ADDUCTOR MUSCLE STRESS AND HIP JOINT LOAD IN 90° CUTTING MANOEUVRES AND THEIR POSSIBLE LINK TO GROIN INJURIES

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Epidemiological studies on groin injuries in soccer have often linked them to kicking and cutting manoeuvres (CM) although no biomechanical studies exist that prove this link for CMs. The present study investigated the hip joint kinematics and kinetics of a 90° CM. Thirteen participants were investigated with a 3D movement analysis system and a force platform. Results showed hip joint angles to be slightly higher than in previous studies on smaller CM angles. Hip moments in the frontal and transverse plane were similar to those of inside passing while the muscle stress in gracilis and adductor longus were 43 % and 44 % lower compared to passing. Therefore, CMs might not put the groin region under a dangerous load, allowing for a shift of focus in injury prevention to kicking and passing movements.

KEYWORDS: Change of direction, inverse dynamics, modelling, AnyBody

INTRODUCTION: In sports with kicking and fast CMs, like soccer and other team sports, groin injuries are a large problem (Arnason et al., 2004; Serner et al., 2015). From this, it has been deduced that both kicking and CMs are a major causes for the development of groin problems like strains and osteitis pubis.
Many epidemiological studies have been published regarding the incidence of groin injuries in soccer (Ekstrand & Hilding, 1999; Hölmich, Thorborg, Dehlendorff, Krogsgaard, & Gluud, 2014) and other sports (Orchard, 2015). It has been speculated, that high muscle forces that are repeatedly applied to the adductors and the pubic symphysis during a CM or kick would put an athlete under the risk of a groin injury (Hiti, Stevens, Jamati, Garza, & Matheson, 2011). Recently it has been shown that this could be true for movements like kicking and passing (Dupré et al., 2018) where high muscle stress in adductor longus and gracilis was found. For CMs, very few sources have looked into the biomechanical factors that might cause groin injuries:
Previous studies have investigated hip joint moments and angles among other parameters in an attempt to clarify possible links between groin injuries and CMs. Edwards, Brooke and Cook (2017) could not establish cause and effect between an altered movement variability during CMs and a history of groin pain. Franklyn-Miller et al. (2017) found different movement strategies in subjects with groin pain, but could not connect the different strategies to the different diagnoses. Hence, it remains unclear if groin pain alters the movement strategy. It remains equally unclear, how CMs might be linked to the initial development of groin injuries.
Therefore, the purpose of this study was to investigate 3D kinematics and kinetics, including muscle stress of the adductor longus and gracilis, of a 90° CM regarding the load that might be applied to the groin to provide insight into the possible link to injuries like groin strains and osteitis pubis.

METHODS: Thirteen male participants were tested in this study (76 ± 5.8 kg; 177 ± 6.5 cm). All participants were active soccer players and trained two to four times per week. Each one gave his written consent to participate and the universities ethics board approved the study.
To reproduce a realistic player to ground interaction, the study was performed on third generation artificial turf (LigaTurf, Polytan, Burgheim, Germany). This was laid out on the floor, housed in wooden frames in a 90° angle, so that run-up and exit of the CM could be done on

the turf (Figure 1). All participants wore the same shoes for the study (Copa Mundial, Adidas, Herzogenaurach, Germany). They had to perform five valid trials with their right leg and were instructed to perform the CM as fast as possible. As they used their right leg, the CM was performed to the left (Figure 1).

Thirteen infrared cameras (F40, Vicon, Oxford, UK) were used to collect kinematic data at 200 Hz. Twenty-eight retro-reflective markers were placed on anatomical reference points of the lower extremity with double sided adhesive tape on the participants' skin. From this, a seven segment anatomical model was created that consisted of the pelvis as well as thigh, shank and foot of both legs. Ground reaction forces were collected with two 90x60cm force plates (Kistler, Winterthur, Switzerland) operating at 1000 Hz. Inverse dynamics were calculated in AnyBody (Version 6.0, AnyBody Technology, Aalborg, Denmark) with a modified version of the Anatomical Landmark Scaled Model (Lund, Andersen, de Zee, & Rasmussen, 2015) that utilizes a spherical knee joint with three degrees of freedom. Kinematic and kinetic data were low-pass filtered with a recursive second order Butterworth filter and a cut-off frequency of 20 Hz. Joint moments are presented as external moments. Muscle stress was calculated using the forces from the simple muscle model provided by AnyBody with a polynomial muscle recruitment criterion of the power three and physiological cross sectional area from (Klein Horsman, Koopman, van der Helm, Poliacu Prosé, & Veeger, 2007).

