REDUCED MOVEMENT ADAPTABILITY IN SIDESTEPPING – A POSSIBLE SOURCE OF INJURY RISK

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Adapting to different task constraints provides insight into how malleable an athlete's movement dynamics are. The purpose of this pilot study was to investigate whether athletes can adequately change their preferred movement strategy during sidestepping when exposed to a manipulation task. Reduced movement adaptability was hypothesized to be one risk factor for ACL injuries. Fourteen male team sport athletes were investigated. The response to the manipulation task was intra-individual, with rearfoot strikers being less able to adapt their movement strategy and the resulting movement was even higher associated with ACL risk factors. Forefoot strikers were able to adapt their movement. This suggests, that athletes need to be investigated individually as group-based analyses might cover effects and that movement adaptability should be considered when evaluating injury risk.

KEYWORDS: cutting manoeuvres, adaptability, manipulation, injury.

INTRODUCTION: Fast sidestepping tasks have been identified as one of the most common ACL injury-related movements during team sports (Arendt & Dick, 1995; Boden, Griffin, & Garrett, 2000) and were frequently investigated in this context. Studies that researched the injury mechanism, identified a combination of increased non-sagittal knee joint moments and a nearly extended knee joint to put the ACL under stress (B. P. Boden, Dean et al., 2000; Koga et al., 2010). These loading characteristics were especially identified in athletes that use a movement strategy with a heel strike at the initial touch-down of the execution contact (David et al., 2017; Donnelly et al., 2017; Ogasawara et al., 2019). This was supported by a study by B. P. Boden et al. (2009), who reported a rear or flat foot strike pattern in ACL injury situations from video data. Rearfoot striking was found to occur in combination with limited preorientation of the body towards the new movement direction and strong deceleration during the execution contact (David et al., 2018).

Although the relationship between ACL relevant load and the described movement strategy seems to be reasonable, it is debated to what extent these strategies occur during real injury situations. These situations could result from demands that arise from changes in the boundary conditions of the movement (e.g. unpredictable opponent actions, ground conditions) when the athlete is not keeping control through adapting the movement (B. P. Boden, Griffin et al., 2000). The ability to react adequately to changes in the environment might be related to the adaptability of the athlete. So far, movement adaptability during sidestepping has been neglected in investigations of ACL injury risk. High movement adaptability could allow the athlete to use different movement strategies to cope with the demands of fast sidestepping. In contrast, subjects that exhibit less flexible coordination patterns may be less able to adapt to the environmental perturbations experienced during sports. These perturbations applied to a less flexible system may result in ligament injury.

It was hypothesized, that athletes can adapt their movement strategy to some extent from planned to unplanned manoeuvres and also from the preferred condition to one that includes a manipulation task to simulate unexpected conditions. Further, it was hypothesized, that athletes using forefoot landing show a higher movement adaptability in comparison to athletes that prefer rearfoot striking - due to less degrees of freedom in the ankle joint, which is also associated with higher ACL relevant knee joint load.

METHODS: Fourteen healthy male team sport athletes were investigated during sidestepping using a 24 camera Qualisys system (200 Hz, Miqus M3, Qualisys) and a lower-body marker set (David et al., 2017). To monitor vertical GRF without having the athlete to hit a force plate, in-shoe pressure distribution was captured (100 Hz, Novel, Pedar-x; Munich, Germany) and transferred into Force. Athletes gave written informed consent, the study was approved by the Universities ethical committee.
All athletes were characterized by the research team during the planned trials as either showing a forefoot-landing (Strategy A) with preorientation or a rearfoot-landing without preorientation strategy (Strategy B, Figure 1). The strategy identified subsequently determined the task manipulation that the athlete was asked to do. The manipulation task for strategy A athletes was to widen the penultimate step before sidestepping to restrict preorientation. The strategy B athletes were asked to generate as much GRF as possible during the penultimate contact before sidestepping to lower the braking force they otherwise need to generate during the execution step of the manoeuvre (David et al., 2018). The idea of transferring the braking part of the movement towards the preparation phase was to decomplexify the cutting step and allow the subject to rotate earlier and place the foot more flexible. The athletes completed four conditions, 90° pre-planned & unplanned sidestepping with and without task manipulations.
Vertical GRF, step width and length, foot-to-floor and pelvis preorientation angles were calculated in Matlab (R2020a) using the peak pressure values obtained by the Pedar-insoles, the foot and the pelvis markers (David et al., 2018). These parameters were used as the control variables to determine whether the athlete was able to execute the given manipulation task. The manipulation task was solved successfully if a significant difference was detected to the preferred strategy using Wilcoxon signed rank test (α = 0.05). The time-series data from the foot-to-floor and pelvis orientation angles were analysed using paired t-tests in Statistical parametric mapping.

