

## VICTORY OR DEFEAT- HOW MOVEMENT STRATEGIES DESTINGUISH FAST DIRECTION CHANGES FROM CUTTING MANEUVERS WITH HIGH INJURY RISK

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Cutting maneuvers (CM) are frequently executed in sports. This task is relevant as it is a key ability for team sports players (TSP) but also bears the risk of ACL tears. An analysis of the movement strategies (MS) and musculoskeletal loads (MSL) occurring during CMs could reveal factors for efficient CMs and major triggers governing the occurrence of ACL tears. This study investigated the MS and MSL during 90° CMs in 51 subjects with different sex and sportive background to analyze the variety of CM execution. Results indicate that sportive background and sex influences movement execution and MSL. Track and field athletes (TFA) had the same peak velocity as TSP, but produced it during the first step after the turn, whilst TSP kept speed by increased curve leaning. Females show higher knee adduction moments which increases the risk of injuries.

**KEYWORDS:** AnyBody, cutting maneuver, performance, injury

**INTRODUCTION:** Cutting maneuvers are a frequent task in team sports and the ability to do fast direction changes is characterized by the term agility (Sheppard und Young 2006). Agility is the ability to change direction with a high speed in response to a stimulus and is an important component of many sports (Sheppard und Young 2006). Usually, agility unites two principal components: Next to perception and decision making, agility is strongly characterized by subject specific direction change mechanics. Although the influence of leg strength, sprint velocity, or jumping performance on cutting performance was investigated to characterize direction change mechanics (Brughelli et al. 2008; Jones et al. 2009; Young et al. 2002; Young und Farrow 2006), results were inconsistent so that objective key factors defining high or low agility are still lacking. Potential explanations for that could be testing characteristics such as long distance sprinting before execution of the direction change or many repetitions (leading to fatigue). The potentially high variability of movement execution is an additional factor, which has been neglected so far. Dempsey et al. (2007) showed that changing the turning technique also changes the amount of knee joint load (Dempsey et al. 2007). The results give an idea of the amount of influence of movement execution on musculoskeletal loading as the authors reported a mean effect size of 0.81 (Dempsey et al. 2007). The documented changes in turning technique might have led to an unfamiliar movement for the subject and therefore bias the results. Additionally the knowledge of those movement strategies leading to risky direction changes is also important for injury prevention. In competitive team sports an injury rate of 3.7 per 1000 match hours has been reported (Hootman et al. 2007) with an even higher rate for lower extremity injuries in young players and in less experienced youth team sports athletes (Peterson et al. 2000). The purpose of the present study is to detect movement strategies with respect to a high performance in CM and to reveal disadvantageous strategies which are related to musculoskeletal loading.

**METHODS:** A group of 51 subjects (Table 1) was included in the study, subjects were chosen to fit either in to a group of male team sports players (male TSP), or female team sports players (female TSP), or male track and field athletes (male TFA) with their main discipline in sprint or jump and no history of team sports engagement, or female track and field athletes (female TFA) with their main discipline in sprint or jump and equally no history of team sports participation. TFAs were chosen since they have the same focus on leg strength as the TSPs

but without the focus on direction changes during their training regimes. All subjects had to be free of injury and pain and confirmed written consent to the participation of this study.

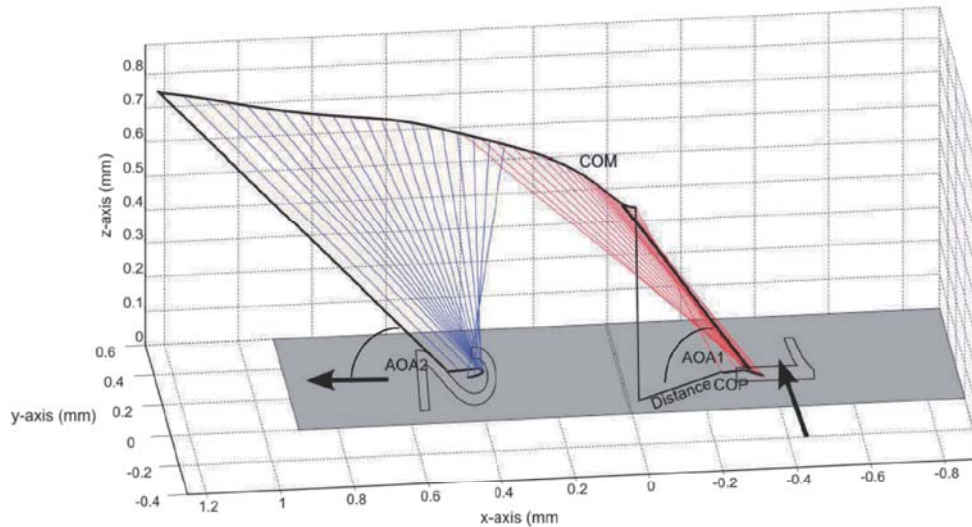
**Table 1 Description of the included subjects.**

