EFFECTS OF 90-MINUTE MATCH SIMULATION ON WHOLE-BODY DYNAMIC STABILITY IN UNANTICIPATED SIDE CUTTING

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The purpose of this investigation was to identify the effects of soccer match-specific physical exertion on deployment of movement strategies to control the centre of mass (CoM) in the medio-lateral direction during unanticipated side cutting. Twenty-one healthy male recreational soccer players completed a 90-minute over-ground soccer match-simulation. Integrated to the match-simulation were 45° unanticipated side cutting tasks using a 4-5 $m \cdot s^{-1}$ approach speed. Performance outcomes, peak knee abduction moments (peak KAM), and whole-body dynamic stability variables were calculated for the side cutting tasks. A reduction in the capacity to generate medio-lateral forces from sagittal methods may explain the drop in average medial CoM acceleration and change of direction angle. An ankle movement strategy, represented by a lateral movement of the centre of pressure (CoP) position, appears to have been deployed to mitigate any additional drop in side-cutting performance. A single match-simulation may be insufficient to increase injury risk markers unless the individuals are already showing signs of a reduced ability to mitigate unnecessary movement deviations.

KEYWORDS: change of direction, fatigue, centre of mass control, knee.

INTRODUCTION: Each time a dynamic task is executed success is dependent on the efficient deployment of movement strategies that allow for control of the centre of mass (CoM) and may indicate the status of whole-body dynamic stability (Sankey et al., 2020). When dynamic tasks like side cutting are repeated, perhaps over the course of a prolonged bout of physical exertion, it is possible that the development of fatigue may lead to reduced efficiency in the deployment of those movement strategies. If those movement strategies start to fail, the control of the CoM is compromised to the extent that movement deviations become detrimental to task performance or even dangerous. This may result in undesirable joint mechanics like those reported previously for the knee and Anterior Cruciate Ligament (ACL) injury (Hewett et al., 2005). The extent to which deployment of whole-body dynamic stability movement strategies and dangerous deviations are affected by repetition, like that observed in soccer match-play, remains unknown. Typical responses to physical exertion appear to be kinematic postural adjustments including, a more extended knee (Raja Azidin et al., 2015; Whyte et al., 2018); increases in knee abduction angles (Collins et al., 2016); and increases in internal rotation angles of the knee (Tsai et al., 2009). That said, as control of the CoM is the primary aim in human movement, it is possible that mechanics that are typically reported to contribute to increased ACL injury risk are themselves a consequence of poor control of the CoM in the new direction of travel. Quantifying the mechanical change following match-specific bouts of physical exertion may provide valuable information for injury screening or training intervention, whether preventative, or as a method of tracking athletic condition when aiming to return-to-play. Therefore, the aim of this investigation was to identify the effects of a match-specific bout of exertion on deployment of movement strategies to provide medio-lateral control of the CoM during unanticipated side cutting.

METHODS: Twenty-one healthy male recreational soccer players participated in this study. Each participant had at least 6 years playing experience, consisting of between one and two sessions a week, for one to two hours per session. The participants had a mean (± SD) age of 26 ± 7 years; mean height of 1.8 ± 0.1 m; and mean mass of 79.2 ± 11.2 kg. All participants were free from injury for at least 6 months, and written consent was retrieved from every participant. Following familiarisation sessions each participant completed a 90-minute over-ground soccer match-simulation. Integrated to the match-simulation were 45° unanticipated side cutting tasks using a 4-5 $m \cdot s^{-1}$ approach speed. 3D motion capture and ground reaction force data were collected. Kinematics and kinetics, and task execution variables were calculated using a lower limb and trunk model. Performance outcomes, peak knee abduction moments (peak KAM), and whole-body dynamic stability variables were calculated for the side cutting tasks, with an average of 4 trials per participant, per 15-minute block of the simulation, inclusive of a pre-simulation condition and a 15-minute break for half-time. In total there were seven within-group levels. Five distinct whole-body dynamic stability movement strategies were identified (see figure 1), based on factors that influence the medial ground reaction force (GRF) vector during ground contact in the side cutting manoeuvre following Induced Acceleration Analysis (IAA) outlined in previous research (Sankey et al., 2020). To investigate the effect of the match-simulation, multiple ANOVAs were conducted using SPSS and SPM1D. Separate analyses were conducted on four participants (high peak KAM group) who demonstrated high peak KAM two SDs above the mean of the rest of the participant group (low peak KAM group).

