TRANSVERSE PLANE HEAD-TRUNK COORDINATION DURING ANTICIPATED AND UNANTICIPATED SIDESTEPPING TASKS

Sam Zeff [1], Gillian Weir [2], Joseph Hamill [2], and Richard Van Emmerik [1]

Motor Control Laboratory, University of Massachusetts, Amherst [1]
Biomechanics Laboratory, University of Massachusetts, Amherst [2]

The purpose of this study was to examine head control during anticipated and unanticipated sidestepping tasks. Twelve collegiate male soccer players performed seven anticipated and seven unanticipated sidestepping tasks. Head and trunk orientation and coordination were assessed during the preparatory and stance phases of the change of direction stride. The head and trunk were less oriented toward the new travel direction with reduced planning time. During the change of direction stride, participants aligned the head with the new travel direction but the trunk lagged behind to a greater extent during the preparatory phase when planning time was reduced. No differences in head and trunk coordination patterns were reported during the stance phase. These different head and trunk orientation and coordination patterns may impact perceptual awareness and potential for injury.

KEYWORDS: head control, coordination, change of direction, anticipation.

INTRODUCTION: Change of direction involves lateral translation of the body as well realigning the body with the new travel direction. Aligning the head with the new travel direction facilitates gaze realignment and may provide the central nervous system with a preferential reference frame for the utilization of visual and vestibular information (Pozzo et al., 1990, Warren et al., 2001). During change of direction tasks head direction precedes heading direction (whole-body trajectory) when walking along curved trajectories (Authie et al., 2015), and during sidestepping tasks (Hollands et al., 2001; Patla et al., 1999). Hollands et al. (2001) immobilized the head to the trunk during sidestepping tasks and observed earlier trunk motion onset with respect to the turning cue delivery compared to a head free condition, suggesting head realignment may be prioritized during sidestepping tasks. Head direction change prior to changes in heading direction has been observed with adequate planning time, but may not be as prevalent when planning time is reduced as Mornieux et al. (2014) has reported that the head was less oriented in the new direction of travel with reduced planning time. The trunk is oriented toward the stance leg during forward locomotion, as well as during sidestepping tasks but more so when planning time is reduced (Hinrichs, 1987; Mornieux et al., 2014). What has not been assessed in prior research is how the coordination between the head and trunk changes during sidestepping tasks. From a dynamical systems perspective, principles of coordination emerge from the interaction of the underlying degrees of freedom in the system (Hamill et al., 2012). Bernstein defined coordination as a problem of mastering the redundant degrees of freedom involved in a particular movement, or reducing the number of independent variables to be controlled (Bernstein, 1967; Turvey, 1990). When assessing anticipated and unanticipated sidestepping tasks, Weir et al. (2019) reported a significantly increased in-phase coordination pattern between the trunk-pelvis and thigh-shank during the stance phase of unanticipated sidestepping tasks compared with sidestepping tasks with adequate planning time. Understanding the head-trunk coordination strategies utilized during sidestepping tasks may provide greater insights into the organization of the degrees of freedom that are important for the control of directional change.

Therefore, the purpose of this study was to: 1) assess head and trunk orientation and 2) head-trunk coordination during anticipated and unanticipated sidestepping in the transverse plane. It was hypothesized that: 1) the head and trunk would be less oriented toward the new direction of travel when planning time was reduced; and 2) there would be a more trunk dominant coordination pattern between the head and trunk during anticipated compared to unanticipated tasks.

