

A multimodal framework to assess differences in dynamic visual acuity between athletes with and without recent sport-related concussion

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Abstract

Purpose

To determine if a dynamic visual acuity (DVA) task performed during standing and walking could differentiate performance between athletes with and without recent concussion history.

Methods

Interuniversity athletes ($N = 30$, age = 20.9 years $\pm$ 1.4) with recent SRC history but were asymptomatic (SRC = 14; females = 6) were compared to athletes without recent SRC (CONTROL = 16; female = 7). A DVA task was completed while seated, standing, and during low- and moderate-intensity treadmill walking. A Tumbling 'E' target was presented randomly in either random walk (R) or horizontal (H) motion (2.31m/s), in one of four orientations; responses were selected using a handheld keypad. Performance was characterized as a change in DVA score from Seated (logMAR) and response time (RT, ms). A linear mixed-effects model was fitted for DVA change scores and a generalized mixed effects model for median RT.

Results

For each motion type, the SRC group exhibited worse DVA change scores during standing and walking compared to CONTROL ($p < .05$). Whereas both groups responded faster during treadmill walking for both R- and H-motion ($p < .001$). Only two athletes (14%) in the SRC group experienced mild symptoms that did not affect completion of the protocol.

Conclusion

A multimodal DVA assessment including standing and walking conditions may be a feasible approach to detect differences in visual-cognitive performance for athletes following clinical recovery of concussion.

Introduction

Recovery from sport-related concussion (SRC) remains challenging for clinicians to characterize due to the inherent variability of individual signs and symptoms that impact several health domains. Resulting neurological impairments commonly affect vision (Master et al., 2016; Murray et al., 2020), balance control (Parrington et al., 2019; Powers et al., 2014), and cognitive functions (Howell et al., 2018, 2020) that are essential for sport performance. While management of SRC remains highly dependent on the symptom reporting, growing literature suggests that persisting sensorimotor and cognitive dysfunctions may remain undetected and contribute to an increased risk of musculoskeletal injury following return-to-sport (RTS) (Brooks et al., 2016; Cross et al., 2016; Fino et al., 2019; Hunzinger et al., 2021; Jildeh et al.,

2021; Lynall et al., 2017). To address lingering concerns, multimodal assessments provide a promising approach to characterize concussion-related deficits on vision-based tasks while maintaining balance (Mitchell et al., 2025; Mitchell & Cinelli, 2019) and following physical exertion (Mitchell et al., 2024; Sicard et al., 2019, 2021). Despite emerging evidence, clinical recommendations for vision and cognitive assessment strategies remain vaguely defined without a framework to guide multimodal progressions in preparation for RTS. The lack of evidence-informed approaches highlights a critical need to explore objective clinical strategies that may be sensitive to motor control deficits independent of SRC-related symptoms.

Following concussion, up to 85% of individuals may experience vision-related concerns (Kapoor & Ciuffreda, 2002; Samadani et al., 2015), with approximately 69% attributed to oculomotor (Master et al., 2016) or related vestibular dysfunctions (Anzalone et al., 2017; Mucha et al., 2014). Although there is a high incidence of visual dysfunctions post-concussion, the impact on higher order visual perception processing remains unclear. A dynamic visual acuity (DVA) assessment may provide be a feasible solution that challenges visual and cognitive functions through motion processing, object recognition, and gaze behaviours to quickly recognize the details of a moving target (Hirano, 2018). The moV&, V&MP Vision Suite software program (University of Waterloo) has been utilized as a correlate of visual and cognitive function in research demonstrating enhanced performance in athletes compared to non-athletes while seated (Yee et al., 2021) and during standing and walking at moderate intensities (Mitchell et al., 2026). Improved DVA performance during moderate-intensity exercise may be attributable to athletes' increased facilitation of visual and cognitive processing areas within the frontoparietal network (Davranche & Audiffren, 2004; Markett et al., 2021; Shaw et al., 2023). Similarly, high performance athletes tend to elicit greater exercise-induced benefits on visual and cognitive tasks compared to the general population (Cereatti et al., 2009; Chmura et al., 1998; Hüttermann & Memmert, 2014). However, the impact of recent SRC history on visual perception processing during concurrent exercise remains unclear.

