THE EFFECTS OF EXERCISE ON COGNITIVE FUNCTION, AND BALANCE IN HEALTHY INDIVIDUALS – A PILOT STUDY

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Concussion is defined as an injury to the brain caused by forces applied to the head. Approximately 10-20% of concussed individuals develop post-concussion syndrome (PCS), characterized by persistent symptoms beyond 10 days including balance and cognitive deficits. The purpose of this pilot study was to explore the effect of a four-week exercise program on physiological, cognitive, and balance variables in a sample of healthy, physically active individuals to gather preliminary information to apply to a future PCS population. Statistically significant changes in reaction time and balance measures were observed. No changes in heart rate, blood pressure, memory, or visual motor speed were observed. Balance improvements in this healthy sample suggest that future exploration of a similar exercise program in those experiencing PCS may provide valuable information.

KEY WORDS: Aerobic, balance, exercise, cognition, concussion

INTRODUCTION: Concussion is an injury defined as a complex pathophysiological process affecting the brain induced by forces causing linear, rotational, and angular movement, or a combination thereof (McCrory et al., 2013). The 2013 Canadian Community Health Survey reported that 94,000 concussions affected Canadians (58,000 males and 36,000 females) aged 12 years and older between 2009 and 2010 (Statistics Canada, 2013). Most individuals who sustain a concussion recover in less than two weeks, but 10-20% experience lingering symptoms of concussion beyond two weeks; these enduring and persistent symptoms beyond two weeks are diagnosed and labelled as post-concussion syndrome (PCS). There is no specific method of rehabilitating PCS and rest is generally the prescribed treatment and standard of care (Moser, Glatts, & Schatz, 2012). Presently, however, there is limited evidence that extended rest, beyond 7-10 days, will benefit those with PCS positively. Generally, subjects are instructed to engage in cognitive and physical rest which includes no school or work, driving, screen time, chores, physical exercise, or activity that results in perspiration (Moser et al., 2012). An extended period of cognitive and physical rest beyond the first 7-10 days may result in improvement in some cases or, conversely, increased physical, psychological, and/or social stress in the form of physical deconditioning, hyperawareness of the symptoms, or loss of productivity at work or school (Kleffelgaard, Roe, Soberg, & Bergland, 2012). Early evidence now suggests the benefits of an active exercise program for those experiencing concussion related symptoms (Koo et al., 2013; Leddy et al., 2013). Therefore, the purpose of this pilot study was to investigate the effects of a supervised and structured four-week aerobic exercise and balance exercise program on resting heart rate, blood pressure, cognitive function, and balance in a normal, healthy population.

METHODS: Ethical approval was obtained prior to the commencement of this study. Ten healthy participants (see Table 1) absent of any debilitating injury or condition that would prevent them from exercising were recruited into the study. Participants who were between 18 and 30 years of age, and were regularly physically active for 150 minutes or more on a weekly basis prior to entering the study were included. Participants completed an initial assessment, four-week exercise program, and a final post-exercise assessment. The initial assessment began with measurement of resting heart rate and resting blood pressure. Next, participants completed a cognitive assessment using the computerized Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery. The ImPACT battery is widely used to

Table 1. Participant Characteristics

Age (years)	M=22.90, SD=2.28
Height (cm)	M=171.20, SD=6.91
Weight (kg)	M=74.94, SD=12.29
Gender	7 males; 3 females

assess cognitive function following concussion in both research and clinical settings. For this study the ImPACT assessed verbal memory, visual memory, reaction time, and visual motor speed of the participants. Lastly, participants performed the Balance Error Scoring System (BESS) protocol on an AMTI force platform. Participants stood in a double leg stance position with the feet touching (side by side), hands on his/her iliac crests with their eyes closed; single leg stance position standing on the non-dominant leg with hands on his/her iliac crests and their eyes closed; and tandem stance 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 (Figure 1).

Figure 1. A. Double leg stance; **B.** Single leg stance; and **C.** Tandem stance performed during BESS protocol and exercise program.

The BESS was completed on a force platform and values of displacement in centre of pressure (COP) during each of the six trials were recorded. Displacement in COP was assessed by measuring both the average velocity of COP, in addition to the area of COP throughout the duration of BESS trials. After completing the initial assessment measures, all participants then attended 12 exercise sessions over a four-week period (three times per week); each session required approximately 40-60 minutes. 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 5 minutes. Participants then completed three sets of balance exercises in double leg, single leg, and tandem stances on both legs as previously described. Exercises for all participants were progressively increased in intensity over the course of the four weeks following a structured exercise progression template. Incremental progressions in intensity and duration of aerobic exercise and balance retraining were completed on a weekly basis. The duration, surface, and whether eyes were open or closed was also progressively modified to increase the challenge of balance exercises. After completing 12 exercise sessions, participants were re-examined following the same protocol described for the initial assessment. Data analysis was completed using IBM SPSS 20 to evaluate any change that occurred following the exercise program. Changes observed in dependent variables were assessed for statistical significance using Paired Samples T-Tests, with an alpha level of .05.

