IS FRONTAL PLANE PROJECTION ANGLE RELATED TO STIFF LANDING PATTERNS? AN ANALYSIS OF DROP JUMP AND TUCK JUMP TASKS

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The purpose of this study was to examine the relationship between frontal plane knee projection angle (FPPA) and sagittal (hip and knee flexion) plane landing kinematic measures during a drop jump (DVJ) and a tuck jump assessment (TJA) test in male youth football players. Eighty-one post-pubertal male footballers were recorded performing DVJ and TJA tasks, and FPPA as well as hip (HF) and knee (KF) flexion angles at peak flexion were retrospectively assessed. The main results show that players with greater knee FPPA (valgus) display lower HF values than players with no knee valgus alignment during DVJ landings, but not during TJA. A DVJ pattern which exhibits knee valgus and limited HF angles may increase the risk of knee injury and thus, strategies for hip strengthening and technique modification should be applied to players with this mechanical profile.

KEYWORDS: anterior cruciate ligament, soccer, kinematic, young athletes.

INTRODUCTION: Knee injuries are common among individuals participating in team sports (Griffin et al., 2006). In most cases, knee injuries (including anterior cruciate ligament [ACL] tears) occur in athletes by non-contact mechanisms (Della Villa et al., 2020). Some situational patterns of increased risk of injury have been identified for team sport athletes who suffered a non-contact knee injury, including landing from a jump (Della Villa et al., 2020). The adoption of an excessive dynamic valgus motion at the knee and stiff landings (i.e., less peak hip and knee flexion) have been identified as one of the dominant injury patterns during the execution of jumping and landing tasks (Yu & Garrett, 2007). Likewise, limited hip and knee flexion during landings have also been associated with increased dynamic knee valgus in female youth footballers (Pollard et al., 2010), which may increase even more the likelihood of suffering a severe knee injury. However, whether (or not) such inverse association between sagittal and frontal plane knee kinematics at landing might also occur in male youth football players is still unknown.
The DVJ test has been commonly used as a screening task to identify athletes who adopt inappropriate lower extremity movement patterns associated with knee injuries (Leppänen et al., 2017). Recently, the TJA has also been proposed for a comprehensive assessment of landing mechanics. However, few researchers have quantitatively assessed lower extremity kinematics during the TJA (Robles-Palazón et al., 2021) and none of them have explored potential association between frontal and sagittal plane movements. Therefore, the aim of this study was to examine the relationship between frontal (knee FPPA) and sagittal (HF and KF) plane landing kinematic measures during a DVJ and a TJA in male youth football players. Additional analyses were included to identify potential differences in sagittal plane measures for those individuals who display (or not) deficits in frontal plane knee kinematics.

METHODS: A cross-sectional observational design was used. Eighty-one male youth football players (16.7 ± 1.1 years; 177.2 ± 6.7 cm; 67.9 ± 8.6 kg; 2.3 ± 0.8 years from peak height velocity [PHV]) completed this study. Participants met the following inclusion criteria: 1) engaged regularly in football training and competitions, 2) were free of musculoskeletal injuries and delayed onset muscle soreness at the time of testing, and 3) had passed PHV (i.e., players at post-PHV stage, using the equation of Mirwald et al., 2002). A standardised dynamic warm-up was performed before data collection. After 3 familiarisation repetitions, participants performed 2 DVJ trials from a 40 cm height box and a single TJA trial (which involves repeated tuck jumps for a period of 10 s). Two-dimensional video cameras (Panasonic Lumix DMC-FZ200, Japan) sampling at 100 Hz were positioned in both frontal and sagittal planes to capture the tests, and players' landing technique was retrospectively analysed through Kinovea (v. 0.8.15, USA). For each video, knee alignment (valgus *vs*. varus) in the frontal plane at the point of maximum knee flexion (FPPA), as well as HF and KF angles at peak flexion (i.e., the deepest landing position) in the sagittal plane were calculated for players' dominant leg (i.e., preferred kicking leg) by the same researcher following the methodology previously described (Robles-Palazón et al., 2021) (Figure 1). For the DVJ, the first landing (i.e., the rebound jump phase) was considered for the analysis. Values >0º were indicative of knee valgus, whereas values ≤0º represented neutral (0º) and knee varus (i.e., negative values) alignments. The mean values over the 2 trials for the DVJ, and the mean of the 2 worst repetitions (maximum FPPA scores) identified across the period of 10 consecutive seconds during the TJA were used for analysis.

