MATURITY RELATED CHANGES IN INTER-SUBJECT VARIABILITY DURING CUTTING MANOEUVRES OF ADOLESCENT SOCCER PLAYERS

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The incidence of various injury rises with the onset of puberty and the growth spurt around 13 years. The biomechanical reasons are unclear. Therefore, the purpose of this study was to investigate the kinematics of the hip and knee joint of pre peak height velocity (PHV) and mid PHV soccer players during a 90° cutting manoeuvre. Twenty-two participants in two groups were investigated with a 3D movement analysis system and a force platform. Results showed no statistical difference in the time series of the hip and knee joint kinematics. Average variability of the knee flexion and internal rotation angle were significantly higher for the pre PHV group. This indicates a consolidation of the movement technique during the phase of the growth spurt, caused by the fast changes in length and masses of the segments.

KEYWORDS: peak height velocity, inverse dynamics, modelling, growth, soccer

INTRODUCTION: Injuries to the groin are a common injury in soccer players (Serner et al., 2015). Adductor injuries specifically make up one third (Ekstrand, Hägglund, & Waldén, 2011) of all muscle injuries in soccer and cause a disproportionate amount of absence from training (Gilmore, 1998). This is not only a problem for adult players, but also adolescent soccer players.

The incidence of groin injuries has been studied from an epidemiologic standpoint in various sports (Ekstrand & Hilding, 1999). Nevertheless, only few studies have investigated the possible biomechanical reasons for groin injuries (Edwards, Brooke, & Cook, 2017; Franklyn-Miller et al., 2017). In soccer, the most likely causes for groin injuries are repeated passes and kicks of the ball (Dupré, Funken, et al., 2018). Although, numerous studies have connected groin injuries to changes of direction like 90°-cutting manoeuvres, biomechanical studies have only shown inconclusive results so far regarding the influence of movement variability and muscle stress (Edwards et al., 2017; Dupré, Vincent, David, & Potthast, 2018).

However, like most injuries, muscle injuries like groin strains have been shown to occur after the beginning of puberty around the age of 13 (Backous, Friedl, Smith, Parr, & Carpine, 1988). It has been proposed that the sudden increase in the injury incidence is due to a lack of coordination and strength or greater risk taking (Backous et al., 1988). Previous investigations also showed, that for short soccer passes, the amount of force needed to accelerate the lower leg, more than doubles between the age of 11 and 14 (Dupré et al., 2017). This was attributed to the fast growth in length and weight that happens during this period (Iuliano-Burns, Mirwald, & Bailey, 2001), called peak height velocity (PHV), which increases the moments of inertia and forces needed to accelerate the legs. It is likely that such fast growth influences the stability of movement patterns as the body needs to adapt to the changed proportions.

Therefore, the purpose of this study was to compare the hip and knee joint kinematics and their variability in between soccer players before the phase of PHV and during PHV, while performing a 90°-change of direction.

METHODS: Twenty-Two adolescent soccer players from a local soccer club were tested for this study. Each one gave his written consent to participate and the universities ethics board approved the study. Based on their anthropometric data, the players were divided into two groups based on their maturity level, which was determined according to Mirwald, Baxter-Jones, Bailey & Beunen (2002). This method was used to calculate the estimated time of PHV. Participants whose estimated time of PHV was more than half a year away at the time of the measurement were assigned to the Pre_PHV group, which can be seen as pre-

pubertal. Participants that were less than half a year post or pre of their estimated time of PHV were assigned to the Mid_PHV group. Anthropometric data of the two groups is presented in Table 1.

Table 1: Anthropometric data of the two investigated groups of young soccer players

	N	Age (y)	Time to PHV (y)	Height (m)	Mass (kg)
Pre_PHV	12	13.1 ± 0.56	1.07 ± 0.52	1.56 ± 0.07	44.8 ± 4.74
Mid_PHV	10	13.52 ± 0.37	0.1 ± 0.28	1.66 ± 0.07	52.5 ± 5.64

The testing was performed on third-generation artificial turf (LigaTurf, Polytan, Burgheim, Germany) to produce a real world equivalent shoe to ground interaction. For the force plates, two aluminium frames were fixed onto the plates so that the artificial turf could be securely mounted on top of the force plates. All participants wore their own shoes. They had to perform five valid 90°-cutting manoeuvres (CM) to the left with their right foot on force plate 1 and their left foot on force plate 2 (Figure 1). Most previous studies have investigated CD angles between 30° and 60° (Edwards et al., 2017; Pollard, Davis, & Hamill, 2004) but showed smaller abduction loads than reported for 90° CM (Dupré, Vincent, David, & Potthast, 2018). Therefore, 90°-cutting was investigated, as the higher loads are more likely to be connected to injuries.

