TASK CONSTRAINTS MODIFY INTRISIC HEAD-TRUNK DYNAMICS DURING RUNNING AND SIDESTEPPING

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The purpose of this study was to examine head movement control during running and sidestepping tasks. Fourteen collegiate male athletes performed running and sidestepping tasks. Sagittal and transverse head and trunk angles, vertical trunk displacement and head-trunk coordination were assessed during the flight and stance phases. The sidestepping task resulted in greater transverse and sagittal plane head and trunk range of motion. During stance, transverse plane head-trunk coordination was more in-phase, with reduced vertical trunk-sagittal head anti-phase coordination during sidestepping tasks. During sidestepping tasks, visual field reorientation required greater contributions from the head in the transverse plane, but with reduced sagittal plane compensation, reduced perceptual awareness may be observed, with negative implications on sport performance and injury risk.

KEYWORDS: HEAD CONTROL, INTRINSIC DYNAMICS, COORDINATION, SIDESTEPPING

INTRODUCTION: Athletes are required to obtain accurate perceptual information to inform the neuromuscular system of relevant environmental features. The type of visual stimuli in sport settings may modify neuromuscular activation patterns (Lee, Lloyd, Lay, Bourke, & Alderson, 2019), thus modifying injury risk. The pursuit of visual information requires a stable head, achieved through compensatory head on trunk rotations in each plane (Imai, Moore, Raphan, & Cohen, 2001; Pozzo, Berthoz, & Lefort, 1990). During forward locomotion, trunk rotations have been suggested to help reduce center of mass (CoM) displacement while minimizing lower extremity and pelvic perturbations from reaching the head (Preece, Mason, & Bramah, 2016). In the transverse plane, “out-of-phase” trunk rotations with the pelvis provide a platform for arm rotations; these upper extremity rotations counter lower extremity rotations, minimizing whole body angular momentum and reducing whole body CoM deviations during locomotion (Bruijn, Meijer, van Dieën, Kingma, & Lamoth, 2008). Vertical trunk oscillations, in addition to sagittal and transverse plane trunk rotations, have the potential to perturb head position in space, and thus the perceptual systems housed in the head, throughout locomotor tasks.

In the sagittal plane, greater anti-phase coupling was observed between the sagittal head-vertical trunk CoM displacement couple (63%) than the sagittal head-sagittal trunk couple (52%) during the stance phase of running (Lim, Hamill, Busa, & van Emmerik, 2020). This suggests the compensatory head rotations, which are the most prevalent coordination pattern during stance, may be more responsive to locomotor generated vertical CoM displacement than sagittal plane trunk rotations while running. A different head-trunk relationship has been shown in the transverse plane (Cromwell et al., 2004; Lim et al., 2020). In the transverse plane, trunk rotations are not fully compensated by the head during forward walking and running tasks, as shown by a primarily trunk dominant coordination pattern during stance while running (94.5%), but greater contributions from the head have been observed with increased visual task demands (Cromwell et al., 2004; Lim et al., 2020). To successfully change direction, the CoM must be laterally moved toward the new direction of travel; thus this may require a different trunk control strategy than forward running, as the transition from a forward running task to a new direction may be accompanied by greater trunk range of motion (Preece et al., 2016; Weir, Stillman, et al., 2019; Weir, van Emmerik, Jewell, & Hamill, 2019) and a smaller vertical CoM range of motion (Hinrichs, Cavanagh, & Williams, 1987; Wyatt, Weir, van Emmerik, Jewell, & Hamill, 2019). Collectively, these findings suggest: 1) trunk rotations are not fully compensated by the head in the transverse plane during forward locomotion; and 2) demands placed on both the head and trunk have the potential to modify head-trunk intrinsic coordination dynamics.

Change of direction movements are common in team sports but require the reorientation of the visual field, thus placing greater demands on the head than straight running. Sidestepping requires modification to trunk motion, but the effects on the compensatory head-trunk intrinsic dynamics remain unknown. Therefore, the purpose of this study was to determine to what degree task constraints during a sidestepping task modify the intrinsic head-trunk dynamics typically observed during forward running. We hypothesized that the sidestepping task would increase the magnitude of transverse plane head and trunk rotations and decrease vertical trunk CoM translation range of motion compared to the straight running task. To assess changes in relative motion between the head and trunk, we used a vector coding analysis on transverse plane head-trunk as well as sagittal head-vertical trunk couples. We also hypothesized that in the transverse plane trunk dominancy would be reduced during direction change, with greater head contribution than during a straight running task. Lastly, we assessed to what degree the sagittal plane head compensatory motion to vertical trunk motion was modified by the sidestepping task.

