EFFECTS OF AN 8-WEEK KNEE INJURY PREVENTION PROGRAM AND TECHNIQUE MODIFICATION TRAINING ON CHANGE-OF-DIRECTION PERFORMANCE

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The purpose of this analysis was to determine whether an 8-week knee injury prevention program with an additional focus on change-of-direction (COD) technique training results in improved COD performance compared to a control training group with a focus on linear sprint training. Although both groups showed indicators for superior performance during a 135-degree COD, such as a more effective reorientation of the body, the COD technique modification component was ineffective in improving overall COD completion time or ground contact times. Follow-up analyses will show whether the COD group adopted a safer COD movement strategy following training, e.g. by reducing the knee valgus loading.

KEYWORDS: ACL injury, sidestepping, knee valgus, injury prevention

INTRODUCTION: Exercise-based knee injury prevention programs (KIPPs) have been developed to effectively lower the risk for ACL rupture in multi-directional team sports, e.g. FIFA11+ or Knäkontroll (Arundale et al., 2018). These programs typically consist of multiple training modalities such as strength and balance exercises plus sport-specific running and jumping drills to condition the athletes' neuromuscular system and promote safe movement strategies. Despite their success to reduce overall injury rates, however, most multi-modal training programs include very few exercises related to improving change-of-direction (COD) movements even though such manoeuvres account for a large proportion of non-contact ACL injuries (Johnston et al., 2018). This conflict indicates that KIPPs could be more effective if they also improved COD movement strategies in addition to their existing benefits.

One way to achieve this goal could be to incorporate more targeted COD technique modification drills into KIPPs that encourage e.g. trunk inclination into the intended direction of travel or lower hip and knee abduction during ground contact – movement interventions that have been shown to reduce knee valgus loading during CODs as a suspected ACL injury risk factor (Donelon, Dos'Santos, Pitchers, Brown, & Jones, 2020). Some of those technique modifications that lower knee valgus loading, however, may also limit maximum COD performance, a trade-off known as the injury-performance conflict (Dos'Santos, Thomas, Comfort, & Jones, 2018). Therefore, the overarching aim of this project was to determine whether an 8-week KIPP combined with a specific COD technique modification component leads to 1) safer movement strategies as quantified by reduced knee valgus loading and 2) improved or at least maintained performance during a maximum 135-degree COD in comparison to an 8-week KIPP with a non-specific linear sprint training component in a group of sports science students.

This paper presents the first analysis of this project and focuses on the COD performance aspect. Recent studies have suggested that faster COD completion times were associated with larger propulsive forces during the final foot contact (FFC), larger braking forces during the penultimate foot contact (PFC), shorter ground contact times, and the ability to re-orient the ground reaction force into the intended direction of travel (Dos'Santos, Thomas, Comfort, & Jones, 2021; Dos'Santos, Thomas, McBurnie, Comfort, & Jones, 2021). The current study investigated a sharp cutting angle of 135-degree because CODs in the angular range between 90-180 degrees 1) force athletes to perform substantial braking and re-

acceleration, 2) lead to the largest knee valgus loading (Dos'Santos, Thomas, & Jones, 2021), and 3) occur frequently during multi-directional team sports (Dos'Santos et al., 2018).

Specifically, we tested the hypothesis that the COD training group would show larger improvements in COD performance than the sprint training group as quantified by faster COD completion times facilitated through a larger braking impulse during the PFC, shorter ground contact times, higher peak propulsive forces during the FFC, and a more effective re-orientation of the body's momentum.

METHODS: Twenty-four healthy sports science students (11 females; age range 21-27 years, >3 strenuous exercise sessions per week; diverse sport and training backgrounds) volunteered to participate in baseline measurements while 22 participants (two female drop-outs) completed the training program and follow-up measurements. Following baseline testing, individuals were quasi-randomly assigned to either the sprint group (SG) or COD group (CODG) and were asked to participate in supervised 30-minute gym-training sessions at least twice per week over eight weeks. The first half of the training was identical between groups and consisted of straight running, strength, and balance exercises selected from the FIFA11+ injury prevention program. During the second half, the CODG completed lateral movement and COD drills (Dos'Santos, Thomas, McBurnie, et al., 2021) while the SG practiced linear acceleration and maximum velocity sprinting. All exercises increased in difficulty every two weeks. Training supervisors provided individual technique feedback with the goal to improve performance (both groups) and at the same time reduce knee joint loading (CODG only).

