VISUAL TASK CONSTRAINTS INFLUENCE HEAD CONTROL AND COORDINATION VARIABILITY IN CONTACT SPORT ATHLETES

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We sought to determine whether contact sport participation affects visual acuity, head control, and coordinative variability during locomotor tasks. Thirteen contact and eleven noncontact athletes completed treadmill walking tasks with and without a visual Landolt C task (identify open circle orientation). During baseline, head motion did not differ between groups, but contact athletes had reduced pelvis-thigh variability compared to noncontact athletes. During the visual condition only noncontact athletes reduced vertical head displacement which may reflect an adaptive motor strategy not present in contact athletes. These differences were accompanied by significantly reduced coordinative variability in contact athletes compared to noncontact athletes. These findings highlight motor alterations associated with contact sport status, which have the potential to impair perceptual awareness in sport-specific settings.

KEYWORDS: Dynamic visual acuity, sub-concussion, perception-action

INTRODUCTION: Sub-concussive head impacts, defined as repetitive head impacts that do not elicit concussion symptomology or warrant a clinical concussion diagnosis, are a routine part of contact sport participation. Sub-concussive head impacts elicit both oculomotor and locomotor alterations that could disrupt visual perception (Brown et al., 2022; Gallagher et al., 2020; Parker et al., 2008). Vestibulo-ocular screenings have identified oculomotor deficits following head impact exposure in contact athletes (Brown et al., 2022). These oculomotor deficits appear specific to contact sport participation, as noncontact sport athletes exhibit improved oculomotor performance across a season of sport participation while contact sport athletes do not exhibit this improvement (Gallagher et al., 2020). Prolonged head impact exposure through contact sport participation increases mediolateral center of mass (CoM) movement while locomoting and reduces gait speed compared to noncontact controls (Parker et al., 2008). How these gait changes induced by sub-concussive head impacts affect perceptual awareness is currently not well understood.

The locomotor system acts to “stabilize” the head-in-space, providing a consistent platform for perceptual awareness (Hamill et al., 2020; Mulavara & Bloomberg, 2003). During locomotor tasks that impose head stability constraints, reduced mediolateral and vertical head motion is partially achieved through increased lower extremity coordination variability (Lim et al., 2020), which highlights the need for whole-body coordination modifications to support visual perception (Mulavara & Bloomberg, 2003). More adaptive motor systems may utilize a greater number of degrees of freedom, observed through increased coordination variability, to minimize perturbations to the head (Lim et al., 2020), and thus the visual field. Variations in coordinative patterns provide insight into systemic flexibility, as reduced coordination variability is commonly observed in neurologically impaired populations (Van Emmerik et al., 2005). As sport participation requires advanced visual perceptual abilities to identify relevant environmental features (Fajen et al., 2008), elucidating the effects of repetitive sub-concussive head impacts on dynamic visual acuity and coordination during locomotion is important to understand possible impairments due to contact sport.

Therefore, the purpose of this study was to determine whether cumulative head impact exposure in contact sport athletes affects dynamic visual acuity, head control and lower extremity coordinative variability during locomotor tasks with and without a visual task constraint. Changes in head control were assessed through mediolateral and vertical head CoM range of motion, and coordinative variability through pelvis-thigh and thigh-shank intralimb couplings.

METHODS: Thirteen contact (Hockey; Age: 21.3±1.3 years) and eleven noncontact (Baseball; Age: 20.7±1.5 years) collegiate sport athletes completed two treadmill locomotor tasks (120 seconds each) at preferred speeds while looking straight ahead without (baseline) and with a visual Landolt C task. The visual task required participants to verbally identify the orientation of Landolt C optotypes, normalized to a static standing condition. Kinematic data were recorded using an 8-camera motion capture system (Qualisys, Inc., Gothenburg, Sweden), sampled at 100 Hz and filtered with a fourth-order, zero-lag, low-pass Butterworth filter at 6 Hz.