METHODS: Twelve male collegiate soccer players (20.2 ± 0.9 yrs, 1.81 ± 0.07 m, 71.63 ± 6.44 kg) completed a series of anticipated and unanticipated run, run-stop and sidestepping tasks using their dominant limb. The dominant leg was determined by asking participants which leg they would kick a soccer ball with or land from a jump. All participants were right limb dominant. Their right limb will be referred to as their stance limb. Run and run-stop tasks were used for task randomization to limit predictability of the unanticipated sidestepping tasks and were not used formally in analysis. Symbols representing these tasks (i.e. arrow or stop sign) were displayed on a 1.65 m television screen at the end of a 20 m runway. Participants were instructed to run at 4.0 ± 0.5 ms^{-1} down the runway and perform the task displayed on the screen. During these tasks, the screen either displayed the task prompt before the initiation of the run (anticipated) or it appeared at approximately penultimate (left) toe-off (LTO) prior to contacting a force platform with the dominant leg to perform the task (unanticipated). An unanticipated task prompt was triggered by the athlete running through a set of timing gaits. Kinematic data were recorded using an 11-camera motion capture system (Qualysis, Inc., Gothenburg, Sweden) sampling at 240 Hz. Participants were fitted with 70 14 mm retroreflective markers as per a customised 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 define the trunk. All participants wore standardized indoor soccer footwear provided by the laboratory. Mean spatial-temporal, segment orientation and segment coordination were calculated for 7 anticipated and 7 unanticipated sidestepping trials. Spatial-temporal variables include pre-contact velocities (average CoM velocity from LTO to right heel strike (RHS)) and change of direction angle (angle between the two CoM position vectors from LTO to left heel strike). Segment orientation was calculated independently for the head and trunk as the angular position in the transverse plane at LTO relative to the global coordinate system. Segment coordination was calculated using a modified vector coding technique (Chang et al., 2008) for each participant and each sidestepping condition for the preparatory and stance phase to quantify in-phase, anti-phase, proximal (trunk) dominant and distal (head) dominant coordination patterns. To understand which patterns were most prevalent, the percentage from which each coordination pattern emerged was quantified using frequency plots. To determine coordination pattern frequency, head-trunk angle-angle plots were created for each trial. The phase angle was calculated from the angle of two points relative to the right horizontal within the angle-angle plot, with the mean phase angle calculated from multiple trials using circular statistics. The binning frequency was calculated as the percentage of phase angles for the preparatory and stance phases of the change of direction stride within bins previously defined by Chang et al. (2008). The preparatory phase was defined as LTO to RHS and stance from RHS to right toe off (RTO). Differences in spatial-temporal variables and coordination pattern frequencies in anticipated and unanticipated 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 analysis were conducted in a customized MATLAB program (MathWorks R2019a, Natick MA). Means, standard deviation and 95% confidence intervals for 7 trials of each condition are presented.

RESULTS: No statistically significant differences were observed between approach velocities (anticipated, 4.4 ms^{-1} ± 0.3, unanticipated 4.5 ms^{-1} ± 0.2, $p = 0.87$, ES = -0.24). Change of direction angle was greater during anticipated (40.51° ± 4.87) compared to unanticipated conditions (32.63° ± 5.16) ($p < 0.01$, ES = 1.45). There was a large effect for differences observed between conditions in head orientation ($p < 0.01$, ES = 1.44) and small effect for trunk orientation ($p = 0.13$, ES = 0.34) between the two conditions at LTO (Table 1). Initial anti-phase coordination between the head and trunk was observed during both sidestepping tasks (Figure 1). A delayed shift towards a more in-phase coordination pattern during unanticipated sidestepping was due to delayed onset of trunk reorientation compared to the anticipated condition. Small effects were observed during the preparatory phase with greater in-phase transverse plane head and trunk coordination occurring during anticipated conditions ($p = 0.179$, ES = 0.41) and a more head dominant coordination pattern occurring when planning time was reduced ($p = 0.223$, ES = -0.37) (Table 2). During stance, a predominantly in-phase coordination pattern was observed during both anticipated and unanticipated sidestepping (Figure 1), with a trunk dominant coordination pattern occurring during late stance. Small effects were observed during the stance phase with a greater frequency of trunk dominant coordination pattern when planning time is reduced (p = 0.221, ES = -0.37; Table 2).

