EFFECTS OF WALKING VERSUS COMPLETING A NEUROCOGNITIVE TASK ON BREATHING PHYSIOLOGY IN HEALTHY INDIVIDUALS – A PILOT STUDY

Patrick Siedlecki[1], Paolo Sanzo[1], Carlos Zerpa[1], and Ian Newhouse[1]

School of Kinesiology, Lakehead University, Thunder Bay, Canada[1]

The purpose of this study was to examine the effects of walking at different speeds and elevation versus completing a neurocognitive task on end-tidal carbon dioxide ($ETCO_2$) and respiratory rate (RR) in a healthy population. Eleven healthy participants completed the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) battery and walked on a treadmill under four conditions (slow versus fast walking and uphill versus downhill). A CapnoTrainer was used to measure $ETCO_2$ and RR during the tasks. Statistically significant increases were observed in RR ($t(10)=5.52$, $p=.001$) during the ImPACT; $ETCO_2$ ($F(4,7)=14.18$, $p=.002$) during all four walking trials; and RR ($F(4,7)=7.02$, $p=.01$) during the last three walking trials. Therefore, future investigations using a similar methodology and protocol are warranted in a concussed population.

KEY WORDS: Respiratory rate, concussion, end-tibial carbon dioxide

INTRODUCTION: Affecting over 94,000 Canadians annually, concussion can be characterized as a temporary disturbance of brain function that is the result of a linear and/or rotational force being transmitted to the head causing a complex pathophysiological process to occur (Statistics Canada, 2011). Furthermore, approximately 10-20% of these individuals will go on to develop post-concussion syndrome (PCS; McCrory et al., 2013).

Post-concussion syndrome occurs when concussion symptoms persist beyond the acute concussion phase; 10 days after the concussive blow (McCrory et al., 2013). Individuals who have sustained a concussion may experience a wide-range of symptoms. Four core symptom dimensions have been identified to be associated with concussion (Pardini et al., 2004). These were described as emotional symptoms (i.e., sadness, nervousness, and irritability), cognitive symptoms (i.e., attention problems and fatigue), somatic symptoms (i.e., visual problems, dizziness, headaches, and nausea), and sleep disturbances (i.e., insomnia). Patients with PCS may have any combination of these symptoms and have been found to cause cognitive and physical deficits (McCrory et al., 2013). However, due to the variability of symptomatology, it is unclear which treatment is beneficial. Therefore, treatments must be selected based on subjective clinical complaints and objective observations. Of these signs and symptoms, abnormal breathing physiology and dysfunctional breathing patterns have not been thoroughly researched in the concussed population.

Currently, only one study has examined breathing patterns in PCS patients. Clausen et al. (2016) found that female athletes with PCS had elevated end-tidal carbon dioxide ($ETCO_2$) levels during submaximal aerobic exercise compared to healthy participants. End-tidal carbon dioxide is the peak amount of carbon dioxide (CO_2) at the end of an exhaled breathe and represents partial pressure CO_2 (PCO_2; McLaughlin, 2014). The elevated $ETCO_2$ levels may have also contributed to aggravated symptoms and inhibited physical functioning (i.e., reduced maximum intensity and duration of workload). However, there is no current literature that has explored the effects that other tasks (i.e., rest versus the performance of a physical or cognitive task) have on breathing.

Abnormal breathing physiology and dysfunctional breathing pattern can play a pivotal role in negatively affecting an individual's life. In 2007, the Public Health Agency of Canada reported that over 11% of the country's population has a chronic respiratory disorder (i.e., asthma, lung cancer, or cystic fibrosis). Similar global incidence rates have also been reported by the World Health Organization (World Health Organization, n.d.). These disorders may affect the quality of breathing and may result in altered PCO_2. Thomson et al. (1997) stated that if PCO_2 is just 1 mmHg below the average range, 35-40 mmHg (McLaughlin, 2014), blood flow to the brain may be reduced by up to 20% and may further

negatively affect other physical or cognitive processes. Therefore, measuring these variables may assist in diagnosing or monitoring the disorder. With the vast amount of individuals who have a respiratory disorder, the addition of also sustaining a concussion may hinder recovery time and contribute to persistent concussion-like symptoms.
Therefore, the purpose of this study was to investigate the effects of completing a neurocognitive test using the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) battery versus a physical task such as walking on a treadmill under different walking conditions (slow versus fast and uphill versus downhill) on $ETCO_2$ and respiratory rate (RR) in a healthy population. This was also an exploratory study investigating the feasibility of using a similar methodology in the future within a concussed population.

