STATIC BALANCE IN INDIVIDUALS WITH POST-CONCUSSION SYNDROME

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A concussion is an injury to the brain caused by linear and/or rotational forces applied to the head. The majority of concussions typically resolve spontaneously within a period of 7-10 days. In 10-20% of individuals, however, the symptoms persist beyond 10 days and are termed post-concussion syndrome (PCS). The purpose of this pilot study was to evaluate the effects of a supervised and structured four-week aerobic and balance exercise program on static balance measures in a sample of individuals with PCS. Statistically significant changes in velocity and length of centre of pressure during balancing tasks were observed in response to the exercise program. These improvements in balance and symptoms suggest that further research into the benefits of exercise based treatment for improving balance deficits associated with PCS is warranted.

KEY WORDS: Concussion, balance, aerobic exercise

INTRODUCTION: Concussion is a form of mild traumatic brain injury induced by linear, rotational, and angular forces resulting from the brain colliding within the skull leading to a disruption of the complex physiological processes (McCrory et al., 2013). Between 2009 and 2010, 94,000 concussions were reported in Canadians 12 years and older (Statistics Canada, 2013). Currently, the recommended method of treatment for concussion is cognitive and physical rest until the symptoms resolve (McCrory et al., 2013). Prescribed rest often leads to symptom resolution in 80-90% of concussions within roughly 10 days; however, in 10-20% of individuals, the symptoms continue to persist beyond this time frame (Moser, Glatts, & Schatz, 2012). This phenomenon of lingering concussive symptoms is termed post-concussion syndrome (PCS).

Presently, there is limited evidence supporting prolonged rest as a prescribed treatment for PCS. Prolonged rest may actually be more detrimental resulting in increased physical, psychological, and/or social stress in the form of physical deconditioning, hyperawareness of symptoms, or loss of productivity at work, in sport, or school (Kleffelgaard, Roe, Soberg, & Bergland, 2012). Conversely, early evidence suggests the benefits of active exercise in reducing the symptoms associated with PCS.

The clinical presentation of PCS, however, is highly variable with patients often reporting variable symptoms such as difficulty with cognitive tasks, reporting headache pain and dizziness, and demonstrating balance dysfunction (McCrory et al., 2013). Approximately 30% of individuals experiencing concussion report balance issues (Guskiewicz, 2011). Limited research is available on how to best address the ongoing balance issues that are sometimes present following concussion. As highlighted previously, often general symptoms resolve with the first 1-2 weeks following concussion but when issues related to balance persist, the optimal strategies to resolve this remain elusive. Therefore, the purpose of this pilot study was to evaluate the effects of a supervised and structured four-week aerobic and balance exercise (AEB) program on measures of static balance in a sample of individuals with PCS.

METHODS: After obtaining ethical approval from the academic institution, consent was obtained from the prospective participants diagnosed with PCS. Pre-treatment evaluation included the measurement of anthropomorphic variables (height and weight), resting blood pressure, and heart rate; and the assessment of static balance using the Balance Error Scoring System (BESS) protocol on an AMTI force platform. Participants stood in a double leg stance

(DS) position with the feet touching (side by side), hands on his/her iliac crests with their eyes closed; single leg stance (SL) position standing on the non-dominant leg with hands on his/her iliac crests and their eyes closed; and tandem stance (TS) position standing with the toes of the non-dominant foot touching the heel of the dominant foot, hands on his/her iliac crests, and their eyes closed. The BESS protocol was completed on a force platform and values of displacement in centre of pressure (COP) during each of the six trials were recorded. Testing consisted of one trial in each of the described positions on a firm surface, followed by one trial in each testing position standing on a foam pad, for a total of six trials lasting 20 seconds each. The BESS protocol was completed on an AMTI force platform (connected to a desktop computer) to measure the amount of displacement in the participant's COP during each of the testing trials. Velocity and displacement values of COP were recorded.

Each participant completed 12 supervise one hour AEB retraining sessions over the course of four weeks (three sessions per week). Participants used a heart rate monitor and maintained the intensity of the exercise at a given target exercise heart rate for each supervised session. Sessions began with a five minute warm-up on a cycle ergometer at a self-selected speed and resistance until he/she reached their respective target HR. Once the target intensity was achieved, participants continued to cycle at the desired intensity for 20-35 minutes. After completing the cycling component, participants rested for five minutes. Participants then completed three sets of balance exercises in DS, SL, and TS positions on both legs. See Table 1 for the template of exercise progressions over the course of the four-week program. Incremental progressions in intensity and duration of aerobic exercise and balance retraining were completed on a weekly basis. The duration, surface, and difficulty of the balance tasks (eyes open versus eyes closed) were also progressively increased to challenge the participant's balance.

After completing the 12 supervised and progressive AEB sessions, participants were re-evaluated using the same pre-treatment assessment test battery. Data analysis was completed using IBM SPSS 20 for Windows to evaluate change after the completion of the AEB program. Changes observed in the dependent variables were assessed for statistical significance using paired samples t-tests with an alpha level set at 0.05. Bonferroni corrections were also applied where necessary.