During baseline testing, participants provided written informed consent and basic information about demographics, sport participation, and injury history. After a standardized bike ergometer warm-up, participants completed six repetitions of a maximum-speed 135-degree COD (Figure 1a) with a minimum of three familiarization and practice trials. COD performance and movement were evaluated based on timing gates to monitor COD completion time, two floor-embedded force plates to analyze ground reaction forces (GRFs, 1000 Hz) and 3D optical motion capture to record full-body kinematics. This paper is based on the timing gate and force plate data only. All GRFs were filtered using a fourth-order Butterworth low-pass filter with a cut-off frequency at 20 Hz. GRF-based outcome variables included ground contact times of the PFC and FFC, the braking impulse during the PFC in the anterior-posterior direction, i.e. the approach direction, the resultant peak propulsive force in the horizontal plane during FFC push-off (RHF in Figure 1a inset), and the orientation of the resultant GRF vector in the horizontal plane at the time point of peak force (RA in the Figure 1a inset).

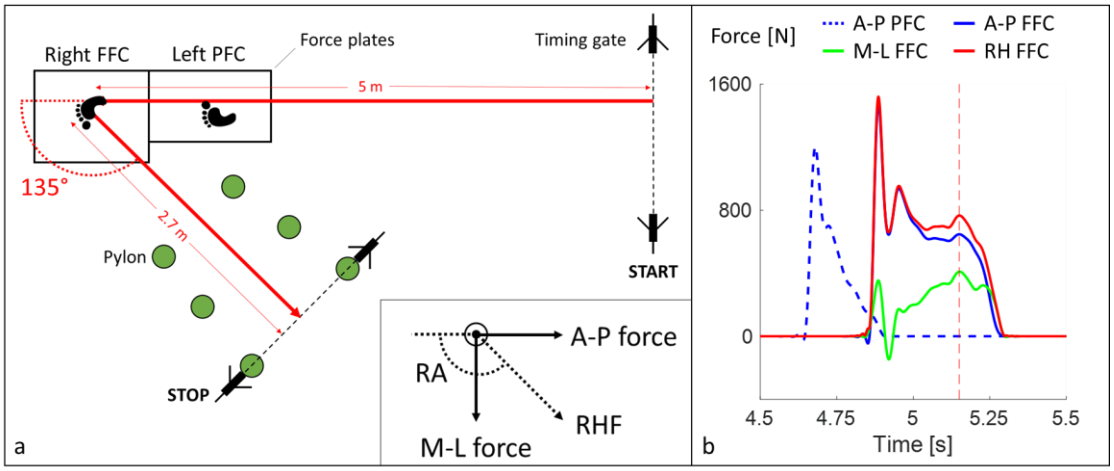

Figure 1: 135-degree COD set-up (a). Example for ground reaction forces of one 135-degree COD (b). The dashed red line marks the peak horizontal propulsive force during push-off.

For each outcome variable and testing time point, we determined the mean out of the three fastest CODs according to the COD completion time. We used repeated measures ANOVAs with the within-subject factor 'training' (baseline vs. follow-up) and the between-subject factor 'group' (SG vs. CODG) to investigate main and interaction effects for each outcome variable

and where applicable paired t-test for post-hoc comparisons at a significance level of alpha = 0.05. Effect sizes were interpreted according to partial eta-squared with η_p^2 < 0.06, < 0.14, and ≥ 0.14 indicating small, medium, and large effects (Cohen, 1988).

RESULTS: All 22 participants completed at least one training session per week (≥8 sessions in total) with a slightly higher training adherence in the SG (mean±SD training sessions per week, 1.7±0.4) compared to CODG (1.4±0.3). There were no significant main effects of training ($F_{(1,20)}$=0.985, p=0.333, η_p^2=0.047) nor interaction effects ($F_{(1,20)}$=1.168, p=0.293, η_p^2=0.055) with respect to COD completion times (Figure 2a). There was a trend towards an interaction effect ($F_{(1,20)}$=4.044, p=0.058, η_p^2=0.168) with respect to ground contact times during FFC. Specifically, the SG showed shorter contact times following training (SG-pre: 0.44±0.10s; SG-post: 0.41±0.07s) while contact times in the CODG were unchanged or even slightly increased (CODG-pre: 0.39±0.05s; CODG-post: 0.40±0.06s).

There was a significant training effect on the anterior-posterior braking impulse following training ($F_{(1,20)}$=6.698, p=0.018, η_p^2=0.251) without a significant interaction effect ($F_{(1,20)}$=1.699, p=0.207, η_p^2=0.078). On average both groups showed a larger braking impulse following training, however, post-hoc comparisons only reached statistical significance for the SG (pre: -0.104±0.030 Ns/BW; post: -0.121±0.031 Ns/BW, p=0.012) but not the CODG (pre: -0.131±0.019 Ns/BW; post: -0.137±0.013 Ns/BW, p=0.375).