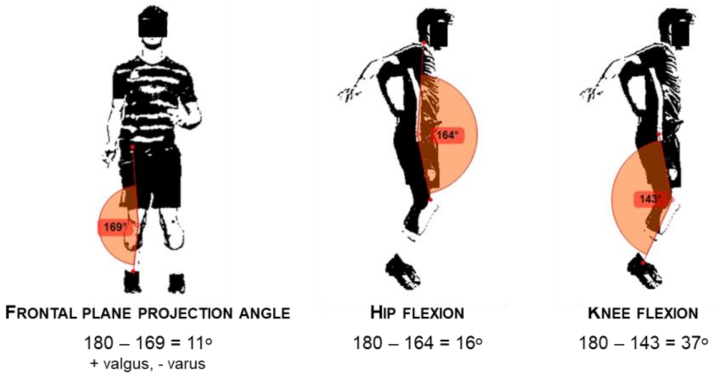

Figure 1: Frontal and sagittal plane kinematic variables measured during DVJ and TJA tests.

Before conducting statistical analysis, intra-rater reliability for all kinematic measures was assessed using a two-way random intra-class correlation coefficient ($ICC_{2,1}$) with absolute agreement on a randomly selected sub-section of the participants involved in this study (n = 25). To do this, videos were evaluated on 2 occasions separated by a week. Large ICCs (>0.92, 95%CIs: 0.75-0.99) revealed good-to-excellent reliability for all measures assessed.

The distribution of raw data sets was checked using the Kolmogorov-Smirnov test and demonstrated that all data had a normal distribution ($p > 0.05$). Descriptive statistics, including means and standard deviations (SDs), were calculated for all measures. To determine the strength of relationship between frontal and sagittal plane lower extremity kinematics, the Pearson's correlation coefficients (r) were calculated. Magnitudes of correlations were assessed using the following scale of thresholds: <0.8 low, 0.8-0.9 moderate, and >0.9 high (Hopkins, 2000). To examine potential differences between valgus (>0º) *vs.* no valgus (≤0º) group in HF and KF angles, an independent sample t-test was used. Cohen's d effect sizes were also calculated to interpret the magnitude of differences between valgus and no valgus groups using the following classifications: <0.2, trivial; 0.2-0.5, small; 0.5-0.8, moderate; >0.8, large (Cohen, 1988). In addition, the proportion of athletes with valgus/no valgus who also show low KF and HF was calculated. For this purpose, players were divided into groups based on their peak KF and HF angles during the landing tasks. However, there is a lack of robust cut-off scores to identify athletes at high risk of loading the knee joint based on these sagittal kinematic variables. The mean HF and KF angles reported for injured players by previous prospective studies (Della Villa et al., 2020; Leppänen et al., 2017), together with the authors' extensive experience in screening athletes, were then used to define a high or low flexion pattern during the DVJ. For the TJA, there are a lack of prospective studies in which the landing mechanics have been quantitatively analysed. Therefore, and considering the different landing technique showed during the DVJ and TJA tasks in the sagittal plane measures, mean differences between both tests for HF and KF were considered for the cut-off score selection in the TJA (Robles-Palazón et al., 2021). As a result, participants who exhibited HF values ≥60º in the DVJ and ≥30º in the TJA were assigned to the high HF group. For KF, values ≥75º in the DVJ and ≥55º in the TJA were used to classify players at high KF landing group. Those players who exhibited values below these figures were assigned to the low flexion groups. Chi-squared (χ^2) test was used to examine the existence of a relationship between the frontal plane (valgus and no valgus) and sagittal plane (low and high flexion) groups. The α level was set at < 0.05. All statistical analyses were performed using the JASP computer software (version 0.13.1).

RESULTS: Correlation analyses showed low relationship (all *r* values < 0.3) between FPPA and HF, as well as between FPPA and KF measures for both DVJ and TJA tests (Figure 2). When comparing valgus *vs.* no valgus groups, the t-test analysis reported lower HF angles for players classified in the valgus group during the DVJ (58.6º for valgus group *vs*. 66.6º for no valgus group; $p = 0.03$; $d = 0.53$). No differences ($p > 0.05$) between valgus and no valgus groups were found for HF and KF during the TJA (Figure 3). Finally, the proportion analysis conducted in this study found that in approximately 62% of youth football players with knee valgus alignment a low HF pattern is also shown during the DVJ ($\chi^2 = 5.242$; $p = 0.02$). No differences were found for HF between valgus and no valgus groups in the TJA neither for KF in both tests ($\chi^2 = 0.264$–1.545; $p > 0.21$) (Figure 4).

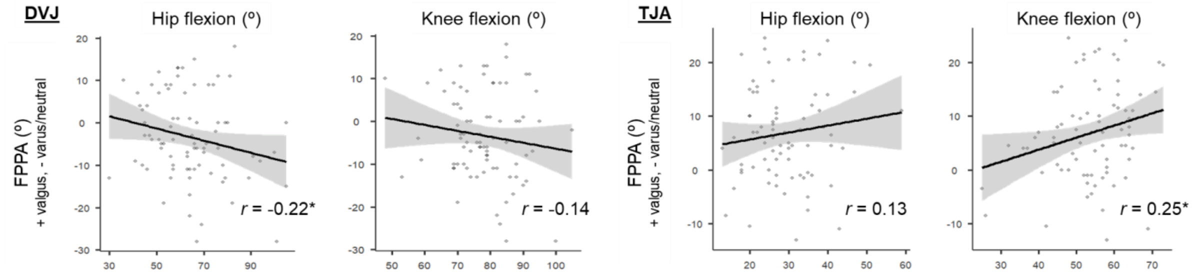

Figure 2: Correlation measures of frontal and sagittal plane variables in the DVJ and TJA tests.