Strategy A	**Strategy B**
Movement Strategy	
Fore-foot landing + body pre-orientation + long penultimate step	Rear-foot landing + minor body pre-orientation + wide penultimate step
Movement characteristics	
Highest braking forces during last approach contacts	Highest braking forces during EXEC contact
Aim of manipulation task	
Limit fore-foot landing and body pre-orientation	Transfer braking force to penultimate ground contact
Manipulation task	
'Make the last step as wide as possible'	'Generate as much GRF during the penultimate ground contact'

Figure 1: Criteria for strategy selection and manipulation tasks.

RESULTS: The turns to the left and right side were significantly different for all athletes and the aforementioned parameters, and were therefore treated as independent data for the analysis. For the planned trials, athletes that were preferring Strategy A (N=6) were able to execute the manipulation task by significantly increasing their step width by about 218 % ($p = 0.002$). This resulted in a significant reduction of the preorientation about 40.8 % ($p < 0.001$).
Overall, Strategy B athletes (N=20) significantly increased the braking force during the penultimate contact by about 128.6 % ($p=0.006$). However, not all athletes were able to execute the manipulation task as shown in Figure 2. The adaptation resulted in a significant increase of step width ($p < 0.001$) about 153.31 %. The significant decrease in preorientation ($p < 0.001$) about 39.7 % is linked to the increase in step width but was an unwanted effect of the manipulation task, as we expected preorientation to increase (Figure 1).

For the unplanned tasks, the Strategy B athletes did not significantly increase the braking force during the penultimate contact also no difference was detected for the force generated during the transition step. In contrast to this, the Strategy A athletes could also solve the manipulation task during the unplanned movements by significantly increasing their step width by about 112.1 % ($p = 0.03$) which resulted in a decrease of preorientation ($p = 0.03$) about 49.7 %.

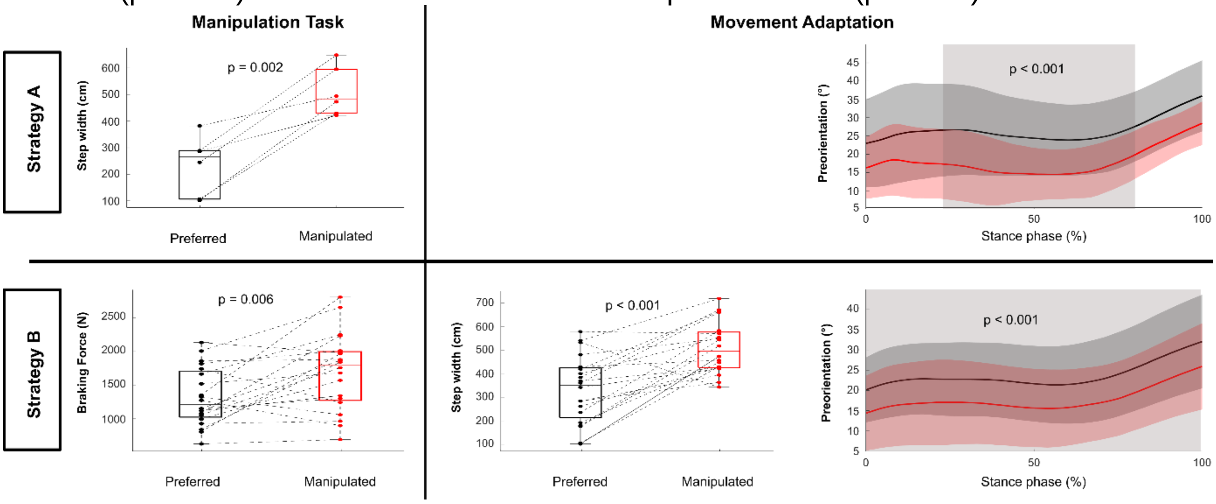

Figure 2: Rows: Adaptations of Strategy A (upper row) and Strategy B (lower row) athletes during planned sidestepping to the manipulation task. First Column: Ability of the athletes to fulfil the manipulation task. Second and third Column: Effects of the manipulation task.

DISCUSSION: This study aimed to investigate whether athletes can adapt their preferred movement strategy due to a manipulation task. From a methodological perspective, the success of such a new paradigm would allow researchers and coaches to get insight into the adaptability of an athlete or their risk of getting injured. We had hypothesized, that athletes using strategy B would be less flexible due to a reduced degree of freedom in the ankle joint as a result of rear-foot striking. This suggested lack of adaptability was further speculated to be one reason for more frequently occurring knee joint injuries within these group (Boden et al., 2009). As the movement strategy itself is a complex combination of different segment and joint postures and generated force pattern, we decided not to ask them to change their strategy but to complete a task that was suggested to have an impact on the strategy.
As hypothesized, strategy A athletes were able to adapt their movement pattern both in the planned and unplanned condition whereas the strategy B athletes were only flexible enough to respond during the planned condition. Moreover, although they were able to execute the manipulation task and increased the braking force during the penultimate contact, this did not result in an increase in preorientation, decrease of step width or a foot strike angle towards forefoot striking but the opposite was the case. Although this result does not support the hypothesis that a transfer of the braking force will enable the athlete to rotate earlier, this still supports the second hypothesis, that strategy B athletes are less able to adapt their movement strategy. Also, the response to the manipulation task was not uniform for all Strategy B athletes. Although the overall result showed a successful adaptation, five athletes showed a decrease of braking force while all Strategy A athletes adapted. However, we did not include an even number of athletes of both groups, and the number of included athletes is too small to rely on this result so therefore further confirmation is required. The effect on the preferred movement strategy varied among the participants. While some athletes showed the hypothesised effects, others did not. The reasons for this may be as follows: Some athletes were successful in solving the manipulation task but their 'solution' to the task was combined with unwanted movement adaptation. For others, solving the task was so demanding, that they slowed down and therefore were not able to execute fore-foot striking or body pre-orientation anymore. It could also be possible that that the changes were not visible within our chosen outcome variables, for example, changes in muscle activation patterns such as co-contraction or adaptation of joint angles are possible but were not evaluated for this pilot study. However, these will be analysed in the future.

