CONCUSSION HISTORY DOES NOT INFLUENCE CARDIOVASCULAR STRESS REACTIVITY



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A Senior Comprehensive Project
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Abstract

The present study aimed to investigate differences in stress reactivity between those with a concussion history and those without. Previous research has shown that anxiety and stress may lead to negatively impact quality of life postconcussion. It was hypothesized that those with a history of concussion would have more stress reactivity than those with no history. Participants (N=21) were undergraduate students of Allegheny College. The participants completed a standards three-phase stress reactivity task. There was no evidence of significant differences in stress reactivity between those with a concussion history and those with no history of concussion. These findings suggest that the increased anxiety in situations is a perception and is not translated into changes in autonomic responses to stress.

Keywords: concussion history, postconcussion, stress reactivity, anxiety

The Effect of Concussion History on Stress Reactivity

Current Definition of Concussion

A concussion is a traumatically induced alteration in mental status, not necessarily resulting in the loss of consciousness and most often result from sudden acceleration and/or deceleration of the freely moving head (Collins et al., 1999; Guskiewicz et al., 2003). The prevalence of concussion in athletes differs between sports, with around 300,000 concussions alone annually and football having the highest rates of concussion (Guskiewicz et al., 2003).

There are a variety of symptoms that can be present in a concussion. The most common symptoms include nausea, headache, fatigue, sensitivity to light and noise, sleep disturbances, and general confusion (Master, Balcer, & Collins, 2014).

Concussions constitute a major health problem due to the large number of people who experience this injury the potentially serious long-term consequences. The potential for continuous postconcussive symptoms and impairments, such as early onset of dementia and anxiety, and a decrease in life satisfaction, can prevent returning to premorbid functioning (Stalnacke, 2007). Postconcussive problems can affect anyone, including young adults who are in the process of completing their education and establishing future careers (Stalnacke, 2007).

Concussion on the Cellular Level

On the cellular level of concussion, there is a neurometabolic cascade that occurs within the brain. After a biomechanical injury to the brain, there is an abrupt release of neurotransmitters and irregular ionic fluxes. Further neuronal depolarization occurs when excitatory transmitters, such as glutamate, bind to N-methyl-D-aspartate (NMDA) receptor, with an efflux of potassium and influx of calcium. These shifts in ion levels lead to acute changes in cellular physiology. Therefore, in an effort to restore neuronal membrane potential, the sodium-

potassium pump works overtime. This pump requires increased amounts of adenosine triphosphate (ATP) that triggers a drastic jump in glucose metabolism, creating a "hypermetabolism." This hypermetabolism occurs when there is diminished cerebral blood flow and the demand triggers an energy crisis.

The resulting crisis is a mechanism for postconcussive vulnerability, which makes the brain less able to respond adequate to second-impact syndrome that potentially leads to longer lasting deficits. After the initial period of accelerated glucose utilization, the injured brain goes into a period of depressed metabolism. The energy crisis may be worsen by persistent increases in calcium, which may impair mitochondrial oxidative metabolism. The uncontrolled calcium accumulation can directly activate pathways leading to cell death and intra-axonal calcium flux has been shown to disrupt neurofilaments and microtubules, impairing post-injury neural connectivity (Giza & Hovda, 2001; Shaw, 2002; DeLellis, Kane, & Katz, 2009; Chamard et al., 2013). There are also several other components of postconcussion pathophysiology which may include the generation of lactic acid, decreased intracellular magnesium, free radical production, inflammatory responses, altered neurotransmission, and glial cell changes.

Long-Term Deficits of Concussion: Anxiety

Most people who suffer from concussion experience symptom resolution within ten days, but those that do not may result in long-term cognitive deficits and mental illnesses, such as anxiety and depression. Anxiety and depression are the most common mental illnesses when suffering from a concussion and even after one has returned to premorbid cognitive function, these illnesses may not resolve (Schoednhuber & Gentilini, 1988). Postconcussive anxiety or stress were grouped together and defined as 'somatic preoccupation' which negatively impact recovery from concussion and may lead to longer lasting implications (Iverson, Zasler, & Lange,

2007; Edmed & Sullivan, 2012). These ‘somatic preoccupations’ may last anywhere from a few weeks to five years post-injury and can result in limitations to everyday life, including work and daily activities, that were not anxiety-inducing activities before concussion (Masson, Maurette, & Salmi, 1996; Mazaux, Masson, & Levin, 1997; McCauley et al., 2001). Previous research has shown that those suffering from postconcussive anxiety also report heightened irritability and concentration deficits when compared to those without a concussion history (Bryant & Harvey, 1999).

