Effects of Subconcussive Head Injury on Anxiety

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Abstract

Pediatric traumatic brain injury (TBI) is the leading cause of death and disability in children and affects approximately 322,000 children under the age of nine every year. Thus, concussion rates and outcomes in adolescents and young adults have received much attention in recent years. Separately from concussions, repeated subconcussive head injury is thought to increase risk for cognitive and behavioral decline. In particular, the relationship between subconcussive head injury and mental health requires study. For example, the effects of subconcussive head injury on ability to manage anxiety remain unknown. Previous work has shown that TBI can lead to deficits in ability to manage anxiety. The present study examined the relationship between subconcussive head injury and ability to manage anxiety. Subconcussive head injury frequency and severity was measured using a subconcussive head injury scale adapted from Marchi et al. (2013). Results revealed no significant correlation between scores on the anxiety inventory and scores on the subconcussive head injury scale. Findings from this study imply that an increased number of head hits does not lead to an increase of anxiety symptoms.
Effects of Subconcussive Head Injury on Anxiety

Head Injury

Chronic traumatic encephalopathy (CTE) is a progressive degenerative disease of the brain found in people with a history of repetitive brain trauma (Spiotta, Shin, Bartsch, & Benzel, 2011). While the incidence, prevalence, and possible short and long term health consequences of concussions are well described (Wiebe, Comstock, & Nance, 2011), the effects of repeated subconcussive head injuries remain unclear. Subconcussive head injuries result from rapid cranial impact following a head hit during the deceleration of the body following initial impact which lead to long-term neurological deficits, but are not recognized as concussions (Bailes et al., 2013). Several highly publicized cases of professional athletes who died at a young age were later found to have CTE. Currently, the effects of subconcussive head injury are not being studied in the general population. A general population cohort would include participants who have occupational hazards that may include subconcussive head injuries, victims of abuse who sustained a subconcussive head hit, epileptics, and participants who may have sustained subconcussive head injuries from everyday activities.

Accumulated subconcussive head injuries have been hypothesized to contribute to the long-term consequences of contact sport participation (Broglio, & Guskiewicz, 2014; Spiotta, Shin, Bartsch, & Benzel, 2011). McCalister et al. (2012) conducted a study of head hit impact on cognitive performance using collegiate football and hockey players. They found athletes’ scores on performance tests for new learning were significantly negatively correlated with greater head impact exposure experienced over the duration of one playing season (McCalister et al., 2012). Yet, none of the athletes in
the study had a diagnosed concussion. Talavage et al. (2014) studied the effects of head hits obtained during the playing season had on neurological functioning during the playing season, and about three months after the season ended, using high school football players. They found that the football players who did not report having a prior concussion, still had significant neurological deficits and impairment to the prefrontal cortex. Studies such as this one underscore the need for further research into the short and long term consequences of subconcussive head injuries.

Symptoms of concussion can occur with no noticeable changes in pathology, and may be so subtle that even an MRI would not be able to detect them (Van Kampen et al., 2006). Concussion under diagnosis suggests that a subconcussive head injury, where an individual does not quite meet the threshold for a concussion diagnosis, is largely undetected in the general population. Moreover, as subconcussive head injuries are not a recognized medical condition (unlike concussion), tracking the effect of this condition hasn’t occurred in the health care system. However, if subconcussive head injuries lead to negative outcomes, recognizing and tracking them will be important to improve health care.

Symptoms associated with having a concussion have been shown to last years after the initial impact. Moreover, mental illnesses associated with repeated concussion include depression, anxiety, and post traumatic stress disorder (Bryan, 1999). Indeed, many of the long-term effects of concussion overlap with symptoms of anxiety disorders. The following symptoms are included in the detection of post-concussive syndrome: fatigue, headaches, dizziness, sleep disturbance, difficulty concentrating, irritability, apathy or affective disturbance, or personality changes (Barlow, 2014; Brown,
Campbell, Lehman, Grisham, & Mancill, 2001). Thus, the symptoms that overlap between post-concussive symptoms and general anxiety disorder include: difficulty concentrating, irritability, and sleep disturbances (Yuelong, 2014). The overlap of symptoms between post-concussive symptoms and anxiety may suggest that damage to brain circuits involved with mediating anxiety could lead to the development of an anxiety disorder. Willer & Leddy (2006) stated that patients with post-concussive symptoms might have semi-permanent brain injury, therefore the structural changes in the brain of the individual have not returned to the same orientation as before their brain injury (Willer & Leddy, 2006). This may suggest that further research is needed to find if post-concussive symptoms and anxiety are due to the semi-permanent damage of brain structures associated with anxiety.

