ARTICLE IN PRESS

International Journal of Psychophysiology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Repetitive head impacts do not affect postural control following a competitive athletic season

Nicholas G. Murray[a,*], Katelyn E. Grimes[a], Eric D. Shiflett[a], Barry A. Munkasy[a], Nathan R. D'Amico[b], Megan E. Mormile[a], Douglas W. Powell[c], Thomas A. Buckley[d,e]

[a] School of Health and Kinesiology, College of Health and Human Services, Georgia Southern University, P.O. Box 8073, Statesboro, GA 30458, United States
[b] Department of Health, Human Performance, and Recreation, Office for Sport Concussion Research, University of Arkansas, Fayetteville, AR, United States
[c] School of Health Studies, University of Memphis, 106 Elma Roane Fieldhouse, Memphis, TN 28152, United States
[d] Department of Kinesiology and Applied Physiology, University of Delaware, 540 College Avenue, Newark, DE 19716, United States
[e] Interdisciplinary Program in Biomechanics and Movement Science, University of Delaware, 540 College Avenue, Newark, DE 19716, United States

ARTICLE INFO

Keywords:
Subconcussive
Repetitive head impacts
Concussion
Postural control

ABSTRACT

Evidence suggests that Repetitive Head Impacts (RHI) directly influence the brain over the course of a single contact collision season yet do not significantly impact a player's performance on the standard clinical concussion assessment battery. The purpose of this study was to investigate changes in static postural control after a season of RHI in Division I football athletes using more sensitive measures of postural control as compared to a non-head contact sports. Fourteen Division I football players (CON) (age = 20.4 ± 1.12 years) and fourteen non-contact athletes (NON) (2 male, 11 female; age = 19.85 ± 1.21 years) completed a single trial of two minutes of eyes open quiet upright stance on a force platform (1000 Hz) prior to athletic participation (PRE) and at the end of the athletic season (POST). All CON athletes wore helmets outfitted with Head Impact Telemetry (HIT) sensors and total number of RHI and linear accelerations forces of each RHI were recorded. Center of pressure root mean square (RMS), peak excursion velocity (PEV), and sample entropy (SampEn) in the anteroposterior (AP) and mediolateral (ML) directions were calculated. CON group experienced 649.5 ± 496.8 mean number of impacts, 27.1 ± 3.0 mean linear accelerations, with ≈1% of total player impacts exceeded 98 g over the course of the season. There were no significant interactions for group x time RMS in the AP ($p = 0.434$) and ML ($p = 0.114$) directions, PEV in the AP ($p = 0.262$) and ML ($p = 0.977$) directions, and SampEn in the AP ($p = 0.499$) and ML ($p = 0.984$) directions. In addition, no significant interactions for group were observed for RMS in the AP ($p = 0.105$) and ML ($p = 0.272$) directions, PEV in the AP ($p = 0.081$) and ML ($p = 0.143$) directions, and SampEn in the AP ($p = 0.583$) and ML ($p = 0.129$) directions. These results suggest that over the course of a single competitive season, RHI do not negatively impact postural control even when measured with sensitive non-linear metrics.

1. Introduction

Sport-related concussions are a major health concern that effect all levels of athletic play including measurable deficits such as postural instability, cognitive impairment, and neurologic symptoms (e.g., headaches, dizziness) (McCrory et al., 2017). The effect of multiple concussions over the course of an athletic career can lead to an increased risk of early onset Alzheimer's disease, mild cognitive impairment, depression, and overall later-life cognitive impairments (Guskiewicz et al., 2005; Guskiewicz et al., 2007). However, repetitive head impacts (RHI), independent of concussion, have been associated with the development of the progressive degenerative brain disease known as Chronic Traumatic Encephalopathy (CTE) (McKee et al., 2016; McKee et al., 2013; McKee et al., 2016). This is supported by a recent report that has confirmed the presence of CTE in 99% of post-mortem retired National Football League (NFL) players and 87% of all American football players across different levels of play (Mez et al., 2017); however these results must be viewed cautiously given an acknowledged selection bias in the studies. However, the role of RHI in the development neurodegenerative pathologies remains inconclusive (Bailes et al., 2013; Solomon et al., 2016).

