THE EFFECT OF CONCUSSION HISTORY ON POSITIONAL BALANCE ABILITY IN RUGBY UNION ATHLETES

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Head traumas account for 29% of all injuries in professional rugby. Concussions are thought to have only a short-term effect on balance. The purpose of this study was to investigate whether concussion history affected a rugby team's ability to maintain balance and determine which sensory system was most affected. Thirty male academy rugby athletes separated into backs and forwards performed the m-CTSIB on the Biodex Balance SD system. The forwards, who had more rugby experience and concussions in comparison to the backs, produced substantially larger sway index scores (worse balance) in all four conditions. Useful future research could involve a longitudinal study which allowed baseline balance scores to be established and compared over time.

KEYWORDS: mild traumatic brain injury (MTBI); Biodex Balance SD; modified Clinical Test for Sensory Integration of Balance (m-CTSIB); backs; forwards.

INTRODUCTION: Rugby union is the world's most popular collision team sport with 120 countries affiliated with World Rugby. Over time the physical demands of the sport placed on athletes at the professional level have increased; especially the force and velocity of contact events between athletes. This increase in physicality has led to professional rugby having one of the highest reported incidence rates of match injuries; head traumas consistently account for up to 29% of all injuries (Kemp, Hudson, Brooks, & Fuller, 2008). Kemp et al. (2008) found that of the 6.6 head injuries per 1000 athlete-hours in English rugby union athletes, 4.1 were concussions. Additionally the concussions found accounted for 62% of all head injuries and resulted in athletes being removed from the sport for an average of 13 days per concussion (over half of all time off from head injuries) (Kemp et al., 2008). Kemp et al. (2008) also highlighted that the risk of receiving a concussion differs between backs and forwards, with forwards taking part in the more physical aspects of the game such as set pieces, rucks and mauls, and backs producing higher velocity tackles and collisions during play.

A number of authors (Sosnoff, Broglio, Shin, & Ferrara, 2011) have identified poor balance as part of the pathological condition of a concussion. It is currently believed (Sosnoff et al., 2011) that the ability for the three sensory systems (visual, vestibular and somatosensory) to communicate is lost as a consequence of a concussion, resulting in an inability to maintain appropriate balance. The vestibular system has two main purposes; the first is to enable the eyes to stay fixed on a stationary target while the head or body is moving and the second is to in maintaining balance along with somatosensory and visual input. Athletes suffering from concussion who performed the modified Clinical Test for Sensory Integration of Balance (m-CTSIB) demonstrated an increase in postural sway (worse balance) in comparison to control participants without head injury (Evans, Ketcham, Folger, Vallabhajosula, & Hall, 2015). Interestingly these increases in postural sway continued for up to three days and were most evident when the athletes were either on a foam or moving surface. Sosnoff et al. (2011) have also found that these decreases in postural stability can last for longer than three days. Given the major gaps in the potential effects that concussions may have on balance, the purpose of this study was to (1) investigate whether having a history of concussion affected a rugby team's ability to maintain balance and (2) determine which sensory system was that most affected. We postulated that a history of concussion would be accompanied by an increased sway index score; with eyes open and closed standing on a foam surface conditions having the highest (worst) scores.

METHODS: Thirty male academy (high-performance development) rugby athletes separated into backs and forwards (see Table 1) performed the m-CTSIB on the Biodex Balance SD

system (Biodex Medical Systems, Inc., Shirley, NY, USA). All athletes were free of any acute or chronic injury and were cleared for full competitive play by the team's medical staff. Testing took place during the athletes' respective off-season after a rest day (~24-h). This study was approved by the Auckland University of Technology ethics committee (#13/378).

Table 1. Characteristics for backs and forwards and inferences for mean change.