Since athletes tend to optimize DVA performance during moderate intensity treadmill walking (Mitchell et al., 2026), a progressive assessment framework using different exercise intensities may be a feasible and sensitive clinical approach to detect SRC-related deficits. Therefore, the aim of the current study was to determine if performance on the moV& DVA task while standing and walking is sensitive enough to differentiate between athletes with and without a recent history of SRC. It was hypothesized that athletes with recent SRC history will have worse changes in DVA score accuracy from seated and slower response times during standing and treadmill walking compared to athlete controls. A secondary hypothesis is that all athletes will complete the DVA protocol without provocation of symptoms.

Methods

Participants:

The current study protocol was approved by the Research Ethics Board at the university. Prior to beginning the study, written informed consent was provided by each participant. Thirty interuniversity athletes from rugby, field lacrosse, and soccer teams were recruited from athletics departments at two local universities. Participants included female and male athletes with recent SRC reported from six months up to approximately three years prior for which they had achieved clinical recovery of symptoms (SRC = 14, females = 6) and athlete controls without recent SRC in over four years (CONTROL = 16, females = 7). Inclusion criteria was based on previous studies that conducted similar assessments (Mitchell et al., 2024, 2025; Sicard et al., 2019, 2021). All athletes reported normal or corrected-to-normal vision, and if they reported wearing prescription glasses or contact lenses during sport competition, were instructed to wear them during the DVA protocol. Participants were advised to avoid exercise two hours prior to participating in the study and caffeine up to three hours prior to help mitigate potential effects on DVA performance (Mitchell et al., 2024; Redondo et al., 2021). Participants were excluded if they reported a history of recent SRC within the previous six months or reported persisting SRC-related symptoms; and/or a history of vestibular-ocular motor, neurological, and/or binocular vision disorders.

Experimental Design

Pre-Screen Assessment:

Participants first completed a detailed intake questionnaire, including health and sport participation history. A pre-screen assessment was conducted for each participant including the Vestibular-Ocular Motor Screen (VOMS) and static visual acuity (SVA) while seated. The VOMS is a valid and reliable measure of vestibular and oculomotor function, consisting of seven items, including smooth pursuits, saccades, near point convergence (NPC), VOR, and visual motion sensitivity (VMS) (Anzalone et al., 2017; Mucha et al., 2014; Petit et al., 2019). For each item, the onset or provocation of the following symptoms: headache, dizziness, nausea, and foggiess, is rated using a 11-point Likert scale (0 to 10). A positive outcome is indicated by an individual reporting an increase in baseline symptoms of 1/10 on oculomotor or 2/10 or greater on vestibular items (Eagle et al., 2021; Mucha et al., 2014).

Monocular and binocular SVA was assessed using Early Treatment Diabetic Retinopathy Study (ETDRS, Precision Vision) vision charts. SVA was measured as the log of the minimum angle of resolution (logMAR) from the retina to the smallest letter size read on the ETDRS chart viewed from 4-metres (m). A positive logMAR score is associated with a larger character on the ETDRS chart (e.g., poorer SVA), whereas a negative score is associated with smaller characters and better visual acuity (Bailey & Lovie-Kitchin, 2013; Kuo et al., 2011). Participants were included in the study with a SVA score of less than or equivalent to 0.3 logMAR (20/40) and a difference between left and right monocular SVA no greater than 0.1 logMAR (Casson & Racette, 2000; Rubin et al., 2000).