Despite the possible role of subconcussive head injuries in producing long term brain and behavior abnormalities, brain injury prevention efforts in youth and adult contact sports have typically focused on minimizing only an athlete's concussive episode risk. Although the effect of repetitive subconcussive trauma in contact sports has received increased attention recently, it has yet to be fully addressed (Spiotta, Shin, Bartsch, & Benzel, 2011). With more awareness and funding being put towards head injury research, researchers are beginning to pursue studies in subconcussive head injury. For example, specific neuropsychological test are being developed to detect frequency of subconcussive head injuries. One such tool, the Head Hit Index, developed by Dr. Damir Janigro of the Cleveland Clinic measures subconcussive head injury frequency and severity.
Head Hit Index

The HHI is a self-report questionnaire comprised of items about collision events involving possible head injury experienced by an individual. The HHI self-report index measures both frequency and severity of individual head hits, and can be administered to a large group of participants at a time. The HHI asks about the number of collisions experienced by a participant, number of episodes of contact involving the head, number of significant episodes of contact to the head, and presence of acute head injury symptoms such as headache, neck pain, or nausea (Marchi et al., 2013). A composite score ranging from zero to six is calculated for each participant.

HHI score is associated with the presence of biomarkers in the blood stream of blood-brain barrier disruption (BBBD). These biomarkers are distress signal like proteins released by the blood-brain barrier after brain injury (Zongo et al., 2012). The blood brain barrier is a semi-permeable membrane that protects the brain by blocking harmful toxins from entering the brain. Even mild brain impacts are known to disrupt the integrity of the blood-brain barrier, and the protein S100B is a type of protein that is released from astrocytes in response to blood-brain barrier disruption (Marchi et al., 2013). S100B is present even in cases where there was not a diagnosable concussion (Marchi et al., 2013). A significant correlation between S100B blood levels and HHI score has been demonstrated. Specifically, Marchi et al. (2013) showed that football players with a higher HHI scores had significantly higher S100B blood protein levels. In addition, S100B levels increased only in players who had multiple subconcussive hits during a game (Marchi et al., 2013). These findings suggest that the HHI is a valid tool for
measuring subconcussive head injury.

**Anxiety**

Anxiety disorder is one of the most common psychological disorders among youth, and has been called the largest mental health problem in the country (Kandel, 1997). Anxiety disorder is characterized by fluctuating levels of persistent and uncontrollable worry, fatigue, insomnia, muscle tension, difficulty concentrating, and irritability (Kandel, 1997), all of which can cause individuals to feel frightened, distressed, or uneasy (Yuelong, 2014). Anxiety disorders are highly prevalent psychological disorders that can have a negative impact on an individual's physical and social well being (Scanlon, 2015), and previous studies have shown that anxiety symptoms are strongly correlated with chronic medical illness, lowered quality of physical health, and physical disabilities (Comer, 2014). Post-concussive symptoms include: complaints of memory difficulty, headache, vertigo, depression, anxiety, concentration difficulty, blurred vision, and fatigue (Mittenberg, DiGuilio, Perrin & Bass, 1992). Both symptoms of anxiety and post-concussive symptoms lead to poor physical health.

Mittenberg, DiGuilio, Perrin & Bass (1992) studied whether symptoms of mild head trauma were related to what head trauma patients actually thought were post-concussive symptoms. They found that among headaches and vision problems, anxiety was prevalent as a post-concussive symptom as reported by control participants and found in the experimental group of participants who had previously experienced a mild head injury (Mittenberg, DiGuilio, Perrin & Bass, 1992). This finding further suggests the
need for research on the overlap of symptoms of post-concussive symptoms and anxiety.

Anxiety sensitivity, a suite of cognitive factors that can lead to the development of anxiety (Kashdan, Zvolensky, & McLeish, 2008), is related to how people manage and regulate anxiety. The neural underpinnings of anxiety sensitivity are not well known (Hayes & Feldman, 2004), however, researchers have suggested that anxiety sensitivity combines with the physical and behavioral causes of anxiety that lead to the development of anxiety (Eifert & Forsyth, 2005; Hayes, Wilson, Gifford, Follette, & Strosahl, 1996). Hayes, Wilson, Gifford, Follette, and Strosahl (1996) reported that experiencing anxiety can bring about cognitive mechanisms meant to reduce anxiety (Hayes, Wilson, Gifford, Follette, & Strosahl, 1996). Thus, damage to those mechanisms caused by a head injury might cause deficits in a person’s ability to reduce anxiety.

Anxiety can also produce harmful physiological symptoms such as autonomic nervous system deregulation and chronic inflammation (Thayer, Friedman, & Borkovec, 1996). McNaughton and Corr (2004) found that these anxiety symptoms cause the brain’s behavioral inhibition system (consisting of the anterior thalamus, cingulate cortex, and the prefrontal cortex) to malfunction and become over-sensitive to stimuli, which leads to chronic anxiety (McNaughton, & Corr, 2004). Specifically, decreased activity of the prefrontal cortex leads to difficulty in regulating emotions related to anxiety (Sylvester et al, 2012). These findings further suggest that traumatic brain injury and
disruption of certain pathways in the brain lead to the development of anxiety. Deficits in the brain’s behavioral inhibition system may lead to the development of anxiety.