RESULTS: There were no significant differences in resting heart rate, systolic blood pressure, or diastolic blood pressure. Additionally, there were no significant changes in cognitive functions of verbal memory, visual memory, or visual motor speed with ImPACT testing. Notably, there was a statistically significant increase in reaction time (t(9)=-2.472, p=.035) post-exercise while performing cognitive tasks (pre-exercise M=.528, SD=.054s; post-exercise M=586, SD+.089s; see Figure 1). A number of significant differences in measures of balance were observed after the exercise program (see Figure 2). The BESS total score was significantly reduced (t(9)=5.763, p=.0001) post-exercise (pre-exercise errors M=10.6, SD=3.61; post-exercise errors M=4.1, SD+1.45). Analysis also revealed significant reductions in average velocity of COP (cm/s) during double foam stance (t(9)=4.687, p=.001; pre-exercise M=1.76, SD=.47; post-exercise M=1.23, SD=.18), single leg firm stance (t(9)= 3.086, p=.013; pre-exercise M=2.3, SD=.59; post-exercise M=1.77, SD=.34), single leg foam stance (t(9)=2.649, p=.027; pre-exercise M=4.73, SD=2.78; post-exercise M=2.91, SD=.98), and tandem firm stance (t(9)= 2.359, p=.043; pre-exercise M=1.78, SD=.58; post-exercise M=1.29, SD=.19) when performing the BESS protocol. Furthermore, statistically significant reductions in area of COP (cm^2) were observed during double foam stance (t(9)=4.469, p=.002; pre-exercise M=2.04, SD=.84; post-exercise M=1.15, SD=.46), single leg firm stance (t(9)=2.281, p=.049; pre-exercise M=2.07, SD=1.63; post-exercise M=1.38, SD=1), single leg foam stance (t(9)= 3.005, p=.015; pre-exercise M=9.32, SD=5.84; post-exercise M=4, SD=2.54), and tandem firm stance (t(9)=2.487, p=.035; pre-exercise M=1.71, SD=1.41; post-exercise M=.60, SD=.26) during the BESS protocol.

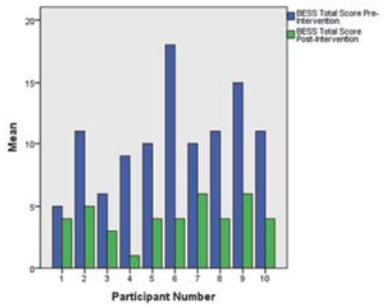

Figure 1: Bess total scores (number of errors) pre- and post-exercise.

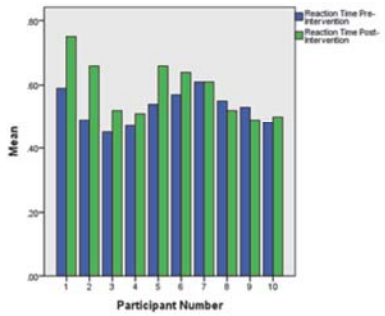

Figure 2: Reaction time (seconds) pre- and post-exercise.

DISCUSSION: The purpose of this pilot study was to investigate the effects of a supervised and structured four-week aerobic and balance exercise program on resting heart rate, blood pressure, cognitive function, and balance in a normal, healthy population as a preliminary study for proof of concept to be later applied to a PCS population. While minimal to modest changes were hypothesized to be observed following the exercise program in this population, several distinct results were found. Significant reductions in the BESS total scores were observed. The BESS is a widely used clinical tool for the assessment of static balance following concussion, with established normative data collected from healthy, post-secondary aged individuals. Based on the improvements observed in BESS scores in healthy individuals in response to the exercise program it seems plausible that concussed individuals experiencing balance impairments may also benefit from a similar exercise program. Significant reductions in average velocity of COP and area of COP were also observed in four of six BESS trial positions. These findings in a healthy population provide evidence that further exploration of an exercise program similar to the one administered may be applied in a subsequent study and possibly aid in

improving balance deficits in patients with PCS. Since the exercise program elicited improvements in individuals with no underlying conditions of impaired balance, it seems plausible, that similar or greater improvements may be observed in a population with PCS. Conversely, no significant changes in resting heart rate, systolic, or diastolic blood pressure were found in this healthy sample. If an individual experiencing PCS has been prescribed a period of cognitive and physical rest for weeks or months, however, the resulting physical deconditioning may impair regulation of heart rate and blood pressure and this has been hypothesized as a reason individuals with PCS continue to experience persistent signs and symptoms. Therefore, this may result in different findings in the future application of this exercise program to a symptomatic population. Similarly, no significant differences were observed in verbal and visual memory, or visual motor speed, however, reaction time significantly increased when completing the ImPACT test battery. The increased reaction time may be attributed to a learning effect and the fact that participants consciously took more time to react to the stimuli in order to avoid incorrect responses. However, it is notable that although reaction time increased, the delay in reaction time was very small (.06 seconds). Even though participants were slower to respond to the tasks, responses and scores were no better than those measured pre-exercise. Therefore, a progressive exercise program may foster improvements in impaired integration of sensory information by challenging the neuromuscular system to adapt to new demands and by extension result in greater ability to maintain balance. Future studies should investigate the impact of a supervised aerobic and balance exercise based program for individuals with PCS, as long as exercise is administered below symptom threshold.

CONCLUSION: The current pilot study revealed that a supervised four-week aerobic and balance exercise program administered to a sample of healthy, physically active individuals resulted in improvements in static balance, average velocity, and area of COP. The information and results gained from this study may be practically applied to assist in the future development of an aerobic and balance exercise program for individuals experiencing PCS. Therefore, follow up studies should explore the application of exercise in a PCS population.

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