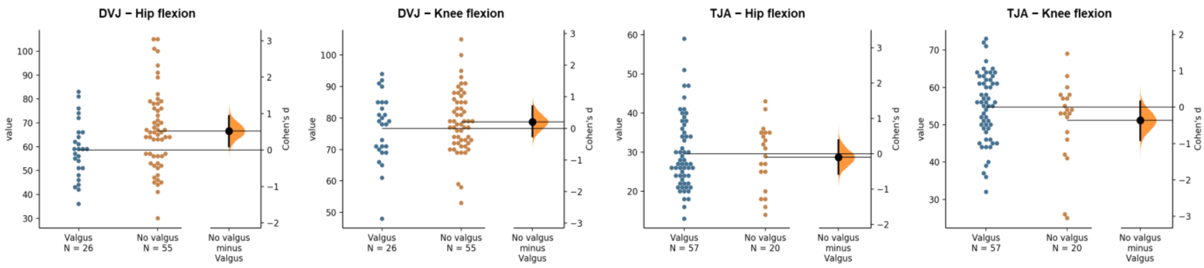

Figure 3: Gardner-Altman estimation plots for comparisons between valgus and no valgus groups for sagittal plane measures.

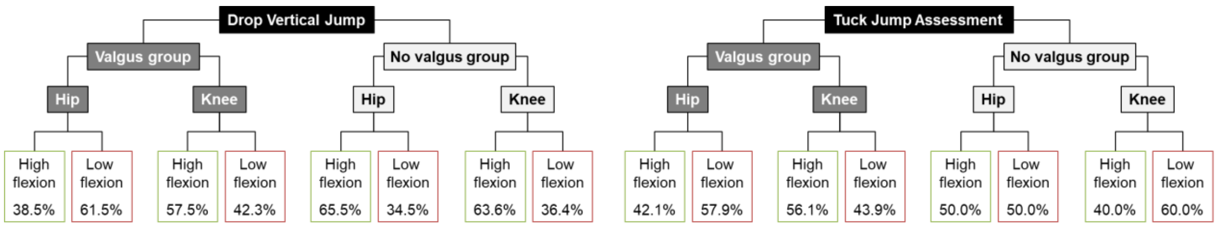

Figure 4: Proportion of players with valgus or no valgus in the frontal plane and low or high flexion in the sagittal plane during the DVJ and TJA tests.

DISCUSSION: This study reveals that there is no relevant association between knee FPPA and sagittal plane peak HF and KF in the landing phase of the DVJ and TJA tests ($r < 0.3$). However, when the values of the FPPA obtained from both tasks were categorised as valgus or no valgus, our results showed significant differences in the magnitude of HF during the DVJ. Most players who present knee valgus during landing from a DVJ in the frontal plane adopted also a lower HF pattern in the sagittal plane. These results are in agreement with previous studies examining relationships between frontal and sagittal plane kinematics during DVJ landings in female athletes (Pollard et al. 2010). Increased ACL strain is a result of three loads applied to the knee (e.g., valgus and rotation moments, and anterior shear force). Reduced HF has shown to be a predictor of greater anterior shear forces during the landing phase of a drop jump (Shultz et al., 2009). Therefore, and although still under discussion (Collings et al., 2021), the combination of both frontal and sagittal plane deficits might be viewed as a potential high-risk biomechanical profile that could predispose to knee injuries. Furthermore, when the sagittal plane variables were categorised (high *vs.* low flexion groups), our results documented that 62% of players with knee valgus also showed a limited HF pattern. It has been suggested that poor strength of the sagittal plane musculature (i.e., hip extensors) may contribute to this landing strategy of less HF (Pollard et al. 2010). Athletes with weak hip extensors may rely more on their passive structures (i.e., ligaments) to decelerate their body centre of mass in the frontal plane. Thus, the development of neuromuscular control training programs in players to reduce both valgus and stiffer landing techniques is essential. These programs should incorporate a combination of trunk and lower extremity strength, dynamic stability and plyometric exercises (Griffin et al., 2006).

CONCLUSION: Post-pubertal footballers with greater FPPA (knee valgus) display a lower HF pattern than players with no knee valgus alignment during DVJ landings, but not during TJA. This DVJ landing strategy may notably increase the risk of knee injury. Hence, strategies for hip strengthening and technique modification should be applied to permit reductions in knee FPPA and increases in KF and HF in players with this mechanical profile.

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