Standard clinical post-concussion assessments include postural stability, cognition, and self-reported symptoms which are components of the Sport Concussion Assessment Tool-5 (SCAT-5) (McCrory et al.,

* Corresponding author at: School of Health & Kinesiology, Georgia Southern University, P.O. Box 8076, Statesboro, GA 30460-8076, United States.
E-mail address: nmurray@georgiasouthern.edu (N.G. Murray).

http://dx.doi.org/10.1016/j.ijpsycho.2017.09.018
Received 15 December 2016; Received in revised form 28 July 2017; Accepted 25 September 2017
0167-8760/

2017). Multifaceted assessment batteries are highly sensitive to acute concussion (≤ 0.96) (Broglio et al., 2014); however, these assessments have failed to identify differences following a season of RHI (Gysland et al., 2012; Miller et al., 2007; McAllister et al., 2012). Conversely, neuroimaging studies have identified alterations in brain physiology (e.g., reduced white matter diffusion) following a single athletic season (Breedlove et al., 2014; McAllister et al., 2012) which may be dose dependent for impacts (Bazarian et al., 2014). Thus, these findings seem to indicate that a season of RHI has adverse effects on the brain when measured by neuroimaging, but not standard concussion related clinical measures. This finding is not particularly surprising, as recent evidence supports the argument that physiological recovery persists well beyond apparent clinical recovery (Kamins et al., 2017). Furthermore, there has been limited investigation of the association between RHI and postural control.

Postural control requires the integration of multiple components of the nervous system including the motor, sensory, and cognitive systems, and thus is a marker of neurological health (Winter, 1995). Impaired postural control is a cardinal sign of a concussion and multiple methods exist to quantify the magnitude of instability (Murray et al., 2014; Buckley et al., 2016). While the SCAT-5 recommends the modified Balance Error Scoring System (BESS) (Riemann and Guskiewicz, 2000) despite limited psychometrics (McCrory et al., 2017; Buckley et al., 2017), clinically the original BESS is the most commonly utilized although the substantial limitations, most notably a practice affect, reduces the clinical applicability (Buckley et al., 2015; Burk et al., 2013). The Sensory Organization Test (SOT), a force platform-based exam with challenging sensory perturbations, has identified impaired postural control up to 96 hours post-concussion, but also likely suffers from practice effects (Cavanaugh et al., 2006; Reed-Jones et al., 2014; Buckley et al., 2016). Other more sensitive methods of measuring the postural control system suggest that those with a prior concussion history have impaired postural control reflected as alterations in gait and postural stability (Martini et al., 2011; Buckley et al., 2015). However, these approaches have either failed to identify or have not evaluated changes in postural control from RHI over the course of a football season with both measures actually showing large performance improvements potentially due to the practice effects (Gysland et al., 2012). This suggests that standard clinical postural control measures are insensitive to potential changes, if any, associated with football related RHI.

To improve postural control sensitivity and objectively, center of pressure (CoP) kinematics and entropic measures have been utilized to identify impaired postural control well beyond clinically measured recovery (Gao et al., 2011; Sosnoff et al., 2011; Powers et al., 2014; Murray et al., 2014). Traditional measures of postural stability (e.g., sway kinematics) provide information regarding mechanical balance performance, while nonlinear measures may be more sensitive to the dynamics of the underlying neuromuscular strategy (Stergiou and Decker, 2011; Williams et al., 2016). Nonlinear measurements such as approximate entropy (ApEn) and sample entropy (SampEn) may detect subtle differences in the moment-to-moment regularity within the center of pressure time-series and be sensitive to subtle variations in the characteristics of CoP profiles (Cavanaugh et al., 2006; Cavanaugh et al., 2005; Stergiou and Decker, 2011; Williams et al., 2016). Furthermore, research has indicated that these non-linear measures are capable of detecting subtle differences in the time-series center of pressure profile even in the absence of notable differences in traditional measures such as sway excursions (Cavanaugh et al., 2006; Stergiou and Decker, 2011). As such, the use of nonlinear measures in postural stability offers a unique quantitative analysis that provides a distinct perspective relating to the adaptability of the underlying neuromuscular system (Buckley et al., 2016).