METHODS: Fourteen male collegiate soccer players (age: 20.1 ± 1.8 yrs, height: 1.82 ± 0.07 m, mass: 71.8 ± 6.3 kg) completed a series of overground straight running and anticipated sidestepping tasks on their dominant leg. All participants were right limb dominant. Participants were instructed to run at 4.0 ± 0.5 $m \bullet s^{-1}$ and perform the task which corresponded with arrows (forward, straight run; left sidestep) displayed on a 1.65 m television screen at the end of a 20 m runway. The sidestepping task was considered successful if the approach velocity was met and they contacted a 45° black line ±10° with their ipsilateral limb. Kinematic data were recorded using an 11-camera motion capture system (Qualisys, Inc., Gothenburg, Sweden) sampling at 240 Hz and filtered with a zero-lag fourth-order low pass 14 Hz Butterworth filter. Participants were fitted with 70 14 mm retroreflective markers as per a customized full body marker set. Four markers were fixed to the head via a head band. Four markers were placed on the suprasternal notch, xiphoid process, C7 and T10 to track trunk motion. All participants wore standardized indoor soccer footwear provided by the laboratory.

Segment kinematics and segment coordination were calculated for 7 straight run and 7 sidestepping trials during the flight and stance phases as determined from the unfiltered ground reaction forces (i.e., > 10N). The flight phase was defined as left toe off to right heel strike and stance from right heel strike to right toe off. The right limb will be referred to as the stance limb. Transverse plane head and trunk, sagittal plane head and vertical trunk CoM translation were calculated relative to the global coordinate system. Range of motion was quantified by subtracting the maximum from the minimum of each segment during both flight and stance phases. Segment coordination was calculated using a modified vector coding technique (Chang et al., 2008) for each participant, condition and trial for the flight and stance phase to quantify in-phase, anti-phase, proximal (trunk) dominant and distal (head) dominant coordination patterns. Phase angles were calculated from the angle of two points relative to the right horizontal based on the transverse plane head-trunk couple and the sagittal head-trunk vertical COM movement couple for each trial, with the mean phase angle calculated from multiple trials using circular statistics. To understand which patterns were most prevalent, the percentage from which each coordination pattern emerged was quantified using frequency plots. The binning frequency was calculated as the percentage of phase angles for the flight and stance phases within bins previously defined by Chang et al. (2008).

Differences in range of motion and coordination pattern frequencies during straight running and sidestepping were assessed with paired t-tests and effect sizes (ES), defined as small (0.2), moderate (0.5) and large (0.8). All statistical analyses were conducted in a customized MATLAB program (MathWorks R2019a, Natick MA). Means and standard deviation for 7 trials of each condition are presented.

RESULTS: In the transverse plane, greater head and trunk range of motion were observed during sidestepping compared to the straight running task during both the flight and stance phases (Table 1). Sagittal plane head range of motion was significantly greater during the stance phase and greater vertical trunk displacement was observed during the flight and stance phases during the sidestepping stride.

Greater transverse plane trunk dominancy was observed for the flight (p = 0.018, ES = 0.73) and stance phases (p < 0.001, ES = 2.18) during the forward running compared to sidestepping (Figure 1A). Greater in-phase coordination was observed during sidestepping compared to forward running during stance in the transverse plane (p <0.001, ES = -1.71). In the vertical trunk - head sagittal couple, head dominancy was greater during the flight phase (p = 0.004, ES = -0.95) but less during the stance phase (P <0.001, ES = -1.14) for straight running versus sidestepping (Figure 1B). During the stance phase, greater anti-phase (p < 0.001, ES = 1.18) and reduced in-phase (p = 0.032, ES = -0.64) coupling was observed during straight running compared to sidestepping in the sagittal plane (Figure 1B).

Table 1: Mean and standard deviation range of motion during the flight and stance phase.