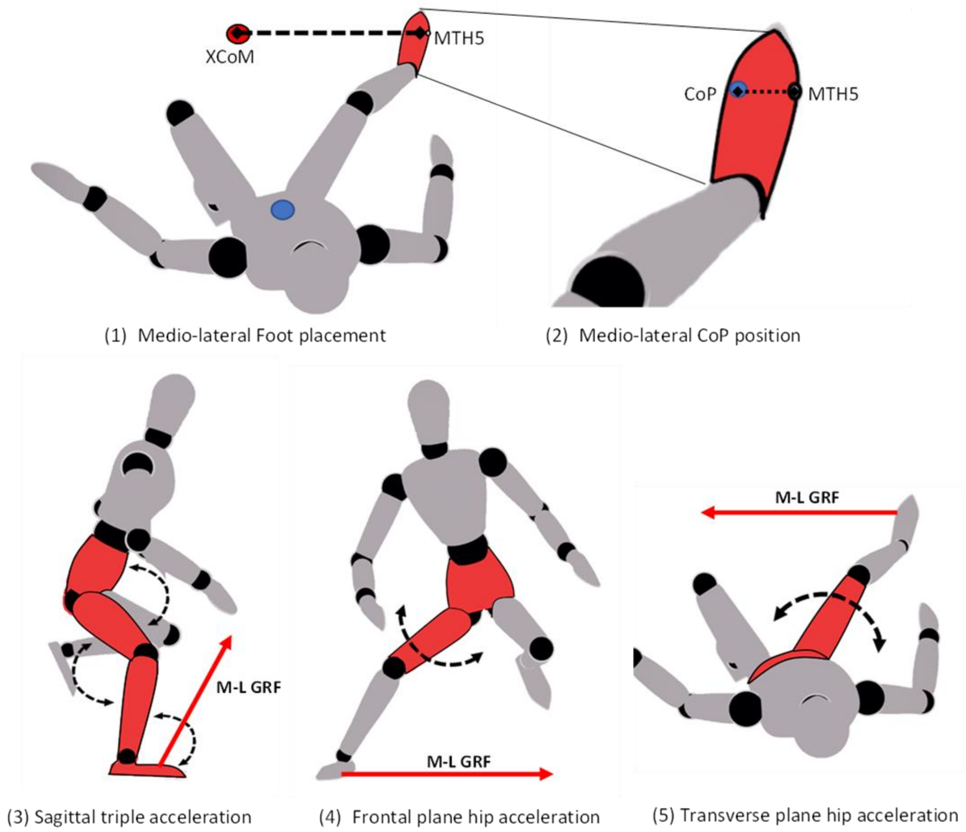

Figure 1. Five distinct Whole-body dynamic stability mechanisms adapted from Sankey et al., (2020).

RESULTS: Side cutting performance reduced significantly over the course of the match-simulation (see table 1). Peak knee abduction moment reduced, but not significantly with elapsed match-simulation time. In terms of the whole-body dynamic stability mechanisms, foot placement remained consistent, however, the centre of pressure (CoP) moved significantly more lateral with exertion time. Sagittal plane loading, specifically in the weight acceptance phase of the side cutting, had reduced significantly by the end of the match-simulation, however, frontal plane hip acceleration remained consistent. There was a significant reduction in the contribution of transverse plane hip acceleration with time, however, only in the brief period just before toe-off.

Table 1. Comparison of the performance outcome variables (mean ± *SD*) for 45° unanticipated side cutting tasks from pre-simulation (Pre-Sim) and over the course of six 15-minute blocks of a 90-minute match simulation. Significance of main effect from within-group analyses is also presented.

Performance Outcome		Pre-Sim	First half (mins)			Second half (mins)			Significance
			0-15	15-30	30-45	60-75	75-90	90-105	
Touchdown Velocity (m·s^{-1})	mean	4.74	4.80	4.78	4.75	4.68	4.71	4.67	p=0.056 [np]
	SD	*0.36*	*0.30*	*0.24*	*0.31*	*0.29*	*0.32*	*0.38*	
Toe-off Velocity (m·s^{-1})	mean	4.57	4.64	4.63	4.60	4.57	4.53	4.50	p=0.270 [np]
	SD	*0.37*	*0.36*	*0.32*	*0.39*	*0.41*	*0.44*	*0.49*	
Av. Medial CoM accel. (m·s^{-2})	mean	6.46	7.00	6.76	6.40	6.26	6.04	5.88	*p<0.001 [np]
	SD	*1.19*	*1.41*	*1.64*	*1.50*	*1.22*	*1.62*	*1.47*	
Change of direction angle (°)	mean	19.52	20.42	19.67	18.60	18.68	17.98	17.93	*p<0.001[GG]
	SD	*4.31*	*4.34*	*4.97*	*4.36*	*4.73*	*4.73*	*4.76*	
Contact Time (s)	mean	0.224	0.220	0.219	0.217	0.220	0.218	0.222	p=0.893 [np]
	SD	*0.021*	*0.021*	*0.021*	*0.021*	*0.020*	*0.022*	*0.024*	
Knee Angle @ TD (°)	mean	23.24	25.09	23.93	22.10	21.34	19.75	19.41	*p=0.005[GG]
	SD	*9.25*	*8.12*	*9.32*	*9.93*	*9.67*	*10.02*	*10.24*	
Peak KAM (N·m/kg^{-1})	mean	0.72	0.83	0.78	0.71	0.57	0.59	0.57	p=0.05 [np]
	SD	*0.71*	*0.65*	*0.79*	*0.72*	*0.50*	*0.61*	*0.52*	

