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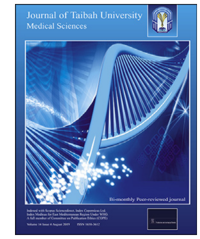

Original Article

The effects of foot position on lower extremity kinematics during single leg squat among adolescent male athletes

Norain Mohd Azhar, BSc, Nor Fatinah Affandi, BSc, Mohamad Saufi Zuhan Mail, BSc and Shazlin Shaharudin, PhD *

Exercise & Sports Science Program, School of Health Sciences, Universiti Sains Malaysia, Kota Bharu, Malaysia

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الملخص

أهداف البحث: حققت هذه الدراسة في تأثير وضع القدم في المستوى العرضي على حركيات الأطراف السفلية أثناء القرفصاء بساق واحدة.

طرق البحث: أُجريت هذه الدراسة المقطعية بين رياضيين ذكور مدربين تدريبا عاليا. وتمت إضافة فقط المشاركين من ذوي الركبة الطبيعية الروحية عند اختبار الهبوط الإسقاطي الفحصي. قام ١٢ رياضيا مبتدئا بالتقرفص بساق واحدة، مع الحفاظ على زاوية انثناء الركبة عند٦٠ درجة. طُبقت جلسات القرفصاء بثلاثة أوضاع للقدم: المعتدل (صفر درجة)، وتقريب القدم (-١٠ درجة)، وإبعاد القدم (+١٠ درجة). استخدم التحليل الحركة ثلاثي الأبعاد لالتقاط القياسات الحركية للطرف السفلي المفضل لدى المشاركين. تمت مقارنة القياسات الحركية للورك والركبة في المستويات السهمية والجبهية والعرضية أثناء القرفصاء وعلى ثلاثة أوضاع للقدم باستخدام تحليل التباين أحادي الاتجاه "أنوفا".

النتائج: ظهر لدى المشاركين معدلا طبيعيا من الركبة الروحاء الديناميكية [٥.٣ درجة (± ١.٦)]. لم تُلاحظ أي فروق ذات دلالة إحصائية في انثناء الورك، وتقريب الورك والدوران الداخلي عبر أوضاع مختلفة للقدم. وبالمثل، لم يُلاحظ وجود فروق ذات دلالة إحصائية في ثني الركبة، وتقريب الركبة والدوران الداخلي عبر أوضاع مختلفة للقدم.

الاستنتاجات: لا تؤثر التغييرات الصغيرة في وضع القدم في المستوى العرضي على حركيات الطرف السفلي عند القرفصاء بساق واحدة عند الذكور المراهقين المدربين تدريبا عاليا أثناء وضعية الركبة الروحاء الديناميكية ضمن النطاق الطبيعي. وقد توفر نتائجنا إرشادات حول أساليب أكثر أمانا للهبوط، والتمحور والقطع أثناء التدريب والحالات المتعلقة بالألعاب.

الكلمات المفتاحية: السلسلة الحركية من أسفل إلى أعلى؛ أروح الركبة الديناميكية؛ الشباب؛ القرفصاء

Abstract

Objectives: The purpose of this study was to investigate the effect of transverse plane foot position on lower limb kinematics during a single leg squat.

Methods: This was a cross-sectional study conducted among highly-trained male athletes. Only participants who showed normal knee valgus during a drop landing screening test were recruited. Twelve junior athletes performed single leg squats while maintaining a knee flexion angle of 60°. The squats were executed in three foot positions: neutral (0°), adduction (−10°), and abduction (+10°). Three-dimensional motion analysis was used to capture the lower extremity kinematics of the participants' preferred limb. The hip and knee kinematics in the sagittal, frontal, and transverse planes during squatting were compared across the three foot positions using one-way ANOVA.

Results: The participants showed a normal range of dynamic knee valgus (5.3°±1.6). No statistically significant differences were observed in hip flexion ($p = 0.322$), adduction ($p = 0.834$), or internal rotation ($p = 0.967$) across different foot positions. Similarly, no statistically significant differences were observed in knee flexion ($p = 0.489$), adduction ($p = 0.822$), or internal rotation ($p = 0.971$) across different foot positions.

Conclusion: Small changes in transverse plane foot position do not affect lower extremity kinematics during single leg squat in highly trained adolescent males with normal dynamic knee valgus. Our findings may provide guidance on safer techniques for landing, pivoting, and cutting during training and game situations.

* Corresponding address: Exercise & Sports Science Program, School of Health Sciences, Universiti Sains Malaysia, 16150, Kota Bharu, Kelantan, Malaysia.

