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A Culture that Fosters Concussions: Does Increased Education Lead to More Accurate Reporting of Concussions?

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A CULTURE THAT FOSTERS CONCUSSIONS:

DOES INCREASED EDUCATION LEAD TO MORE ACCURATE

REPORTING OF CONCUSSIONS?

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Dissertation Approval

This is to certify that the thesis presented to us by Michael Heptig on the 5th day of April, 2016, in partial fulfillment of the requirements for the degree of Doctor of Psychology, has been examined and is acceptable in both scholarship and literary quality.

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Abstract

With over 1.7 million incidents reported annually, concussion has become the most common class of traumatic brain injury (TBI) in the United States (Bazarian, Zhu, Blyth, Borrino, & Zhong, 2012). As staggering a statistic as this may be, many believe it fails to represent the true number of concussions because the non-reporting of symptoms has been commonplace among athletes (Khurana & Kaye, 2012; Williamson & Goodman, 2006). The aim of this study was to determine those factors that influence the reporting of concussion symptoms. Specific variables that were examined include the amount of concussion education provided (determined by requisite amount of concussion education in minutes), number of required participants in training, the utilization of baseline neurocognitive testing, the number of years concussion legislation has been in place, and the presence of a certified athletic trainer. A review of current literature is included. This study used original data, collected from superintendents of high schools across the country. Participants completed an online survey, via Survey Monkey, which included questions regarding the number of student-athletes, number of diagnosed concussions, amount of requisite concussion education, and concussion management protocols at each high school. The number of years that concussion legislation has been in place was found to be a significant factor in the reporting of concussions. The findings can be used to further improve concussion management in high schools and raise awareness about the occurrence of non-reporting in sports. Potential explanations, limitations, and implications are explored as well.

Keywords: concussion, high school sports, education, non-reporting, concussion legislation

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Chapter 1: Introduction

Statement of the Problem

With over 1.7 million incidents reported annually, concussion has become the most common class of traumatic brain injury (TBI) in the United States (Bazarian, Zhu, Blyth, Borrino, & Zhong, 2012). As staggering as this statistic may be, many believe it fails to represent the true number of concussions because non-reporting of symptoms is commonplace among athletes (Khurana & Kaye, 2012; Williamson & Goodman, 2006). Given the difficult nature of determining how often concussive episodes go unreported, estimates of the number of athletes who fail to report concussive symptoms vary from 20% - 60% (Chrisman, Quitiquit, & Rivara, 2013). In fact, a recent qualitative study involving 50 varsity athletes found that not one would definitively stop playing when faced with a hypothetical situation in which he or she had experienced concussion symptoms (Chrisman et al., 2013). Among the most common reasons given for failing to report symptoms is lack of knowledge regarding the seriousness of such an injury. One study which examined 1,532 football players found that only 47.3% who incurred a concussion reported their symptoms; “did not think it was serious enough” was the reason given by 66.4% of those who failed to report (McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Although some have hypothesized that a lack of education regarding concussions may be the singular underlying cause (Bramley, Patrick, Lehman, & Silvis, 2012; Kaut, DePompei, Kerr, & Congeni, 2003), research has shown that a number of other factors may also play a critical role in this phenomenon. To this end, Chrisman et al. (2013) identified the ambiguity of symptoms, a belief by athletes that they are supposed to play injured, concern about letting the team down, and the attitude of the coach as influential factors that determine whether or not an athlete will report concussive symptoms.

Essentially, these findings point to a culture, relative to concussion-reporting, that has been created by teammates, coaches, parents, and an individual's own beliefs which influences whether or not an individual will report concussive symptoms. This assumption is further supported by the Theory of Planned Behavior (Ajzen, 1991; Register-Mihalik et al., 2013) which attempts to identify factors that play a critical role in the decision-making process of individuals. Essentially, the most influential predictor of a behavior is the intention to perform that behavior. According to the theory, intention is broken down into the three critical factors of attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). As it relates to a failure to report concussion symptoms, attitudes refer to an individual's appraisal of the ramifications of performing a behavior, which in this case is returning to play. Subjective norms refer to the pressure one feels to perform a behavior from those people whose opinion matters (e.g., coach, parent, teammate). Perceived behavioral control reflects an individual's perception regarding his or her own ability to perform a behavior (reporting concussion symptoms) (Kroshus, Baugh, Daneshvar, & Viswanath, 2014; Register-Mihalik et al., 2013). Because it is believed that these are the most critical factors mediating an athlete's intention to report concussion symptoms, more extensive education to all parties involved (e.g., athlete, coach, athletic trainer, parent, teammate) may serve as a protective factor against non-reporting.

Failure to report concussion symptoms represents a significant issue for a variety of reasons. Most notably, a second insult to the brain prior to healing from the original traumatic event can cause permanent brain damage or, in severe cases, even prove fatal (Khurana & Kaye, 2012). Furthermore, symptomatology following a concussive episode may include a temporary decline in cognitive functioning, impaired impulse control, and/or mood fluctuations which can cause significant academic and social issues if the parents, teachers, and coaches of the student-athlete are unaware of the underlying etiology (Moser, 2007).

The variability in recovery from post concussive symptoms (PCS) further complicates the issue. Although a majority of individuals fully recover from PCS within ten days, it may take 10-15% of individuals a matter of weeks to months for PCS to completely subside (McCrory et al., 2013). The consensus statement created during the 4th International Conference on Concussion in Sport held in Zurich, Switzerland in November of 2012, is a seminal document used by physicians and health care professionals who deal primarily with concussion; according to this document there is no hard-fast rule about the time when an individual should return to play following a concussive episode (McCrory et al., 2013). However, due to the longer recovery periods seen in children and adolescents who have experienced a concussive episode, it is recommended that an even more cautious approach be taken with this population (McCrory et al., 2013).

Given the fact that completely eliminating concussion from sport is an unrealistic goal, a preventative approach may comprise the best treatment for concussion. Unfortunately, there is a paucity of research regarding specific risk factors for concussions. A recent study attempting to uncover risk factors revealed little new evidence, finding no relationship between equipment (e.g., head gear, mouthpieces), neck strength, or legislation with a reduction in concussion risk (Benson et al., 2013). In fact, only fair-play rules (e.g., tournament points added for staying under a specific number of penalties per game) and elimination of body checking in youth ice hockey were found to reduce the number of concussions significantly (Benson et al., 2013). Interestingly enough, one study did find a positive correlation between concussion legislation and diagnosed concussions (Bompadre et al., 2014); the study indicated that as the number of years that concussion legislation was in place increased, so too was there an increase in the number of diagnosed concussions. This finding may imply that concussion legislation is a mitigating factor in non-reporting of concussion symptoms. In an attempt to complement the current literature on concussion risk factors, an examination of possible causes for failing to report concussive symptoms may be the most prudent measure taken in increasing the safety of high school athletics. Consequently, determining the most influential factors (i.e., amount of education in minutes, baseline neurocognitive assessment, presence of an athletic trainer, number of participants that receive education, state legislation) of an effective concussion management protocol in reducing resistance to symptom-reporting is critical to the physical, academic, and social well-being of the concussed child.

Purpose of Study

The current study attempted to determine if a relationship exists between the amount of concussion education provided (determined by amount of concussion education in minutes) and the average number of concussions diagnosed in high school sports per student-athlete. Specifically, whether an increase in education provided to all involved parties (i.e., coaches, parents, trainers, and student athlete) led to a higher rate of reported concussion incidents per student-athlete as compared with schools that required a lesser amount of concussion education. If a relationship was found to exist, the findings would essentially imply that more extensive education would decrease the occurrence of unreported concussive episodes. Although more comprehensive education regarding concussions has been shown to be an effective preventative measure in at least one study (Bramley et al., 2012), only male soccer players were examined, making the findings difficult to generalize to athletes from other sports or to female athletes. In an effort to further such research, the current survey study attempted to determine the most effective practices and preventative measures in concussion management across a variety of common high school sports. The main purpose of this study was to discover whether or not athletic programs that provide more extensive education regarding concussions serve to create a culture that is vigilant in its approach to concussion reporting. If so, schools which provided more extensive concussion education would show a higher prevalence of concussion diagnoses resulting from school athletics when compared with schools that required a lesser amount of concussion education. This study also attempted to determine whether the number of participants required to receive this education (student, parent, coach, athletic trainer, etc.), the presence of an athletic trainer, the number of years that state concussion legislation has been in place, and required baseline neurocognitive testing are also influential factors in the reporting of concussion symptoms.