Data processing was performed with Matlab R2017a (The MathWorks, Natick, Massachusetts). Parameters were time-normalized to ground contact on the force plate. Mean peak values were calculated from individual trials.

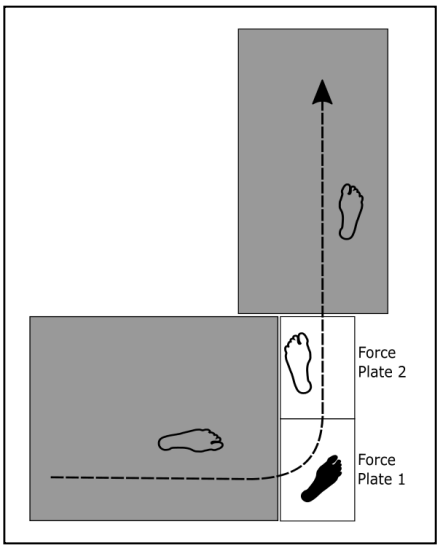

Figure 1: Drawing of the turf and force plate setup. Only right-footed contacts on force plate 1 were analysed. The arrow represents the direction of movement.

RESULTS & DISCUSSION: The aim of this study was to investigate the kinematics and kinetics at the hip joint during the turning step of a 90° CM. This is the first study to investigate this in a 90° CM as previous studies focused on 45° or 110° CMs, respectively (Edwards et al., 2017; Franklyn-Miller et al., 2017; Houck, Duncan, & Kenneth, 2006; Kim et al., 2014).

Table 1
Discrete values of the investigated parameters. Values are shown as mean ± standard deviation. Joint moments are normalized to body mass. Positive values represent the first named part of each movement plane. Moments are calculated as external joint moments.

Parameter	Plane (+/-)	Maximum	Minimum
Angles [°]	Flexion/Extension	47.46 ± 6.07	-0.49 ± 6.46
	Adduction/Abduction	-12.53 ± 4.05	-25.58 ± 4.25
	Internal/External Rotation	18.84 ± 6.63	-8.28 ± 9.09
Moments [Nm/kg]	Flexion/Extension	2.54 ± 0.47	-1.84 ± 0.35
	Adduction/Abduction	0.79 ± 0.31	-1.22 ± 0.25
	Internal/External Rotation	0.61 ± 0.16	-0.32 ± 0.12
Parameter	**Muscle**	**Maximum**	
Muscle stress [kPa]	Adductor Longus	94.42 ± 15.41	
	Gracilis	258.31 ± 37.63	