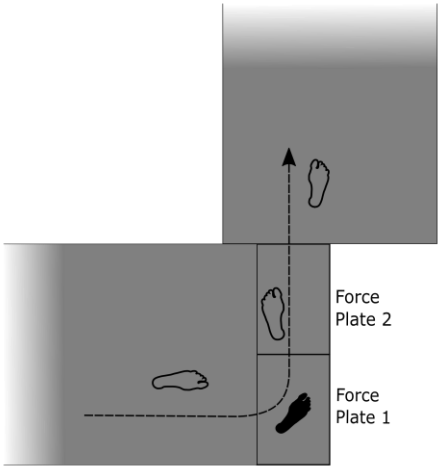

Figure 1: Drawing of the turf layout, the movement direction of the participants and their foot placement. The black foot indicates the analysed force plate contact.

Kinematic data was collected with 13 infrared cameras (F40, Vicon, Oxford, UK) at 200 Hz. Twenty-eight retro-reflective markers were fixed to anatomical reference points on the participants lower body with double sided adhesive tape. Kinetic data was collected with two 90x60 cm force plates (Kistler, Winterthur, Switzerland) at 1000 Hz. The kinematic data was used to create a seven segment anatomical model consisting of the pelvis, thighs, shanks and feet in AnyBody Modelling System (Version 6.0, AnyBody Technology, Aalborg, Denmark). This model was modified to incorporate a spherical knee joint with three degrees of freedom (Dupré, Dietzsch, Komnik, Potthast, & David, 2019). Kinematic and kinetic data was low-pass filtered with a recursive second order Butterworth filter at 20 Hz. Data processing and statistical analysis were performed in Matlab 2017a (The MathWorks, Natick, Massachusetts). Parameters were time-normalized to ground contact on the force plate. To quantify the inter-subject variability of the movement, the groups mean was subtracted from every participants mean. The result was then averaged to get the average deviation of the subject from the groups mean.
Nonparametric Statistical Parametric Mapping (SPM) was used to analyse the time series of the six parameters. Mann-Whitney U Tests were used to calculate the p-value for the deviation values. The alpha-level was set to 0.05.

RESULTS & DISCUSSION: The purpose of this study was to investigate the influence of maturity in young soccer players on their hip and knee joint kinematics during 90° cutting manoeuvres. To the author's knowledge this is the first study to do so as previous studies have focused on intra-subject variability (Edwards et al., 2017). Compared to previous studies on joint kinematics during cutting (Dupré et al., 2018; Pollard, Davis, & Hamill, 2004), the data presented here shows higher standard deviations (Figure 2). Furthermore, some curves like that of the hip flexion are vertically shifted compared to (Pollard et al., 2004) and show greater range of motions. This result is most likely to the different cutting angle in the present study, as Pollard et. al. investigated 45° cutting.

SPM analysis did not find significant differences in the time series between the two groups. However, Table 2 shows that the inter-subject variability at the knee is significantly higher in the Pre_PHV group in the sagittal and transverse plane. The higher standard deviations and average deviation of the Pre_PHV group indicate that around the time of PHV the subjects adapted similar techniques to perform a 90° cutting manoeuvre. Previous research has shown, that the development of physiological parameters like strength and speed peaks during PHV (Philippaerts et al., 2006). This development might enable adolescents to perform the technique like more mature players.

Table 2: Means of the inter-subject deviation from the groups mean in degrees. The bottom row shows the p-value for the Mann-Whitney U Test between the two groups.

	Hip Flexion	Hip Adduction	Hip Rotation	Knee Flexion	Knee Adduction	Knee Rotation
Pre_PHV	6.84	4.71	4.85	5.09	2.16	5.73
Mid_PHV	4.31	2.86	3.98	1.82	1.38	2.36
p-value	0.093	0.339	0.531	**0.023**	0.249	**0.044**

The consolidation towards one technique is possibly connected to the rise in injury incidence that has been previously reported for adolescents (Backous et al., 1988). Less physically mature children might adapt their habitual technique in younger years to perform a certain movement. However, entering the phase of PHV during which the segment length' and masses grow exponentially and thereby the moment of inertia as well, could make such individual techniques impossible or uneconomical to perform. Therefore, physically more mature children seem to adapt techniques that are more similar.

