THIGH MUSCLE ACTIVITY IN EXPERIENCED FEMALE HANDBALL PLAYERS DURING PREPLANNED AND UNPLANNED SIDESTEP CUTS

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The purpose of this study was to assess if there is a difference in the thigh muscle activation patterns between a preplanned and unplanned sidestep cut performed by n = 31 experienced female handball players. Electromyogram vector fields containing the muscle activity of the vastus medialis, vastus lateralis, semitendinosus, and biceps femoris from 100 ms before ground contact until toe-off were created and compared using Statistical Parametric Mapping. Results show lower activity in the unplanned cut. When comparing individual muscles, vastus medialis was the only muscle showing differences between tasks, with the unplanned task eliciting lower activity right before initial ground contact. The findings of this study indicate that the knee joint might be more vulnerable to external knee joint moments in unplanned cutting tasks due to lower muscle pre-activity.

KEYWORDS: ACL, cutting, EMG, sidestepping.

INTRODUCTION: Sidestep cutting maneuvers are high-risk movements for non-contact anterior cruciate ligament (ACL) injuries. This maneuver is very common and represents the main injury situation in handball (Olsen et al., 2004). While the overall incidence rate is high in both sexes, it is higher in females (Gornitzky et al., 2016). Studies indicate that muscular pre-activity might be an important risk factor for ACL injury during sidestep cutting (Zebis et al., 2009). Furthermore, thigh muscle activation patterns in jump tasks have been proposed as a potential risk factor for ACL injury (Smeets et al., 2019). However, neither of these studies compared thigh muscle activation patterns between preplanned or unplanned conditions. A better understanding of muscular activity in planned and unplanned tasks associated with a high risk of injury might be valuable in the design of sport-specific screening tasks and effective training methods to improve neuromuscular control. Therefore, the purpose of this study was to compare thigh muscle activation patterns between planned and unplanned handball-specific sidestep cuts in female handball players. We tested the hypothesis that there is no difference between both cutting conditions.

METHODS: Data of n = 31 experienced female handball players (mean ± SD: 19.5 ± 3.9 years, 1.69 ± 0.05 m, 65.4 ± 6.7 kg) were obtained. The study was approved in compliance with the Declaration of Helsinki. Electromyography (EMG) data of the vastus medialis (VM), vastus lateralis (VL), semitendinosus (ST), and biceps femoris (BF) ipsilateral to the throwing arm were collected at 2000 Hz. The electrode placement was done in accordance with the Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM) recommendations. Following a standardized warm-up protocol and familiarization period, players performed a minimum of three valid sidestep cuts per condition in a randomized order. All trials started from a ~6 m approach distance with an angle of ~35° to the long axis of the force platform and included the following conditions: 1) a sidestep cut with a predetermined cutting direction without any defenders or handling of a ball (reference condition, REF), 2) a sidestep cut with a predetermined cutting direction to fake and pass a static human defender following the reception of a pass thrown by a team mate (preplanned, PP), and 3) a sidestep cut for which the cutting direction was not predetermined, players were instructed to catch a ball and subsequently pass three variably moving defenders. In this condition, a middle defender and one of two outside defenders positioned on either side of the middle defender pressured the attacker upon catching the ball, and the player was instructed to evade the defenders to the direction of the outside defender that remained static to cut away from the pressure. This resulted in an unplanned cutting direction (unplanned, UP) (Mai et al., 2022).

EMG data were bandpass filtered at 10 to 500 Hz, full-wave rectified, and smoothed with a 4th order low-pass Butterworth filter at 10 Hz (Meinerz et al., 2015). The stance phase was determined as the time period in which the unfiltered vertical ground reaction force exceeded 20 N. For statistical analyses, data were time-normalized to 201 data points from 100 ms before initial ground contact (IC) to toe-off resulting in IC being situated at around 24% and 25% for the PP and UP condition, respectively. PP and UP muscle activity was normalized to the maximum activity in REF. An overall EMG {VM, VL, ST, BF} (time) vector field was initially created for each participant and task. While statistically comparing the overall vector fields between the two tasks would have been sufficient to accept or reject the null hypothesis, an anterior {VM, VL} (time) vector field, a posterior {ST, BF} (time) vector field, a medial {VM, ST} (time) vector field, a lateral {VL, BF} (time) vector field, and two diagonal vector fields – a {VM, BF} (time) vector field and a {VL, ST} (time) vector field – were also created (Smeets et al., 2019). These additional vector fields along with the individual muscle activation patterns were considered to explore which muscles or muscle combinations potential differences in the overall activity might be mostly attributed to. Subsequently, seven Hotelling's T^2 tests, the Statistical Parametric Mapping (SPM) vector field equivalent to the paired *t*-test (Pataky et al., 2013), were performed, with the alpha level set to $\alpha = 0.05$. Individual muscle activity was compared using SPM paired *t*-tests with Šidák-corrected alpha levels of $\alpha = 0.0127$. All analyses were performed in MATLAB (R2021b, The Mathworks, Natick, USA).