Chapter 2: Literature Review

Prevalence, Impact, and Definitions

With conservative estimates ranging from 1.7 – 3.8 million incidents per year, concussion resulting from sports or from other recreational related activities has become the most common form of traumatic brain injury (TBI) (Bazarian et al., 2012). Once believed to be a completely reversible neuronal episode, current research has proven this initial assumption to be erroneous. Most commonly transpiring in contact sports, concussions can have devastating immediate and long-term effects. Even more disconcerting is the pervasiveness of concussion incidence in youth sports and the damage concussion can have on the still developing brain. An estimated 7.7 million students participate in high school sports (National Federation of State High School Associations, 2014); therefore, concussion prevention has become an increasing public health concern. In response to such staggering statistics, research on the immediate and long-term effects of concussion has increased dramatically in recent years.

Much of the research attempting to determine the incidence rate of concussion in youth sports has used the construct Athletic Exposure (AE) as the common denominator. AE is defined as one athlete participating in one practice or competition (Marar, McIlvain, Fields, Comstock, 2012). Findings suggest that approximately 2.5 concussions occur per 10,000 AEs, with incidence rates during competition nearly six times higher during competition than in practice (Marar, et al., 2012). The four sports involving males that had the highest incident rate of concussion in the years between 2008 – 2010 were football, wrestling, soccer, and basketball (Marar, et al., 2012). The four sports involving females that had the highest incident rate in the years between 2008 – 2010 were soccer, basketball, lacrosse, and softball (Marar, et al., 2012). Research has shown repeatedly that female athletes are more susceptible than male athletes to a concussive episode (Marar, et al., 2012; Lincoln et al., 2011). As a result of these findings, the current study analyzed survey responses only from those schools which offer each of these eight sports. This approach will allow the findings to be generalized across gender and to a wider range of sports than has been examined in previous studies (Chrisman et al., 2013).

Attempts to operationalize the term concussion have been arduous and exhaustive. Classified as a mild TBI (mTBI), a consensus definition was reached during the 4th International Conference on Concussion in Sport held in Zurich, Switzerland in November of 2012. In summation, a concussion is a “complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” typically resulting in the rapid onset of short lived neurological impairment, which resolves spontaneously and may or may not involve loss of consciousness (McCrory et al., 2013). Such a comprehensive and all-encompassing definition notwithstanding, the exact pathophysiology of concussion is still not completely known. Much of the present understanding was derived through inferring knowledge about the human brain from animal research and from experimentally induced concussion. Unfortunately, due to the varying methods by which concussions were induced and the diversity of experimental settings used, much of the data are incongruous (Webbe, 2006).

Consensus Statement on Concussion in Sport

First developed in 2001 at the inaugural International Conference on Concussion in Sport in Vienna, Austria the Consensus Statement provides the latest scientific discoveries and findings regarding concussion from the leading experts in the field (McCrory et al., 2013). The most recent revision was developed from the deliberations at the 4th International Conference on Concussion in Sport held in Zurich, Switzerland in November 2012 (McCrory et al., 2013). This statement is intended to serve not only as a scientific record of the conference, but also to provide a summary of the most recent research on sports concussion, its management, and areas in need of further research. Significant to the current study, the Consensus Statement acknowledges the importance of concussion education, but emphasizes the dearth of research on the efficacy of the current practices. Consequently, the current investigation will attempt to build on current research and advance the knowledge base in regard to concussion education practices. To this end, a brief review of the biomechanics, theoretical underpinnings, and pathophysiology of concussions follows.

Biomechanics of a Concussion

Concussion occurs from direct impact or impulse insults to the brain that neither penetrate nor fracture the skull (Webbe, 2006). The fact that there is no penetration or fracture is what classifies concussion as an mTBI rather than a TBI. The impact or impulse causes an acceleration-deceleration event between the skull and brain. The immediate impact of the skull on the brain causes what is referred to as a coup injury and the opposing action on the opposite side is referred to as a counter coup injury (Webbe, 2006).

Impact injuries occur when there is a direct insult to the skull such as those typically seen in contact sports. Impulse injuries are those that occur in the absence of impact to the skull such as those seen in blast injuries (Webbe, 2006). Concussion resulting from these types of injuries instigates the sudden stretching of neuronal and axonal membranes which initiates a cascade of neurometabolic and neurochemical events (Webbe, 2006; Signoretti, et al., 2011).

Two different types of force can be imparted upon the brain during a concussive episode depending on the nature of the insult: linear and rotational (Webbe, 2006). Linear force results from that force applied in a straight line, occurring from direct blows to the face or abrupt stopping of forward movement. Rotational force is typically imparted upon the brain following an injury to the side of the head (Webbe, 2006). It has also been hypothesized that concussive episodes occurring from rotational force may be more likely to result in loss of consciousness. Injury resulting from rotational forces will be most impactful at areas of grey-white differentiation, beginning at the cortical level and possibly reaching the brainstem (Webbe, 2006). This progression could explain the reason why many concussions do not lead to loss of consciousness. Simply put, if the insult to the brain is not severe enough, the force from the impulse or impact may not reach the brainstem which could be a logical way to explain the reason why loss of consciousness does not occur in all concussive episodes.

Theoretical Underpinnings

Resulting from conflicting research, an abundance of theories has surfaced in an attempt to explicate the pathophysiology of concussions. One of the earliest attempts to explain the phenomenon was the Vascular Theory. Symonds' proposal (1935) originally speculated that concussion was due to a brief cerebral ischemia resulting from vasoconstriction or obstruction of cerebral blood flow. Current research has given some credence to this assumption, although this manages to aid only in the explanation of many of the PCS commonly seen (Webbe, 2006). The Vascular Theory fails to account for the immediate clinical presentations of concussion, such as loss of consciousness, amnesia, and vestibular malfunctions. Furthermore, symptom presentation would occur much slower if vasoconstriction and decreased cerebral blood flow were the only culprits.

In an attempt to explain the more immediate effects of concussion, the Reticular Theory was surmised by Denny-Brown and Russell in 1941, emanating from the understanding that the brainstem reticular formation played a primary role in consciousness (as cited in Webbe, 2006, p. 52). Because diagnosis of concussion was originally predicated on loss of consciousness, this seemed auspicious. This theory hypothesized that brainstem trauma would occur from intense rotational acceleration causing the shearing of tissue. Evidence from damaged brainstem axons in monkeys and rats that were subject to experimentally induced concussion has supported this theory (Webbe, 2006). Much of the basis for this theory has been substantiated and does well to explain many of the instantaneous symptoms following concussion; however, it fails to account for the long term effects and amnesia.

The Centripetal Theory, pioneered by Ommaya and Gennarelli in 1974 (as cited in Webbe, 2006, p. 52), posited that concussion was caused by rotational accelerations in the brain rather than linear ones. This theory also attempted to link loss of consciousness with the severity of the concussion. Rather than encompass the entirety of the concussive experience, this theory focused solely on loss of consciousness and effects on the brainstem and neglected to account for other symptoms seen in concussion victims (Webbe, 2006).

The Pontine Cholinergic Theory argued that the concussive insult excited an inhibitory cholinergic system located in the dorsal pontine tegmentum (Webbe, 2006). Consciousness would be disrupted when the neurons served by the cholinergic synapses were inhibited. The most significant opponent to this theory came from a study providing a cholinergic antagonist prior to experimentally induced concussions. If this theory were true, blocking acetylcholine should have prevented many of the concussive symptoms. Unfortunately, this was not the case (Webbe, 2006).

The convulsive hypothesis theorized that the clinical manifestation of concussion and epileptic seizures show significant similarities; therefore, they may also share a common pathophysiological mechanism. If proven true, it may offer significant insight into the neuronal activity that ensues following concussion. Substantial evidence to support this theory through the use of electroencephalographic (EEG) data has been found (Webbe, 2006).

