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Full Length Article

Concussion is associated with altered preparatory postural adjustments during gait initiation

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ABSTRACT

Gait initiation is a useful surrogate measure of supraspinal motor control mechanisms but has never been evaluated in a cohort following concussion. The aim of this study was to quantify the preparatory postural adjustments (PPAs) of gait initiation (GI) in fifteen concussion patients (4 females, 11 males) in comparison to a group of fifteen age- and sex-matched controls. All participants completed variants of the GI task where their dominant and non-dominant limbs as the 'stepping' and 'support' limbs. Task performance was quantified using the centre of pressure (COP) trajectory of each foot (computed from a force plate) and a surrogate of the centre of mass (COM) trajectory (estimated from an inertial measurement unit placed on the sacrum).

Concussed patients exhibited decreased COP excursion on their dominant foot, both when it was the stepping limb (sagittal plane: 9.71 mm [95% CI: 8.14–11.27 mm] vs 14.9 mm [95% CI: 12.31–17.49 mm]; frontal plane: 36.95 mm [95% CI: 30.87–43.03 mm] vs 54.24 mm [95% CI: 46.99–61.50 mm]) and when it was the support limb (sagittal plane: 10.43 mm [95% CI: 8.73–12.13 mm] vs 18.13 mm [95% CI: 14.92–21.35 mm]; frontal plane: 66.51 mm [95% CI: 60.45–72.57 mm] vs 88.43 mm [95% CI: 78.53–98.32 mm]). This was reflected in the trajectory of the COM, wherein concussion patients exhibited lower posterior displacement (19.67 mm [95% CI: 19.65 mm–19.7 mm]) compared with controls (23.62 mm [95% CI: 23.6–23.64]). On this basis, we conclude that individuals with concussion display deficits during a GI task which are potentially indicative of supraspinal impairments in motor control.

1. Introduction

Concussion assessment has undergone an evolution in recent years (Doherty et al., 2017; Johnston, Doherty, Buttner, & Caulfield, 2017). The traditional clinical assessment of concussion was initially based on a grading scale of injury severity, and this has evolved to become a multifaceted assessment of patients' function in an individualised manner (McCrory et al., 2013). Indeed contemporary assessment of concussion now includes a multimodal evaluation of symptoms, cognition and motor function (Register-Mihalik, Littleton, & Guskiewicz, 2013).

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The evaluation of motor function following concussion has been limited to static postural control (Powers, Kalmar, & Cinelli, 2014) and continuous gait (Parker, Osternig, Van Donkelaar, & Chou, 2006) tasks. However, it remains unclear how concussion may affect motor tasks of dynamic balance such as gait initiation.

Initiation of gait requires preparatory postural adjustments (PPAs) to stabilise the postural perturbation induced by a forthcoming voluntary movement (Bouisset & Do, 2008). As such, evaluation of gait initiation (GI) may be useful for understanding whether concussion impairs the PPAs needed to execute the transition from standing posture to cyclic gait (Halliday, Winter, Frank, Patla, & Prince, 1998). To date however, no data are available on motor performance during GI in a population with a history of concussion.

GI is achieved by PPAs that first shift the centre of pressure (COP) posteriorly and laterally. This process enables the centre of mass (COM) of the body to accelerate anteriorly and contra-laterally to the stepping limb (Ledebt, Bril, & Breniere, 1998). These events occur before any observable movement of the feet (Ledebt et al., 1998). The COP then moves medially from its posterior and lateral position toward the stepping foot, during which there is corresponding movement of the vertical projection of the COM. Finally, the COP transitions to the support foot as the individual takes their first step. This corresponds with the initial double support phase of the first step, and ends with toe-off of the support foot.

Optimal performance during GI is represented by an efficient transition from static stance to cyclic gait with minimisation of the risk associated with this volitional perturbation on controlled stability; it is underpinned by both the movement of the COP during GI and the corresponding movement of the COM of the body.

Quantification of PPAs is typically achieved using force plates and camera-based systems in gait analysis laboratories. Recently however, inertial measurement units (IMUs) which contain accelerometers and/or gyroscopes have provided an interesting alternative to obtrusive and expensive laboratories for gait and balance assessment (Horak & Mancini, 2013; Mancini, Zampieri, Carlson-Kuhta, Chiari, & Horak, 2009) including the analysis of GI (Mancini et al., 2009; Martinez-Mendez, Sekine, & Tamura, 2011).

Recently published research has demonstrated impaired PPAs during GI in patients with impairment of the central nervous system as evidenced by decreased velocity and magnitude of COP displacement (Hass, Waddell, Fleming, Juncos, & Gregor, 2005; Hass, Waddell, Wolf, Juncos, & Gregor, 2008). However, little is known about the effect of concussion on GI.

Therefore, the purpose of this investigation was to investigate whether patients who were symptomatic following concussion exhibit altered PPAs during a GI task, as determined with IMU and COP outcomes. We hypothesised that concussion patients would exhibit impaired PPAs during GI (decreased magnitude of COP displacement [measured with a force plate], and COM displacement [measured with an IMU]).

2. Methods

2.1. Participants

The recruitment site used for the present investigation was a university affiliated hospital emergency department 'concussion-clinic'. This clinic manages a caseload patients across the full spectrum of concussion severity: those with acute concussion in whom symptoms resolve within what is considered an 'acceptable' timeframe of 7–10 days (McCrory et al., 2005), and those with persistent symptoms that extend beyond this.

Fifteen patients were recruited at convenience from the clinic, within 1-month of sustaining a concussion. The diagnosis of concussion was made by a hospital physician (JR) and was consistent with that of the latest international expert consensus definition (McCrory et al., 2013) as an injury caused by a direct blow to the head, face, neck, or elsewhere in the body resulting in impaired neurological function and clinical symptoms.

After evaluation at the ED, prospective subjects were informed about the study and provided written permission (parent/-guardian permission if a subject was younger than 18 years) for study investigators to relay detailed study information via telephone contact. If participants were interested, they provided informed consent.

A convenience sample of fifteen age- and sex-matched 'healthy' participants were also recruited and tested. These controls (parent/guardian if a participant was younger than 18 years) were informed about the study via posters and flyers placed in the catchment area of the hospital, wherein they were provided with details to contact investigators if they chose.

All prospective participants were interviewed; provided they met the study inclusion and exclusion criteria, they were considered eligible for enrollment. The following exclusion criteria were adopted for all participants: 1) any lower extremity injury that may affect gait; 2) history of cognitive deficiencies; 3) history of $\geq$3 previous concussions (to ensure exclusion of those with chronic mild traumatic brain injury (Howell, Osternig, & Chou, 2013); 3) loss of consciousness following the concussion for >1 min (McCrory et al., 2013); a previously documented concussion in the previous year. Participant demographics for each group are provided in Table 1. The institutional review board of the university and that of the hospital approved the study protocol. All subjects and parents/guardians (if a subject was younger than 18 years) provided written consent to participate in the study.