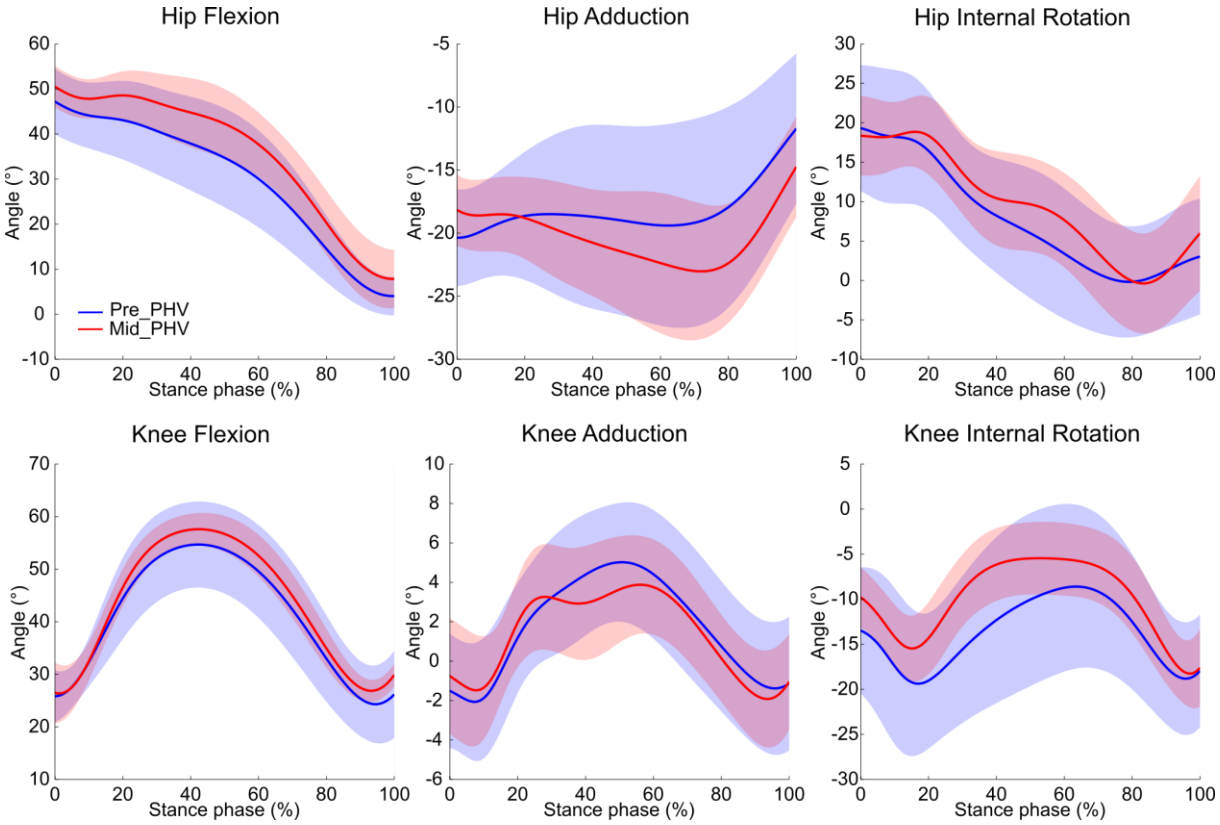

Figure 2: Time normalized, averaged time series of joint angles for the Pre_PHV (blue) and Mid_PHV (red) groups. Shaded areas represent the standard deviation.

It is unlikely, that the consolidation of the cutting technique alone is the reason for a rise in the injury incidence. Nevertheless, it indicates that certain adaptations are made during the

growth spurt in reaction to the fast change of body proportions, which might be responsible for the occurrence of injuries. A further possibility is that the effect is due to a more competitive nature of the participants in the Mid_PHV group. Other studies have speculated that the higher injury incidence of adolescent players might stem from a more competitive attitude during sport (Backous et al., 1988). Time to complete of the cutting manoeuvres was not analysed, but it is possible that the Mid_PHV group was more motivated and had to choose a movement path was optimal to complete the change of direction as fast as possible and therefore showed less average deviation.

CONCLUSION: The influence of peak height velocity and physical maturity on the adolescent rise in injury incidence remains unclear. Less inter-subject deviation of the more mature group indicates that entering PHV induces the adaptation of a more common technique. It has to be investigated if this adaptation promotes injuries. Further research is needed to clarify the effects of fast growth during adolescence and if the reduction of inter-subject variability seen here can be reproduced in movements such as soccer passes.

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