In sum, current thinking in the field utilizes an eclectic approach, taking bits and pieces from each of these theories to describe the wide range of manifestations possible in concussion victims. One interesting possibility is that there are different mechanisms that cause loss of consciousness and the immediate symptoms from a concussion, separate from those that cause amnesia and other post-concussion symptoms. McCrory (2001) postulated that there may be two different types of concussion: brainstem concussion and cortical concussion. Through the use of advancing technology, studies utilizing high-resolution magnetic resonance imaging (MRI) have offered real-time images of the structural and molecular changes that occur following concussion, providing a more comprehensive understanding of the pathophysiology of concussion (Barkhoudarian, Hovda, & Giza, 2011).

Pathophysiology of Concussion

Concussion results from a traumatic insult, resulting from an outside force that transmits acceleration and deceleration forces to the brain causing a complex neurometabolic and neurochemical cascade of events (Signoretti et al., 2011). Immediately following the insult, there are increases in blood pressure and decreases in cerebral blood flow. Simultaneously, sudden stretching of axons leads to an increased permeability in neuronal membranes which allows for an immediate and indiscriminate increase in ions (Signoretti et al., 2011).

Normally voltage-dependent ion channels open, causing a release of excitatory amino acid neurotransmitters, most notably glutamate (Khurana & Kaye, 2012). Glutamate binds to the N-methyl-D-aspartate (NMDA) receptor causing massive neuronal depolarization. Consequently, an efflux of potassium and influx of calcium severely alters the homeostatic intra and extra-cellular relationship of these ions, leading to extensive changes in cellular physiology (Giza & Hovda, 2001). In response, the sodium-potassium pump attempts to restore homeostasis by working at maximal capacity. This adenosine triphosphate (ATP) dependent pump requires an unobtainable level of ATP during a concussive episode, triggering a dramatic increase in glucose metabolism referred to as hypermetabolism (Giza & Hovda, 2001).

As a result of the decreased cerebral blood flow, supplies of glucose run short, causing a cellular crisis during which the demand cannot meet the supply. Complicating the neurometabolic event further, increasing levels of calcium overload mitochondria disrupting their oxidative metabolism worsening the energy crisis (Giza & Hovda, 2001). Calcium overloading has also been shown to lead to axonal swelling, disruption, and apoptosis (cell death). This excitatory phase, which has been likened to seizure activity as noted in the convulsive hypothesis, has been shown to last between a few minutes and up to four hours (Khurana & Kaye, 2012). This is followed by severe neuronal depression referred to as “spreading depression” typically lasting from one week to three months (Signoretti et al., 2011). This neuronal depression leads to increased vulnerability to a second concussion which can have far more devastating effects. Other secondary phenomena that occur include lipid peroxidation, mitochondrial swelling, and initiation of apoptotic processes (Webbe, 2006).

Symptomatology of Concussion

Given the fact that conventional structural neuroimaging (e.g., CT, MRI) typically contributes little to a concussion evaluation, diagnosis of a concussion typically depends on the symptoms experienced by the athlete during the acute phase of the concussion

(McCrory et al., 2013). It is also important to note that a concussive episode should be viewed as an evolving injury and symptoms may not occur immediately following the insult. It is for this reason that a player with a diagnosed concussion should not be allowed to return to play the same day of the injury (McCrory et al., 2013).

Symptoms during the acute stage of a concussion typically result in changes in one or more of the following four clinical domains: physical (e.g., headache, dizziness, nausea, balance issues); cognitive (e.g., impaired memory, attention, reaction time); behavioral (e.g., irritability, depression, anxiety), and/or sleep disturbance (e.g., insomnia, hypersomnia) (Faure, 2010; McCrory et al., 2013). Although these symptoms typically resolve in 7 – 10 days, approximately 15% of individuals experience persistent symptoms. One study demonstrated cognitive deficits in children and adolescent athletes lasting up to three years (Johnson, 2012). Among the factors that have been hypothesized to contribute to prolonged symptoms are pre-morbid conditions (e.g., migraines, depression, ADHD), gender (female), age (childhood and adolescence), previous concussions, and severity of symptoms (Ferullo & Green, 2010; McCrory et al., 2013).

Prolonged effects of concussion including lasting depression and neurocognitive impairment have also been observed in high school athletes who have incurred multiple concussions (Covassin, Moran, & Wilhelm, 2013; Kontos, Covassin, Elbin, & Parker, 2012; Moser et al., 2005). In fact, symptom-free athletes who had incurred three or more concussions had scores on cognitive tests similar to those athletes that had recently experienced a concussion (Moser et al., 2005). This implies that there may be lasting neuropsychological impairments for individuals who sustain multiple concussions. Furthermore, research has also demonstrated that individuals with a history of past concussions are six times more likely to incur another concussion (Zemper, 2003). These findings provide further evidence for the need of effective concussion management protocols to be in place for student-athletes. Insuring the proper care and attention is given following a concussive episode is essential to mitigating both immediate and long-term repercussions. Although the effects of multiple concussions over an extended period of time can have long-lasting effects, a second concussion occurring prior to the brain being given the chance to heal from a first concussion can be devastating.

Second Impact Syndrome

As recently as 2006, research concluded that concussions were a completely reversible neurological episode (Pellman & Viano). Continued research has proven this belief to be untrue, providing evidence that a concussive episode can have several serious and long lasting side effects. Among the most distressing consequences, and pertinent to the current study, second impact syndrome (SIS) is a somewhat controversial, rare, and often fatal mTBI; this is believed to occur when a second traumatic brain insult occurs before the brain is able to recover from the initial energetic crisis caused by the original concussion, resulting in rapid cerebral edema and herniation (Bowen, 2003; Weinstein, Turner, Feuer, & Kuzma, 2013). Essentially, the two concussions seem to have a cumulative effect. Following a concussive episode, the brain goes through an extremely vulnerable stage during which the metabolic imbalance incurred as a result of a first concussion has not resolved. Suffering a second concussion during this period can have catastrophic effects. Specifically, SIS is believed to occur in younger athletes (i.e., 20 years of age or younger) due to dysregulation in the brain’s blood supply and mitochondrial dysfunction (Bowen, 2003; Marshall, 2012). This dysregulation is believed to cause intracranial vascular engorgement leading to edema and the increase in cranial pressure that typifies SIS (Bowen, 2003). Animal research examining SIS has added to the fund of knowledge regarding this phenomenon by showing definitively that two or more concussive episodes which occur in close succession result in impairments that are significantly greater than a sum of singular blows would predict (Webbe, 2006).

SIS is most commonly seen in sports-related concussions because of the desire for athletes to return to the field of play. Unfortunately, this has led to multiple deaths and seems more likely to happen in younger, still developing brains (Khurana & Kaye, 2012; Marshall, 2012). The normally reversible energetic crisis occurring after the first concussion can become permanent if the brain is not allowed the time to heal. Since there is no way to measure accurately that time when the brain has fully recovered from the neurometabolic cascade of events seen in the brain of concussion victims, return-to-play protocols have become increasingly important to the ongoing safety of athletes. Equally as troubling as the immediate effects are the cumulative effects of multiple concussions most often seen in the athletes of contact sports.

Chronic Traumatic Encephalopathy

Chronic traumatic encephalopathy (CTE) is a neurodegenerative disease shown to affect motor functions, emotional regulation, social awareness, and cognitive functioning (Costanza et al., 2011). It is defined as an “accumulation of abnormal hyperphosphorylated tau (p-tau) in neurons and astroglia distributed around small blood vessels at the depths of cortical sulci and in an irregular pattern” (McKee et al., 2016). Originally known as dementia pugilistica, CTE was first identified by Harrison Stanford

Martland in 1928 to describe a specific constellation of neurologic symptoms that affected boxers (as cited in McKee et al., 2016, p. 76). Recent neuropathological studies have identified cases of CTE in athletes as results of participation in a variety of contact sports (i.e., football, soccer, ice hockey, rugby), as well as in military personnel exposed to explosive blasts (as cited in McKee et al., 2016, p. 76); the first case was identified in an American football player occurring as recently as 2005 (Omalu et al., 2005). Moreover, research has shown that a history of mTBIs is the only risk factor consistently associated with CTE (Maroon et al., 2015) and has identified contact sports as the greatest risk factor for CTE (Bieniek, 2015).