Because both head injury and anxiety prevalence have been increasing in the past years (Moore, Sphor, & Hope, 2006), further research on their interaction is necessary to develop treatment methods for those affected by head injury and anxiety. Mooney and Speed (2001) studied anxiety and mild traumatic brain injury and found that 24% of their participants who had prior mild traumatic brain injuries were also diagnosed with an anxiety disorder (Mooney & Speed, 2001). Anxiety disorders have been frequently documented in individuals following a mild traumatic brain injury. Rao and Lyketsos (2002) found some of the most common post traumatic brain injury anxiety symptoms to be fearfulness, intense worry, generalized uneasiness, social withdrawal, inter-personal sensitivity and anxiety dreams (Rao & Lyketsos, 2002). Their results emphasize the need to further study the relationship between head injury and anxiety.

**Beck Anxiety Inventory**

The Beck Anxiety Inventory is a 21-item scale that assesses the severity of anxiety in adults over the age of 17. Its 21 items are grouped into four subscales; neurophysiological, subjective, panic, and autonomic (see Table 3). The Beck Anxiety Inventory measures symptoms of anxiety that do not overlap with symptoms of depression. Because two of the most commonly treated mental disorders are anxiety and depression, often symptoms of both disorders are difficult to distinguish using surveys. The Beck Anxiety Inventory was created to measure the severity of self-reported symptoms of anxiety as distinct from depression symptoms (Beck et al., 1988).
Morin et al. (1999) created a six subscale model of the Beck Anxiety Inventory including somatic (6 items), fear (3 items), autonomic hyperactivity (3 items), panic (4 items), nervousness (3 items), and motor tension (2 items) as subscales (Morin et al., 1999). Osman et al. (2002) further studied the four subscale model of the Beck Anxiety Inventory with neurophysiological (6 items), autonomic (4 items), subjective (7 items), and panic (4 items) (Osman et al., 2002).

The Beck Anxiety Inventory has been tested for test-retest reliability and internal consistency reliability. The test-retest reliability study for a group of 83 participants consisted of a one-week interval between initial scale administration and the start of cognitive therapy. The test-retest correlation was 0.75 and was statistically significant (Beck et al., 1988). Internal consistency tests were from a group of 160 participants. From this group, Beck et al. (1988) found that the Beck Anxiety Inventory had high internal consistency reliability, Cronbach coefficient alpha= .92. Moreover, a comparable level of internal consistency, Cronbach coefficient alpha= .94, was found in a group of 40 hospital patients with diagnosed anxiety disorders (Beck et al., 1988).

Beck et al. (1988) assessed the Beck Anxiety Inventory’s ability to discriminate symptoms of anxiety from symptoms of depression. One group of participants included a large sample of adults (aged seventeen years and older) with a diagnosed anxiety disorder from various demographic groups, and obtained through hospitals and other medical centers. That sample was compared to a control sample of participants with diagnosed depression, and no form of documented anxiety disorder (Beck et al., 1988). The median score for the participants with an anxiety diagnosis was 24 and the median score for the participants with depression was 13, and 25% of participants in the anxiety
group reported total scores higher than the highest scores in the group of participants with depression (Beck et al., 1988). These findings suggest that the Beck Anxiety Inventory has optimal discriminant validity and can distinguish symptoms of anxiety from symptoms of depression.

**Present Study**

More research is needed on the effects of subconcussive head injury and its associations with mental illness such as anxiety. This study investigated the relationship between subconcussive head injury using Head Hit Index scores (Marchi et al., 2013) and anxiety using Beck Anxiety Inventory scores (Beck et al., 1988). Research shows the appearances of anxiety when various brain structures in the behavioral inhibition system have been disrupted by even a mild head injury (McNaughton & Corr, 2004). Thus, I hypothesized that scores on the HHI and Beck Anxiety Inventory would be positively correlated. I also hypothesized that scores on the Beck Anxiety Inventory and Head Hit Index would be positively correlated with participant GPA.

**Methods**

**Participants**

The participants consisted of 113 students from a small Midwestern liberal arts college aged 18-22 years old. Twenty-five (22.1%) males and 87 (77.0%) females participated. Participants were recruited through classroom visits and word of mouth. The mean age was 20.19 years, and the mean GPA was a 3.207. The participant pool was comprised of freshmen (33.6%), sophomores (13.3%), juniors (29.2%), and seniors (23.9%). The majority of the participants (93.8%) were Caucasian, 2.7% were African
American, 1.8% were Mexican American, 0.9% were Latino, and 0.9% described themselves as Other. Collegiate athletes made up 25.7% of all participants; 24.8% of participants had sustained a previous concussion, and 43.4% of participants believed they had taken a hit to the head that they felt may have been a concussion. Approval for this study was obtained from the university Institutional Review Board.