Right heel contact was defined as the maximum anterior heel marker value with respect to the local pelvis coordination system, while right toe off was defined as the maximum posterior toe marker distance with respect to the local pelvis coordination system, confirmed via visual inspection. The final 20 right stance phases from each walking trial, normalized from right heel contact to right toe off, were used to quantify head CoM range of motion and coordination variability. Mediolateral and vertical head CoM displacement were quantified by subtracting the maximum from the minimum relative to the global coordinate system. Visual task effects on mediolateral and vertical head displacement were also assessed through a percent change from baseline. Segment coordination variability was calculated using a vector coding technique based on the average coupling vector length (Sparrow et al., 1987; Van Emmerik et al., 2014). The average variability was taken from the early (0-33%), middle (34-66%) and late (67-100%) stance phases. Visual task performance was assessed by the number of correct responses (% accuracy). Group differences in gait speed and visual task performance were assessed with independent samples t-tests ($\alpha < 0.05$) as well as Cohen's *d* effect sizes. Range of motion, task effects (% change), and coordination variability data were non-normally distributed; differences in these variables were assessed through Mann-Whitney U tests using asymptotic *p* values ($\alpha < 0.05$). The *r* statistic was quantified to assess effect sizes, defined as small > 0.1, moderate > 0.3, and large > 0.5 using the z value. All statistical analyses were conducted in SPSS (Version 28.0.1.1). Mean and standard deviation for each dependent variable and group are presented.

RESULTS: Ten noncontact athletes reported a history of contact sport participation (mean time since contact exposure 6.8±5.2 years), while all contact athletes' most recent contact sport exposure was 4 months prior to their respective testing session. Moderate effects in preferred gait speed between groups were observed, though not statistically significant (Contact: 1.14±0.08 m/s; Noncontact: 1.05±0.17 m/s; $p = 0.10$, $d = 0.34$). Visual task performance did not significantly differ between groups (Contact: 98.97±1.45%; Noncontact 98.71±1.36%; $p = 0.65$, $d = -0.19$). No significant differences in mediolateral head CoM displacement were observed during baseline or visual conditions (Table 1). Both groups reduced mediolateral head motion during the visual task (negative % change), although the % change from baseline did not significantly differ between groups (Contact: -11.92±8.11%; Noncontact: -6.26±13.21%; $p = 0.361$, $r = 0.25$). Contact athletes had significantly greater vertical displacement during the visual condition compared to noncontact athletes ($p = 0.03$, $r = 0.44$; Table 1). This group difference emerged from a significant difference in % change from baseline (Contact: -0.02±3.69%; Noncontact: -4.36±5.95%; $p = 0.035$, $r = 0.41$), with the contact group showing no change and the noncontact group a reduction in displacement during the visual task condition. During baseline conditions, contact athletes displayed significantly reduced coordination variability of the pelvis-thigh couple during late stance only (Table 1). However, during the visual Landolt C task contact athletes displayed significantly reduced midstance coordination variability of the pelvis-thigh couple, as well as reduced coordination variability of the thigh-shank couple during early, middle, and late stance compared to noncontact athletes.

Table 1: Head CoM displacement and joint variability group means ± SD.

	Baseline				Visual			
	Contact	Noncontact	*p*	*r*	Contact	Noncontact	*p*	*r*
Head CoM Disp.								
Mediolateral	1.88±0.43	1.86±0.31	0.885	0.03	1.65±0.35	1.72±0.21	0.087	0.35
Vertical	4.29±0.55	3.85±0.67	0.099	0.34	**4.29±0.48***	**3.69±0.71***	**0.030**	**0.44**
Pelvis-Thigh Var.								
Early	15.33±5.68	20.98±13.37	0.664	0.09	11.81±3.66	17.58±10.99	0.125	0.31
Middle	2.78±1.14	5.92±6.95	0.111	0.33	**2.43±0.61***	**5.17±4.99***	**0.046**	**0.41**
Late	**7.06±1.40***	**10.78±5.00***	**0.014**	**0.50**	6.77±1.18	11.07±6.04	0.140	0.30
Thigh-Shank Var.								
Early	5.44±1.92	8.52±6.84	0.235	0.24	**3.63±0.66***	**6.06±4.01***	**0.034**	**0.43**
Middle	4.49±1.39	7.42±5.71	0.087	0.35	**4.65±1.10***	**7.68±4.74***	**0.019**	**0.48**
Late	2.66±0.51	3.60±1.87	0.125	0.31	**3.78±0.76***	**6.93±4.82***	**0.026**	**0.46**

Note: Head CoM displacement values are in cm. Variability values are in degrees. Significant group differences are bolded and denoted with *