CTE can be definitively diagnosed only post-mortem and onset is insidious; the evolution of the disease is extremely rapid with only a two to three-year period between clinical onset and late manifestations (Costanza et al., 2011). MRI of brains from deceased individuals who had suffered multiple concussions showed common abnormalities. Among these were cortical atrophy, diffuse axonal injury, periventricular white matter disease, and hippocampal atrophy (Costanza et al., 2011). Microscopic examination has provided a further understanding of the sequelae of CTE. Among the most prominent features seen in the brains of deceased individuals who suffered from multiple traumatic brain injuries were neurofibrillary tangles (NFTs) and glial tangles (GTs) (Gavett, Stern, & McKee, 2011). CTE is referred to as a tauopathy because the main protein that NFTs are composed of is the protein tau (Gavett et al., 2011). Tauopathies are degenerative brain diseases caused by extra deposits of the protein tau in the brain. Other common tauopathies are frontotemporal dementia and Alzheimer’s disease. Beta-amyloid deposits and wide-spread TDP-43 proteinopathy have also recently been cited as characteristics of CTE (Gavett et al., 2011).

Although research has not supported a specific sequential evolution of the disease, CTE can manifest itself in a variety of ways. Early stages of CTE are normally characterized by affective disturbances (most commonly depression), lack of insight, outbursts of anger, and confusion. Psychotic features such as erratic behavior, social instability, and the initial features of Parkinson's disease present themselves as the disease progresses. General cognitive functions progressing to dementia, accompanied by speech and gait abnormalities, are seen in the later stages of the disease (McKee et al., 2009).

Assessment

As the evidence base begins to grow, and knowledge of the devastating effects of concussion increase among the public, the outcry for effective on-field assessment techniques has dramatically risen. Unfortunately, many of the current assessment tools utilized by on-field physicians rely, at least in part, on the self-reported symptoms of the concussed athlete. It has been borne out in studies that non-reporting of symptoms is commonplace among athletes because of their competitive drives to return to the game (Khurana & Kaye, 2012; Williamson & Goodman, 2006). As a result, more comprehensive sideline examinations such as the Sports Concussion Assessment Tool (SCAT3) or the Standardized Assessment of Concussion (SAC) are now the norm because they rely less on self-report measures (Khurana & Kaye, 2012). Specifically, the SCAT3, a brief neuropsychological assessment that assesses memory and attention, has proven both effective and practical (McCrory et al., 2013). In addition, a child version of the SCAT3 is available to assess for concussion in subjects aged 5-12 years (McCrory et al., 2013). It is believed that such assessments should be repeated 2-3 hours, 24 hours, 48 hours, and 72 hours following concussion because the appearance of symptoms may be delayed several hours following the concussive episode (McCrory et al., 2013; Khurana & Kaye, 2012). Furthermore, under no circumstances should a concussed individual be permitted to re-enter a contest on the same day of injury (Khurana & Kaye, 2012).

A comprehensive examination by a trained medical professional is required to make a formal concussion diagnosis. Given the multifarious symptomology of concussions, assessment should involve the evaluation of a wide range of domains. A determination regarding whether or not an individual is experiencing physical symptoms (e.g., headache, dizziness), cognitive impairment (e.g., slowed reaction times, memory impairment), sleep disturbance, emotional changes, and/or behavioral changes should be considered compulsory because these are the most common PCS. Additionally, an inquiry should be made in regard to actual physical signs (e.g., loss of consciousness, amnesia) that occurred during the moments immediately following the suspected concussion. Reported symptoms that fall into one or more of these domains would indicate a concussive episode (McCrory et al., 2013).

Baseline neurocognitive testing prior to participation in sports has also become a more common requirement in high school athletics. The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) is one of the most widely used computerized neurocognitive assessments in North America (Schatz & Sandel, 2012). The ImPACT battery was created with the specific intention of identifying concussion in athletes (Allen & Gfeller, 2011). The ImPACT takes approximately 20-25 minutes to administer and examines the attention, memory, processing speed, and reaction time of the test-taker. Also, included at the beginning of the assessment is a self-report symptom checklist and concussion history questionnaire (Allen & Gfeller, 2011). One study found the ImPACT able to identify accurately 82% of concussed high school athletes (Schatz, Pardini, Lovell, Collins, & Podell, 2006), demonstrating the reliability of the instrument. However, the reliability of any assessment is dependent on proper administration and interpretation by appropriately trained individuals. Unfortunately, Moser, Shatz, & Lichtenstein (2013) found that improper administration of baseline neurocognitive testing by untrained individuals is commonplace in many schools.

Concussion State Laws

Demonstrating the importance of reducing the impact of mTBIs among young athletes, all 50 states including Washington, DC have passed legislation with the intent of addressing the impact of mTBIs among young athletes. The final state to pass concussion legislation officially was Mississippi in January 2014 (Harvey, 2013; Concussion Laws by State, 2014). It is important to note, however, that the requirements set forth in each state's legislation have significant variability. In addition, although state legislation requires concussion management in high school sports, the onus for creating the protocol and educative materials to be utilized is placed on each high school, leading to significant differences in concussion management between and among school districts even in the same state. Furthermore, although most medical professionals require neurocognitive testing prior to an athlete receiving medical clearance to return to play, not one state law required baseline neurocognitive testing for student-athletes at the time of this study (Concussion Laws by State, 2014).

The galvanizing incident that heightened the awareness of mTBIs across the country occurred in 2006 when 13-year-old star high school football player, Zachary Lystedt, suffered a second concussion after being allowed to re-enter a game 15 minutes after a first concussion (Lueke, 2011). The result was a brain hemorrhage which required a decompressive craniectomy involving the removal of both sides of his cranium (Lueke, 2011). This incident prompted the family to lobby for a law that would prevent more children from suffering the same devastating consequences. In 2009, the state of Washington passed what is now referred to as the Zachary Lystedt Law in an effort to achieve this very goal. Recent statistics have reported nearly double the number of documented concussions in Seattle public high schools since the institution of this law (Bompadre et al., 2014), providing evidence of its success. Subsequent state laws included the same core elements seen in the Zachary Lystedt Law. The three core elements of this law included annual concussion education provided to athletes and parents, the mandatory removal from play for athletes suspected of having concussions, and clearance by an appropriate medical professional before the concussed athlete can return to play (Harvey, 2013). Although a majority of states have these elements written into their concussion legislation, the implementation and methods for disseminating concussion education are decided at a district level, leading to concussion management protocols varying widely. The term "appropriate medical professional" is also defined differently by each state. For instance, in Pennsylvania an appropriate medical professional can be a "licensed physician who is trained in the evaluation and management of concussions, a licensed certified health care professional trained in the evaluation and management of concussions and designated by such licensed physician" (The General Assembly of Pennsylvania, 2011) or a "licensed psychologist neuropsychologically trained in the evaluation and management of concussions or who has postdoctoral training in neuropsychology and specific training in the evaluation and management of concussions" (The General Assembly of Pennsylvania, 2011). A breakdown of state specific concussion legislation is provided in the Appendix section of this document (Table 8).

Return-to-Play Protocols

Proper management during the post-concussive phase is critical for decreasing the risk of long-term symptoms, reducing complications during the acute phase of recovery, and expediting recovery (Halstead & Walter, 2010; Waryasz, & Tambone, 2013). One of the most popular responses to the problem of concussion in youth sports has been the mandating of return-to-play protocols. The first such protocol, developed as part of the Lystedt Law, was adopted by the state of Washington following the injury of star high school football player, Zachary Lystedt. This law has served as a template for many of the states that have since mandated return-to-play guidelines in youth sports. Although this law states the need for clearance from a medical professional before returning to play, the guidelines which are utilized by medical professionals are many times created on an individualized basis (McCrory et al., 2013) due to the evolving nature of concussion recovery. Despite this, there is commonality in a majority of return-to-play protocols.