Table 1
Exercise Progression Template

Mode of Exercise		**Week 1**	**Week 2**	**Week 3**	**Week 4**
Aerobic	Heart Rate Reserve Intensity	20%	30%	40%	50%
	Duration (min)	20	25	30	35
Balance	Surface	Firm	Foam	Firm	Foam
	Duration (sec)	15	15	20	20
	Eye Condition	Open	Open	Closed	Closed

RESULTS: Nine participants with PCS (mean age 16.33 years ± 2.55) who experienced persistent symptoms of concussion (mean 99.88 days ± 79.25) completed the study. There were significant reductions in the average velocity of the COP during DS foam position ($t(8)=4.06$, $p=.004$) and SL foam position ($t(8)=3.80$, $p=.005$) when performing the BESS protocol. Similarly, there were significant reductions in the length of the COP values during the DS foam position ($t(8)=4.06$, $p=.004$), and SL foam position ($t(8)=3.80$, $p=.005$) when performing the BESS protocol (see Table 2 and 3).

Table 2
Velocity of COP (cm/sec) Pre- and Post-Treatment Change

Balance Condition	Pre-Treatment Mean (±SD)	Post-Treatment Mean (±SD)	Paired Samples T-Test
DS Firm	0.78 (±.20)	0.85 (±.44)	$t(8)=-0.86$, $p=.41$
SL Firm	2.15 (±.56)	2.03 (±.72)	$t(8)= 0.73$, $p=.48$
TS Firm	1.61 (±.88)	1.71 (±.80)	$t(8)=-0.74$, $p=.48$
DS Foam	1.88 (±.69)	1.37 (±.44)	$t(8)=4.06$, $p=.004$*
SL Foam	3.00 (±.88)	2.41 (±.89)	$t(8)=3.80$, $p=.005$*
TS Foam	2.98 (±1.20)	2.29 (±.94)	$t(8)=1.73$, $p=.12$

* indicates significant change following exercise program

Table 3.
Length of COP Trajectory (cm) Pre- and Post-Treatment Change

Balance Condition	Pre-Treatment Mean (±SD)	Post-Treatment Mean (±SD)	Paired Samples T-Test
DS Firm	15.53 (±3.97)	17.06 (±8.81)	$t(8)=-0.87$, $p=.41$
SL Firm	43.05 (±11.25)	40.52 (±14.40)	$t(8)=0.73$, $p=.48$
TS Firm	32.12 (±17.62)	34.16 (±16.04)	$t(8)=-0.74$, $p=.48$
DS Foam	37.51 (±13.79)	27.44 (±8.84)	$t(8)=4.06$, $p=.004$*
SL Foam	59.97 (±17.68)	48.22 (±17.78)	$t(8)=3.80$, $p=.005$*
TS Foam	59.69 (±24.03)	45.81 (18.82)	$t(8)=1.73$, $p=.12$

* indicates significant change following exercise program

DISCUSSION: The purpose of this investigation was to evaluate the effects of a supervised and structured four-week AEB program on static balance measures in a sample of individuals with PCS. The BESS protocol was utilized within this study as a standardized measure to assess static balance for individuals with PCS. The BESS protocol was performed on an AMTI force platform to acquire accurate and standardized measures of COP displacement during each of the balance trials. All nine participants within this study were engaged in competitive sport/activity, including: ice hockey, soccer, American football, cheerleading, volleyball, and tennis.

The findings suggest that changes in the velocity and length of the COP trajectory were observed following the AEB treatment program. More specifically, improvements were observed in the DS and SL foam conditions for both velocity and length of COP. These improvements may result in balance changes that may carry over when individuals complete functional tasks of daily living and sport-related skills. Improved balance during DS on a foam surface may indicate greater control of balance during prolonged periods of standing at school, work, or during daily sport related activities. In a sporting context, improvements in SL balance on a foam surface may have the most clinical relevance. Sports such as hockey or soccer expose the athlete to many instances when he/she will have to maintain his/her balance on one leg dynamically and statically. Improved balance in SL positions on a foam surface may carry over to assessments completed by healthcare providers and coaches examining balance in order to determine Return to Play in sports that often demand the athlete to be able to control him/herself on one leg. Furthermore, better balance in an unstable position such as SL may lower re-injury risk by reducing the chance of a fall wherein another concussion may occur. The improvement of this skill in older individuals who present with balance dysfunction related to PCS may also assist in reducing the risk of falls.

CONCLUSION: The current study revealed that further exploration into the use of a supervised and progressive four-week AEB program administered to individuals with PCS is warranted to examine the clinical utility and to explore the effects of balance measures such as velocity and length of the COP trajectory during static balance tasks. Further investigation into the utility of exercise based treatments on other balance, kinematic, and kinetic variables in the concussed population is warranted.

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