**Materials**

The demographic section of the questionnaire included questions pertaining to age, gender, height, weight, race, athletic participation, year in school, current GPA, and primary language spoken. The section of the questionnaire containing the Beck Anxiety Inventory served to quantify severity of anxiety symptoms in the participant. Each item describes a symptom of anxiety and is rated on a four point scale: “not at all” (0); “mildly” did not bother much (1); “moderately” it was very unpleasant, but I could stand it (2), and “severely” I could barely stand it (3) (Beck et al., 1988). Individual item scores are summed for the total score. The maximum score on the Beck Anxiety Inventory is 63, scores in the 0-7 ranges indicate minimal level of anxiety, scores from 8-15 indicate mild anxiety, scores from 16-25 indicate moderate anxiety, and scores between 26-63 indicate severe anxiety (Beck et al., 1988).

Participants were asked questions about a previous sport they participated in, the position they played, how much time they were active per game playing, their age when they began playing, and how many years they played the sport. The section of the questionnaire about head injury included questions about whether the participant had experienced a concussion, diagnosed or perceived, at any point in their lives. Head Hit Index (HHI) questions were adapted from Marchi et al. (2013) to be relevant to a
population not involved with collegiate athletics. Participants checked boxes indicating the frequencies of collisions with another person, episodes of contact involving the head, and episodes of significant contact involving the head where they experienced nausea, headaches, neck pain, and/or dizziness. Frequency options in the boxes included zero, one to two, three to four, five to nine, 10 to 19, and 20 and above.

**Procedure**

All participants were told they had the opportunity to participate in an experiment called Cognition and Management. They were informed that participation in the study was completely voluntary. Consent forms were then distributed to all participants. Once all participants had returned a signed consent form, they were given a questionnaire to complete. Participants were told the questionnaire should only take 10 to 15 minutes of their time, and to answer all questions honestly and to the best of their ability. Participants then completed the questionnaire. Following completion of the questionnaire, the participants returned their questionnaires to a designated spot at the back of the classroom and was provided a debriefing form that explained that the study’s purpose was to examine the relationship between subconcussive head injury and an individual's anxiety level. All consent forms and questionnaires were collected separately from participants to ensure anonymity.

**Statistical Analysis**

After data collection was complete, SPSS computer software was used for data analysis. In order to test if the initial hypothesis that the Beck Anxiety Inventory would be significantly correlated with the HHI, a bivariate correlation analysis was used with the Beck Anxiety Inventory score as the dependent variable. The HHI score was the
independent variable, participants were given a value of 0-6 for each HHI question based on the number of times they collided with another person and the number of times they experienced significant episodes of contact involving the head (Table 2).

A bivariate correlation analysis was used to determine if the Beck Anxiety Inventory’s four subscale model including neurophysiological, subjective, panic, and autonomic (Table 3), and six subscale model including somatic, fear, panic, nervousness, autonomic hyperactivity, and motor tension (Table 4) were significantly correlated with HHI. Subscales were created using factor analysis and scores were calculated by summing the total number of points for each item under the subscale for a total score. Scores for each of the subscales were calculated by summing the total of points each participant reported for each item in the subscale. Bivariate correlation analyses were also used to analyze possible associations between the Beck Anxiety Inventory’s 21 individual items, and HHI score.

In order to determine if there was a significant correlation with the Beck Anxiety Inventory and GPA, a bivariate correlation analysis was used with GPA as the dependent variable and the Beck Anxiety Inventory score as the independent variable. Again using bivariate correlation analysis, the Beck Anxiety Inventory was broken down into subscales four (Osman et al., 2002) or six (Morrin et al., 1999) to examine subscale relationships with GPA.

Independent t-tests were performed with the Beck Anxiety Inventory as the dependent variable, and gender as the independent variable. Independent t-tests were also performed on the four (Osman et al., 2002) or six (Morrin et al., 1999) subscales with gender as the independent variable. Independent t-tests were also performed using
whether or not the participant was a college athlete as the independent variable and the HHI and the Beck Anxiety Inventory scores as dependent variables.

**Results**

In our study, the Beck Anxiety Inventory had high internal consistency reliability, Cronbach coefficient alpha= .90. We did not find a significant correlation between the Beck Anxiety Inventory (BAI) score and HHI score (Figure 1). We did not find a significant correlation between HHI scores and any of the BAI’s four subscale scores (neurophysiological, autonomic, subjective, and panic). However, a significant negative correlation was found between the fear subscale and the HHI, r=-0.232, n=83, p<0.05 (Figure 2). Finally, Of the 21 items on the BAI, we found a significant negative correlation between “fear of losing control” ratings and the HHI score, r=-0.281, n=83, p<0.05 (Figure 3).