A basic template for return-to-play guidelines was created at the 4th International Conference on Concussion in Sport (McCrory et al., 2013), which emphasized the use of a graduated protocol requiring the concussed athlete to progress through a series of six steps (Appendix B). Initially, there is an expectation of limited physical activity and cognitive rest until all symptoms of the concussion have subsided for a full 24 hours. By gradually increasing activity in a stepwise fashion through each stage, and by increasing the activity level each day, the athlete could progress through the entire protocol within a week (McCrory et al., 2013). If any PCS occur during the process the athlete is expected to return to the previous step of the protocol in which he or she was asymptomatic until all PCS resolve for a full 24 hours and only then proceed to the next step (McCrory et al., 2013). Neuropsychological testing has also been identified as a helpful tool in the management of concussion (Halstead & Walter, 2010). It is important to note that due to a typically longer recovery period, to different physiological responses, and to specific risks associated with concussion during childhood and adolescence, a more conservative return-to-play approach is recommended (McCrory et al., 2013).

Return-to-School Protocols

Much less attention has been paid to the cognitive deficits seen following a concussive episode and to the effects these deficits can have on students returning to school following such an incident. Multiple studies have shown cognitive impairments following a concussive episode during the acute stage of injury, as well as prolonged effects for children and adolescents who incur multiple concussions (Covassin et al., 2013; Moser et al., 2005). Consequently, one of the suggestions from the 4th International Conference on Concussion in Sports was that schools should implement a concussion management team which monitors these very occurrences and ensures the proper modifications and accommodations are provided for the recently concussed athlete (McCrory et al., 2013). Unfortunately, this suggestion is not mandated by law, resulting in the limited practice and utilization of such a team. It is important to note, however, that many organizations have been working to create such a protocol to be utilized by schools across the country. One such example was created by Nationwide Children's Hospital and can be found at http://www.nationwidechildrens.org/academic-concussion-management.

Adherence to Concussion Protocols

Although much time and research has been spent developing return-to-play and return-to-school protocols, they are effective only when the student athlete demonstrates compliance. One study found that at least 40.5% of student-athletes returned to play prematurely following a concussive episode, failing to wait until they were asymptomatic (Yard & Comstock, 2009). Also interesting to note, significant differences were found in regard to gender; male athletes are almost twice as likely to be noncompliant in regard to return-to-play guidelines (Yard & Comstock, 2009). Given these alarming findings and the still developing brains of student-athletes, it is critical that coaches, parents, and medical professionals work together with the student-athlete to ensure adherence to protocols. Considering the fact that research involving other medical populations has identified increased education as a significant predictor of increased medical adherence (Javadpour, Hedayati, Dehbozorgi, & Azizi, 2013), one could hypothesize that this finding may be generalizable to the concussion population.

Research Linking Concussion Education and Concussion Reporting

One of the seminal studies investigating the incident rate of concussion in high school sports found that between the academic years of 1997-1998 and 2007-2008 concussion rates more than quadrupled (Lincoln et al., 2011). A greater in-depth examination of this trend reveals that the most substantial increases occurred during the 2004-2005 academic year which coincided with an increase in athletic trainer coverage in all of the locations being studied. The authors of this study also cited increased media coverage, new state laws, and treatment recommendations provided by a variety of sports governing bodies (e.g., National Collegiate Athletic Association, National Athletic Trainers' Association, National Federation of State High School Associations) during this time period as other possible reasons for the increased concussion rate (Lincoln et al., 2011).

One of the first studies to examine the phenomenon of unreported concussions surveyed 1,532 varsity football players from Milwaukee, Wisconsin (McCrea, et al, 2004). Players were administered an anonymous questionnaire in which they were asked to identify whether or not they had sustained a concussion during the prior season and whether or not they had reported these. Data obtained from this study revealed that over 50% of concussions went unreported. Participants were also required to give reasons why they had not, if they had decided not to report the concussion. Findings indicated that the most common reasons players failed to report concussion symptoms were that they did not think it was serious enough, they did not want to leave the game, they were unaware it was a concussion, and they did not want to let the team down (McCrea et al, 2004). Specifically, the reasons "did not think it was serious enough" and "unaware it was a concussion" provide credence that additional education regarding concussions may have reduced the incidence of non-reporting.

A more recent qualitative study conducted by Chrisman et al. (2013) attempted to identify the most influential factors related to concussive symptom reporting in high school athletics. This study examined football players, boys' soccer players, and girls' soccer players, requiring athletes from each sport to respond to four hypothetical scenarios. Findings from this study suggested that although student-athletes were aware of the dangers of a concussion, none would definitively stop playing due to a number of specific themes. The most common themes identified were a competitive drive to keep playing, ambiguity of symptoms, a belief that an athlete is supposed to play injured, not wanting to let the team down, and their coaches' attitudes toward concussion reporting (Chrisman et al., 2013). This evidence provides direction for the future of concussion prevention by implying that targeting these areas will decrease non-reporting of concussions, thus increasing the safety of high school athletics.

As referenced previously, there is also evidence that the institution of concussion legislation has led to an increase in concussion incidence. Hypothesized to be a result of increased awareness and closer monitoring, statistics showed that documented concussions more than doubled in Seattle high schools the two years following the passing of the Lystedt law in the state of Washington (Bompadre et al., 2014).

In summary, studies have continually pointed to the notion that expanded access to trained professionals and a greater awareness of concussion symptomology have led to an increase in concussion incidence. Furthermore, the attitudes of both coach and teammates seem to play an integral role in whether or not a student-athlete will report concussion symptoms. The importance of these factors is further supported and understood when considered through the lens of the Theory of Planned Behavior (Ajzen, 1991).

Theory of Planned Behavior

It is seemingly inexplicable that one would fail to report concussive symptoms in light of the dire consequences that can result from a subsequent mTBI prior to the brain healing from a first concussive episode. As true as this may be, the Theory of Planned Behavior does well to explain this occurrence (Ajzen, 1991). In short, this theory identifies attitudes, subjective norms, and perceived behavioral control as the three elements most influential to an individual's behaviors.

The Theory of Planned Behavior (Ajzen, 1991) attempts to identify factors that play a critical role in the decision making process of individuals. Essentially, the most influential predictor of a behavior is the intention to perform that behavior. Intent is operationalized as the cumulative effect of attitudes, subjective norms, and perceived behavioral control. As it pertains to the reporting of concussion symptoms, attitudes refer to the belief that an individual has regarding the consequences of a behavior (returning to play). Subjective norms refer to the belief an individual holds regarding what those others who are important to him/her expect (e.g., coach, parent, teammate). Perceived behavioral control refers to an individual's beliefs regarding his or her ability to perform a behavior (reporting concussion symptoms) (Chrisman et al., 2013; Register-Mihalik et al., 2013). A recent study found evidence that the factors identified by the Theory of

Planned Behavior (i.e., attitudes, subjective norms, perceived behavioral control) were factors that influence an individual's intention to report concussion symptoms (Register-Mihalik et al., 2013).

Regarding attitudes, education relating to concussion plays a critical role in the development of a proper respect and understanding of concussion. A lack of knowledge with regard to the possible consequences of sustaining a second concussion prior to healing from an initial concussion can be lethal (Khurana & Kaye, 2012). Further education on the symptoms and possible consequences of concussion could mitigate this risk; this is the reason why this study hypothesized that more comprehensive education provided to the student-athlete would lead to more concussion reporting.

The second factor as designated by the Theory of Planned behavior, subjective norms, pertains to the individuals that surround a student-athlete. Specifically, what do the coaches, parents, and teammates expect of the student-athlete? One study revealed that among the most troubling and influential beliefs held by the student-athlete is the idea that their coaches and teammates expect them to return to the game; that there is a perceived weakness of reporting a concussion and that having to be removed from competition displays fragility (Chrisman et al., 2013). The commonality of these beliefs offers further support about the importance of subjective norms in the decision making process concerning whether or not an athlete will report concussion symptoms.

The third aspect of the Theory of Planned Behavior that relates to reporting of concussion symptoms is perceived behavioral control, or an individual's belief about his or her own ability to perform a behavior (Chrisman et al., 2013; Register-Mihalik et al., 2013). In one study that examined this aspect, the question was asked: "Would you report concussive symptoms?" Most athletes stated that it depended on the coach and team (Chrisman et al., 2013), implying that the approachability of the coach directly affects whether or not the athlete feels comfortable reporting concussive symptoms.