		Straight Run	Sidestepping	p	ES
Transverse Plane					
Flight	Head (°)	2.45 ± 1.26	28.44 ± 10.40	**< 0.001**	-1.89
	Trunk (°)	4.08 ± 1.84	23.19 ± 9.79	**< 0.001**	-2.49
Stance	Head (°)	5.12 ± 1.75	23.12 ± 10.40	**< 0.001**	-1.72
	Trunk (°)	21.53 ± 4.75	28.44 ± 9.74	**< 0.001**	-0.87
Sagittal Plane					
Flight	Head (°)	1.94 ± 1.23	1.52 ± 1.31	0.360	0.25
	CoM (m)	0.04 ± 0.01	0.07 ± 0.02	**< 0.001**	-1.65
Stance	Head (°)	3.29 ± 1.20	5.63 ± 2.03	**0.002**	-1.04
	CoM (m)	0.07 ± 0.01	0.11 ± 0.02	**< 0.001**	-2.32

Note: ° symbol indicates angular range of motion while vertical CoM displacement in shown in meters (m).

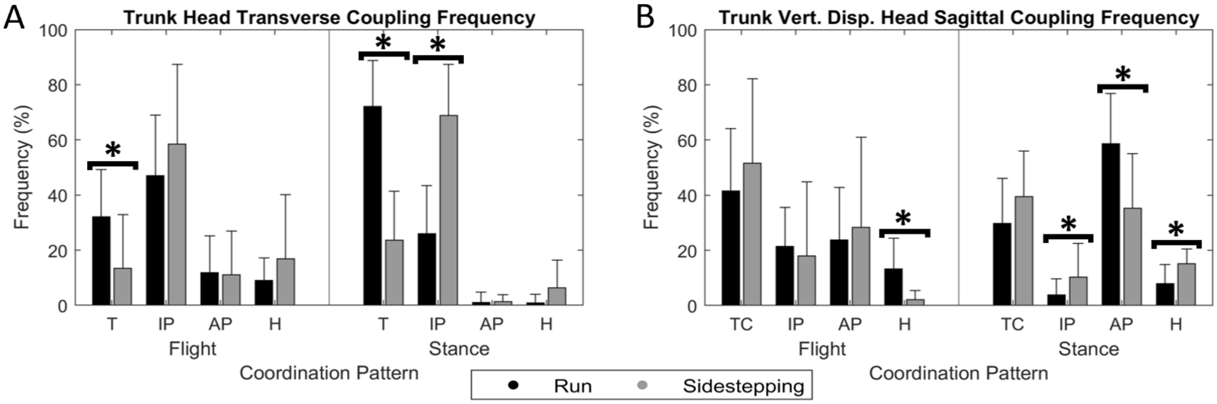

Figure 1: Coupling angle frequency plots for A) transverse and B) sagittal plane couples.
T = Trunk dominant, IP = In-phase, AP = Anti-phase, H = Head dominant, TC = Trunk CoM.
*** indicates statistical significance at p < 0.05 by a paired t-test.**

DISCUSSION: The purpose of this study was to determine to what degree task constraints during a sidestepping task modify the intrinsic head-trunk dynamics during forward running. Our first hypothesis was partially met, as we observed greater transverse plane head and trunk motion during the sidestepping compared with running. However, we observed greater vertical trunk displacement as a result of direction change which contradicts prior observations (Hinrichs et al., 1987; Wyatt et al., 2019). We directly compared trunk CoM in the same sample while prior literature reported whole body CoM in two separate studies with different protocols and different samples, which may have led to different findings than what we report here. Our second hypothesis was also partially met. Direction change requires reorientation to the visual field which increases visual task constraints. In agreement with prior literature (Cromwell et al., 2004; Lim et al., 2020), greater contributions from the head were observed as visual task constraints increased during sidestepping, as shown by the increased in-phase coordination compared to forward running in the transverse plane. Interestingly, reduced anti-phase and greater in-phase coordination compared to straight running suggests the greater vertical trunk range of motion is not as well compensated by sagittal head motion during the sidestepping task. Reductions in compensatory motion may increase perturbations to the visual field, which has the potential to negatively impact perceptual awareness in sport specific settings. As the type of visual stimuli can impact neuromuscular control in sport specific settings (Lee et al., 2019), reducing the quality of visual information through increased perturbations may impact the athlete’s ability to differentiate changing stimuli in their sport, potentially hindering both performance and injury avoidance tactics.

CONCLUSION: Task constraints have the potential to modify intrinsic head-trunk dynamics during running tasks commonly seen in sport. Direction change requires the reorientation of the body to the visual field, placing greater demands on the head and thus leading to increased contributions from the head in the transverse plane head-trunk coordination compared to straight running tasks. Realigning to the visual field allows the individual to obtain desirable visual information about the new travel path. However, the quality of that visual information during sidestepping may be impaired due to reduced compensatory head motion in the sagittal plane which may impact both performance and player safety in sport.

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