standing position and the location of T12 and S2 were marked on it. Then the curvature (from T12 to S2) was transferred to paper, and the length (L) and depth of the deepest point of the arch (H) were measured. The lordosis angle was calculated using the formula $\theta = 4 \cdot \arctan(2H/L)$, where θ is the lordosis angle and H and L are the depth and length of the curvature, respectively (Youdas et al., 2006). Lumbar hyperlordosis was considered a lumbar lordosis angle higher than 47 degrees, according to a previous nation-wide study (Rajabi & Latifi, 2010).

The kinematic measurements were performed using a Vicon motion capture system (Vicon Motion Systems, Oxford, United Kingdom) with 6 Bonita 10C cameras with the sampling rate of 240 Hz in the sports biomechanics laboratory of the Faculty of Physical Education and Sports Sciences, University of Tehran. Sixteen passive reflective skin markers were attached to the subject's body according to the plug-in gait marker set (4 markers on the left and right ASIS and PSIS, 2 markers on lateral femur epicondyles, 2 markers on the upper 1/3 of the right lateral and two markers on the lower 1/3 of the left medial sides of the thighs, 2 markers on the upper 1/3 of the right lateral and two markers on the lower 1/3 of the left medial sides of the shanks, 2 markers on the lateral malleolus, 2 markers between the 2^{nd} and 3^{rd} metatarsals, and 2 markers on the left and right calcaneus) (Baker et al., 2009; Davis III et al., 1991). The static pose was first captured for two seconds (Munro et al., 2012 18). Dynamic tests were performed after an initial 3–5 minutes warmup. The dynamic functional tasks included single-leg jump landing and single-leg squat on the dominant side. All the participants performed 5 single-leg trials from a single-leg standing position to 60° knee flexion. In order to control the speed of movement, the pacing was controlled using a metronome with a rate of 60 beats per minute, and the person had to descend in two beats and ascend again in two beats. The depth of the squat task to 60° was determined by placing a block behind the participant, and the gluteal muscles contacted the block at 60° knee flexion. The non-dominant leg was held with 90° knee flexion and 45° hip flexion during the whole task. The test was considered successful if: 1) the person maintained the correct position during the test; 2) he performed the test at the predetermined pace; 3) the suspended leg did not touch the ground; 4) the heel of the dominant foot rested on the ground (Figure 1) (Mauntel et al., 2014).

For the single-leg jump-landing test, the individuals were asked to stand on a 40-centimeter step with their hands on their iliac crest. Then they were asked to bend the test leg (dominant leg) knee in a relaxed position, while the other foot remained on the step. The individuals were then instructed to jump up and land on the test leg, maintaining balance for 3 seconds (Mauntel et al., 2014) (Figure 2).

Data were analyzed using Microsoft Excel 2013 and SPSS version 21. The Shapiro-Wilk test was used to check the normality of the data, and the independent sample t-test was used for between-group comparisons ($\alpha = 0.05$).

Results

Table 1 presents the demographic characteristics of the participants. As shown in Table 2, there was a significant difference in the lumbar lordosis angle between the two groups ($p \leq 0.05$).

There were significant differences in the knee dynamic valgus angle between players with and without increased lumbar lordosis during both the single-leg squat task (p = 0.029) and the single-leg jump-landing task (p = 0.047). Players with a normal lumbar lordosis angle showed significantly lower (6.423 degrees and 8.921 degrees) knee dynamic valgus than the players with lumbar hyperlordosis, during the single-leg squat and single-leg jump landing, respectively.

Discussion

This study aimed to compare knee kinematics in male university football players with and without lumbar hyperlordosis during functional activities. Our findings revealed a significantly larger knee dynamic valgus in athletes with lumbar hyperlordosis during both single-leg squat and single-leg jump-landing tasks. This indicates that individuals with this condition may have reduced knee stability, which is a potential risk factor for lower extremity injuries.