Taken as a whole, these findings provide evidence that an individual's attitude toward reporting of concussive symptoms is significantly influenced by his or her knowledge base regarding the topic and also by the attitudes of teammates, coaches, and parents. To this end, one may conclude that the amount of concussion education required for all involved parties (e.g., coaches, teammates, parents, student-athletes) may play a critical role in creating a culture that encourages concussion reporting. It is the combination of theory and research that has led to these beliefs and to the hypotheses being tested through the current study.

Hypotheses

Through an examination of the concussion management protocols in high school athletic programs it was hypothesized that those schools which provide more extensive concussion education (determined by requisite amount of concussion education in minutes) to a wider range of involved individuals (e.g., coach, parent, student, athletic trainer) would result in higher reported incident rates of concussion. This belief was based on the Theory of Planned Behavior which describes the factors that impact an individual's choice of behavior, specifically, whether or not a high school athlete will report concussion symptoms. It is also important to note that although the typical statistic used to determine concussion rate is based upon the number of diagnosed concussions per AE, that statistic is better served with a prospective study. Because the current investigation is collecting data retrospectively, concussion rate was determined using the formula: number of reported concussions ÷ number of student-athletes. This variable was utilized in an effort to create a standardized measure to deal with the variability of school size in order to compare data obtained from schools of different sizes more effectively. All data collected for the current study were specific to the 2013-2014 school year. As such, the hypotheses being tested by the current investigation are as follows:

Hypothesis I. More extensive, required concussion education to the student-athlete (measured by requisite amount of education in minutes) will be positively correlated with the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) as measured by data obtained via online survey (Appendix A).

Hypothesis II. More extensive, required concussion education to all other participants (measured by cumulative requisite time of education to coach, parent, and athletic trainer in minutes) will be positively correlated with the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) as measured by data obtained via online survey (Appendix A).

Hypothesis III. Schools which require baseline neurocognitive testing (e.g., ImPACT test) prior to participation in high school sports will have a significantly higher average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) when compared with schools that do not require neurocognitive baseline testing.

Hypothesis IV. The number of required participants mandated to receive concussion education according to a school concussion management protocol will positively correlate with the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) as measured by data obtained via online survey (Appendix A). Specifically, schools that require more members to receive concussion education (e.g., coach, trainer, parent, student-athlete) will report a significantly higher number of diagnosed concussions when compared with high schools that require fewer individuals to receive education (e.g., coach, trainer, athlete; coach, parent, athlete; coach, athlete).

Hypothesis V. Total amount of education to all participants in minutes (student-athlete, coach, parent, athletic trainer), number of required participants in training, the utilization of baseline neurocognitive testing, the number of years that concussion legislation has been in place, and the presence of a certified athletic trainer will significantly predict the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) in high school athletics.

Chapter 3: Method

Overview

Approval was obtained through PCOM's Institutional Review Board prior to the initiation of any study-related procedures. To determine the impact that prior concussion education has on the reporting of concussion symptoms in high school athletics, high school superintendents were asked to complete an online survey (Appendix A) which provided quantitative data about the number of student-athletes, number of diagnosed concussions, and information regarding concussion education programs in place.

The central research question was:

- Does a more thorough concussion education program, as determined by amount of time required in minutes, lead to a higher average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes)?

Secondary research questions for this study were:

- Does baseline neurocognitive testing (e.g., ImPACT) prior to participation in high school athletics lead to a higher average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes)?
- Does the number of involved members in concussion education influence the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes)?

- Does the amount of required education, the number of required participants in training, the utilization of baseline neurocognitive testing, the number of years that concussion legislation has been in place, and the presence of a certified athletic trainer significantly predict average concussion rate per student-athlete (number of diagnosed concussions ÷ number of student-athletes) in high school athletics?

Study Design and Justification

The current study utilized a retrospective cross-sectional survey design to examine the impact that the amount of concussion education, and the number of individuals that were required to receive concussion education, had on the average rate of concussion diagnoses per student-athlete in high school athletics during the 2013-2014 school year across the United States of America. High school superintendents from across the country completed a 20 question online survey via Survey Monkey (Appendix A) providing information as it relates to diagnosed concussions and concussion management protocols in place. Specifically, in attempting to determine the effect that concussion education has on the reporting of concussion symptoms, this study utilized a survey which requested data from the previous school year, making a retrospective cross-sectional survey design a logical choice.

Participants

Superintendents from across the country were provided with a 20 question online survey (Appendix A) via Survey Monkey. Inclusion criteria required in order for a response to be included in the data being analyzed were as follows. First, the high school needed to be of the public variety and located in one of the 50 United States or Washington, DC. Data from private and charter schools were excluded from the current study because many of those schools do not fall under state concussion legislation (Concussion laws by state, 2014). Furthermore, the high schools included in the study comprised only grades 9-12. Consequently, the age range of student-athletes being examined ranged from 13-19.

Second, certain athletics needed to be offered to ensure that the statistics being compared include the sports in which concussion incidents are most prevalent, as well as to provide an equal number of sports for each gender. Sports that were required to be offered at a high school in order for its data to be included in the study were football, male soccer, female soccer, male basketball, female basketball, female lacrosse, wrestling, and softball. These sports were specifically chosen because they have been shown to be the four sports with the highest incident rate with each gender (Marar, et al., 2012).

Finally, although not considered a criterion for exclusion, data were collected to determine which schools currently employ an athletic trainer. This is an important factor because one study found that 94.4% of concussions were assessed by an athletic trainer (Meehan, d’Hemecourt, Collins, & Comstock, 2011), demonstrating their importance in concussion management. Unfortunately, one study reported that only 42% of American schools employ a certified athletic trainer (Chrisman et al. 2013).

Measures

A 20 question survey was constructed by the investigator to examine the current concussion management protocols utilized across the country in high school athletic programs (Appendix A). The questions from the survey required short, constructed responses, demographic information, and yes-no answers. Data were obtained anonymously through an online survey via Survey Monkey.

Procedure

To examine these variables, this study surveyed superintendents across the country (Appendix A). A list of superintendents and their contact information were obtained online via school/district websites. To determine the required number of participants necessary to achieve significant results, a power analysis was conducted. Two separate recruitment methods were utilized in an attempt to obtain the number of participants necessary to achieve statistically significant results.

First, the names of public high schools were obtained from the Department of Education website for each state. Each high school was arranged in alphabetical order and assigned a number. Twenty schools from each state, as well as Washington, D.C., were selected randomly using random.org's random integer generator. An email (Appendix C) with a link to the survey was then sent to the superintendent of each of the randomly chosen schools. The email contained an invitation to participate, explanation of the study, and approximate time requirement (15 – 20 minutes). Additionally, a statement regarding consent procedures was included. This inclusion stated that by completing the survey they were consenting to the utilization of the information provided, that their responses would remain anonymous and confidential, and that their participation was voluntary. Finally, participants were provided with the email address of the principal investigator if they wanted a copy of the results or if they had any questions relating to the survey. With the inclusion of all 50 states, as well as Washington, D.C., a total of 986 emails were sent during the initial recruitment process because there were only two high school superintendents found in Washington, D.C., 15 in Hawaii, and 11 in Arizona. All responses were reviewed by the investigator to ensure that there were no duplicate responses. Also, a disclaimer was placed at the bottom of the email sent as a secondary safety measure to guard against multiple submissions from the same school. Finally, contained in the email was a statement regarding superintendents who may oversee more than one high school, requesting that they fill out the survey for each individual high school rather than a composite of all the high schools they oversee. To increase response rate, the email also requested that the superintendent forward the survey link to any other superintendents that he or she believed may be willing to participate. Because the required number of participants (n = 109) was not recruited initially, subsequent emails were sent twice more, following the same procedure, with a total of 2,958 emails sent in all.

The second recruitment method utilized the snowball method. Specifically, personally known superintendents from the state of New Jersey were recruited and asked to recruit fellow superintendents to fill out the survey for the proposed survey. This method was utilized in an attempt to increase response rate.