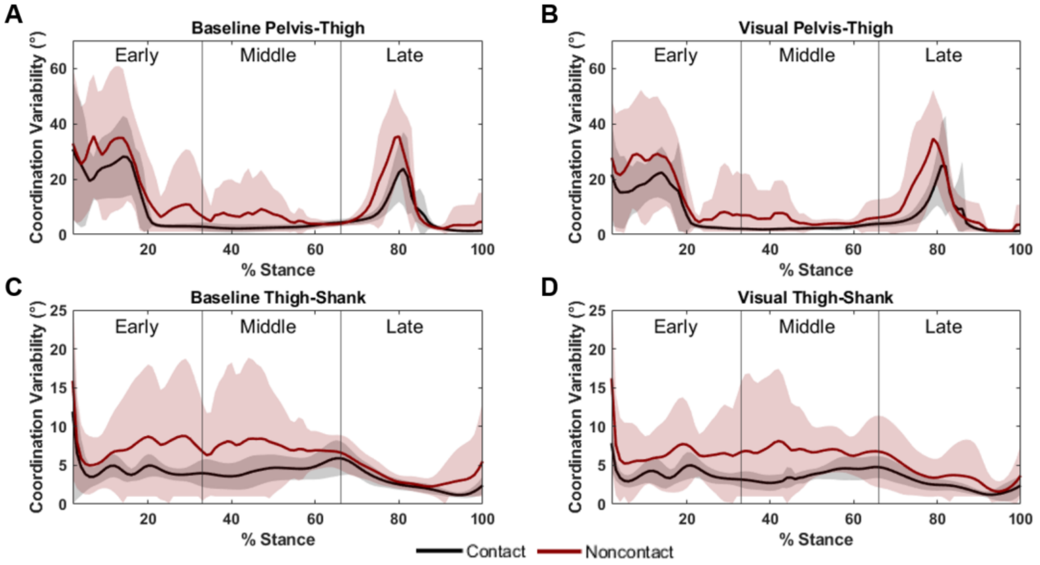

Figure 1: Coordination variability means and SD for pelvis-thigh (A-B) and thigh-shank (C-D) coordination variability during walking without (baseline) and with a Landolt C visual task (visual). Vertical lines separate the early (0-33%), middle (34-66%) and late (67-100%) stance phases.

DISCUSSION: The purpose of this study was to determine whether contact sport participation affects dynamic visual acuity, head control and coordinative variability during locomotor tasks with and without a visual task constraint. Mediolateral head CoM displacement did not differ between groups during treadmill walking in the present study, in opposition of with prior findings of increased whole-body mediolateral CoM displacement during overground walking (Parker et al., 2008). However, group differences in vertical head CoM displacement emerged with the inclusion of the visual task constraint. Noncontact athletes reduced vertical head CoM displacement in response to a visual task relative to baseline, while for the contact athletes vertical head CoM displacement did not appear to change across conditions. The lack of adaptation in head motion in contact athletes was accompanied by significant reductions in both pelvis-thigh variability during midstance as well as thigh-shank variability across the entire stance phase compared to non-contact athletes during the Landolt C visual task. These group-based reductions in coordination variability may reflect a less flexible system, similar to prior reports in neurologically impaired populations (Van Emmerik et al., 2005). While prior studies suggest contact sport impairs oculomotor performance (Brown et al., 2022; Gallagher et al., 2020), this study suggests that any oculomotor changes do not appear to negatively affect dynamic visual acuity during the current treadmill walking task, as reflected by the absence of differences in dynamic visual acuity between groups. In light of hockey specific head impact exposure(Wilcox et al., 2014), which has been shown to induce impairments persisting months post-contact exposure (Bazarian et al., 2014; Parker et al., 2008), group differences in the present study may partially be attributed to sport-specific differences between hockey and baseball.

CONCLUSION: While visual task performance did not differ between groups, the underlying locomotor dynamics that contribute to head stability differed based on contact sport status. These findings underscore persistent changes in head control and lower extremity variability, which may be exacerbated when athletes are exposed to more demanding movement and visual constraints. These results highlight the changes in movement adaptation and coordination variability associated with contact sport exposure status, which have the potential to result in perceptual deficits under more challenging sport-specific conditions. Findings from this study may be used to support coaches' decisions to reduce head impact exposure throughout the season to support athlete health and safety.

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