METHODS: Eleven participants (7 male and 4 females; mean age 23.7 years ± 4.9; mean height 169.8 cm ± 5.6; mean weight 72 kg ± 11.3) participated in the study. Participants were eligible to participate if they were between the ages of 18-35 years and were excluded if they had a physical injury (i.e., lower limb fracture, muscle strain, or ligament sprain), a neurological disorder (i.e., stroke, concussion, or cerebral palsy), or a respiratory disease (i.e., asthma or influenza) that may have affected their ability to safely complete a walking or cognitive task.
Ethical approval from the academic institution was obtained prior to participant recruitment. Once written consent was obtained, general demographic information on the participant was recorded using the demographic interview (i.e., name, year of birth, age, history of neurological or respiratory disorders). The participant's weight (kg) and height (cm) was also measured and recorded during this process.
Following the demographic interview, a respiratory questionnaire was completed. The Nijmegen Questionnaire (NQ) was used to ensure the participant's breathing fell within the questionnaire's normal breathing pattern range (total score ranging from 0-23). After completing the NQ, participants were fitted with a nasal cannula which was connected to a capnography breath analyser, CapnoTrainer©. The CapnoTrainer© collected $ETCO_2$ and RR data throughout the entire test session. Participants were also instructed at this time to breathe through their nose and refrain from talking during the tasks.
During the neurocognitive task, baseline $ETCO_2$ (mmHg) and RR (breaths/min) were collected for 40 seconds (only the last 20 seconds of the baseline data was used in the statistical analysis) during quiet breathing while resting in a sitting position. Next, the ImPACT was completed on a laptop computer with a wireless mouse to assess the participant's neurocognitive ability and to simulate a neurocognitive task. The participant was instructed to raise his/her hand when beginning a new module to track progression through the test. After completing the ImPACT, a two minute recovery period occurred to allow for the breathing pattern to return to baseline values.
During the physical task, baseline breathing data was also collected for 40 seconds during quiet breathing while resting in a standing up-right position. There were four different walking trials completed that varied on walking speed and treadmill elevation. Each walking trial lasted three minutes (only the last 60 seconds of the data was used in the statistical analysis) and was followed by a two minute rest period. During the rest periods, the treadmill came to a complete stop and participants rested on the treadmill in a standing position. The first three walking trials consisted of walking at a slow self-selected speed between 3-4 mph with the treadmill elevated to a 0% (T1), 5% (T2), or -5% grade (T3). The fourth trial was a fast self-selected speed between 4.5-5.5 mph with the treadmill set to a 0% grade (T4). Participants completed the session in a single, 45-60 minute period.
Descriptive statistics were used to compare the mean and standard deviations for individual $ETCO_2$, and RR data that was collected through the CapnoTrainer© and was transferred into Microsoft's Excel computerized program for initial analysis. Data analysis was then completed using IBM SPSS 24 for statistical analysis. Statistical significance was determined with an alpha level of $p<.05$. Two dependent samples t-tests were run to determine if significant differences existed between pre- and post-neurocognitive task on $ETCO_2$ or RR. Additionally, one-way repeated measures ANOVAs were run to determine if

significant differences existed between the baseline and the four walking trials on $ETCO_2$ and RR. Bonferroni post-hoc analyses were performed to determine which task(s) were different.