We found a significant negative correlation between the total BAI score and GPA, r=-0.162, n=109, p<0.05 (Figure 4). When analyzing the four subscales of the BAI, we found a significant negative correlation between the panic subscale and GPA, r=-0.271, n=109, p<0.01 (Figure 5). After analyzing the six subscales of the BAI, we found a significant negative correlation between the somatic subscale and GPA, r=-0.203, n=109, p<0.05 (Figure 6).

No significant effects of gender were found on the HHI scores or BAI scores. Whether or not the participant was a college athlete did not have an effect on HHI scores or BAI scores (Table 5). There was a significant positive correlation between the total perceived head hits score and total HHI scores, r=-0.285, n=65, p<0.05.
Discussion

In this study we show that Head Hit Index (HHI) score does not predict overall BAI score. However we show that HHI predicts score on the fear subscale of the Beck Anxiety Inventory (BAI). Specifically, a higher HHI score is associated with decreased fear. We also show that score on the BAI predicts GPA. Specifically, we found that more anxiety is associated with a lower GPA. We also show that score on the panic subscale of the BAI is associated with GPA. Specifically, panic symptoms of anxiety (heart pounding or racing, feelings of choking, difficulty breathing, and fear of dying) are associated with a lower GPA.

There was a significant negative correlation between the fear subscale of the BAI and HHI. The HHI measures frequency of collisions with another person, episodes of contact involving the head, and episodes of significant contact involving the head where they experienced nausea, headaches, neck pain, and/or dizziness. The fear subscale of the BAI includes items “fear of dying”, “scared”, and “fear of losing control.” There was also a significant negative correlation between HHI and item “fear of losing control” on the BAI. These findings suggest that the increased number of subconcussive head injuries an individual sustains, the less they experience feelings of losing control, fear, or fear of dying. Further research is needed to examine the effects of subconcussive head injury on behavioral inhibition and fear modulation. The outcomes of this study show a need for extended research on the relationship between the effects of subconcussive head injury and psychological disorders. This study also highlights the need for treatment and potential mental health counseling programs for individuals who sustain a subconcussive head injury.
Previous fMRI studies by Monk et al. (2008) studied anxiety by monitoring neural activity in participants. They found that compared to participants who did not report symptoms of anxiety, participants who reported experiencing anxiety symptoms showed enhanced activation in the amygdala and prefrontal cortex (Monk et al., 2008). This suggests that these anxiety related activation patterns reflect greater sensitivity and hypervigilance to threats. Further analyses found that activations in the amygdala and in the prefrontal cortex of anxious individuals are negatively correlated during measurements of anxiety presence, suggesting increased pre-frontal cortex activation is associated with reduced response of the amygdala (Monk et al., 2008). Damage to the amygdala during young adulthood, when behavior regulation has yet to fully mature, may lead to problems with regulating anxiety later on in life (Whittle et al., 2008). When damage to the amygdala, responsible for autonomic responses associated with fear, is paired with damage to the prefrontal cortex, associated with regulating anxiety, the result may be a reduction in the activity of the fear neural circuit in the brain.

A significant correlation was not found between the effect of subconcussive head injury and overall severity of symptoms of anxiety score. However, a significant negative correlation was found between the total fear subscale score of an anxiety measure and effect of subconcussive head injury. The lack of a significant correlation between head injury and anxiety is consistent with the findings of Schoenhuber & Gentilini (1988). Their findings revealed that there was no significant correlation between head injury and scores on an anxiety measurement (Schoenhuber & Gentilini, 1988). These findings may suggest that head injury may not increase of severity of anxiety symptoms, but rather decrease the severity of symptoms.
Our results show that the BAI score is negatively correlated with GPA. Thus, a high score on the BAI predicts low GPA. This finding is consistent with Eisenberg et al.'s (2009) findings that mental health predicts academic success during college. Kiselica, Baker, Thomas, and Reedy (1994) found in a study of causes and treatments of anxiety disorder, that students who exhibited symptoms of anxiety were found to have more cases of problem behavior, and were lower on academic achievement and aptitude than students who did not show presence of anxiety symptoms (Kiselica, Baker, Thomas, & Reedy, 1994). Anxiety can enhance awareness and alertness to a point that may hinder student academic performance (Kiselica, Baker, Thomas, & Reedy, 1994). These findings along with the findings we present here highlight the need for conducting more research on the effect of mental health, specifically the presence of anxiety in college students on academic success.

In our study, the somatic subscale of the BAI was negatively correlated with GPA. The somatic subscale consists of the items “wobbliness in legs”, “dizzy or light headed”, “heart pounding or racing”, “unsteady”, “difficulty breathing”, and “indigestion”. Strauss (1990) found that students with anxiety tend to show an increased rate of attention deficits, oppositional behavior, and have more somatic pain than students who do not have symptoms of anxiety (Strauss, 1990). Because the classroom environment can already be a source of anxiety for students, somatic symptoms of anxiety might impede academic success in students. This finding increases interest in the effect presence of anxiety has on academic success.