			Forwards–Backs	
	Backs (n = 15)	Forwards (n = 15)	Mean change; 90% CL	Qualitative inference
Age (y)	24 ± 4	20 ± 1	-4.5; ±1.7	Large** -ive
Body-height (m)	1.8 ± 0.0	1.9 ± 0.1	0.034; ±0.044	Small** +ive
Body-mass (kg)	90 ± 8	103 ± 11	13; ±6	Large* +ive
Rugby experience (y)	7.1 ± 4.4	10 ± 4	3.0; ±2.5	Moderate* +ive
Concussions (total)	5	9		

Values are means ± standard deviation; mean change; ±90% confidence limits (90% CL); -ive and +ive, substantial negative and positive change with forwards relative to backs; small, moderate and large inferences: 25-74%, possibly (*); 75-94%, likely (**).

Data collection: Following a general self-selected lower-extremity dynamic warm-up, athletes were asked to remove their shoes and socks and to position both feet in the centre of the locked platform on the Biodex Balance SD System in a self-assessed "comfortable" standing position. In an upright posture (~15° knee flexion) and both arms folded across the chest, athletes completed the four unique tests which comprise the m-CTSIB: (1) eyes open, firm surface; (2) eyes closed, firm surface; (3) eyes open, foam surface; and (4) eyes closed, foam surface. Each test lasted for 20s and all athletes received an identical "cueing" script to eliminate potential variation. The script instructed athletes to maintain their balance to the best of their ability for the duration of each test and when eyes were meant to be opened, to find a point on the wall in front of them at eye level and to focus on that point. No other visual and audio feedback/encouragement was provided.

Additionally, medical personnel from the academy team and all of the athletes' individual club teams were contacted for concussion history data. A concussion was defined as a direct / indirect blow to the head followed by a variety of symptoms that may include any of the following: headache, dizziness, loss of balance, blurred vision, "seeing stars", feeling in a fog or slowed down, memory problems, poor concentration, nausea, or throwing-up. It was also noted that getting "knocked out" or being unconscious does NOT always occur with a concussion. This definition was adapted from the present World Rugby RugbyHealth project conducted in New Zealand between 2012–2015 (further details can be found at: https://sprinz.aut.ac.nz/areas-of-expertise/interdisciplinary-research/rugby-codes).

Data processing: Data were collected at 20Hz via the Biodex m-CTSIB Utility Software v3.0. Calculations are described in detail elsewhere (Arnold & Schmitz, 1998), but in short, sway index was calculated using the degrees of tilt about the centre-of-pressure; relecting the standard deviation of the fluctuations around the zero point of the platform. A smaller sway index score represents better balance while a larger score represents worse balance.

Data analysis: Pre-loaded m-CTSIB data collected on 1,440 student-athletes using the same methodologies mentioned above were included as default normative data with which to compare and contrast, albeit anecdotally, our results ("Addendum: Biodex software for Balance System SD and Portable Biosway. Version 2.0," 2011). Magnitude-based inferences were used to assess the standardised effects (the difference between the forwards and backs was divided by the standard deviation of the backs; effect size [ES]) of sway index scores using previously established methods (Hopkins, Marshall, Batterham, & Hanin, 2009). If the confidence limits were within the levels of the negative, trivial or positive mechanistic scale, the outcome was noted as clear and the likelihood of the true effect observed was described. If the confidence limits spanned all three levels, the outcome was noted as unclear.

RESULTS: Forwards were younger (ES = -1.6), taller in stature (ES = 0.47), heavier in body-mass (ES = 1.3), had more rugby experience (ES = 0.72) and had more concussions compared to backs (9 vs. 5, respectively). Forwards produced substantially larger sway index scores in all four conditions (eyes open firm surface, ES = 0.62; eyes closed firm surface, ES = 0.88; eyes open foam surface, ES = 0.50; eyes closed foam surface, ES = 0.52) compared to backs as seen in Table 2.

Table 2. Sway index scores of the Biodex m-CTSIB assessment, comparison between backs and forwards and inferences for mean change.