Table 1: Transverse plane head and trunk orientation (°) at LTO. '-' indicates orientation opposite new direction of travel

Segment	Condition	Mean (°) (SD)	95% CI	p	Effect Size
	ANT	7.55 (1.14)	4.39, 13.12	0.005	1.44
Head	UNANT	3.37 (1.76)	-2.09, 7.92		
	ANT	-5.59 (1.08)	-9.83, -0.87	0.134	0.34
Trunk	UNANT	-8.42 (1.55)	-9.73, -5.14		

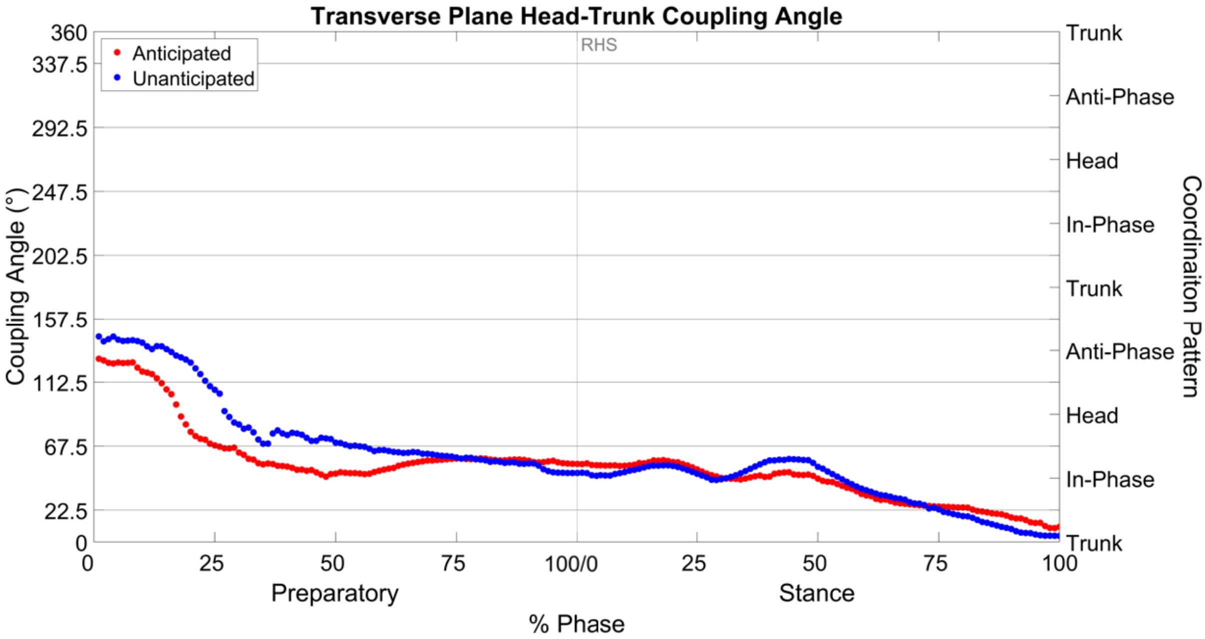

Figure 1: Transverse plane head-trunk mean coupling angle during anticipated and unanticipated sidestepping tasks throughout the change of direction stride. The binning method allows for the percent classification of a coordination pattern, illustrated by the right vertical axis.

Table 2: Binning percentages for Head-Trunk couples throughout the preparatory and stance phase of anticipated (ANT) and unanticipated (UNANT) sidestepping

	Preparatory				Stance			
	Frequency (95% CI)				Frequency (95% CI)			
	ANT	UNANT	p	ES	ANT	UNANT	p	ES
Head	15.92 (3.90, 27.93)	23.08 (10.42, 35.74)	0.223	-0.37	6.33 (1.20, 11.46)	5.58 (-0.63, 11.80)	0.839	0.06
In-Phase	54.00 (35.45, 72.55)	44.25 (28.38, 60.12)	0.179	0.41	68.25 (57.78, 78.72)	67.00 (56.00, 78.00)	0.750	0.09
Anti-Phase	9.75 (3.02, 16.48)	11.75 (5.62, 17.88)	0.681	-0.12	2.17 (0.03, 4.31)	0.92 (-0.73, 2.56)	0.295	0.32
Trunk	20.33 (4.21, 36.46)	20.92 (10.16, 31.67)	0.940	-0.02	23.25 (13.68, 32.82)	26.50 (17.12, 35.88)	0.221	-0.37