Data obtained were analyzed to determine if there is a correlation between education and average rate of concussion diagnosis per student-athlete while concurrently determining if the current protocols in place are effective. Specifically, the number of concussions diagnosed was divided by the number of total student-athletes on a per school basis. This was performed to provide an average number of concussions per student-athlete for each school. This variable was utilized in an effort to create a standardized measure to deal with the variability of school size, in order to compare more effectively, the data obtained from schools of different sizes. Subsequently, these data were compared with the amount of concussion education provided to the student-athlete individually, as well as to all participants as a whole (time requirement in minutes) to determine if lack of concussion education is a possible risk factor for non-reporting of concussion symptoms.

Data related to the administration of baseline neurocognitive testing and incident rate of concussion were also analyzed. Rates of concussion incidence were compared between schools to determine if baseline neurocognitive testing would result in a higher average incidence rate of concussion per student-athlete in high school athletics. Data related to the employment of an athletic trainer and incident rate of concussion were also analyzed. Rates of concussion incidence were compared between schools to determine if employment of an athletic trainer would result in a higher average incidence rate of concussion per student-athlete in high school athletics.

Finally, a regression model was utilized to determine if the total amount of education provided to all parties, the number of required participants in training, the utilization of baseline neurocognitive testing, the number of years that concussion legislation has been in place, and the presence of a certified athletic trainer significantly predicted average concussion rate per student-athlete in high school athletics.

Data relative to amount of concussion education, the number of required participants in concussion training, the utilization of baseline cognitive testing, the presence of a certified athletic trainer, and the average number of concussions per student-athlete (number of reported concussions ÷ number of student-athletes) were obtained via survey results from Survey Monkey. The number of years in which state concussion legislation has been in place was obtained via http://www.edweek.org/ew/section/infographics/37concussion_map.html and links to the actual legislative document for each state was provided on http://www.edweek.org/ew/section/infographics/37concussion_map.html.

Statistical Analysis

An a priori power analysis was conducted to determine the number of participants necessary for any statistically significant findings to be interpreted with confidence. The power analysis was conducted for all three statistical analyses being utilized by the current study (Pearson correlation, point-biserial correlation, and multiple linear regression) and the highest number of participants necessary was chosen ($n=109$), with a medium effect size ($\rho = 0.3$), an alpha level set at 0.05, and a power of 0.80. Several statistical tests were conducted to test the stated hypotheses. Four correlational tests were performed to test hypotheses one (Pearson), two (Pearson), three (Point-biserial), and four (Pearson), based on the type of variables being compared. A multiple linear regression analysis was conducted to determine if these variables not only had a relationship with average number of concussions per student-athlete (number of reported concussions ÷ number of student-athletes) but also to ascertain if they had some predictive quality relating to average number of concussions per student-athlete.

According to Kazdin (2003) a Bonferroni adjustment must be made to the alpha level to reduce the possibility of a Type I error when a number of comparisons are made on the same set of data. This analysis involved conducting 3 tests on the same data; one regression and two correlations (Pearson). Simply put, the Bonferroni adjustment is determined by dividing alpha ($\alpha = .05$) by the number of comparisons ($n=3$). Therefore, the alpha level for each test will be set at $\alpha = 0.0167$. All statistics were calculated through the use of the Statistical Package for the Social Sciences (SPSS) Version 22.

Hypothesis I. The amount of required concussion education to the student-athlete (measured by total amount of education in minutes) will be positively correlated with the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) as measured by data obtained via online survey (Appendix A). To test this hypothesis a Pearson correlation (r) was conducted to measure the degree and direction of linear relationship between these two variables.

When conducting a correlation, certain assumptions must be tested to assure any result is valid. Specifically, the variables being examined must have a linear relationship. A second assumption that must be met is homoscedasticity, or that the variance of the dependent variable is the same for all levels of the predictor. To test these assumptions a scatter plot was created using SPSS and was visually examined to ensure a linear relationship and homoscedasticity.

Hypothesis II. The amount of required concussion education to all other participants (measured by cumulative time of education to coach, parent, and athletic trainer in minutes) will be positively correlated with the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) as measured by data obtained via online survey (Appendix A). To test this hypothesis a Pearson correlation (*r*) was conducted to measure the degree and direction of linear relationship between these two variables.

Hypothesis III. Schools which require baseline neurocognitive testing (e.g., ImPACT test) prior to participation in high school sports will have a significantly higher average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) when compared with schools who do not require neurocognitive baseline testing. To test this hypothesis a point-biserial correlation was conducted because one of the variables is dichotomous (required baseline neurocognitive testing vs. not required baseline neurocognitive testing).

Hypothesis IV. The number of required participants mandated to receive concussion education according to a school concussion management protocol will positively correlate with the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) as measured by data obtained via online survey (Appendix A). Specifically, schools that require more members to receive concussion education (e.g., coach, trainer, parent, student-athlete) will evidence a higher average number of diagnosed concussions per student-athlete when compared with high schools that require fewer individuals to receive education. To test this hypothesis a Pearson correlation (*r*) was conducted to measure the degree and direction of linear relationship between these two variables.

Hypothesis V. Total amount of education to all the participants in minutes (student-athlete, coach, parent, athletic trainer), the number of required participants in training, the utilization of baseline cognitive testing, the number of years that concussion legislation has been in place, and the presence of a certified athletic trainer will significantly predict the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) in high school athletics. To test this hypothesis a multiple linear regression was conducted.

When conducting a multiple linear regression, certain assumptions must be tested to assure that any result is valid. For this test, non-collinearity is assumed among the predictor variables (Lomax & Hahs-Vaughn, 2012). To assure that this is true, a Pearson product-moment correlation coefficient was calculated to determine if there was any multicollinearity between the predictor variables, ($r \geq 0.8$); and collinearity diagnostics were performed. Independence of errors must also be assumed when running a multiple regression analysis. According to Field (2009) the Durbin-Watson statistic is used to test for the existence of serial correlations between errors in regression. This therefore evaluates whether or not there is a correlation between adjacent residuals, thereby allowing for a test of the assumption of independence errors. Durbin-Watson statistics that are less than 1 or greater than 3 are indicators of potential problems in this regard. A third assumption that must be met is homoscedasticity, or that the variance of the dependent variable is similar across the levels of the predictors. To test this assumption a scatter plot was created using SPSS and was visually examined to ensure homoscedasticity.

Chapter 4: Results

Participants

To examine the relationship between concussion education and the accurate reporting of concussions in high school athletes, a group of volunteer participants were collected by sending out a survey via email, utilizing a Survey Monkey internet hyperlink to randomly selected school administrators across the United States. Additionally, members were recruited using a snowball recruitment method in the state of New Jersey. The initial participant "seeds" for the snowball collection method were personally known school administrators across the state of New Jersey. The survey was open for seven months and during that time period 2,958 emails were sent, requesting participation. At the closing of the survey it was found that 232 individuals had opened the survey link. Of the 232 respondents, 138 did not meet inclusion criteria (i.e., was not a high school; did not offer the required sports), and 22 did not complete the survey or had omitted items. The data for these 160 participants were omitted from the data analysis because of missing data and because of not meeting inclusion criteria, thus leaving 72 individuals who completed the survey and met inclusion criteria.

A demographic breakdown of the states in which the 72 individuals who completed the survey resided are shown in Table 1.