We found that the panic subscale of the BAI was negatively correlated with GPA.
The panic subscale includes items “feeling hot”, “indigestion”, “face flushed”, and “sweating.” All but “indigestion” are considered to be somatic symptoms of anxiety (Beck et al., 1988). Reiss et al. (1991) argue that when a person with high anxiety experiences the somatic symptoms of anxiety, he or she is likely to fear that the symptoms are uncontrollable and will inevitably lead to severe consequences (such as losing control of themselves). This fear then exacerbates the somatic symptoms of anxiety that initially caused the fear, and can precipitate a panic attack (Reiss et al., 1991). These somatic symptoms could possibly present themselves in individuals during high anxiety situations in the classroom. The relationship between panic symptoms of anxiety has been previously studied in relation to academic success. While Lau, Calamari and Waraczynski (1996) found a significant correlation between anxiety sensitivity and panic symptoms in the youth, they did not find a significant correlation between students with symptoms of panic symptoms of anxiety and GPA. They attributed their lack of significant findings to not using an anxiety measurement scale that was sensitive enough to detect presence of anxiety in their participants (Lau, Calamari & Waraczynski, 1996).

We found a significant positive correlation between perceived head hits and HHI scores. Thus, the more times a person believed that they had experienced a concussion, the higher their HHI score was. The topic of suspecting concussions and reporting potential concussions has been previously examined. Baugh, Kroshus, Daneshvar, and Stern (2014) found that between 1.6 and 3.8 million concussions due to school athletics and other recreational sports are sustained every year among high school and college athletes in the United States (Baugh, Kroshus, Daneshvar, & Stern,
2014). Part of mitigating the burden of problematic post-concussive symptoms from head injuries depends on whether players accurately report symptoms of suspected concussions to an athletic trainer or member of a coaching staff (Baugh, Kroshus, Daneshvar, & Stern, 2014). Our findings that perceived head hits and HHI score were significantly correlated could possibly mean that an individual’s assumption that they had experienced a concussion was correct, or, that they had experienced a subconcussive head injury instead that went undetected.

Gender did not influence BAI or HHI scores. Thus, gender did not show to have an effect on HHI scores. While no effect of gender on the HHI was found, previous research by Ilie et al. (2014) found in a study that males have a 47% higher likelihood of acquiring a traumatic brain injury (Ilie et al., 2014). The fact that males are more likely to experience a traumatic brain injury also suggests they are more likely to experience subconcussive head injury. Guitierz, Conte, and Lightbourne (2014) studied the effects of subconcussive head hits on cognitive functioning in female high school soccer players during a single playing season. While results of their study did not show a significant correlation between the head hits and cognitive functioning, they predicted that a longitudinal study measuring subconcussive head hits over an athlete’s entire career might show a significant decline in cognitive functioning (Guitierz, Conte & Lightbourne, 2014). McLean, Asnaani, Litz, and Hofmann (2011) found that while previous research has shown that females tend to have a higher prevalence of anxiety, their study pertaining to creating data on the national presence of anxiety disorders present by gender, assess gender differences in the onset, course and patterns of comorbidity in anxiety disorders, and examination of rates of physical and occupational
impairment associated with anxiety disorders across genders revealed that gender, the age of onset and duration of anxiety disorder was not significantly different between the male and female participants in their study (McLean, Asnaani, Litz, & Hofmann, 2011).

There was no association between being a collegiate athlete and scores on the HHI. This indicates that participating in college athletics did not lead to an increased number of subconcussive head hits. Henry and de Beauont (2011) found that while awareness and research about subconcussive head hits is increasing, many athletes are still “faking good” when reporting symptoms (Henry & de Beaumont, 2011). In terms of faking good, athletes were not accurately reporting the severity of their symptoms in order to stay eligible to participate in their sport. The generally dismissive attitude towards concussions in sports is still prevalent and continues to influence the reporting of subconcussive symptoms, further research on the aversive long term effects of subconcussive head hits is needed to help change this mentality.

Another explanation for the low association could be that the participants who were college athletes may have sustained a high frequency of head hits at low magnitudes. Gysland et al. (2012) studied the effects of subconcussive head injury in collegiate football players to see if subconcussive head injuries sustained over the course of a season led to cognitive deficits. They found using an accelerometer in players’ helmets that many while players sustained a high number of low impact head hits, that my not have as great of an effect on players in a short period of time as head hits if a higher magnitude would. In future subconcussive head injury research, the effect of subconcussive head injuries above a particular frequency should be analyzed.
The participant pool in our study may have limited our ability to extract the effects of subconcussive head hits on anxiety and academic performance. The majority of our participant pool were non-athletes who were not participating in sports were head injury may be more prevalent, and would not be as exposed to head injury as athletes. About 22% of participants did not complete the HHI portion of the questionnaire. This may have skewed our findings about the association between the BAI and HHI. All of the participants in the study were young adults, under the age when the prefrontal cortex considered to be fully developed.