NB: '' denotes significance with a Bonferroni corrected alpha level (α = 0.007) for multiple comparisons; '[np]' denotes Friedman's Non-Parametric repeated measures test; '[GG]' denotes Greenhouse-Geisser correction for violation of Sphericity assumption.*

In separate analysis, the high peak KAM group were found to generate higher medio-lateral forces from sagittal plane triple acceleration mechanism in addition to higher opposing or counter-movement forces from the frontal plane hip acceleration mechanism compared to the low peak KAM group. However, the low peak KAM group were always able to provide sufficient counter-movement forces to mitigate any issues with sagittal plane efficiency (excessive sagittal plane forces) through frontal plane hip acceleration alone. The high peak KAM group consistently displayed a deficit of around 30% between excessive sagittal plane loading and opposing frontal plane countermovement forces.

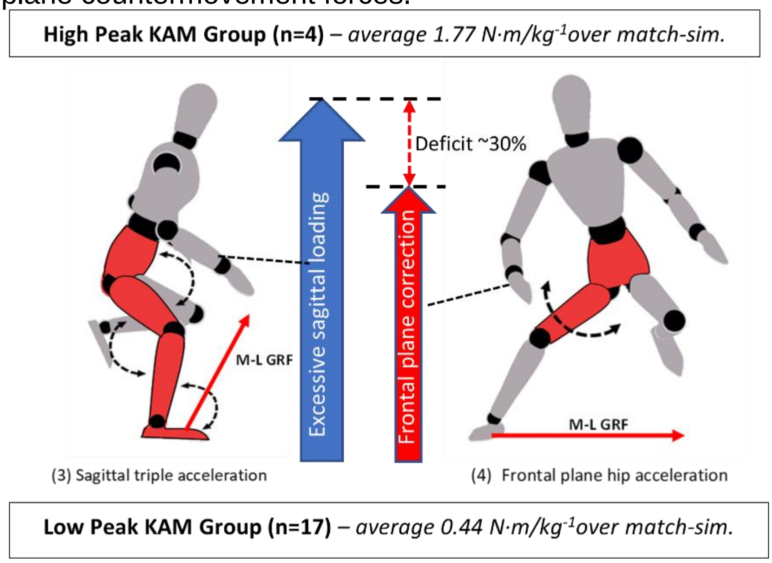

Figure 2: Key comparison of the high peak KAM vs low peak KAM groups for key Whole-body dynamic stability mechanisms.

DISCUSSION: The purpose of this investigation was to identify the effects of soccer match-specific physical exertion on deployment of movement strategies to control the CoM in the medio-lateral direction during unanticipated side cutting. Whilst injury risk, expressed by undesirable peak knee abduction moments, did not appear to change significantly, markers of side cutting performance did. A reduction in the capacity to generate medio-lateral forces from sagittal methods may explain the drop in average medial CoM acceleration and change of direction angle. For the overall sample, the most pronounced change over the course of the match-simulation appears to be in the lateral movement of the CoP position, which may be indicative of an ankle strategy to increase the moment arm length and mitigate any additional drop in side cutting performance. Comparison between those participants exhibiting high and low peak knee abduction loading may offer some important findings concerning injury risk. Although the low knee loading group were always able to offer sufficient counter-movement forces to mitigate any issues with sagittal plane efficiency, the high knee loading group were never able to do so. This suggests that the origin of undesirable knee joint loading in the frontal plane may be due to the inability to sufficiently counteract excessive sagittal plane loading through frontal plane mechanisms alone. Thus, one may suggest excessive sagittal plane loading can destabilise control of the CoM and therefore whole-body dynamic stability is compromised along with markers of injury risk.

CONCLUSION: In this study we have shown the effects of soccer-specific match simulation on whole-body dynamic stability movement strategies in unanticipated side cutting, and the possible implications for injury risk and aspects of performance. In conclusion, it appears that a single match-simulation may be insufficient to increase injury risk markers, unless the individuals are already showing signs of a reduced ability to mitigate unnecessary movement deviations, emphasised by reduced whole-body dynamic stability. To the best of our knowledge this is the first study that has reported the roles of movement strategies to control the CoM in side cutting, or more broadly, tasks that involve medio-lateral force generation control, in response to a prolonged bout of physical exertion.

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