Clinical Biomechanics 31 (2016) 107–112

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Technique determinants of knee abduction moments during pivoting in female soccer players

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A R T I C L E I N F O

Article history:
Received 30 April 2015
Accepted 14 September 2015

Editor: K. Burton

Keywords:
Anterior cruciate ligament
Injury
Knee abduction moment
Technique
180° turns

A B S T R A C T

Background: No previous studies have investigated the optimal technique for pivoting with regard to reducing peak knee abduction moments and potential knee injury risk. The aim of this study was to investigate the relationships between technique characteristics and peak knee abduction moments during pivoting.

Methods: Twenty-seven female soccer players [mean (SD); age: 21 (3.8) years, height: 1.67 (0.07) m, and mass: 60.0 (7.2) kg] participated in the study. Three dimensional motion analyses of pivots on the right leg were performed using 10 Qualysis 'Pro reflex' infrared cameras (240 Hz). Ground reaction forces were collected from two AMTI force platforms (1200 Hz) embedded into the running track to examine penultimate and final contact. Pearson's correlation coefficients, co-efficients of determination and stepwise multiple regression were used to explore relationships between a range of technique parameters and peak knee abduction moments. Significance was set at $P < 0.05$.

Findings: Stepwise multiple regression found that initial foot progression and initial knee abduction angles together could explain 35% (30% adjusted) of the variation in peak knee abduction moments ($F_{(2,26)} = 6.499$, $P = 0.006$).

Interpretation: The results of the present study suggest that initial-foot progression and knee abduction angles are potential technique factors to lower knee abduction moments during pivoting.

1. Introduction

Cutting and pivoting have been identified as key actions associated with non-contact anterior cruciate ligament (ACL) injuries in female athletes (Boden et al., 2000; Faude et al., 2005; Olsen et al., 2004), as such actions involve lower limb postures that increase knee abduction moments (Cortes et al., 2011), which could lead to increased ACL strain (Shin et al., 2009, 2011) and subsequent injury. Several studies have investigated optimal cutting technique for reducing knee abduction moments and knee injury risk (Dempsey et al., 2007, 2009; Havens and Sigward, 2015; Jamison et al., 2012; Jones et al., 2015; Kristianlunds et al., 2014; McLean et al., 2005; Sigward and Powers, 2007), whilst no previous studies have examined pivoting or 180° turns in this regard.

Previous research into cutting has revealed that the magnitude of lateral leg plant (Dempsey et al., 2007, 2009; Havens and Sigward, 2015; Jones et al., 2015), lateral trunk flexion (Dempsey et al., 2007, 2009; Jamison et al., 2012; Jones et al., 2015) and initial knee abduction angles (Jones et al., 2015; Kristianlunds et al., 2014; McLean et al., 2005) are influential in determining the magnitude of peak knee abduction moments. McLean et al. (2005) examined initial lower limb postures in 10 male and 10 female NCAA athletes performing 45° side-step cuts and found greater peak knee abduction moments were associated with larger initial hip flexion, internal rotation and knee abduction angles, with knee abduction moments more sensitive to the later 2 variables in females. In addition, Sigward and Powers (2007) found that lateral ground reaction forces (GRF), initial-foot progression, hip rotation and abduction angles could explain 49% of the variation in peak knee abduction moments during 45° cutting in female soccer players. Such technique aspects are a likely result of performance demands. For example, a wide lateral foot placement during cutting is necessary to generate medial GRF to facilitate the direction change.

As mentioned previously, a limitation of previous studies into optimal cutting technique for injury prevention is that with the exception of a few (Havens and Sigward, 2015; Jones et al., 2015; Kristianlunds et al., 2014), the majority of studies have only considered cutting between the angles of 30 and 60°, whilst none have examined pivoting (180°). Notational analysis in male Premier league soccer has shown that changing direction manoeuvres involving greater angles of direction change (90 to 180°) (Bloomfield et al., 2007) can frequently occur, and these may exacerbate knee joint loads. Cortes et al. (2011)

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http://dx.doi.org/10.1016/j.clinbiomech.2015.09.012
0268-0033/

found that pivoting significantly increases knee abduction motion and moments [−12.2 (7.0)°/0.72 (0.3) N m/kg m] compared to drop jump landings [−3.9 (8.0)°/0.14 (0.07) N m/kg m] and 45° cutting [−3.8 (10)°/0.17 (0.5) N m/kg m] in female soccer players. This is perhaps due to the different task demands, with the need to decelerate to a complete stop before accelerating again during the pivot compared to laterally planting the leg and shifting momentum to the opposite side during a 45° cut.

Because of the different task demands between cutting and pivoting many of the parameters previously found with regard to optimal cutting technique may not necessarily be associated with peak knee abduction moments during pivoting. However, some of the variables identified previously such as initial knee abduction (Jones et al., 2015; Kristianlunds et al., 2014; McLean et al., 2005), hip internal rotation angles (Havens and Sigward, 2015; McLean et al., 2005; Sigward and Powers, 2007) and lateral trunk flexion (Dempsey et al., 2007, 2009; Jamison et al., 2012; Jones et al., 2015) might be expected to be associated with peak knee abduction moments during pivoting. Increased initial hip internal rotation angles lead to a more medially placed knee (i.e., greater initial knee abduction angle) relative to the GRF vector, resulting in an increased moment arm that would elevate knee abduction moments during changing direction tasks (Sigward and Powers, 2007). Whereas trunk position during landing and changing direction manoeuvres is often a critical factor in influencing knee joint loads (Mendiguchia et al., 2011) as the trunk is the largest segment of the body and thus, influences the position of the GRF vector relative to the knee joint during such manoeuvres. Therefore, initial knee abduction, hip rotation, and sagittal and frontal plane trunk flexion may influence knee abduction moments during pivoting and thus, should be considered in developing a model of technique for this manoeuvre.