In general, those who suffer from postconcussive anxiety are also more functionally disabled, perceive their cognitive impairment as more severe, and experience increased stress reactivity if they are not able to cope with environmental demands leading to poor psychological adjustments (Bohnen et al., 1992; Fann et al., 1995; Ponsford et al., 2000; Stalnacke, 2007). Overall, the findings concluded that those with a history of concussion are more likely to perceive situations as more stressful, based on self-report, when compared to those with no history of concussion.

Connection of the Present Study to Previous Literature

The studies measured self-reported, rather than an experiment within a laboratory (Masson, Maurette, & Salmi, 1996; Mazaux, Masson, & Levin, 1997; McCauley et al., 2001). Many studies have found that those who suffer from postconcussive anxiety report that they experience greater stress reactivity and perceive themselves as cognitively impaired, but little has been done to investigate if autonomic responses parallel perceptions (Bohnen et al., 1992; Fann et al., 1995; Ponsford et al., 2000; Stalnacke, 2007). In order to examine whether history of concussion is associated with more stress in similar situations as those who do not have a history

of concussion, the present study examined autonomic responses to a stressful task in a controlled setting.

The Present Study

The present study investigates the relationship between concussion history and stress reactivity to examine the potential long-term deficits of concussion, specifically increases in anxiety. It is hypothesized that a history of concussion will show larger stress reactivity indicating that the stress task used elicited a greater response in those participants who indicated a history of concussion.

Method

Participants

The participants (N=21, 62% female) from Allegheny College. Participants were between 18 and 22 years of age and were chosen based upon their participation on Sona Experiment Management System. Volunteers received one credit to apply to the class of their choice. Each of the participants completed the same testing procedure.

Materials

A Dinamap machine and attached blood pressure monitor and cuff (1846SX Vital Signs Monitor NIBP, Critikon, FL) was used to record heart rate and blood pressure during the laboratory tasks. The cord, which connected the Dinamap and cuff, extended from the control room to the testing room via a constructed hole in the wall.

The Paced Auditory Serial Addition Task (PASAT; Gronwall, 1977; Ring et al. 1999) was used as the test which would elicit psychological stress (Appendix B). Following the task, the PASAT Questionnaire was administered (Ring, Burns, & Carroll, 2002; Phillips, Der & Carroll, 2009). The questionnaire consisted of scales from one to seven and had a variety of

questions, such as how much control the participant perceived to have over the task and how stressed they felt during the task (Appendix C).

Procedure

The participants read and signed an informed consent document (Appendix A) and were led to the testing room and instructed to sit in the chair, which faced away from the door. Then, it was explained that the participant will experience three periods: a nine minute baseline period, a nine minute stress test, and a nine minute recovery baseline (Appendix B). Next, the blood pressure cuff was secured to the participant's upper left arm, and once the cuff was secure, the experimenter left the room and closed the door.

Dinamap readings were recorded in three minute intervals and were observed three times for each period. The PASAT stress task began to play through speakers in the testing room via a computer immediately following the baseline observation period. Directly following the third test period, the PASAT task was turned off and the participant began the recovery baseline. After the completion of the third recovery reading, the Dinamap was turned off and the participant was asked to complete a post-test questionnaire about stress levels before, during, and after the test period of the experiment (Appendix C). Lastly, the participant was given a debriefing form and thanked for their participation in the study (Appendix D).

Design

For this experiment, concussion history served as the independent variable and stress reactivity served as the dependent variable. The factors, concussion history or no concussion history, of the study were independent of each other and participants were categorized based on their concussion history. Those who had no history of documented concussion were classified into the no history condition while those who answered that they have sustained one or more

concussion were categorized into the concussion history group. Data analyses included repeated-measures ANOVA to ensure that there was a response elicited by the Paced Auditory Serial Addition Task as well as an independent samples t-test to test for differences between groups.

Results

A Pearson chi-square test revealed no significant difference between gender and concussion history, $\chi^2(1)=0.777$, $p=0.378$. However, there was a significant difference between varsity athletic status and concussion history, $\chi^2(1)= 6.390$, $p=0.011$ as well as age between groups t (16.636)= -0.159, $p= 0.033$.

The Paced Auditory Serial Addition Task elicited significant cardiovascular responses over time of DBP, $F(4,16)= 27.921$, $p<0.01$, SBP, $F(4,16)= 16.051$, $p<0.01$, pulse, $F(4,16)= 26.075$, $p<0.01$, and MAP, $F(4,16)= 17.871$, $p<0.01$.