DVA Assessment:

The DVA software program (moV&, V&MP Vision Suite, School of Optometry & Vision Science, University of Waterloo, Canada) was presented on a 55" LED monitor (1920 x 1080 pixels; Samsung Electronics, South Korea), with a 120Hz refresh rate. The DVA task was viewed from a 4-metre distance positioned at eye-level for each condition based on each participant's height using an adjustable table. A Tumbling "E" target was presented on the monitor moving in either Random Walk (R) or Horizontal (H) motion. During R-motion, the Tumbling "E" moves in an unpredictable pattern continuously for up to 20-seconds per target, while H-motion presents the target more briefly along a rapid and predictable linear path, crossing the screen from left to right once, before exiting the screen immediately. For each presentation, the Tumbling 'E' target appeared in one of four possible orientations (e.g., 'E' prongs facing up, down, left, or right), moving at a constant speed of 2.31m/s (30°/sec); following the same parameters used in previous studies (Mitchell et al., 2024, 2025, 2026; Yee et al., 2021).

Participants held a keypad containing buttons labelled with corresponding directional arrows and were instructed to select the correct orientation of the target they recognized "quickly and accurately". Each button press triggered a new presentation of the moving target with a random change in its orientation. A maximum of five random target orientations were presented for a given target size, with 3/5 correct responses required to proceed. Similar to progressing through each line on the ETDRS vision chart, correct responses led to the target size reducing by 0.1 logMAR. Three incorrect button press responses at a given target size threshold was the stopping criteria for the task and ended the trial.

Experimental Protocol:

Prior to beginning the protocol, athletes completed a familiarization trial of the DVA task in a seated position. Athletes then performed one R- and one H-motion trial in four conditions; Seated, standing (Stand), low-intensity (Walk Low) and moderate-intensity (Walk Mod) treadmill walking (i.e., similar to a previous protocol, Mitchell et al., 2026). Seated and Stand conditions were counterbalanced randomly between participants to mitigate learning effects of the first trial, followed by Walk Low and Walk Mod. Treadmill walking was not counterbalanced to avoid the effects of physical exertion on DVA (Mitchell et al., 2024, 2026). Treadmill walking intensity was determined by heart rate (HR) measurements collected using a wearable chest strap (Dash Wearables, Germany) monitored in real-time using the Polar Beat mobile app (Polar Electro, Finland). For Walk Low, the target HR was calculated for individual participants as approximately 45% of age-predicted maximum HR (HR_{max}; 220 - age) and 60% HR_{max} for Walk Mod. A total of eight DVA trials were completed over approximately 45-minutes with breaks provided between trials or as needed.

Data Analysis:

LogMAR scores for each DVA trial were calculated using per-letter scoring with the same equation from previous studies (Mitchell et al., 2024, 2025, 2026; Yee et al., 2021). The *lowest line read* represents the smallest size threshold achieved and *number of total errors*, the sum of incorrect responses accumulated within a trial. Relative change in DVA score was calculated as the difference of Stand, Walk Low, and

Walk Mod from Seated (Mitchell et al., 2026). Using inverse logMAR scale, a positive change score represents worsened DVA, whereas a negative change indicates improved performance. Clinically meaningful changes in DVA scores were determined as a difference of five characters or 0.1 logMAR, which represents one complete line on an ETDRS chart (Sánchez-González et al., 2021).

For each target presented in a trial, response time (RT) was measured in milliseconds (ms) from the time a new target was presented on the monitor to when a response was selected using the keypad. Since the DVA task increases in difficulty as the target size reduces throughout a trial, median RT was calculated to mitigate bias. In addition, median RT was calculated from a normalized starting size threshold determined as 0.5 logMAR above each participant’s SVA logMAR score.

Statistical Analysis:

Participant demographics, concussion history, and corrective lens use are reported using descriptive statistics (Table 1). All statistical analyses were conducted using *Jamovi* (Version 2.7.15.0, 2025, Sydney, Australia) with an alpha level of $p < .05$. Independent samples t-tests were conducted to examine baseline differences in binocular SVA and raw DVA logMAR scores (Seated). Meaningful differences between groups were calculated using Cohen’s d to estimate small ($d = 0.20$), medium ($d = 0.5$), or large ($d = 0.8$) effect sizes.