E-mail: shazlin@usm.my (S. Shaharudin)

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Introduction

Sports that require cutting, pivoting, landing, or sudden deceleration prior to changing direction commonly result in non-contact injuries to the knee joint.[1] This type of injury is associated with weak lower extremity alignment during dynamic tasks and is often referred to as excessive dynamic knee valgus (DKV).[2] DKV can be defined as a combination of hip adduction, hip internal rotation, knee flexion, knee external rotation, knee abduction, ankle inversion,[3] and ankle dorsiflexion.[4] Moreover, DKV can be distinguished as a body position in which the knee collapses medially from internal-external rotation and/or excessive valgus.[2]

Excessive DKV can be assessed using different screening tests including single leg squat (SLS), drop vertical jump (DVJ), drop landing, and single leg landing.[5] During these tests, excessive DKV can be quantified by evaluating two-dimensional (2D) frontal plane projection angle (FPPA) of the knee joint. For example, the typical range 2D knee FPPAs during DVJ are between 7° and 13° in females, and 3° and 8° in males.[5] Subjects who exceed these angles may be demonstrating kinematics that have an increased risk of non-contact knee injuries, such as patellofemoral pain syndrome (PFPS) and ACL strain.[2,3,5–8] In addition, these tests simulate common motions in sports. For example, the DVJ test mimics the demands of high-acceleration motions that are common in sports with jump-landing tasks, such as soccer, netball, and rugby.[2] Meanwhile, the SLS test can simulate functional activities, gait, and motions performed in sports such as running, hockey, and soccer.[9] SLS is also a reliable clinical evaluation that is commonly used to identify lower limb misalignment, muscle weakness, and core strength deficiencies.[10,11]

Joint movements of the lower extremities are interdependent during closed chain activities, whereby excessive motion at a joint can overload tissues in the subsequent joints of a kinetic chain.[12,13] DKV often has proximal lower limb origins consistent with a top-down kinetic chain, such as hip muscle weakness or trunk control deficits.[14] In particular, weakness or aberrant motor control of the hip abductors and external rotators has been implicated in the development of knee injuries.[14,15] Excessive or aberrant motions at the transverse and frontal planes of the hip joint may cause tibia abduction, foot pronation, and medial motion of the knee joint, all of which indicate DKV.[16] Thus, diminished core and hip muscle strength are related to DKV, and can further affect the kinematics of the entire lower extremity.[14,16] Indeed, during SLS, hip muscle weakness has been associated with greater medial knee displacement.[14,17]

By contrast, a bottom-up kinetic chain contradicts the top-down kinetic chain. A bottom-up kinetic chain is concentrated on the ankle joint, and suggests that an increase of strength, especially in small muscles crossing the ankle joint, may affect movements and joint moments in the ankle, knee, and hip joints.[18] Due to the mitered hinge design of the ankle, increased rearfoot pronation results in greater tibial internal rotation and knee valgus.[18] Hence, foot position is also an adjustable factor that could improve excessive DKV, and further reduce the risk for associated lower limb injuries. For instance, Ishida et al.[19] noted that knee rotation during SLS in young females is associated with toe direction, whereas Khamis and Yhizar[20] observed that ankle eversion caused tibial internal rotation to occur during foot hyperpronation and natural standing. Foot hyperpronation has also been positively associated with traumatic knee injury.[21] In addition, the relationship between limited ankle dorsiflexion range of motion (ROM) and PFPS has been described by Piva et al.[22] Moreover, a recent meta-analysis showed that reduced dorsiflexion ROM was consistently present among individuals with DKV compared to controls, regardless of whether the method of evaluation used weight bearing or non-weight bearing ROM.[23]

Despite the importance of identifying DKV among athletes, its bottom-up kinetic chain has not yet been established, particularly during SLS. Excessive DKV is most likely caused by a combination of hip and ankle muscular strength imbalance. Therefore, comprehensive strategies that focus on the joints that are proximal and distal to the knee should be investigated.[24] This is crucial to determining whether or not knee alignment can be modified during functional tasks.[24] In addition, previous studies on SLS kinematics mostly involved female subjects who were not screened for excessive DKV, which may have influenced the findings. However, the bottom-up kinetic chain during SLS among physically active males has not yet been investigated. Consequently, this study was conducted to investigate the effects of foot position on hip and knee kinematics during SLS, in state-level male adolescent athletes who exhibited a normal range of DKV.

Materials and Methods

Subjects

This study used a cross-sectional design with purposive sampling. A sample size of 12 participants was determined a priori using GPower software (v.3.1.9.2), based on one-way ANOVA with the p-value set at 0.05. The effect size was calculated based on the association of foot position with knee kinetics and kinematics.[19]

All participants were recruited voluntarily through their team's coach. The details of the study methodology were provided and explained to each individual prior to their participation. Participants were encouraged to decide whether or not to participate without the influence of their coach. The study was conducted at a sport science laboratory of a local university. The duration of participation was approximately 30 min for the screening test, and 1.5 h for the 3D SLS test. The test sessions were conducted on separate days, with at least 24 h of rest between sessions.