RESULTS: There was no statistically significant difference in $ETCO_2$ values between the sitting resting $ETCO_2$ (*M*=35.75±3.34) and during the ImPACT battery (*M*=35.20±3.48), *t*(10)=0.67, *p*=.52 (see Figure 1a). There was a significant increase between baseline resting RR (*M*=12.00±3.35) and during the ImPACT battery (*M*=16.88±2.84), *t*(10)=5.52, *p*=.001, *d*=1.66) with RR during the neurocognitive task (see Figure 1b). A one-way repeated measures ANOVA revealed a statically significant difference between tasks (*F*(4,7)=14.18, *p*=.002, n^2=.89). A Bonferroni post-hoc analysis revealed a significant increase between standing baseline $ETCO_2$ (*M*=32.32±2.92) and $ETCO_2$ in all walking trials; T1 (*M*=39.29±3.63, *p*=.001), T2 (*M*=41.40±5.25, *p*=.001), T3 (*M*=37.00±2.37, *p*=.001), and T4 (*M*=41.87±4.5, *p*=.001; see Figure 1c). A one-way repeated measures ANOVA revealed a statistically significant difference between standing baseline RR and the four walking conditions (*F*(4,7)=7.02, *p*=.01, n^2=.80). A Bonferroni post-hoc analysis revealed that there was a significant increase between standing baseline RR (*M*=14.88±4.16) and the RR in the last three walking trials; T2 (*M*=19.03±5.09, *p*=.004), T3 (*M*=19.20±4.19, *p*=.001), and T4 (*M*=21.36±5.79, *p*=.001). However, there was not a significant difference in T1 (*M*=16.97±4.48, *p*=.058; see Figure 1d).

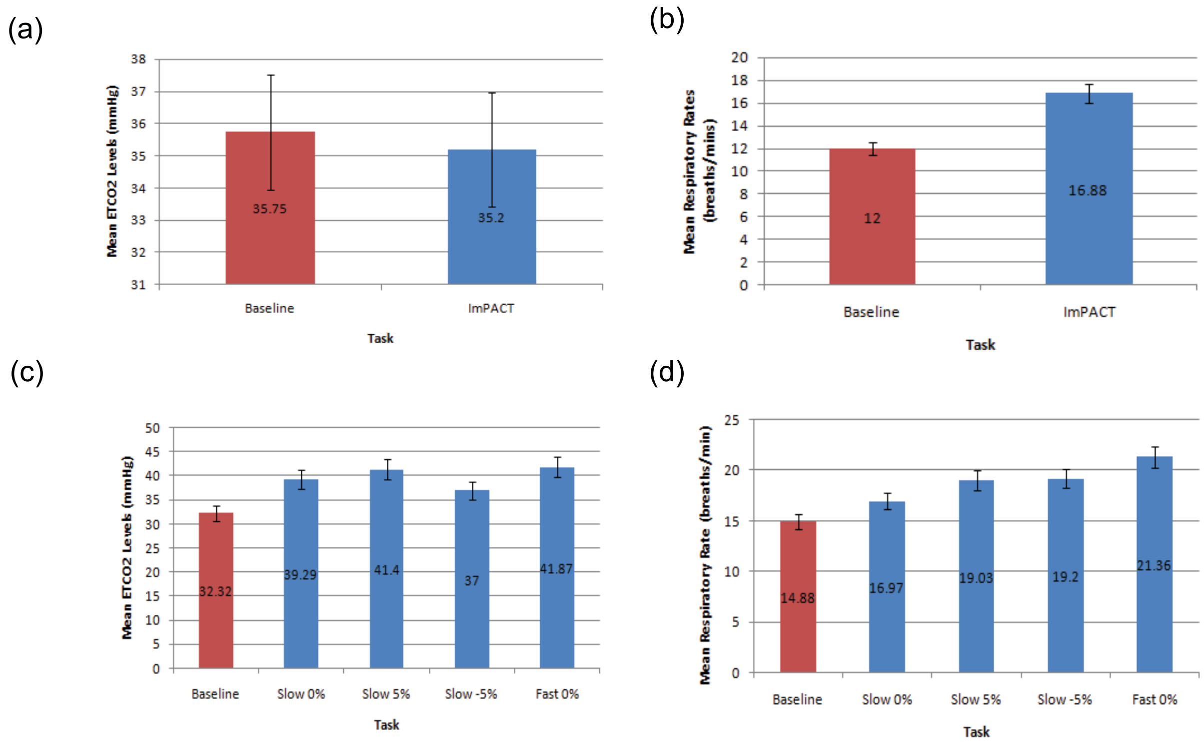

Figure 1. Changes in mean data. (a) $ETCO_2$ (mmHg) levels measured at baseline versus during the completion of the ImPACT test battery; (b) RR (breaths/minute) measured at baseline versus during the completion of the ImPACT test battery; (c) $ETCO_2$ (mmHg) levels measured during baseline versus different walking conditions; (d) RR (breaths/minute) measured at baseline versus different walking conditions.