Figure 1. Single-leg squat task, left: starting position, right: ending position

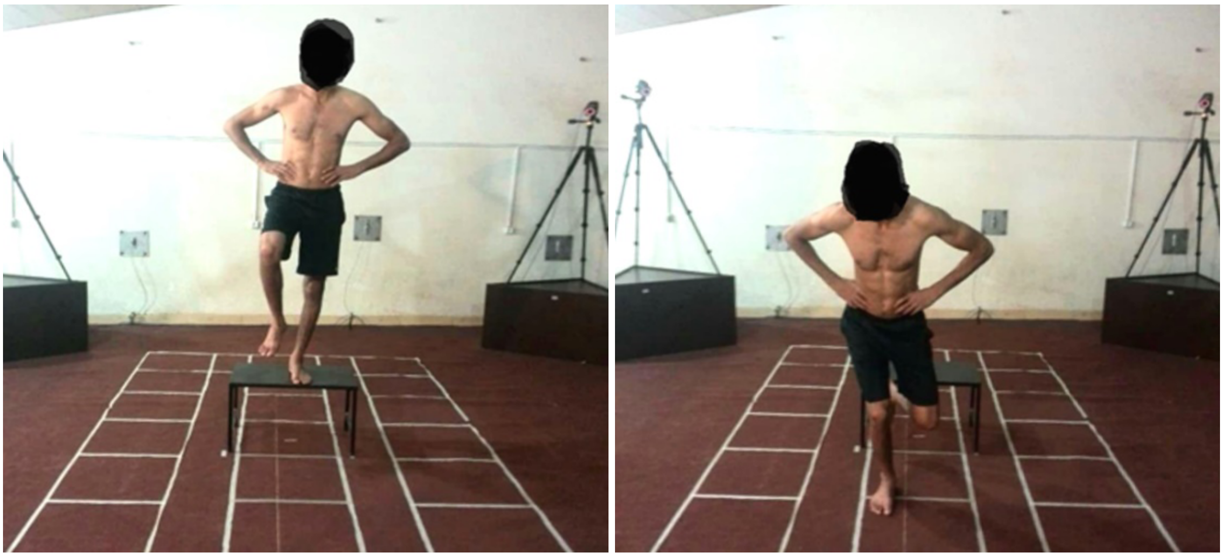

Figure 2. Single-leg jump-landing task, left: starting position, right: ending position

Table 1. Demographic characteristics

Participants	Age (year)	Height (cm)	Weight (kg)
Lordosis	22.53 ± 1.68	176.60 ± 4.28	78.93 ± 4.69
Hyperlordosis	22.66 ± 1.79	177.67 ± 3.47	77.46 ± 5.31

Our results align with previous research indicating that lumbar hyperlordosis can influence lower extremity alignment and function. For example, a study on older adults performing back squats identified lumbar hyperlordosis and knee valgus as common biomechanical errors, suggesting a link between excessive lumbar curvature and knee alignment (Papadakis et al., 2024). Similarly, Jankowicz-Szymańska et al. (2020) found that valgus knees occurred more frequently and were associated with decreased thoracic kyphosis, highlighting the interconnected-

Table 2. Comparison of lumbar lordosis and knee dynamic valgus in single-leg squat and single-leg jump landing in players with and without lumbar hyperlordosis

Variable	Normal lordosis group (mean ± sd)	Hyperlordosis group (mean ± sd)	Mean difference	*t*	*p*-value
Lumbar lordosis (degree)	50.80 ± 3.33	41.60 ± 5.59	6.652	2.102	0.030
Knee dynamic valgus during single-leg squat (degree)	2.90 ± 7.54	−3.51 ± 7.79	6.423	2.294	0.029
Knee dynamic valgus during single-leg jump-landing (degree)	2.46 ± 11.49	−6.46 ± 9.06	8.921	2.083	0.047