Table 1 Participants demographics, sport, history of SRC, and corrective lens prescription.		
Age (years), median (IQR)	CONTROL (n = 16)	SRC (n = 14)
	21 (20, 22)	21 (20, 22)
Sex, Male/Female	9/7	8/6
Current Sport	Rugby = 14 Field Lacrosse = 1 Soccer = 1	Rugby = 13 Field Lacrosse = 1
Total Lifetime SRC, median (IQR)	0 (0, 1)	2 (2, 3)
Time from SRC (months), median (IQR)	60.5 (52.5, 72.5)	10 (6.25, 33.75)
Corrected Lens Prescription, n (%)	7/16 (43.8%)	4/14 (28.6%)
Corrected Lens Worn, n (%)	5/7 (71%)	3/4 (75%)

Change in DVA Scores:

Differences in change in DVA scores from Seated between groups, conditions, and group by condition interactions for each motion type were analyzed by fitting linear mixed effects models for repeat measures. All data were examined to meet assumptions, including normality of residuals,

homoscedasticity, and linearity. Fixed effects included group (SRC and CONTROL) and condition (Stand, Walk Low, and Walk Mod) while random effects terms for the intercept accounted for within-subject variability for each participant ('Subject ID').

Response Time (RT):

For both motion types, observations of the data and significant Shapiro-Wilk tests ($p < .05$) indicated that the data was not normally distributed. Similar to a previous analysis (Mitchell et al., 2024), the data was examined for outliers using a threshold of three standard deviations outside of the mean and carefully reviewed to determine if they were related to performance behaviours (e.g., slower RT as the task increases in complexity). A generalized mixed effects model was fitted using a Gamma distribution with the log link function to determine differences in RT with two fixed effects of group (CONC, CONTROL) and condition (Seated, Stand, Walk Low, and Walk Mod). The interaction of group by condition with random intercepts to account for baseline differences for each participant. Post-hoc analyses were conducted using a Bonferroni correction for pairwise comparisons of any significant interactions or main effects.

For each parameter, Akaike information criteria (AIC) was used as an indicator of model fit. Outcomes for both change in DVA score and RT are presented as estimated means and 95% confidence intervals (95% CI; Table 2). In addition, clinically meaningful positive or negative changes in DVA scores (± 0.1 logMAR) are presented as percentages (Table 2).

Table 2 Relative change in DVA scores from Seated (Mean [95% CI]) and clinically significant percentage of positive (worse) or negative (better) changes (± 0.1 logMAR; % (n)).						
Motion Type	Random Walk			Horizontal		
Condition	Stand	Walk Low	Walk Mod	Stand	Walk Low	Walk Mod
Control	-0.01	-0.01	-0.03	-0.03	0.0	-0.06
Positive	(-0.05, 0.04)	(-0.05, 0.02)	(-0.07, 0.02)	(-0.07, 0.02)	(-0.06, 0.06)	(-0.11, -0.01)
Negative	13% (2/16)	6% (1/16)	13% (2/16)	6% (1/16)	13% (2/16)	0% (0/16)
	13% (2/16)	6% (1/16)	31% (5/16)	25% (4/16)	25% (4/16)	38% (6/16)
SRC	0.04	0.04	0.06	0.06	0.04	-0.01
Positive	(-0.01, 0.09)	(0.0, 0.08)	(0.01, 0.11)	(0.01, 0.10)	(-0.02, 0.10)	(-0.06, 0.05)
Negative	36% (5/14)	21% (3/14)	36% (5/14)	36% (5/14)	36% (5/14)	7% (1/14)
	0% (0/14)	7% (1/14)	7% (1/14)	0% (0/14)	7% (1/14)	21% (3/14)

Results

Vestibular-Ocular Motor Screen (VOMS):

All participants reported no baseline symptoms of headache, dizziness, nausea, and foggiess. During the VOMS, 14% (2/14) athletes in SRC reported brief dizziness and/or foggiess during VOR and/or VMS testing with an average rating of 1.5/10 (SD = 0.7). During the DVA protocol, the same two athletes experienced mild symptoms with one participant reporting brief 2/10 dizziness following R-motion Stand. Symptoms resolved with a short break and the athlete chose to complete the protocol without further concerns. The other participant reported 3/10 dizziness following completion of Walk Mod at the end of the protocol.