We decided not to use force plates to collect the ground reaction forces during this study. Limiting the athlete's movement by having them to hit the force plate would add another level of complexity to the movement or cause a high number of invalid trials. This was unwanted as the number of trials to complete was already 60 to cover all conditions and movement directions. It was therefore decided to use pressure insoles to estimate the force distribution between ground contacts. We used the vertical force obtained from peak pressure distribution as a proxy that also reflects changes in the braking force component.
Due to the nature of this study as a pilot experiment, the results are only preliminary and need to be confirmed by an ongoing study. The number of included athletes is not sufficient to draw clear conclusions. However, the aim was to test and establish a new testing paradigm for sidestepping. These results show that the athletes reacted in a highly individualised manner to the manipulated movement task. This underlines the necessity to investigate the responses of an athlete individually, as group-based approaches may mask these findings (Glazier & Mehdizadeh, 2019). The differences in adaptability could be the result of different baseline strategies.

CONCLUSION: This pilot study reports initial outcomes of a novel paradigm challenging the movement adaptability of athletes during sidestepping. The results, although limited by the small number of included athletes provide initial support for the hypotheses, that the movement strategy that is associated with higher injury risk limits an athlete's ability to adapt to changes in the task. Whilst further analysis is required to understand the mechanisms underpinning the adaptations made by the athletes, a lack of adaptability could further explain the presence of injury situations, even in non-typical ACL injuries.

REFERENCES

Boden, B. P., Dean, G. S., Feagin, J. A., & Garrett, W. E. (2000). Mechanisms of anterior cruciate ligament injury. Orthopedics, 23(6), 573–578.

Boden, B. P., Griffin, L. Y., & Garrett, W. E. (2000). Etiology and prevention of noncontact ACL injury. The Physician and Sportsmedicine, 28(4), 53–60. https://doi.org/10.3810/psm.2000.04.841

Boden, B. P., Torg, J. S., Knowles, S. B., & Hewett, T. E. (2009). Video analysis of anterior cruciate ligament injury: Abnormalities in hip and ankle kinematics. The American Journal of Sports Medicine, 37(2), 252–259. https://doi.org/10.1177/0363546508328107

David, S., Komnik, I., Peters, M., Funken, J., & Potthast, W. (2017). Identification and risk estimation of movement strategies during cutting maneuvers. Journal of Science and Medicine in Sport, 20(12), 1075–1080. https://doi.org/10.1016/j.jsams.2017.05.011

David, S., Mundt, M., Komnik, I., & Potthast, W. (2018). Understanding cutting maneuvers – The mechanical consequence of preparatory strategies and foot strike pattern. Human Movement Science, 62, 202–210. https://doi.org/10.1016/j.humov.2018.10.005

Donnelly, C. J., Chinnasee, C., Weir, G., Sasimontonkul, S., & Alderson, J. (2017). Joint dynamics of rear- and fore-foot unplanned sidestepping. Journal of Science and Medicine in Sport / Sports Medicine Australia, 20(1), 32–37. https://doi.org/10.1016/j.jsams.2016.06.002

Glazier, P. S., & Mehdizadeh, S. (2019). Challenging Conventional Paradigms in Applied Sports Biomechanics Research. Sports Medicine (Auckland, N.Z.), 49(2), 171–176. https://doi.org/10.1007/s40279-018-1030-1

Koga, H., Nakamae, A., Shima, Y., Iwasa, J., Myklebust, G., Engebretsen, L., Bahr, R., & Krosshaug, T. (2010). Mechanisms for noncontact anterior cruciate ligament injuries: Knee joint kinematics in 10 injury situations from female team handball and basketball. The American Journal of Sports Medicine, 38(11), 2218–2225. https://doi.org/10.1177/0363546510373570

Ogasawara, I., Shimokochi, Y., Mae, T., & Nakata, K. (2019). Rearfoot strikes more frequently apply combined knee valgus and tibial internal rotation moments than forefoot strikes in females during the early phase of cutting maneuvers. Gait & Posture, 76, 364–371. https://doi.org/10.1016/j.gaitpost.2019.11.014

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