Previous research (Cortes et al., 2011) has suggested that increased initial foot progression angle away from the direction of travel may account for the high knee abduction moments observed during pivoting. An increased initial foot progression angle or a more rotated pelvis during pivoting would be an attempt by athletes to facilitate the direction change by reducing the amount of rotation required during final contact (the phase when a subject makes contact with the ground and initiates movement into a different direction) and then re-acceleration. However, greater initial foot progression angle (or pelvic rotation) would lead to athletes absorbing the large impact forces at final contact through the frontal plane potentially increasing knee abduction moments, whereas reducing this angle would allow the large forces to be absorbed through the sagittal plane utilising the large knee and hip extensor muscle groups (e.g., peak external knee and hip flexor moments). Furthermore, if the thigh is more abducted or the foot is planted a large distance from the pelvis (i.e., greater last step length or horizontal distance between pelvis and foot) with an increased foot progression angle may further increase the moment arm of the GRF vector relative to the knee joint (similar to the effect of increased lateral leg plant during cutting) and thus increase peak knee abduction moments. Therefore, research into developing an optimal technique for pivoting should investigate these variables to confirm such a hypothesis.

Pivoting requires athletes to decelerate their velocity to zero, before reaccelerating in the opposite direction, whereas cutting involves shifting momentum into a different direction. Therefore, the deceleration strategy during pivoting may be influential in lowering forces during final contact and subsequently knee abduction moments. Graham-Smith et al. (2009) have found that penultimate contact (2nd to last foot contact with the ground during a pivot before moving into a new intended direction) prior to the turn resulted in greater vertical and anterior–posterior GRFs and internal knee extensor moments compared to final contact during a pivot in male soccer players. Thus, analysis of penultimate contact may provide more insight into the optimal technique for pivoting for reduced knee injury risk. Theoretically, if the majority of forward momentum can be reduced during penultimate contact, then lower external knee abduction moments may be experienced during the turn, where injuries often occur (Boden et al., 2000; Olsen et al., 2004) due to lower resultant GRFs. If the deceleration strategy is emphasised towards final contact this will increase resultant GRF at final contact which could increase peak knee abduction moments (Graham-Smith et al., 2009; Jones et al., 2015). Research should perhaps consider the deceleration strategy between penultimate and final contacts by examining a final/penultimate contact peak horizontal GRF ratio (HGRFR). Thus, if greater horizontal force can be generated during the penultimate contact relative to the final contact (i.e., a lower ratio) this may indicate greater braking during the penultimate contact which may lower resultant GRF and subsequent peak knee abduction moments during final contact.

The aim of this study was to investigate the relationships between technique characteristics and peak knee abduction moments during pivoting. The study investigates whether HGRFR, sagittal plane hip and knee joint moments and a number of initial lower limb, pelvis and trunk positions are associated with peak knee abduction moments. It is hypothesised that these variables are related to peak knee abduction moments during pivoting.

2. Methods

2.1. Subjects

Twenty-seven female soccer players [mean (SD); age: 21 (3.8) years, height: 1.67 (0.07) m, and mass: 60.0 (7.2) kg] acted as subjects for the study. All players were registered with Soccer clubs playing in the second tier of English Women's Soccer. Written informed consent was attained from all subjects and approval for the study was provided by the University's ethical committee.

2.2. Research design

Testing took place on an indoor Mondo running surface. Each subject was required to attend the lab on 2 separate occasions. The first occasion was a familiarisation session on the protocols used in the study with data collected on the subsequent session. The pivot involved the subjects running towards 2 force platforms. The first force platform was used to measure GRFs from the penultimate (left) foot contact, whilst the 2nd force platform was used to measure GRFs from the final (right) foot contact. Prior to the turn the subject ran through, a set of timing lights 5 m from the centre of the last platform. The subjects then turned (180°) back to the original starting position once contacting the end force platform with the right leg. Total time to complete the task was measured using a set of Brower timing lights (Draper, UT). The timing lights were set at approximate hip height for all subjects as previously recommended (Yeadon et al., 1999), to ensure that only one body part (i.e., lower torso) breaks the beam. Task completion time was used to monitor performance between trials and subjects. During familiarisation and practice trials subjects were given feedback to regulate the time to complete the task, so that they could gage the speed of approach they used during subsequent data collection. Each subject started approximately 5 m behind the first set of timing lights. Some flexibility was allowed for the exact starting point for each subject to allow for the subjects differing stride pattern as they approached the 2 force platforms. Each subject was allowed time prior to data collection to identify their exact starting point to ensure appropriate force platform contacts.

During data collection all subjects performed a minimum of 6 'Good' trials of the pivot task. A good trial was considered to involve; 1) a straight approach to the force plates without prior stuttering or prematurely turning prior to final contact, 2) contact with the first force platform during penultimate (left) foot contact, 3) contact with the central portion of the last platform during final contact to ensure a homogeneous distance of travel between trials and 4) recording an appropriate time to complete the task [2.65 s (10%)]. Trials were subsequently