RESULTS: Differences in the overall vector field were found between 17.7% and 21.1%, corresponding to 31 ms – 12 ms before IC ($p = 0.023$) and between 92.3% and 94.1%, corresponding to 32 ms – 23 ms before toe-off ($p = 0.040$) (Figure 1). The early differences in the overall EMG vector were also reflected in the anterior (11.1% – 21.6%, $p < 0.001$) and medial (12.5% – 20.4%, $p < 0.001$) (Figure 2) as well as the diagonal EMG {VM, BF} (time) vector (12.2% – 24.2%, $p < 0.001$) (Figure 1). The late differences in the overall EMG vector were also found in the posterior EMG vector (90.5% – 97.6%, $p = 0.006$; Figure 2) and the diagonal EMG {VL, ST} (time) vector (91.8% – 94.8%, $p = 0.025$; Figure 1). Individual muscle comparisons only revealed higher activation for the vastus medialis in PP between 13.0% and 20.6% ($p < 0.001$; Figure 1 and Figure 2).

DISCUSSION: The results demonstrated differences in muscle activation patterns between PP and UP. On the individual muscle level, only differences in the vastus medialis right before IC were found. Vector field analyses, on the other hand, revealed differences in the overall EMG vector and in the combination of muscles both before IC and during late push-off. These discrepancies are not surprising since comparing individual muscles does not account for inter-muscle covariance, and vector-field analysis is more robust to Type II error (Robinson et al., 2015). The paired *t*-tests therefore do not provide sufficient explanation for the vector field differences, and it can hence be concluded that the differences in muscle activation between PP and UP cannot be attributed to single muscle differences. However, it is reasonable to assume that VM contributed most to the Hotelling's T^2 statistic before IC. As the hypothesis did not pertain to a single time point, the whole time series from 100 ms before IC until toe-off was considered. However, from an ACL injury perspective, differences in muscle activity during late push-off are most likely irrelevant (Koga et al., 2010).

Given the time span where early overall differences were found and accounting for electromechanical delay (Begovic et al., 2014; Ristanis et al., 2009), differences in muscle forces around the knee joint can be expected in a time period where ACL injuries are believed to occur (Koga et al., 2010). Lower activity in UP might increase injury risk due to reduced joint stiffness and potentially elevated ligament loading. However, it needs to be noted that it remains unclear if the present results are clinically meaningful.