SVA and DVA Score (Seated):

There were no significant differences in SVA between groups (Mean (SD): SRC = -0.16 (0.10), CONTROL = -0.14 (0.07); $t_{(28)} = 0.86, p = .395$; Table 1). For R-motion DVA while seated, logMAR scores were significantly different between groups ($t_{(28)} = 2.69, p < .05; d = 1.0$) with SRC obtaining lower scores (Mean (SD) = 0.09 (0.09)) compared to CONTROL (Mean (SD) = 0.17 (0.09)). During H-motion, DVA logMAR scores were not significantly different for SRC (Mean (SD) = 0.12 (0.09)) compared to CONTROL (Mean (SD): 0.18 (0.09); $t_{(28)} = 1.80, p = .079; d = 0.67$).

Relative Change in DVA Score from Seated:

For R-motion, there was no significant interaction of group by condition ($F_{(2, 56)} = 0.20, p = .817$). However, a significant main effect between groups ($F_{(1, 28)} = 4.99, p < .05$; Table 2 and Fig. 1a), indicates that CONTROL improved relative DVA scores (negative change) whereas the SRC group had worse (positive) changes in DVA scores from Seated to all conditions (Stand, Walk Low, and Walk Mod).

For H-motion, there were no significant interactions between group and condition ($F_{(2, 56)} = .977, p = .383$) or significant effect of condition ($F_{(2, 56)} = 2.47, p = .094$). A significant main effect of group ($F_{(1, 28)} = 5.14, p < .05$) suggests that the CONTROL group had better change (negative score) from Seated DVA scores compared to SRC. Post hoc pairwise comparisons indicated that the SRC group exhibited the worst (most positive) changes in DVA during the Walk Mod condition compared to CONTROL ($p < .05$; Table 2).

The model fit for H-motion (AIC = -140.9) indicates better model fit than R-motion change in DVA (AIC = -149.0). All change in DVA scores with percentages of clinically meaningful changes from Seated for each motion type are listed in Table 2 and the fixed-effects coefficients for both linear mixed effects models are presented in Table 3.

Response Time (RT):

For R-motion, no significant group by condition interactions were revealed for median RT ($\chi^2_{(3)} = 4.04, p = .257$) nor was there a main effect between groups ($\chi^2_{(1)} = 0.002, p = .959$; see Fig. 2a). There was a significant effect of condition ($\chi^2_{(3)} = 34.14, p < .001$), with post hoc comparisons indicating that both groups responded faster (decreased RT) for both treadmill walking conditions (Walk Low = 1505ms (1301, 1749), Walk Mod = 1381ms (1194, 1597)) compared to Seated (Seated = 1846ms (1597, 2135), $p < .05$; Fig. 2a).

For H-motion, there was no significant interaction of group by condition ($\chi^2_{(3)} = 1.38, p = .711$) or a main effect of group ($\chi^2_{(1)} = 0.16, p = .690$) for median RT. A main effect of condition ($\chi^2_{(3)} = 27.56, p < .001$) indicate that both groups exhibited faster RT during treadmill walking compared to Seated (Seated = 908ms (835, 987), Walk Low = 810ms (745, 880), Walk Mod = 826ms (760, 898), $p < .001$; Fig. 2b). Fixed-effects coefficients for DVA R-motion and H-motion analyses are presented in Table 4. The AIC value for H-motion RT indicates a better model fit (AIC = 1458.5) than R-motion (AIC = 1792.4).

Discussion

The current study aimed to examine how a novel DVA assessment framework progressing from seated to standing and treadmill walking may be sensitive to differences in performance between athletes with and without a recent history of SRC. It was hypothesized that athletes with recent SRC history would have worse changes in DVA scores and slower RT during standing and walking relative to seated than athlete controls without recent SRC. The primary findings partly aligned with this hypothesis such that a greater portion of athletes with recent SRC had worse changes in DVA score from seated during standing and walking compared to controls (Fig. 1). Although athletes with recent SRC had slightly better baseline R-motion DVA scores than the control group while seated, the change in DVA scores may better characterize a relative decline in performance during dual-task conditions for some athletes with previous SRC. In contrast, there were no group differences for RT indicating that all athletes responded similarly with improvements specifically during treadmill walking for each motion type. Despite responding faster, worsened DVA score accuracy for some athletes with recent SRC suggests that single-task or resting conditions may not be challenging enough to detect visual-cognitive deficits beyond clinical recovery.