DISCUSSION: The results showed that completing neurocognitive tasks (ImPACT testing battery) did not significantly decrease $ETCO_2$ levels compared to baseline resting values. This finding does not correspond with past literature because $ETCO_2$ decreases with the completion of cognitive tasks due to cognitive loading on the respiratory system (Grassmann et al., 2016). Despite participants scoring normal NQ and ImPACT scores, the lack of change in $ETCO_2$ may have occurred because participants were familiar with the test and

did not consider the test challenging. Completing the ImPACT was also found to significantly increase RR. Grassmann et al. (2016) reported that RR increased when exposed to a cognitive stimuli and the change is proportional to the perceived challenge of the task. Similar, a significant increase between $ETCO_2$ values measured at rest in a standing position and during different walking conditions was found. This result is supported by previous findings that reported $ETCO_2$ increases with physical exertion (Clausen et al., 2016). Bennett and Fordcye (1993) found that PCO_2 levels were close to or at resting levels during mild and moderate intensity aerobic exercise. In addition, PCO_2 increased slightly as exercise intensity increased up to 75% of an individual's maximum workload capacity and decreased once the lactate threshold was passed (Fluck et al., 2014). The physical intensity of the walking trials was considered mild to moderate; therefore, the results are similar to previous literature. Lastly, a significant increase was found in RR between resting in a standing position and trials T2, T3, and T4. Unlike $ETCO_2$, RR progressively increased with different walking trials. This can be explained by the positive relationship RR has with the intensity of physical exercise. During lower exercise intensities, RR steadily increases at a linear rate before rapidly increasing once the lactate threshold is reached (Bennett & Fordcye, 1993).
This study revealed that a similar protocol should be explored looking at breathing and gait changes in a neurologically impaired and concussed population under different walking and/or running conditions.

CONCLUSION: This study showed that walking under different conditions (speed and elevation) versus the completion of neurocognitive tasks may result in breathing changes in healthy participants. However, these changes did not impact performance. Future investigations examining respiratory changes when completing different physical or sport tasks or walking/running conditions within a concussed population is warranted.

REFERENCES:

Bennett, F. M., & Fordcye, W. E. (1993). Regulation of PaCO2 during rest and exercise: A modelling study. *Annals of Biomedical Engineering, 21*, 545-555.

Clausen, M., Pendergast, D. R., Willer, B., & Leddy, J. (2016). Cerebral blood flow during treadmill exercise is a marker of physiological postconcussion syndrome in female athletes. *Journal of Head Trauma Rehabilitation, 31*, 215-224.

Fluck, D., Braz, I. D., Keiser, S., Huppin, F., Haider, T., Hilty, M. Lundby, C. (2014). Age, aerobic fitness, and cerebral perfusion during exercise: role of carbon dioxide. *American Journal of Physiology- Heart and Circulatory Physiology, 307*, 515-523.

Grassmann, M., Vlemincx, E., von Leupoldt, A., Mittelstadt, J. M., & Van den Bergh, O. (2016). Respiratory changes in response to cognitive load: A systematic review. *Neural Plasticity.*

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvorak, J., Echemendia, R. J. Turner, M. (2013). Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, November 2012. *British Journal of Sports Medicine, 47*, 250-258.

McLaughlin, L. (2014). Capnography assessment. In L. Chaitow, D., Bradley, & C. Gilbert (Eds.). *Recognizing and treating breathing disorders: A multidisciplinary approach*. Toronto, ON: Elsevier Ltd.

Pardini, D., Stump, J., Lovell, M., Collins, M., Moritz, K., & Fu, F. (2004). The post-concussion symptom scale (PCSS): A factor analysis [Abstract]. *British Journal of Sports Medicine, 38*, 654-664. Abstract retrieved from Second International Symposium on Concussion in Sport (Accession No. 032)

Public Health Agency of Canada. (2007). *Life and breath: Respiratory disease in Canada*. Retrieved from http://phac.gc.ca/publicat/2007/ibrdc-vsmrc/index-eng.php

Statistics Canada. (2011). Injuries in Canada: Insights from the Canadian community health survey (Report No. 82-624-X). Retrieved from Statistics Canada website: http://statcan.gc.ca

World Health Organization. (n.d.). *Chronic respiratory diseases*. Retrieved from http://www.who.int/gard/publications/chronicrespiraotrydieases.pdf