There were no significant main effects ($F_{(1,20)}$=1.873, p=0.186, η_p^2=0.086) nor interaction effects ($F_{(1,20)}$=0.372, p=0.549, η_p^2=0.018) with respect to the peak horizontal propulsive force during FFC push-off. However, there was a significant training effect ($F_{(1,20)}$=14.719, p=0.001, η_p^2=0.424) on the resultant GRF vector angle in the horizontal plane with no significant interaction effect ($F_{(1,20)}$=0.456, p=0.507, η_p^2=0.022). Both groups showed a larger angle, i.e. a more posteriorly oriented GRF vector, during follow-up (Figure 2b).

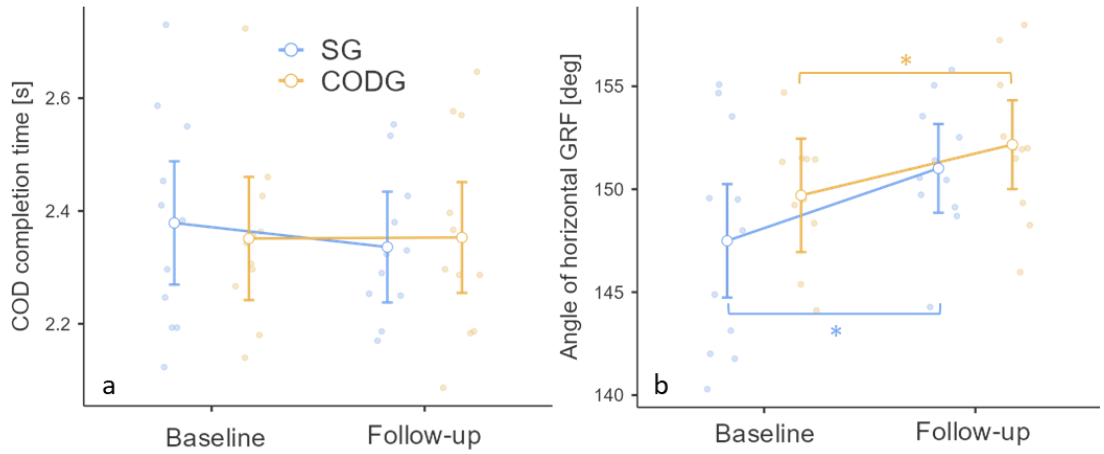

Figure 2: COD completion time (a) and angle of the resultant horizontal GRF at peak force (b). Each graph shows the mean and 95% confidence interval for each group at each time point including the shaded individual data. Asterisks mark significant post-hoc comparisons.

DISCUSSION: The primary hypothesis that there would be larger improvements in COD completion time following an 8-week KIPP plus COD technique modification training compared to an 8-week KIPP plus sprint training was not supported since we did not observe significant reductions in COD completion times pre- and post-training in any of the groups.

This is in contrast to recent studies showing reduced COD completion times at various COD angles following a six-week COD speed and technique modification training (Dos'Santos, Thomas, Comfort, et al., 2021; Dos'Santos, Thomas, McBurnie, et al., 2021). This disagreement may have resulted from the higher training adherence in those studies (2 sessions vs. 1.4 / 1.7 sessions per week in the CODG / SG) or the fact that Dos'Santos and colleagues used the entire 30-minute training sessions for COD drills while our CODG only

spent only half of the 30-minute sessions on COD drills. Furthermore, completion times may be insensitive to small training-related improvements in COD velocity profiles or movement trajectories. For example, the finding of a more posteriorly oriented GRF during the FFC push-off signals a more successful reorientation of the body during the 135-degree COD following training. Given the presence of this effect in both training groups, we assume that the strength and balance training component allowed all participants to execute a sharper COD closer to the intended angle of 135 degrees while maintaining a similar completion time, which would represent superior COD performance (Condello, Kernozek, Tessitore, & Foster, 2016). Our future analysis of the center of mass movement paths will test this assumption.

An increased anterior-posterior braking impulse during PFC was only demonstrated by the SG, which could explain why this group showed a trend towards shorter ground contact times during the FFC. This more pronounced training effect in the SG may stem from the specific training of 'quick push-offs' in this group or the slightly higher training adherence. In addition, faster COD approach speeds in the SG could explain larger braking forces. Our future analysis of the center of mass velocity profiles will provide a more comprehensive assessment of the correlation between COD velocity profiles and GRFs. Similarly, inverse dynamics analyses will reveal whether the COD training group may have achieved the COD movements with a reduced knee valgus loading compared to the sprint group following training.

CONCLUSION: An 8-week KIPP with or without specific COD training resulted in a more posterior orientation of the GRF vector during a 135-degree COD but no significant reduction in COD completion or ground contact times. Possible reasons for the lack of improved COD performance include a low adherence or that the COD training component was too short. Based on the current results, the combined KIPP and COD technique training cannot be recommended to improve COD performance in a heterogeneous group of highly active adults.

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