At first, it was believed that most recovery and physical repair occurs the first six months after the injury. Oddy, Coughlan, Tyerman, and Jenkins (1985) studied a population of young adults following seven years post-injury. They found in their young adult population that the recovery process lasts for years, and many young adult patients will adapt to residual disability (Oddy, Coughlan, Tyerman, & Jenkins, 1985). Our study’s data came from a participant population that consisted of young adults who were asked to recall all head hits they had sustained in the last five years. They may have adapted to their reported head hits, and not have experienced noticeable cognitive deficits.

Further research is needed to examine the effects of subconcussive head injury in the general population. Currently much of the research being done on subconcussive head is in athletics, more studies with participants not involved in athletics would be needed to serve as a comparison for the present study. There was an association between the fear subscale of the BAI and HHI scores, the shows a need to investigate deeper the relationship between subconcussive head injury and variables of fear.
Future studies should also consider testing participants in a non-anxiety inducing environment. Because the classroom can already be a stressful environment for participants, it may be beneficial to test participants in a neutral environment.
References


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**Figure 1:** Beck Anxiety Inventory total scores correlated with Head Hit Index total scores.

**Figure 2:** Fear subscale (six subscale model) of the Beck Anxiety Inventory total scores correlated with Head Hit Index total scores.
Figure 3: Head Hit Index total scores correlated with item total scores for “Fear of losing control.”

Figure 4: Beck Anxiety Inventory total scores correlated with Grade Point Averages of participants.
Figure 5: Panic subscale (four subscale model) total scores correlated with Grade Point Averages of participants.

Figure 6: Somatic subscale (six subscale model) total scores correlated with Grade Point Averages of participants.
In the past 5 years, to the best of your knowledge, on average how many times have you...

a) ...collided with another person? (check one):
   - 0
   - 1 – 2
   - 3 – 4
   - 5 – 9
   - 10 – 19
   - 20+

b) ...experience any episodes of contact involving the head, with or without a helmet? (e.g., a bike helmet) (check one):
   - 0
   - 1 – 2
   - 3 – 4
   - 5 – 9
   - 10 – 19
   - 20+

c) ...have significant episodes of contact involving the head (for example, contact that results in feelings of nausea, headache, neck pain, and/or dizziness)? (check one):
   - 0
   - 1 – 2
   - 3 – 4
   - 5 – 9
   - 10 – 19
   - 20+

**Figure 7:** Head Hit Index used to measure subconcussive head injury.
### Table 1: Descriptive statistics for participants

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<tr>
<td><strong>Age</strong></td>
<td>112</td>
<td>18</td>
<td>31</td>
<td>20.19</td>
<td>1.929</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>113</td>
<td>1</td>
<td>3</td>
<td>1.79</td>
<td>0.432</td>
</tr>
<tr>
<td><strong>GPA</strong></td>
<td>109</td>
<td>1.8</td>
<td>4</td>
<td>3.207</td>
<td>0.5082</td>
</tr>
<tr>
<td><strong>Number of concussions reported</strong></td>
<td>28</td>
<td>1</td>
<td>5</td>
<td>1.64</td>
<td>0.951</td>
</tr>
<tr>
<td><strong>Perceived Concussions reported</strong></td>
<td>90</td>
<td>0</td>
<td>1</td>
<td>0.54</td>
<td>0.501</td>
</tr>
<tr>
<td><strong>Times collided with another person</strong></td>
<td>83</td>
<td>1</td>
<td>6</td>
<td>3.37</td>
<td>1.911</td>
</tr>
<tr>
<td><strong>Number of times experienced contact with head</strong></td>
<td>83</td>
<td>1</td>
<td>6</td>
<td>2.53</td>
<td>1.648</td>
</tr>
<tr>
<td><strong>Significant contact to head experienced</strong></td>
<td>83</td>
<td>1</td>
<td>6</td>
<td>1.99</td>
<td>1.205</td>
</tr>
<tr>
<td><strong>HHI Total Scores</strong></td>
<td>83</td>
<td>0</td>
<td>6</td>
<td>3.52</td>
<td>2.396</td>
</tr>
<tr>
<td><strong>Neurophysiological Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>18</td>
<td>3.3628</td>
<td>3.41755</td>
</tr>
<tr>
<td><strong>Subjective Subscale Total</strong></td>
<td>112</td>
<td>0</td>
<td>16</td>
<td>5.5446</td>
<td>3.59902</td>
</tr>
<tr>
<td><strong>Panic Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>7</td>
<td>1.6726</td>
<td>1.74971</td>
</tr>
<tr>
<td><strong>Autonomic Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>10</td>
<td>3.115</td>
<td>2.38579</td>
</tr>
<tr>
<td><strong>Panic Subscale Total</strong></td>
<td>112</td>
<td>0</td>
<td>6</td>
<td>0.8571</td>
<td>1.32105</td>
</tr>
<tr>
<td><strong>Autonomic Hyperactivity Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>7</td>
<td>2.292</td>
<td>1.84527</td>
</tr>
<tr>
<td><strong>Somatic Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>15</td>
<td>3</td>
<td>3.0178</td>
</tr>
<tr>
<td><strong>Nervous Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>9</td>
<td>4.1858</td>
<td>2.25812</td>
</tr>
<tr>
<td><strong>Motor Tension Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>6</td>
<td>1.2035</td>
<td>1.44642</td>
</tr>
<tr>
<td><strong>Fear Subscale Total</strong></td>
<td>113</td>
<td>0</td>
<td>8</td>
<td>1.354</td>
<td>1.68989</td>
</tr>
<tr>
<td><strong>BAI Total Scores</strong></td>
<td>112</td>
<td>0</td>
<td>40</td>
<td>13.7232</td>
<td>9.41076</td>
</tr>
<tr>
<td><strong>Valid N (listwise)</strong></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Head Hit Index scoring