	Biodex m-CTSIB normative data^ (*n* = 1440)	Backs (*n* = 15)	Forwards (*n* = 15)	Forwards–Backs	
				Mean change; 90% CL	Qualitative inference
Eyes open firm surface	0.43 ± 0.12	0.48 ± 0.14	0.57 ± 0.14	0.090; ±0.089	Moderate* +ive
Eyes closed firm surface	0.66 ± 0.21	0.61 ± 0.23	0.91 ± 0.40	0.30; ±0.21	Moderate** +ive
Eyes open foam surface	0.74 ± 0.19	0.87 ± 0.19	0.99 ± 0.28	0.12; ±0.15	Small** +ive
Eyes closed foam surface	1.85 ± 0.41	1.92 ± 0.72	2.29 ± 0.65	0.37; ±0.44	Small* +ive

Values are means ± standard deviation. M-CTSIB, Modified Clinical Test of Sensory Integration of Balance; ^, ("Addendum: Biodex software for Balance System SD and Portable Biosway. Version 2.0," 2011); mean change; ±90% confidence limits (90% CL); +ive, substantial positive change with forwards relative to backs; small and moderate inferences: 25-74%, possibly (*); 75-94%, likely (**).

DISCUSSION: Little research exists on the long-term effects of multiple concussions on balance. The limited number of studies performed have found that while there were no obvious changes in balance ability there were subtle changes, either in neural or neuromuscular adaptations, that allowed the athlete to compensate for any losses which were missing in the non-concussed group. Sosnoff et al. (2011) stated that prolonged deficits in balance following a concussion are comparable to findings of persistent cognitive deficits following a concussion. This supports the proposition that concussion should now be considered to possess long-term effects rather than just transient effects on cerebral functioning.

When the athletes' data was split into backs and forwards, clear differences in balance ability between the two groups were apparent. The forwards mean sway index scores were greater than that of the backs for all the conditions, with their eyes open and eyes closed on a firm surface scores being 19% and 49% greater respectively. For the foam surface conditions the forwards mean sway index score was 14% greater than the backs during the eyes open test and 19% greater with eyes closed. This highlights that for this team the forwards, who recorded the greater number of concussions, also have worse balance. The division of concussions between positions is consistent with the findings of Fuller et al. (2015) where forwards experienced more concussions and with a greater severity (though not considered significantly different) than those of backs. The difference in balance ability would also be in accordance with the proposition of Sosnoff et al. (2011) that long-term postural control deficits after a concussion are similar to those of prolonged cognitive deficits after a concussion.

When the data from the forwards and backs in the current study are compared to the Biodex' student-athlete normative data ("Addendum: Biodex software for Balance System SD and Portable Biosway. Version 2.0," 2011), the differences between the two positions' scores and the potential implications of these differences can be better understood. The forwards are only within the established normal range for the eyes closed standing on a firm surface condition the backs are within the acceptable range for all conditions apart from the eyes open standing on a foam surface. The backs performing poorly in the eyes open standing on a foam surface suggests that they are more reliant on their somatosensory system rather than utilising them all equally, due to this condition compromising it. The forwards in contrast performed poorly in the eyes open standing on a foam surface and eyes closed version. As the visual and

somatosensory systems are both compromised the athlete has to rely on their vestibular system. A concussed athlete usually performs poorly in these two conditions therefore it could be inferred that the forwards had either recently experienced a concussion or still suffer from the residual effects of previous concussions. However while it may seem that the backs are free from the effects of concussion Evans et al. (2015) found that athletes with a history of concussion only performed worse than their non-concussed counterparts on the Biodex's eyes open standing on a foam surface. It was suggested (Evans et al., 2015) that the process of integrating visual information as well as distorted somatosensory information may be what is most difficult for those who have experienced a concussion. This would be in line with the suggestion of Guskiewicz et al. (2001) that the postural deficits in those who have had a concussion are linked to sensory interaction problems, making it difficult to integrate and process different sensory information. Therefore we would suggest that it is possible that the increase in number of concussions over time also increases the difficulty for the athlete to integrate and process different sensory information.

CONCLUSION: Within our rugby cohort, a history of concussion was associated with a decreased sway index score; suggesting balance may be negativley affected acutely and chronically by a concussion. While it is not possible to alter an athlete's past concussion it is important to know which of the sensory systems are affected, as this knowledge can aid injury preventional strategies moving ahead. As the atheltes in the current study were only tested once, it would be beneficial for authors of future research to perform a longitudinal study with baseline scores established and compared to over time should a concussion occur.

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