ness of spinal curvature and knee positioning (Jankowicz-Szymańska et al., 2020). In addition, our results partially align with previous research by Hashemi Moghaddam et al. (2017), who reported increased angular displacement and velocity at the hip and ankle joints, as well as a larger knee dynamic valgus during gait in women with hyperlordosis (Hashemi-Moghaddam et al., 2017). While the tasks assessed in our study differed, both studies consistently found increased knee valgus angles in individuals with lumbar hyperlordosis. Researchers have suggested that insufficient neuromuscular control of the trunk may contribute to decreased lower extremity stability, leading to increased adduction moments at the knee and potentially higher strain of the knee ligaments. This relationship can be explained by the association between increased lumbar lordosis and anterior pelvic tilt. Anterior pelvic tilt is often accompanied by changes in lower extremity alignment, such as increased knee valgus and hyperextension of the knee. Consequently, these alterations in lower extremity alignment, resulting from increased lumbar lordosis, can contribute to increased knee dynamic valgus and instability (Souza & Powers, 2009).

While numerous studies have investigated the association of lumbar lordosis and various variables, many have focused solely on the alignment and correction of the curvature (Chuter & Janse de Jonge, 2012; Powers, 2003). Some studies have also explored muscular changes in this region, such as muscle length, activation patterns, and imbalances (Jafarnezhadgero & Alavi Mehr, 2019). However, our findings suggest that changes in the lumbopelvic alignment are not limited to local tissue and functional changes within the region but can also affect adjacent regions due to the interconnected nature of the musculoskeletal system (Baldon et al., 2011). The relationship between lumbar hyperlordosis and dynamic knee valgus can be attributed to altered biomechanics and neuromuscular control. Excessive lumbar lordosis is associated with an anterior pelvic tilt, which can lead to compensatory mechanisms affecting lower extremity alignment. This altered posture may increase strain on the intervertebral discs and facet joints, potentially contributing to knee valgus during activities such as squatting (Papadakis et al., 2024).

Furthermore, the sensory input from deep tissue receptors is altered due to the biomechanical changes associated with anterior pelvic tilt and increased lumbar curvature. This disruption in sensory input can lead to impaired motor control and, ultimately, decreased stability in the lumbopelvic region (Padua et al., 2012). Page et al. (2010) demonstrated that trunk muscle activity precedes lower extremity movement and is independent of movement direction as well. Therefore, weakness in the core muscles associated with lumbar hyperlordosis may delay the activation of lower extremity muscles, impairing function. Our findings support this hypothesis, as we observed increased valgus angles in the functional tests.

Researchers have shown that both trunk and lower extremity muscles are activated before ground contact during jumping and landing tasks. Neuromuscular coordination between the trunk and lower extremities plays a crucial role in functional activities such as force absorption, trunk stabilization, force production, and movement control during jumping (Donohue et al., 2015). Given that lumbar hyperlordosis can alter lower extremity alignment, the neuromuscular coordination between the trunk and lower extremities may be disrupted during jumping and landing tasks. This disruption can lead to compensatory strategies that increase the risk of injury, as evidenced by the increased valgus angles observed in our study.

The study has limitations, including a sample size of 30 male football players, limiting generalizability, and a cross-sectional design that prevents causal conclusions. Confounding variables such as muscle strength were not controlled for. The study findings are limited to the two functional tasks, and we suggest assessing more sport-specific movements in the future. Additionally, the study lacked follow-up injury data, which could be gathered in future studies. Addressing these limitations in future research would enhance the findings' robustness.

Conclusion

We observed that football players with lumbar hyperlordosis exhibited significantly larger knee dynamic valgus angles during functional tasks. This increased valgus angle may contribute to decreased knee stability and potentially increase the risk of lower extremity injuries. Therefore, implementing appropriate corrective exercises for the core muscles before and after injury can help prevent the occurrence of such injuries.

Conflict of interest: Author state no conflict of interest

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