	Male TSP	Female TSP	Male TFA	Female TFA
N	13	15	9	14
Age	23.7	21.9	21.8	22.4
Height (m)	1.82	1.76	1.81	1.71
Body mass (kg)	77.2	64.3	76.0	64.6

Before measurements started, all participants had a subject specific warm up with the information to prepare for fast direction changes. During the measurements subjects performed five valid trials of 90° CM to the dominant side with a self-selected speed but maximum effort. A CM is decided to be valid if both feet are placed centrally on the force plates and the subjects had no disturbance during the maneuver. The CMs were performed with the same shoe for all subjects (Under Armour Speed Force ID). The Floor was covered with Polyvinylchlorid (PVC) to provide traction similar to indoor sports grounds.

For the movement analysis 12 infrared cameras (VICON™, Oxford, UK, 200 Hz) and 53 reflecting markers were used. Ground reaction forces were recorded with two force plates (Kistler, 1000Hz) for the turning step and the first acceleration step of the 90° cutting manoeuver. Inverse dynamic calculations were executed by means of an anatomic-landmark-scaled Lower-Body-Model (Lund et al. 2015) of the AnyBody Modeling System (Version 6.0, AnyBody Technology, Aalborg, Denmark). The model anthropometry was slightly modified to better cover the subjects. A detailed Hanavan model was used, including circumferences and lengths of all segments to calculate the segments weight (Hanavan Jr, Ernest P 1964). Force plate data was filtered with a 2<sup>nd</sup> order low pass filter and a cut off frequency of 50 Hz. For the process of final data analysis Matlab (2015a, The Mathworks, Natick, USA) was used.

The following parameters were taken under consideration: The path speed ( $P_{vel}$ ) which is the resultant of the speed in x- and y-direction was normalized to the time between the touch down on the force plate 1 (FP1) and the takeoff on force plate 2 (FP2). The maximum  $P_{vel}$  is used as the performance parameter. The angle of attack (AOA) was calculated for the stance phase on FP1 (AOA1) and FP2 (AOA2). It is defined as the angle between the ground floor and the vector between the center of mass (COM) and the center of force application (COP) (Fig 1). Additionally the distance (Distance) between the projected COM and the COP was calculated for both force plates (Fig 1). The distances were normalized to the subjects' body height. Moments were normalized to body height and body mass and a mean for each subject was built over the 5 valid trials for each subject. The maximum knee adduction moment (KAM) was used as the control parameter for an increased injury risk. GRF was normalized to body mass.

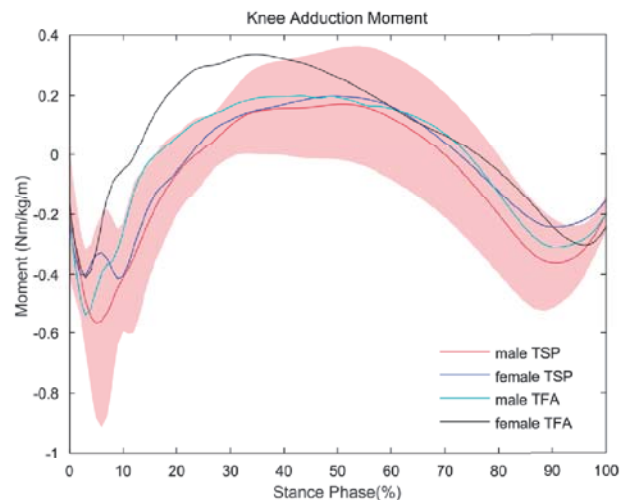


**Figure 1:** COM path of one subject during a 90° CM. The CM is performed with the right foot on FP1 (1). The next step with the left foot on FP2 (2) is the first step after turning. AOA1 and AOA2 for every 5<sup>th</sup> time step on FP1 (red) and FP2 (blue). Exemplary plotted distance between the projected COM and COP (Distance). The black arrows point into the movement direction.

Apart from the GRF the impulse of the GRF was calculated for both force plates. The leg stiffness (LS) was calculated for both legs as the quotient of the peak GRF and the height difference of the COM. A Kruskal-Wallis test for non-parametrical data was used ( $\alpha = .05$ ) to identify whether grouping of the subjects affected the aforementioned parameters. In case of a significant result the Mann-Whitney U test was performed. Pearson's correlation was calculated to detect correlations between the peak  $P_{Vel}$  and the aforementioned parameters in each group. The same was done for the peak KAM and all aforementioned parameters.