The RHI-related changes in postural stability over the course of an athletic season have not been previously investigated using linear and non-linear measures. As such, it is of interest to examine if more these measures of postural stability can detect changes in athletes who experience RHI over the course of a single athletic season when common clinical tests fail to identify differences. Therefore, the purpose of this study was to investigate changes in static postural control following a season of Division I football compared to a non-head contact sports using both traditional and entropic measures of postural control. It was hypothesized that RHI athletes would experience lower regularity as measured by SampEn following post-season measurements, whereas no differences would be observed in sway magnitude values.

2. Methods

2.1. Participants

Fourteen National Collegiate Athletic Association (NCAA) Division I football players wearing instrumented helmets (age = 20.40 ± 1.12 years, concussion history: 0.5 ± 0.8 concussions) and fourteen non-contact competitive cheerleaders (3 male, 11 female; mean age = 19.85 ± 1.21 years, with no prior history of concussion) participated in this study. All participants were free of current musculoskeletal and/or neuromuscular injury beyond the documented concussion injury, had no self-reported history of psychiatric illness, Attention Deficit Hyperactivity Disorder and/or seizures. In addition, no participant had experienced a concussion within the 6 months prior to the initial test nor presented with a clinically unresolved concussion at either testing session and all participants were medically cleared for full unrestricted participation at the time of testing. All participants provided written informed consent as approved by the institutional review board.

2.2. Instrumentation

Kinetic data were collected from a single force platform (1000 Hz, AMTI Inc., Model OR-6, Watertown, MA. USA) embedded level with the laboratory floor. Force platform technology is considered the criterion method for CoP measurements (Winter, 1995; Guskiewicz et al., 2000). Football participant's helmets were instrumented with the Helmet Impact Telemetry System (HITS) (Ridell, Chicago, IL. USA) which records the frequency, location, and magnitude of impacts sustained. The helmet unit consists of six uniaxial accelerometers embedded within the helmet (Beckwith et al., 2012). When an impact acceleration of > 10 gravitational forces (g) is registered on any of the six accelerometers, accelerations were recorded for a period of 40 ms (8 ms prior to the impact and 32 ms following the impact) at 1000 Hz (Crisco et al., 2004; Duma et al., 2005; Breedlove et al., 2014). Recorded impact data is transmitted via a signal transducer within the helmet unit to a receiver and laptop on the sideline where data is displayed in real time. Data is also stored within the helmet with a magnitude > 10 g in the event the controller loses contact with or is out of range of the signal receiver (Duma et al., 2005; Crisco et al., 2004).

2.3. Procedures

All participants completed testing on two occasions: (1) Within 4 weeks prior to the start of the athletic season (PRE), and (2) within 72 h of the conclusion of their respective athletic seasons (POST). At each testing session, participants completed a single quiet standing trial of 120 seconds barefoot feet together on top of a force platform (Gao et al., 2011). Each participant was instructed to remain as still as possible with their hands resting comfortably at their sides for the entire trial. Raw CoP coordinates were recorded and exported via Vicon Nexus 1.8.5 (Vicon Ltd., Oxford, UK) and further analyzed using a custom software (MATLAB 2016a, MathWorks, Inc., Natick, MA, USA). Postural control was characterized by root mean square (RMS), peak excursion velocity (PEV), and sample entropy (SampEn) in the anteroposterior (AP) and mediolateral (ML) directions. The HIT System Sideline