Fast-Feedback on joint biomechanics for team sport athletes:
A feasibility study with implications for injury risk monitoring

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INTRODUCTION: Injuries to the anterior cruciate ligament (ACL) have repeatedly been identified as some of the most common injuries in team sports. As the majority of these injuries are non-contact and more prominent in females, screening for biomechanical risk factors has repeatedly been applied to identify athletes at risk. While these findings are valuable, the analysis is time-consuming where immediate feedback to the athlete and coach would be a desirable scenario. We have used the real-time tracking possibility of modern three-dimensional motion capture systems within a fast computation algorithm to provide information on knee joint loading and biomechanical technique variables immediately following a test trial. With this, it becomes possible to provide ad hoc feedback and assess the immediate response to technique instructions within one training session. In this paper, the application of the setup to a handball-specific test on ACL injury risk was applied to assess the effect of the foot placement strategy as one of the previously identified technique factors associated with high valgus loading of the knee. It was hypothesized that 1) athletes can adapt movement technique and 2) that the change of rearfoot to forefoot placement will reduce the knee abduction (KAM) moment during early contact.

METHODS: Injuries to the anterior cruciate ligament (ACL) have repeatedly been identified as some of the most common injuries in team sports. As the majority of these injuries are non-contact and more prominent in females, screening for biomechanical risk factors has repeatedly been applied to identify athletes at risk. While these findings are valuable, the analysis is time-consuming where immediate feedback to the athlete and coach would be a desirable scenario. We have used the real-time tracking possibility of modern three-dimensional motion capture systems within a fast computation algorithm to provide information on knee joint loading and biomechanical technique variables immediately following a test trial. With this, it becomes possible to provide ad hoc feedback and assess the immediate response to technique instructions within one training session. In this paper, the application of the setup to a handball-specific test on ACL injury risk was applied to assess the effect of the foot placement strategy as one of the previously identified technique factors associated with high valgus loading of the knee. It was hypothesized that 1) athletes can adapt movement technique and 2) that the change of rearfoot to forefoot placement will reduce the knee abduction (KAM) moment during early contact.

RESULTS: The time for the application to calculate and display results was low (<2s). Out of 96 individual cuts, in 73 cuts the athletes were able to adhere to the feedback. In these cases, peak KAM magnitudes within the first 60 ms were significantly lower (1.00 ± 0.45 Nm/kg, $p<0.001$) compared to the cuts where feedback was not translated (1.52 ± 0.50 Nm/kg; Fig1). Similar to peak KAMs, KAM time-curves across the first 60 ms of stance (Fig2A&B) were lower for the feedback translated cuts but not tested for significance.

DISCUSSION: Our preliminary results demonstrate that the developed fast-feedback tool is feasible and allows to assess individual technique variables and the resulting joint loading instantly after execution. It was also demonstrated that athletes are capable to alter their foot strike pattern based on specific, in advance operationalized instructions and to provide immediate verification of the instructions taking effect and most importantly if the change leads to the desired reduction of KAM. Due of the limited sample size, we considered individual cuts rather than mean values per subject. Therefore, caution needs to be paid when interpreting the results.

SIGNIFICANCE/CLINICAL RELEVANCE: The developed tool provides an efficient and customizable biofeedback solution to modify movement technique in critical situations. We envisage future applications based on open-source programming languages (e.g., Python) and musculoskeletal modeling software (e.g., OpenSim) and the integration of alternative motion tracking systems to make the tool accessible to a wider audience in different testing scenarios.

REFERENCES: [1] Krosshaug T *et al*. *Am J Sports Med* 2007. [2] Kristianslund E *et al. Br J Sports Med* 2014. [3] Bill K *et. al.* 2022. Manuscript under review, Frontiers.

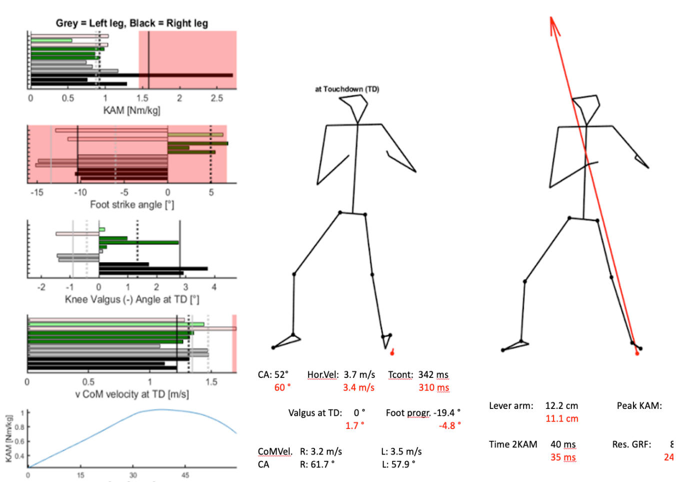

Figure 1: Screen view of the athletes fast feedback, including KAM magnitudes and cutting technique parameters for the left and right leg at the baseline assessment (first six bars from the bottom) and after the individual feedback.

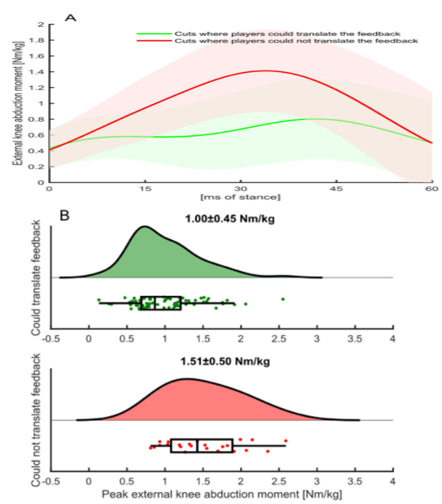

Figure 2: A) Mean KAM curves within the first 60 ms after initial ground contact. Shaded areas represent the SD. B) Distribution and box plots of the peak KAM within the first 60 ms for cuts where athletes translated the feedback (green) and for the cuts where athletes could not translate the feedback (red).