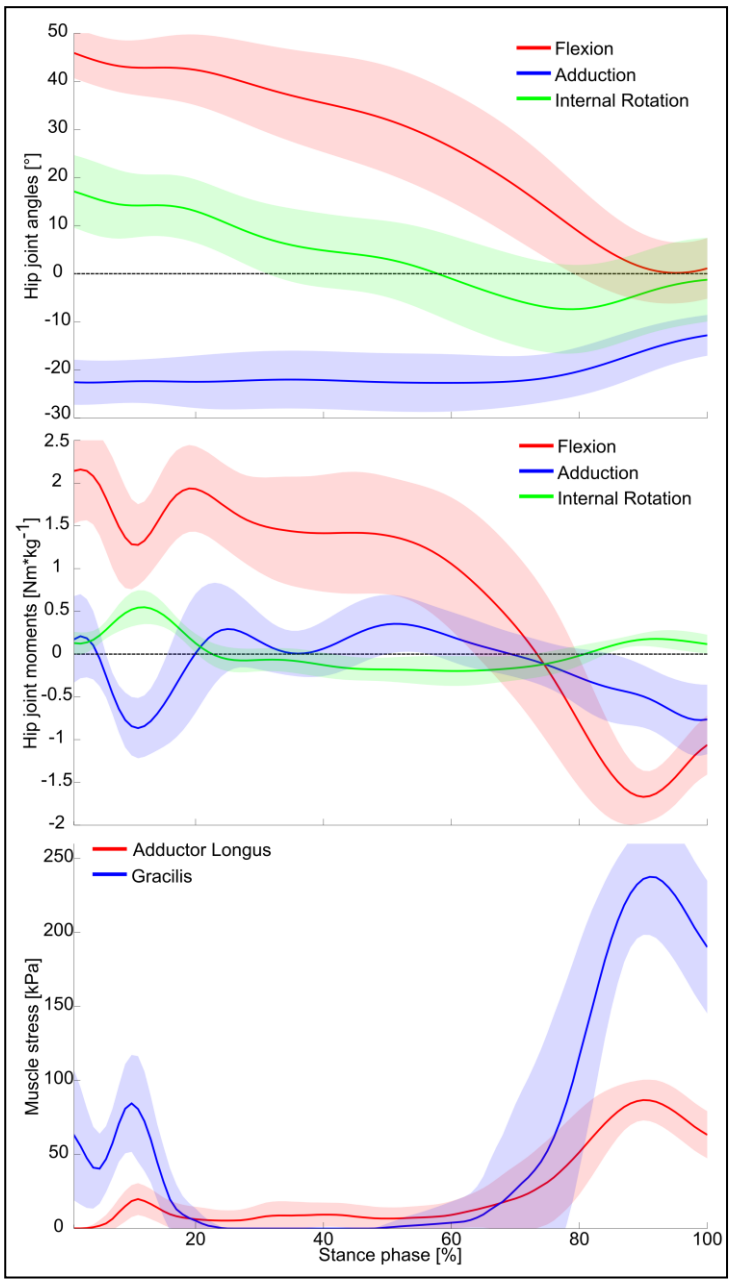

Figure 2: Mean joint angle and moment curves of 13 participants are presented in the two subfigures at the top. The bottom one shows the mean muscle stress of the same participants. Shaded areas indicate the standard deviation.

Hip joint angle curves (Figure 2) are comparable to previous studies where 45° CMs were performed, although mean maximum angles (Table 1) in the present study are higher (Pollard, Davis, & Hamill, 2004). This can be explained by the greater turning angle that has to be negotiated, which requires a higher amount of reorienting the body's segments. Figure 2 also shows that the hip joint stays in an abducted position during the whole CM. Joint moments of the frontal plane are less similar (Pollard et al., 2004), with a higher spike at the beginning of the stance phase which is also evident at the knee joint (David, Komnik, Peters, Funken, & Potthast, 2017). It is likely that this is due to the larger cutting angle which requires more force to decelerate while the body is reoriented and accelerated into the new movement direction.

No previous study has investigated muscle forces or stress during a CM although it is widely speculated that high muscle forces in the groin area during a CM are connected to the various forms of groin injuries. The joint moments in the frontal and transverse plane are similar to those reported for inside passing (Dupré et al., 2016) which is also thought to put the groin region under a high risk of injury. The adduction moment is substantially higher in passing. Sagittal plane kinetics are also different with a 79 % higher flexion moment but a 22 % lower extension moment. Compared to the maximum muscle stress that occurs in adductor longus and gracilis during inside passing (Dupré et al., 2018), it is 43 % lower in gracilis and 44 % lower in adductor longus during a CM. Furthermore, there is only a brief moment at the end of the swing phase where gracilis is put under the highest stress, unlike passing movements where high muscle stress is present during a longer part of the swing phase. This indicates, that CMs put only moderate load on the musculoskeletal system, contradicting previous assumptions made in the literature (Hiti et al., 2011).

While these results show a moderate musculoskeletal load for anticipated CMs, it has been shown, that unanticipated manoeuvres, that are thought to be the norm in team sports, lead to higher joint moments (Kim et al., 2014). Calculating muscle forces has one drawback that is a limitation of this study which is the missing implementation of co-contraction. During a CM, co-contraction has to occur as it is needed to stabilize the hip joint. Muscle forces allo-

cated therefor are not represented in the muscle model and can lead to lower calculated muscle forces. Therefore, future studies should try to build upon the present results and try to further quantify the load acting on the adductors more accurate. This is strongly needed, as the external abduction moment which is countered by the adductors is in the CM as high as in inside passing. Future studies should also investigate the influence of the abdominal muscles on the development of groin related pain as this has been left out in the present study.

CONCLUSION: Assumptions made in previous studies, that CMs promote the development of groin injuries due to high muscle loads acting on the pubic symphysis and the adductor muscles could not be verified. Although these findings may not be conclusive, they provide an important insight for practitioners: Regarding the injury prevention in soccer the results might warrant a stronger focus to prevent adductor overload from pass training. Nevertheless, caution is needed as the presented results are the first attempt to quantify the muscle load during CMs.

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