**RESULTS AND DISCUSSION:** Male athletes are faster than female athletes ( $p = .001$ ). Analysis of the peak  $P_{Vel}$  revealed no significant differences between team sports players and track and field athletes for both sexes. This result suggests that the TFAs' ability to produce high rates of force application is a key ability to be a fast direction changer which is also documented by high correlations between linear sprinting and change of direction speeds (Jones et al. 2009). Interestingly, the correlation between high force rates and peak  $P_{Vel}$  are only seen in female TFAs ( $p = .001$ ,  $r = .770$ ). While the male TSPs peak  $P_{Vel}$  correlated significant with the AOA2 ( $p = .001$ ,  $r = -.816$ ) in means of a more inwards curve slope, the female athletes' peak  $P_{Vel}$  correlated with a more upright position ( $p = .005$ ,  $r = .706$ ).

Female athletes showed higher KAMs for the first stance phase than their male counterparts. However, the standard deviation also indicates women among the study group with lower KAMs. Therefore, different strategies might lead to more or less risk to get injured. The Pearson's correlation identified the upright position of the female TFAs as one of the key factors of a high KAM ( $p = 0.002$ ,  $r = .780$ ). Although



**Figure 2:** left: Knee adduction moments (Nm/kg/m) of male TSP (red), female TSP (blue), male TFA (cyan) and female TFA (black) Shaded red area shows the standard deviation of male TSP. The knee adduction moment is significant ( $p = 0.001$ ) higher for female TFA.

no muscle forces or other parameters linked to high KAMs were included in this analysis, this observed correlation points towards to the position of the angle of attack as one influencing factor. No significant differences were detected for other joint angles or moments for the first stance phase.

Subjects were asked to perform the turning maneuvers with maximum effort, so we did not standardize the run-up speed. This enabled us to find the aforementioned strategies that would have been masked by controlled speeds. We could not find female subjects to have also higher knee abduction moments during the first 20% of stance which is documented in different studies (Malinzak et al. 2001, McLean et al. 1999). This might be due to the not standardized run-up speed. Due to space restrictions it was not possible to detect the breaking step immediately before the turn. This would have allowed us to get an idea of the subject or group specific breaking strategy. The included subjects were chosen due to their history of sports participation. Though none of the track and field athletes documented team sports participation all of them went through gym classes at school including team sports lessons. This might influence their ability to perform fast direction changes.

**CONCLUSION:** The results support the hypothesis that subject specific movement execution has a large effect on performance and on musculoskeletal loading. Increased curve leaning and high force rates correlate with faster CM. An upright position is correlated with increased KMA and therefore associated with a higher risk of injury.

#### REFERENCES:

- Brughelli, M.; Cronin, J.; Levin, G.; Chaouachi, A. (2008). Understanding change of direction ability in sport: a review of resistance training studies. *Sports Med* 38 (12), 1045–1063.
- Dempsey, A. R.; Lloyd, Da. G.; Elliott, B. C.; Steele, J. R.; Munro, B. J.; Russo, K. A. (2007). The effect of technique change on knee loads during sidestep cutting. *Medicine & Science in Sports & Exercise* 39 (10), 1765–1773.
- Hanavan Jr, Ernest P (1964): A mathematical model of the human body. DTIC Document
- Hootman, J. M.; Dick, R.; Agel, J. (2007). Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *Journal of athletic training* 42 (2), 311.
- Jones, P.; Bampouras, T. M.; Marrin, K. (2009). An investigation into the physical determinants of change of direction speed. *J Sports Med Phys Fitness* 49 (1), 97–104.
- Lund, M. E.; Andersen, M. S.; de Zee, M.; Rasmussen, J. (2015). Scaling of musculoskeletal models from static and dynamic trials. *International Biomechanics* 2 (1), 1–11.
- Malinzak, R. A., Colby, S. M., Kirkendall, D. T., Yu, B., & Garrett, W. E. (2001). A comparison of knee joint motion patterns between men and women in selected athletic tasks. *Clinical Biomechanics*, 16(5), 438-445.
- McLEAN, S. G., Neal, R. J., Myers, P. T., & Walters, M. R. (1999). Knee joint kinematics during the sidestep cutting maneuver: potential for injury in women. *Medicine and Science in Sports and Exercise*, 31, 959-968.
- Peterson, L.; Junge, A.; Chomiak, J.; Graf-Baumann, T.; Dvorak, J. (2000). Incidence of football injuries and complaints in different age groups and skill-level groups. *The American Journal of Sports Medicine* 28 (suppl 5), 51-57.
- Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of sports sciences*, 24(9), 919-932.
- Young, W. B.; James, R.; Montgomery, I. (2002). Is muscle power related to running speed with changes of direction? *J Sports Med Phys Fitness* 42 (3), 282–288.
- Young, W.; Farrow, D. (2006). A Review of Agility. *Strength and Conditioning Journal* 28 (5), 24–29.