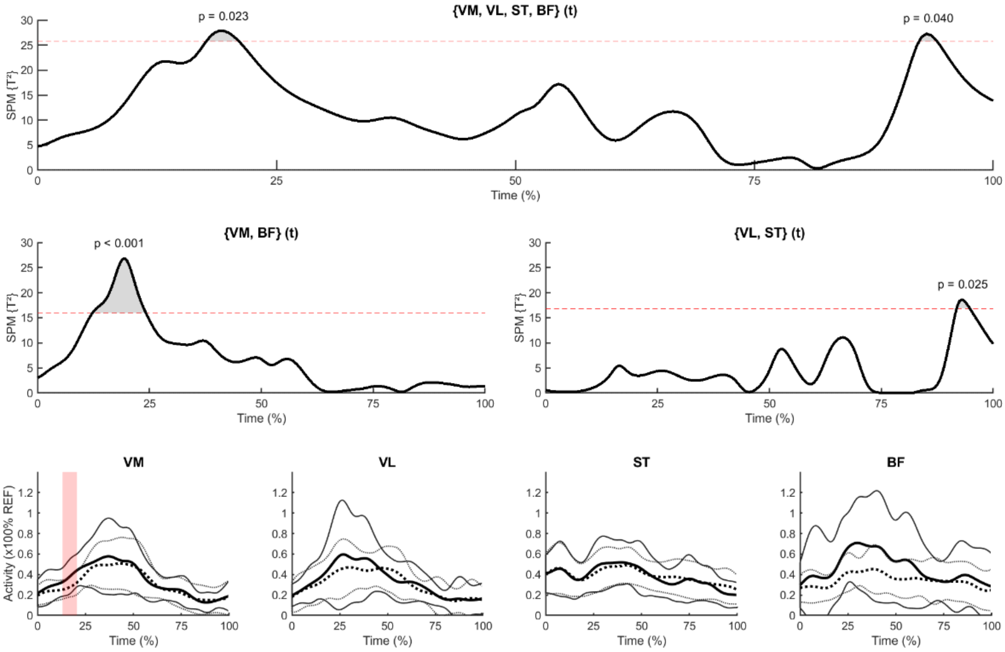

Figure 1: Top row: Trajectory level SPM analysis showing the differences for the overall EMG vectors. The horizontal dashed lines represent the critical random field theory threshold (*p* < 0.05). Middle row: Trajectory level SPM analyses for the diagonal muscle combinations. Bottom row: Activation patterns for the preplanned (solid line) and unplanned cut (dotted line). Red-shaded areas represent time periods with significant differences (*p* < 0.0127). VM, vastus medialis; VL, vastus lateralis; ST, semitendinosus; BF, biceps femoris; REF, reference task.

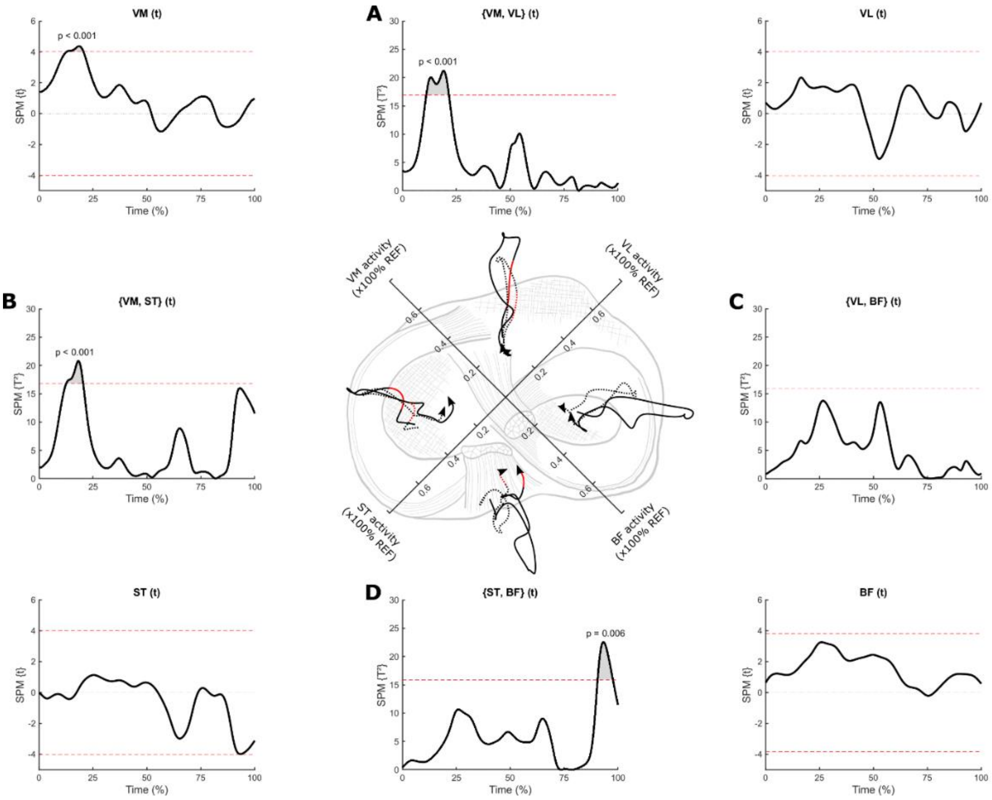

Figure 2: Central figure: Differences in two-muscle activation patterns between the preplanned (solid line) and unplanned cut (dotted line). Red sections represent time periods with significant differences (*p* < 0.05). Background figure: Top view of a knee joint. A, B, C, D:

Trajectory level SPM analyses showing the differences for the anterior, medial, lateral, and posterior EMG vectors. The horizontal dashed lines represent the critical random field theory threshold (p < 0.05). Corner figures: Trajectory level SPM analyses showing the differences for the individual muscle EMG amplitudes. Trajectories exceeding the upper and lower critical threshold indicate higher activity during the preplanned (PP) and unplanned (UP) cut, respectively. VM, vastus medialis; VL, vastus lateralis; ST, semitendinosus; BF, biceps femoris; SPM, Statistical Parametric Mapping; REF, reference task. Illustration based on Smeets et al. (2019).

CONCLUSION: Thigh muscle activity of experienced female handball players differs between PP and UP conditions. While individual muscle analyses provide limited insights, vector field analyses indicate that the knee joint might be better protected against external joint moments in PP compared to UP cutting maneuvers.

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