DISCUSSION: The purpose of this study was to assess transverse plane head and trunk orientation and coordination during anticipated and unanticipated sidestepping. In agreement with previous literature, during change of direction tasks participants align the head with the new direction of travel while the trunk lags behind (Mornieux et al., 2014; Patla et al., 1999). This allows for the realignment of gaze with the new travel direction to enhance visual perception (Warren et al., 2001). However, in this study we observed that reduced planning time changed the coordination between the head and trunk during the preparatory phase. In particular, the head, and to a smaller extent, the trunk, were less oriented toward the intended direction of travel. A greater head dominant coordination pattern was observed during unanticipated sidestepping with reduced in-phase coordination between the head and trunk. Weir et al. (2019) reported differences in coordination patterns between the trunk-pelvis and thigh-shank during the stance phase of anticipated and unanticipated sidestepping tasks. During the stance phase, we did not observe differences in head-trunk coordination, likely due to different demands placed on the head compared to other body segments. Throughout the stance phase, no differences as a function of planning time were reported in head-trunk coordination, despite significant differences in CoM control previously reported (Wyatt et al., 2019). These findings suggest transverse plane head-trunk segmental reorientation and CoM translation may be independent of one another, though future analyses would need to corroborate this observation.

CONCLUSION: In agreement with previous literature we found differences in transverse plane orientation during anticipated and unanticipated sidestepping tasks, predominantly observed at the head during the preparatory phase. Aligning the head with the new travel direction remains a priority during anticipated and unanticipated sidestepping, however the trunk tends to lag behind the head to a greater extent when planning time is reduced, resulting in reduced in-phase coordination between the head and trunk during unanticipated sidestepping compared to anticipated sidestepping during the preparatory phase. Despite preparatory changes, we did not observe differences in during the stance phase of the change of direction stride. As the head contains visual and vestibular systems, the implications of the observed differences in initial orientation and coordination patterns on perceptual awareness and performance following the change of direction stride as a function of different planning times remain unknown.

REFERENCES

Authie, C. N., Hilt, P. M., N'Guyen, S., Berthoz, A., & Bennequin, D. (2015). Differences in gaze anticipation for locomotion with and without vision. *Frontiers in Human Neuroscience*, *9(12)*,1-16.

Bernstein, N. (1967). The Co-ordination and Regulation of Movement. In *Peragamon* (Vol. 1).

Chang, R., Van Emmerik, R., & Hamill, J. (2008). Quantifying rearfoot-forefoot coordination in human walking. *Journal of Biomechanics*, *41*(14), 3101–3105.

Hamill, J., Palmer, C., & Van Emmerik, R. E. A. (2012). Coordinative variability and overuse injury. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology*, *4*(45), 1-9.

Hinrichs, R. N. (1987). Upper Extremity Function in Running. II: Angular Momentum Considerations. *International Journal of Sport Biomechanics*, *3*, 242–263.

Hollands, M., Sorensen, K., & Patla, A. (2001). Effects of head immobilization on the coordination and control of head and body reorientation and translation during steering. *Experimental Brain Research*, *140*(2), 223–233.

Mornieux, G., Gehring, D., Fürst, P., & Gollhofer, A. (2014). Anticipatory postural adjustments during cutting manoeuvres in football and their consequences for knee injury risk. *Journal of Sports Sciences*, *32*(13), 1255–1262.

Patla, A. E., Adkin, A., & Ballard, T. (1999). Online steering: Coordination and control of body center of mass, head and body reorientation. *Experimental Brain Research*, *129*(4), 629–634.

Pozzo, T., Berthoz, A., & Lefort, L. (1990). Head stabilization during various locomotor tasks in humans - I. Normal subjects. Experimental Brain Research, 82(1), 97–106.

Turvey, M. T. (1990). Coordination. *Am Psychologist*, *45*(8), 938–953.

Warren, W. H., Kay, B. A., Zosh, W. D., Duchon, A. P., & Sahuc, S. (2001). Optic flow is used to control human walking. *Nature Neuroscience*, *4*(2), 213–216.

Weir, G., van Emmerik, R., Jewell, C., & Hamill, J. (2019). Coordination and variability during anticipated and unanticipated sidestepping. *Gait and Posture*, *67*(9), 1–8.

Wyatt, H., Weir, G., van Emmerik, R., Jewell, C., & Hamill, J. (2019). Whole-body control of anticipated and unanticipated sidestep manoeuvres in female and male team sport athletes. *Journal of Sports Sciences*, *37*(19), 2263–2269.