In addition to performance outcomes, the secondary hypothesis aimed to determine if the DVA protocol would be feasible for athletes to complete without symptom provocation. While all athletes with recent SRC reported being asymptomatic at rest, two athletes reported mild symptom provocation for the vestibular items of the VOMS with average ratings below the minimal detectable change (2/10) reported for collegiate athletes (Eagle et al., 2021). The same athletes reported brief symptoms during R-motion DVA conditions that did not affect completion of the protocol. Overall, the results suggest that the DVA protocol was feasible with a low incidence of symptom provocation. Due to the variability of recovery outcomes for athletes included in the current study, the specificity of the protocol remains unclear with potential impacts of associated vestibular-ocular motor dysfunction.

Further analysis of group differences during R-motion revealed that the largest discrepancy between groups was during moderate-intensity treadmill walking (Fig. 1a and Table 2). Similar findings were reported recently where recreationally-active students without recent concussion performed worse during a similar condition compared to varsity athletes (Mitchell et al., 2026). The current findings suggest that athletes may require a greater level of task difficulty and physical intensity compared to the general population to detect subtle changes in visual-cognitive function following SRC. More complex visual search demands may better represent the level of chaos encountered within strategic sport environments (Faubert, 2013; van Paridon et al., 2022). The unpredictable nature of R-motion DVA combined with increased physical demands of moderate-intensity walking appeared to exceed the boundaries of attentional capacity for some athletes with a previous SRC, negating the facilitation of exercise-induced benefits elicited by athlete controls. The potential disruption of visual perception processing post-SRC is particularly concerning for athletes returning to high-stress situations on the field of play that require greater attentional investment to interpret dynamic visual scenes for motor performance.

Performance on the DVA task also appears to be modulated by the different spatiotemporal characteristics of each motion type. During H-motion, the Tumbling 'E' target is presented more briefly, moving linearly across a predictable trajectory from left to right, exiting the screen until a button press response initiates the next target presentation. Altered H-motion DVA score accuracy may have been due to the rapid, repetitive target motion stimulating the optokinetic reflex, which has been sensitive to differences in eye movement behaviours post-concussion (Frattini et al., 2024; McDevitt et al., 2016). Altered visual processing during H-motion may challenge standing balance as previous research has indicated that athletes with recent SRC prioritized balance control over DVA score accuracy compared to controls (Mitchell et al., 2025). Although a larger portion of athletes with previous SRC exhibited worse changes in DVA scores from Seated during H-motion, both groups appeared to elicit exercise-induced benefits on performance during moderate-intensity treadmill walking (Fig. 1).

Performance on the DVA task was further evaluated with RT recorded from the handheld keypad. For R- and H-motion, both groups improved with significantly faster responses during treadmill walking (Fig. 2). These findings align with previous evidence of improved RT on similar tasks during concurrent exercise at low- and moderate-intensities (Olson et al., 2016). The DVA task included in the current study also increases in difficulty throughout a trial as the 'E' target incrementally reduces in size, which may have further modulatory effects on the exercise-cognition relationship (Cereatti et al., 2009; Kamijo et al., 2007; Pesce et al., 2007). Specifically, the increased visual search demands and unpredictability of R-motion may be more challenging with greater attentional resources required during walking, as some athletes with recent SRC responded faster but made less accurate decisions compared to seated. Whereas athlete controls were more likely to improve both speed and accuracy during treadmill walking (Fig. 1a and 2a). Similar findings were evident for H-motion, however, there was much less variability observed, likely due to the time constraints of a more rapid target presentation. Based on the increasing difficulty throughout the DVA task, careful interpretation of findings is required as athletes may employ different behaviours as the target size threshold decreases (Fig. 1b and 2b). Overall, the results highlight

the importance of capturing outcome measures of both speed and accuracy to characterize DVA performance behaviours which may optimize the sensitivity of multimodal assessments.