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>&gt; or =to 2 sig Hits, and 4-6 on other 2 categories</td>
</tr>
<tr>
<td>5</td>
<td>&gt; or =to 2 sig Hits, and 3-5 on other 2 categories</td>
</tr>
<tr>
<td>4</td>
<td>&gt; or =to 2 sig Hits, and 2-4 on other 2 categories</td>
</tr>
<tr>
<td>3</td>
<td>1 Sig Hits, and 4-6 on other 2 categories</td>
</tr>
<tr>
<td>2</td>
<td>1 Sig Hits, and 3-5 on other 2 categories</td>
</tr>
<tr>
<td>1</td>
<td>1 Sig Hits, and 2-4 on other categories</td>
</tr>
<tr>
<td>0</td>
<td>1 Sig Hits, and 1 on other categories</td>
</tr>
</tbody>
</table>

Table 3: Four subscale model of the Beck Anxiety Inventory

<table>
<thead>
<tr>
<th>Neurophysiological</th>
<th>Subjective</th>
<th>Panic</th>
<th>Autonomic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbness or Tingling</td>
<td>Unable to relax</td>
<td>Heart pounding or racing</td>
<td>Feeling hot</td>
</tr>
<tr>
<td>Wobbliness in legs</td>
<td>Fear of the worst happening</td>
<td>Feelings of choking</td>
<td>Indigestion or discomfort in abdomen</td>
</tr>
<tr>
<td>Dizzy or Lightheaded</td>
<td>Terrified</td>
<td>Difficulty breathing</td>
<td>Face flushed</td>
</tr>
<tr>
<td>Hands trembling</td>
<td>Nervous</td>
<td>Fear of dying</td>
<td>Sweating (not due to heat)</td>
</tr>
<tr>
<td>Shaky</td>
<td>Fear of losing control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faint</td>
<td>Scared</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4: Six subscale model of the Beck Anxiety Inventory

<table>
<thead>
<tr>
<th>Somatic</th>
<th>Fear</th>
<th>Panic</th>
<th>Nervousness</th>
<th>Autonomic Hyperactivity</th>
<th>Motor Tension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wobbliness in legs</td>
<td>Fear of loss of control</td>
<td>Numbness or tingling</td>
<td>Unable to relax</td>
<td>Feeling hot</td>
<td>Hands Trembling</td>
</tr>
<tr>
<td>Dizzy or light headed</td>
<td>Fear of dying</td>
<td>Feelings of choking</td>
<td>Fear the worst happening</td>
<td>Face flushed</td>
<td>Shaky</td>
</tr>
<tr>
<td>Heart pounding or racing</td>
<td>Scared</td>
<td>Faint</td>
<td>Nervous</td>
<td>Sweating</td>
<td></td>
</tr>
<tr>
<td>Unsteady</td>
<td>Terrified</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty breathing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indigestion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Beck Anxiety Inventory and Head Hit Index distribution between athletes and non-athletes

<table>
<thead>
<tr>
<th>HHI Total</th>
<th>Athlete</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>no</td>
<td>no</td>
<td>55</td>
<td>3.35</td>
<td>2.398</td>
<td>.323</td>
</tr>
<tr>
<td>yes</td>
<td></td>
<td>28</td>
<td>3.86</td>
<td>2.399</td>
<td>.453</td>
</tr>
<tr>
<td>no</td>
<td>BeckTOT</td>
<td>84</td>
<td>13.1429</td>
<td>9.66442</td>
<td>1.05447</td>
</tr>
<tr>
<td>yes</td>
<td></td>
<td>28</td>
<td>15.4643</td>
<td>8.53091</td>
<td>1.61219</td>
</tr>
</tbody>
</table>
Acknowledgements

I would like to thank Dr. Nancy Woehrle for her role as my thesis mentor, the Wittenberg Student Development Board for funding my project, and Dr. Brookings and Dr. Yontz for their commitment as my thesis readers.