There were no differences in stress reactivity between those who have a history of concussion when compared to those who do not have a history of concussion for systolic blood pressure, t(12.096)= 0.305, $p=0.766$, diastolic blood pressure, t(9.326)=-0.435, $p=0.673$, pulse, t(13.660)=0.745, p=0.469, and mean arterial pressure, t(1.423)=-0.886 as can be seen in Table 1.

Discussion

The hypothesis that history of concussion would be associated with greater stress reactivity was not confirmed. This implies that history of concussion does not lead to the interpretation of situations as more stressful and anxiety-inducing when compared to those with no history of concussion. In fact, stress reactivity was low across all four factors: diastolic blood pressure, systolic blood pressure, heart rate, and mean arterial pressure. In addition to no significance between groups related to stress reactivity, there was also no significance in post-PASAT questionnaire data. This indicates that there was no significant difference in responses to the perceptions of stress and control throughout the PASAT between groups.

There are several reasons behind these findings, which may be due to the self-fulfilling prophecy, PASAT practice effects, concussion severity, and cognitive behavioral therapy. First, there is the self-fulfilling prophecy. This idea is that if one believes something to be true, their behaviors and thoughts will mimic that belief. In connection to this study, if a participant perceives themselves as impaired, they will act in parallel to this perception. One of the components of this theory is anxiety distraction. Anxiety distraction is the belief that a challenging situation lowers self worth and failure is anticipated. Therefore, one will not try very hard in a situation that is perceived as challenging so that when failure occurs, it will be less threatening to one's self-worth (Archibald, 1974). Therefore, if those with a history of concussion perceive their cognitive impairment as more severe and that they are not able to cope with environmental demands, they will act in parallel to their perceptions and believe that the feeling of increased anxiety is a cardiovascular response, not just a perception.

Another possible explanation behind these results is that there may have been a practice effect component involved with the stress reactivity task. The PASAT is a commonly used task at Allegheny and was being used in several other studies that were being conducted at the same time as the present study. Therefore, participants may have already been familiar with the task and it may not have elicited the same cardiovascular response compared to the first time the task was administered (Beglinger et al., 2005; Tombaugh, 2006). Practice effects could equally contribute to cardiovascular responses as well as the perception of stress and control throughout the PASAT.

A past study has found that patients suffering from mild traumatic brain injuries in conjunction with postconcussion anxiety complained more of cognitive deficits, despite the lack of evidence of any significant cognitive deficits on the Mini-Mental State examination revealing

that cognitive deficits, due to concussion, were, as perceived by the patient, amplified by the anxiety (Fann et al., 1995). This demonstrates that their interpretation and analysis of the situation is just that, not a real autonomic response. Second, concussion severity may be a factor as to why there were no significant results. The average concussion lasted 5.25 weeks, which indicates that the injuries were not severe (McClincy et al., 2006). This is evidence that the severity of the participating concussions may not have been severe enough to produce long-lasting symptoms, including interpretation of seemingly normal events (Lovell et al., 2003). Lastly, although not reported in this study, cognitive behavioral therapy may be another contributing component as to why there was no significance between groups. Therapy may allow the anxiety to be understood as only a misinterpretation of the situation, rather than an autonomic response or deficit. Cognitive behavioral therapy sessions have involved education, reassurance, and cognitive restructuring to help the patient better understand the nature of recovery from concussion and misperceptions of situations (McCrory & Cantu, 2005). This type of therapy has been found to be beneficial in reducing long-lasting, persistent symptoms, such as the perception of cognitive deficits and misinterpretations of situations (Ponsford et al., 2002; Ryan & Warden, 2003). Although the present study indicates no significance and there are several reasons for it, there is a possibility of a type II error in which there may be a significant difference in stress reactivity between groups.

There were several limitations of the present study. First, there is a possibility that those who have no documented history of concussion may have one, or more, undiagnosed concussions. Undiagnosed concussions may pass unknowingly or be purposeful; such as if one was an athlete and was not willing to seek evaluation as an important game was approaching (Meehan et al., 2013). Next, an additional limitation may be the demographics questionnaire

portion of the study. The demographics did not inquire about therapy or other types of treatment, nor did consider the possibility of a participant already partaking in a different study that also utilized the PASAT. Another limitation of this study is the small sample size. A larger sample size would be a better representation of the proposed investigation.