There are several limitations that warrant consideration for interpretation of the results from the current study. Although the main findings are supported by robust mixed effects modelling, we did not achieve the estimated sample size of 40 participants calculated from a priori power calculations. Data collection for this study was disrupted by the COVID-19 pandemic with restrictions on sport competitions in Canada between March 2020 and July 2021. The sample size in the current study is similar to previous studies that have detected differences in performance between groups using the same custom DVA software program (Mitchell et al., 2024, 2026; Yee et al., 2021). Additionally, the study included university-level athletes from higher risk collision and contact sports who self-reported their history of SRC and recovery outcomes, therefore injury characteristics are highly variable. The impact of repetitive head impact exposures on visual function across a sport season for these athletes, regardless of SRC history, may also be an important consideration (Brooks & Dickey, 2024). Overall, the current findings cannot be generalized based on time from concussion, age, sex or gender, or sport type. The utility of this novel DVA assessment protocol should be examined using longitudinal analyses with more diverse athlete groups throughout concussion recovery and beyond RTS to better understand individual and sport-specific characteristics.

Conclusion

Results from the current study revealed that a multimodal DVA assessment framework may be sensitive to differences in visual-cognitive performance between athletes with and without recent SRC history. Athletes with recent SRC were more likely to exhibit a speed-accuracy trade-off with less accurate decision-making during a more challenging, unpredictable motion condition as balance and physical exertion demands increased. Therefore, a progressive dual-task assessment, including standing and walking, appears to be feasible to assess visual-cognitive function for athletes beyond the recovery of SRC-related symptoms with careful consideration of vestibular-ocular dysfunctions. The current findings have important implications for the development and implementation of more robust multimodal assessment strategies for athletes to help support clinical decision-making.

Declarations

Declaration of Interest Statement: KD is a coinventor of the moV& (V&MP Vision Suite, Waterloo, Canada) software used in this study to examine dynamic visual acuity and is currently exploring commercialization options for this device; however, the device is not available commercially at the moment. KM is an employee in the Canadian Football League (CFL) and member of the CFL Medical Committee.

MC have no conflicts of interest to declare.

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Competing Interests

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Author Contribution

K.M., K.D., M.C. conceived the project paradigm K.M collected the data K.M., K.D., M.C. interpreted the findings K.M wrote the first draft of the manuscript including creating figures and tables K.M., K.D., M.C. edited the final document all authors approved the final document

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Tables

Tables 3 and 4 are available in the supplementary files section

Figures

Figure 1:

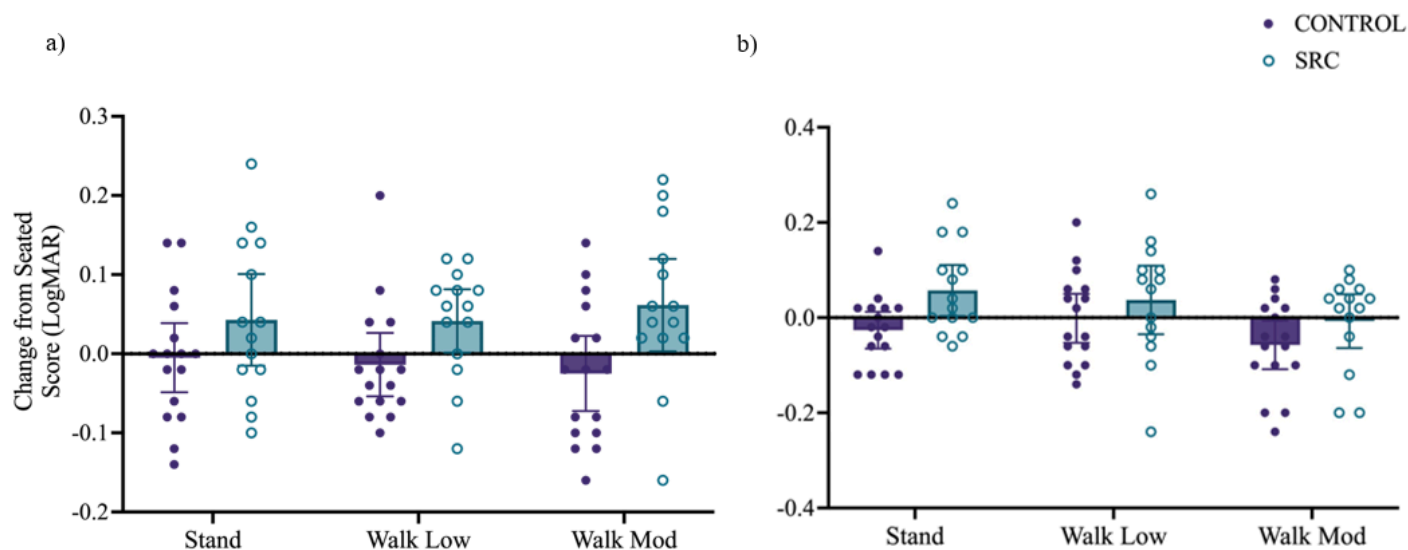


Figure 1

Change in DVA logMAR scores for Stand, Walk Low, and Walk Mod conditions from Seated (Mean and 95% CI) for a) R-motion and b) H-motion.

Figure 2:

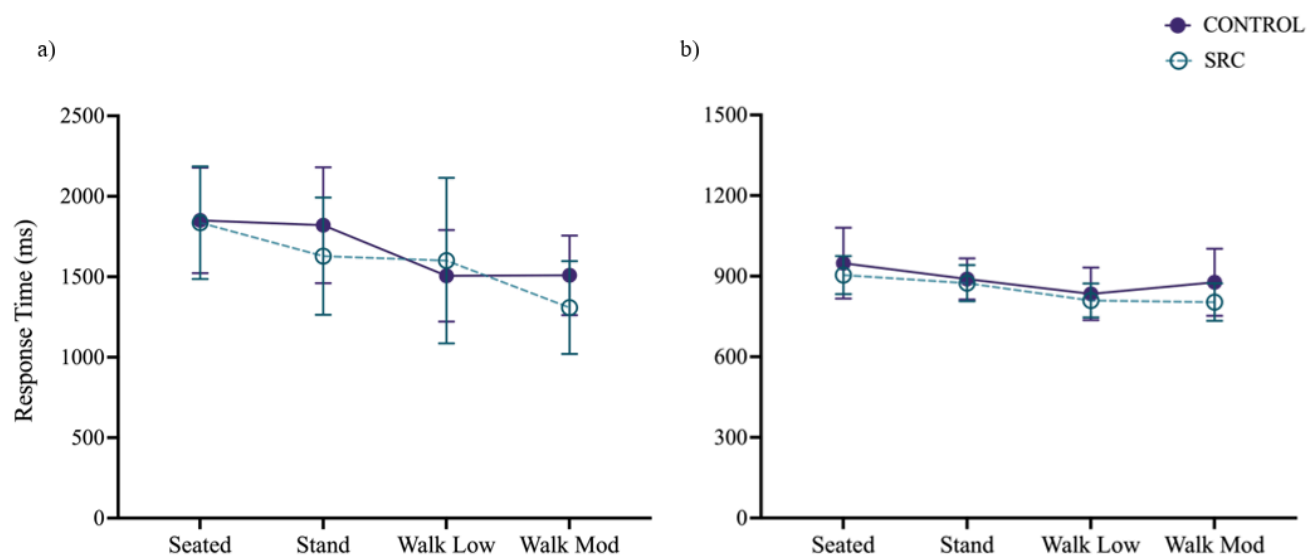


Figure 2

Median RT (ms, 95% CI) for a) R-motion and b) H-motion during Seated, Stand, Walk Low, and Walk Mod conditions.

Supplementary Files

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- [Tables.docx](#)