Given the results, more studies related to this topic should be conducted. Future studies should study several different aspects, which were not taken into consideration during this study. First, future studies should intend to have more participants to increase sample size. Increasing sample size will help minimize the possibility of a type II error. Another aspect that should be considered is requesting more demographic information, such as if one participated in cognitive behavioral therapy throughout the duration of their injury. More extensive demographic questioning will help when analyzing cardiovascular responses. Lastly, a future study could focus on just one group of individuals, such as athletes or non-athletes. This would help to eliminate varying starting baselines and cardiovascular reactions. The future study could be further specified to one sport to eliminate more cardiovascular variability, such as that might be seen between a cross country runner and golf team member.

The previous research has shown that the perception alone can lead to major life implications such as not being able to cope with environmental demands which lead to poor psychological adjustments (Fann et al., 1995; Stalnacke, 2007). These adjustments can result in limitations to everyday life, including work and daily activities, which were not anxiety-inducing before concussion (Masson, Maurette, & Salmi, 1996; Mazaux, Masson, & Levin, 1997; McCauley et al., 2001). Concussions affect more than 300,000 people per year, and with the field still developing, there is still much to be researched regarding the postconcussion period (Guskiewicz et al., 2003). Overall, the present study concluded that there was no significant

difference in stress reactivity between participants with a history of concussion compared to those with no history of concussion. This could indicate that there is no change in cardiovascular reactions to different or stressful situations after suffering a concussion, but rather the perception that they are cognitively disabled and believe themselves to be anxious. This implies that those who may classify themselves as having anxiety may be misdiagnosed. Anxiety is an expensive and time-consuming mental illness, which could possibly require both therapeutic and pharmacological treatment. Said illness could also lead to other life complications such as difficulties at work, strained relationships within family life, and connotations of reduced self-worth. More investigations should be conducted regarding stress reactivity in relation to anxiety to determine whether cardiovascular responses are significantly different between those who have a concussion history compared to those without. These investigations will help determine if those who have a positive history of concussion respond differently to the same situations because they perceive these situations as more stressful. In addition, there is the possibility that there is no difference between those with a concussion history and those without in relation to cardiovascular responses of the same situation. In fact, it may just be all in their head, shown by a change in situational perception, as there was no evidence of significant differences in cardiovascular reactivity between those with a history of concussion and those with no history of concussion.

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Table 1. *Average Background, Concussion History, and Cardiovascular Responses.*

Information	No History N=13 Mean(SD)	History N=8 Mean(SD)	*p*
Age	20.31 (1.377)	20.38 (0.518)	0.033
Gender	43.00	19.00	0.267
Athletic Status	19.00	52.00	0.011
Concussion History			
Number of Concussions	0.00 (0.00)	1.75 (1.49)	0.001
Most Recent Concussion	0.00 (0.00)	5.00 (0.926)	0.001
Duration (in weeks)	0.00 (0.00)	5.25 (6.71)	0.001
Baseline			
DBP	69.59 (9.88)	69.96 (5.66)	0.915
SBP	119.46 (14.53)	123.29(13.15)	0.542
Pulse	70.23 (14.65)	71.71(13.00)	0.813
MAP	87.64 (11.41)	88.58(5.16)	0.799
Stress Test			
DBP	73.62 (10.74)	74.83 (8.46)	0.776
SBP	127.80 (18.25)	130.38 (13.33)	0.713
Pulse	78.74 (16.71)	78.00 (14.83)	0.917
MAP	93.13 (13.08)	94.50 (9.63)	0.786
Recovery Baseline			
DBP	67.21 (8.88)	67.75 (5.22)	0.861
SBP	115.46 (14.70)	116.25 (11.09)	0.891
Pulse	71.21 (15.21)	69.42 (10.87)	0.757
MAP	84.67 (10.87)	87.17 (5.13)	0.486
Reactivity			
DBP	4.03 (2.64)	4.88 (5.12)	0.673
SBP	8.33 (7.65)	7.08 (9.94)	0.766
Pulse	8.51 (6.17)	6.29 (6.90)	0.469
MAP	5.49 (5.16)	5.92 (7.23)	0.886
Post-PASAT Questionnaire			
Perceived Stress	4.15 (1.21)	4.00 (1.07)	0.776
Perceived Control	4.38 (1.04)	4.00 (1.07)	0.919

Notes:

Gender is expressed as percent female, Athletic Status is expressed as percent current varsity athlete, DBP = Diastolic blood pressure measured in mmHg, SBP = Systolic blood pressure measured in mmHg, Pulse = heart rate measured in beats per minute, MAP = mean arterial pressure measured in mmHg.

Appendices

Appendix A.

INFORMED CONSENT

This project is for research and will examine the relationship between the history and recency of concussion and patterns of responses to a cognitive task in the lab. The entire task will take roughly 35 minutes. The rationale for this study is to further research the relationships between concussion and response patterns, as concussion is a new topic within medical field. Participation in this study is voluntary. You can choose to withdraw from this study at any time, without consequences.

The lab task will consist of three separate sections: a baseline period, a cognitive task period, and a recovery period. You will be wearing a blood pressure cuff throughout the lab task. After the task is complete, you will complete a short questionnaire related to Stress levels. There is no foreseeable risk.

There are no personal benefits for participating in this study. All information will remain confidential and will be destroyed at the termination of the study. If you have any questions regarding this study, please contact Kati Broeren at broerenk@allegheny.edu or Dr. Conklin at sconklin@allegheny.edu. If there are questions involving injury or participant rights, please contact the Institutional Review Board Chair at Ann Kleinschmidt, at akleinsc@allegheny.edu..

_____

By signing here you affirm that you are over the age of 18 and give consent to participate in the study.

Appendix B.

Gender: Male Female

Age: _____

Varsity Athlete at Allegheny College: Yes No
Sport: _____

Number of Documented Concussions: 0 1 2 3 Other: _____

Description of past concussion(s), first concussion to most recent:

_____

_____

Last concussion: _____. Length: _____

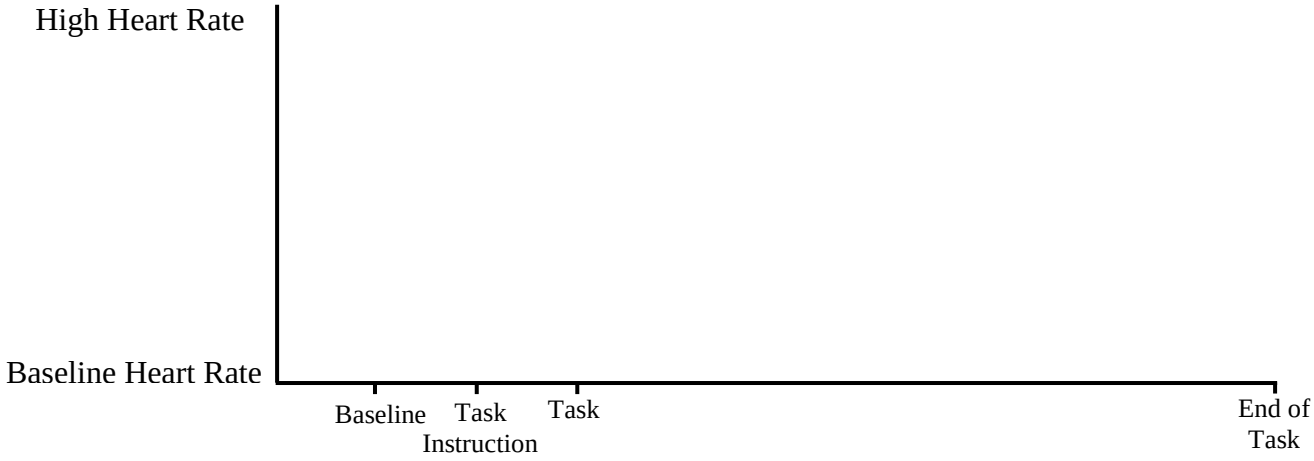
	DBP	SBP	PULSE	MAP
Rest 1				
Rest 2				
Rest 3				
Test 1				
Test 2				
Test 3				
Recovery 1				
Recovery 2				
Recovery 3				

NOTES:

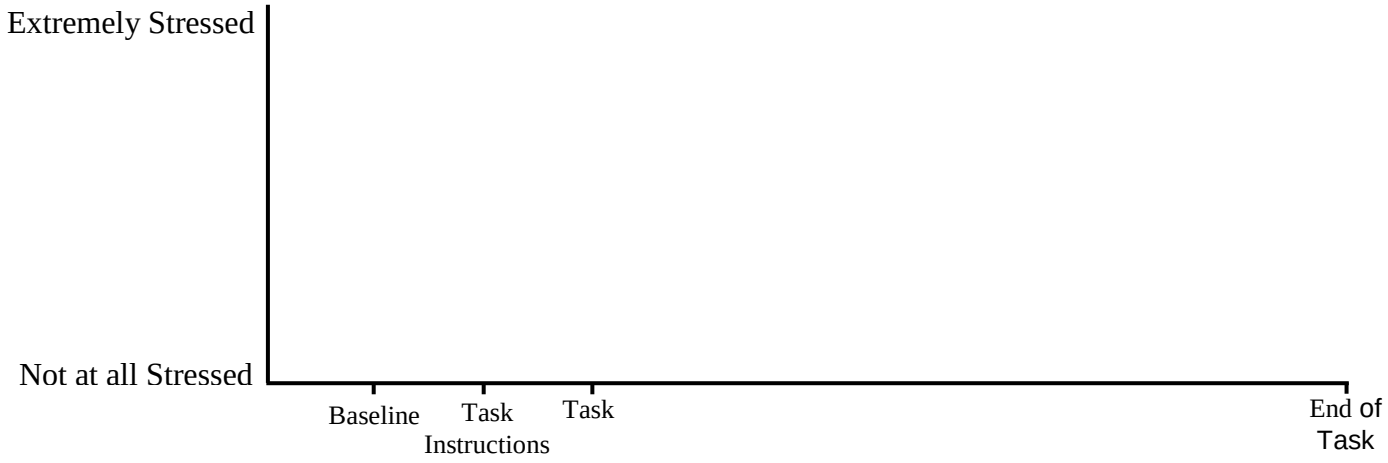
Appendix C.

Following the Stress Task

Please indicate on the graph below your perceived heart rate during each phase of the study by drawing a smooth curve that goes through each point on the x-axis



Please indicate on the graph below how stressed you felt during each phase of the study by drawing smooth curve that goes through each point on the x-axis



Please circle what applies.

How difficult did you find the task?

Not at all difficult 0 1 2 3 4 5 6 Extremely difficult

How stressful did you find the task?

Not at all stressful 0 1 2 3 4 5 6 Extremely stressful

How well do you think you performed?

Not very well 0 1 2 3 4 5 6 Very well

How engaging did you find the task?

Not at all engaging 0 1 2 3 4 5 6 Extremely engaging

How much control did you perceive you had over successfully coping with the demands of the stress task?

1 2 3 4 5 6 7

None Total

Based on the rating scale provided, to what extent do you believe you called out the correct answers during the stress task?

_____ %

0% I was very sure I couldn't do this **10% 20% 30% 40% 50%** I was unsure, I thought it could have gone either way **60% 70% 80% 90% 100%** I was very sure I could do this

Appendix D.

DEBRIEFING FORM

The project you just completed examines the relationship between history and recency of concussion and patterns of responses to a stressful task in the lab. The task that was used is the Paced Auditory Serial Addition Test and the blood pressure cuff monitored your heart rate and blood pressure variability in order to measure stress reactivity.

There are two hypotheses associated with this project. First, those with a history of concussion will have more stress reactivity in the task compared to those with no history of concussion. This means that previous concussions may lead to higher stress in cognitive tasks and possibly daily level. Second, those who have more recent history of concussion will have more stress reactivity compared to those who do not have as recent history of concussion. This means that a recent concussion may lead to higher stress in cognitive tasks and possibly daily life.

The results of this study may be provided upon your request. If you have any questions regarding this study, please contact Kati Broeren at broerenk@allegheny.edu or Dr. Conklin at sconklin@allegheny.edu. If there are questions involving injury or participant rights, please contact the Institutional Review Board Chair, Ann Kleinschmidt, at akleinsc@allegheny.edu. If you are dealing with any problems related to anxiety or other mental illnesses, please contact the counseling center at (814)-332-4368 or visit 304 Reis Hall. If you suspect that you may have a concussion, contact the Winslow Health Center Director, Sue Plunkett, at (814) 332-4355.

Fox, Z., Mihalk, J., Blackburn, J., Battaglini, C., & Guskiewicz, K. (2008). Return of postural control to baseline after anaerobic and aerobic exercise protocols. *Journal of Athletic Training*, 43(5), 456-463.

A cognitive task is being used rather, than a physical task, because there research surrounding physical tasks has reported that stress-related exercise resolves during the recovery period.

Schoenhuber, R. & Gentilini, M. (1988). Anxiety and depression after mild head injury: a case control study. *Journal of Neurology, 51*, 722-724.

Literature shows that those who sustained a concussion complain of posttraumatic symptoms, including anxiety, up to three years post injury. There is no research investing the relationship between posttraumatic symptoms and concussions after three years.