Table 1

Breakdown of survey responses by state meeting inclusion criteria

State	**%**	**n**
Alabama	1.4%	1
Arizona	4.2%	3
Arkansas	1.4%	1
California	15.3%	11
Connecticut	4.2%	3
Florida	1.4%	1
Georgia	6.9%	5
Illinois	1.4%	1
Indiana	1.4%	1
Maine	5.6%	4
Massachusetts	12.5%	1
Missouri	4.2%	3
Nevada	1.4%	1
New Jersey	11.1%	8
New Mexico	2.8%	2
North Carolina	9.7%	7
Oregon	1.4%	1
Texas	4.2%	3
Utah	1.4%	1
Washington	1.4%	1
West Virginia	1.4%	1
Wisconsin	4.2%	3
Wyoming	1.4%	1
Total= (*N*= 72)		

The range in the number of student-athletes at each of the schools represented in the study was 100-3500 total student-athletes, with the mean being 768 student-athletes. The total number of diagnosed concussions during the 2013-2014 school year at each school ranged from 0-69, with a mean of 16.97 diagnosed concussions. The average number of concussions per student-athlete ranged from 0-0.18 with a mean of 0.03. Although this does imply that one could estimate approximately 3 concussions per 100 student-athletes, it is important to note that this statistic could not account for multiple concussions incurred by the same athlete. The amount of concussion education provided was as follows: student-athlete (range = 0-60 minutes; mean = 17.91 minutes), coach (range = 0-360 minutes; mean = 49.53 minutes), athletic trainer (range = 0-600 minutes; mean = 71.53 minutes), parents (range = 0-60 minutes; mean = 9.78 minutes). The total time of concussion education to all participants (i.e., student-athlete, coach, athletic trainer, parent) ranged from 0 – 670 minutes, with a mean of 143.37 minutes. Of the schools that responded, 81.9% reported that they do employ an athletic trainer. Among the schools that responded, 63.9% reported that they required their student-athletes to take baseline neurocognitive testing prior to participating in a sport. Furthermore, 66.7% of student-athletes, 94.4% of coaches, 52.8% of athletic trainers, and 48.6% of parents were required to receive concussion education in some form among the schools that responded. Among those individuals that did receive concussion education, 40.3% were required to take an assessment to ensure that they retained that information. Although the data showed that 94% of schools that responded had a return-to-play protocol in place, only 55.6% had a protocol in place in regard to academic accommodations or a return-to-school protocol following a concussion. Finally, the number of years that concussion legislation has been in place in the states of each of the responding schools ranged from 2-6 years with the mean being 2.83 years.

Participation in the study was on a voluntary basis and all participants remained anonymous. The only identifying information obtained was the aforementioned demographic data.

Hypothesis I

A Pearson product-moment correlation coefficient was computed to assess the relationship between the total amount of education provided to the student-athlete and the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes). No correlation was found between the variables, r (70) = .067, p < .287, thus the null hypothesis was accepted.

Hypothesis II

A Pearson product-moment correlation coefficient was computed to assess the relationship between amount of required concussion education to all other participants (measured by cumulative amount of education to coach, parent, and athletic trainer in minutes) and the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes). No correlation was found between the variables, r (70) = .089, p < .228, thus the null hypothesis was accepted.

Hypothesis III

A point-biserial correlation coefficient was computed to assess the relationship between average concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) and whether or not a school required baseline neurocognitive testing prior to beginning a high school sport. No correlation was found between the variables, r (70) = .056, p < .321, thus the null hypothesis was accepted.

Hypothesis IV

A Pearson product-moment correlation coefficient was computed to assess the relationship between number of participants required to receive concussion education (e.g., coach, parent, student-athlete, and athletic trainer) and the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes). No correlation was found between the variables, r (70) = .151, p < .103, thus the null hypothesis was accepted.

Hypothesis V

A linear multiple regression analysis was conducted. Three cases identified as outliers were removed for this analysis. The ENTER method was employed, using total number of education to all participants in minutes, the number of years that concussion legislation has been in place, the utilization of baseline neurocognitive testing coded (1 = Yes, 2 = No), the presence of a certified athletic trainer coded (1 = Yes, 2 = No), and required number of participants in training as the predictor variables, with average number of concussions per student-athlete as the dependent variable. The ENTER method was used because the predictors were entered simultaneously and not in any particular order. The multiple correlation, R, was .429 with an R square of .184. This would suggest that about 18% of the variability in average number of concussions per student-athlete is attributable to the combination of the predictor variables. The adjusted R square is .119, suggesting that if this study was conducted on the population there would be some shrinkage (.184 - .119) in the amount of variance explained by the regression equation. The R square change is significant F (5, 63) = 2.838, p < .023. The

Durbin-Watson statistic is 2.005. According to Field (2009) Durbin-Watson is “a test for serial correlations between errors in regression models. Specifically, it tests whether adjacent residuals are correlated which is useful in assessing the assumption of independent errors… as a very conservative rule of thumb values less than one or greater three are definitely cause for concern...” The Durbin-Watson statistic suggests that the adjacent residuals are not correlated, indicating that the assumption of independent errors has been met. This is shown in Table 2.

Table 2

Regression model summary for the independent variables and average number of diagnosed concussions per student athlete (N = 69)

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate	R Square change	Durbin-Watson
1	.429	.184	.119	.02271550	.184	2.005

In Table 3 the overall regression equation is significant as shown by a significant F (5, 63) = 2.838, p < .023.

Table 3

ANOVA for the independent variables and average number of diagnosed concussions per student athlete (N = 69)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.007	5	.001	2.838	.023
Residual	.033	63	.001		
Total	.040	68			

As shown in Table 4, the t-tests of the regression coefficients reveal that one of the predictor variables makes a significant contribution to the prediction of number of concussions per student-athlete which is the number of years that concussion legislation has been in place. This is a positive correlation suggesting that as the number of years that concussion legislation has been in place increases so does the average number of concussions per student-athlete. Tolerance statistics measure multicollinearity and Tolerance is the reciprocal of the Variance Inflation Factor (1/VIF). Tolerance variables below .1 indicate serious problems and there is no evidence based on Tolerance statistics that multicollinearity is a problem. Similarly, the VIF indicates whether or not a predictor has a strong relationship with the other predictors. The average VIF is about 1.2; overall it appears that multicollinearity is not a problem. The distribution is normally distributed and the PP plot suggests there is no evidence of heteroscedasticity. It appears that the assumptions of regression have been met. These results suggest that the number of years that concussion legislation has been in place is a significant predictor of the average number concussions per student-athlete.

Table 4

Multiple regression analysis summary for the independent variables and average number of diagnosed concussions per student athlete (N = 69)

Variable	B	SEB	B	T	p
Constant	-.011	.019		-.575	.567
total number of educational hours to all participants (student-athlete, coach, parent, athletic trainer)	2.719E-5	.000	.156	1.208	.231
number of required participants in training	.003	.003	.164	1.218	.228
utilization of baseline neurocognitive testing	-.001	.006	-.030	-.243	.808
number of years that concussion legislation has been in place	.007	.003	.283	2.431	.018*
presence of a certified athletic trainer	.000	.008	-.002	-.014	.989

**p<.05*

Additional Analysis

Additional statistical analyses were conducted to further explore possible relationships among the variables examined in the current study. Multiple Pearson product-moment correlation coefficients were computed utilizing total concussions diagnosed during the 2013-2014 school year, rather than average number of concussions per student-athlete. This decision was made, based on the belief that the investigator-created variable (total concussions diagnosed ÷ number of student-athletes) had a restricted range and therefore would reveal only significant findings with a larger *n* due to the possibility of having a small effect size. Given the fact that past studies have found significant results relating to many of the variables being examined, a decision was made to utilize raw data in terms of total concussions as a dependent variable. These analyses resulted in statistically significant relationships being found between the total number of concussions and concussion education to all other participants (measured by cumulative time of education to coach, parent, and athletic trainer in minutes), r (70) = .210, $p <$ .038; total number of concussions and number of required participants in training, r (70) = .326, $p < .003$; total number of concussions and the number of years that concussion legislation has been in place, r (70) = .300, $p < .005$; total number of concussions and whether or not a school requires baseline neurocognitive testing prior to beginning a sport, r (70) = .258, $p < .014$; total number of concussions and whether or not a school employs an athletic trainer, r (70) = .355, $p < .002$, and total number of concussions and total education provided to all participants in minutes (i.e., student-athlete, coach, parent, athletic trainer), r (70) = .217, $p < .033$.

Subsequently, a multiple linear regression analysis was conducted. Three cases identified as outliers were removed for this analysis. The ENTER method was employed using the total amount of education to all participants in minutes, the number of years that concussion legislation has been a place, the utilization of baseline neurocognitive testing coded (1 = Yes, 2 = No), the presence of a certified athletic trainer coded (1 = Yes, 2 = No), and the required number of participants in training as the predictor variables with total concussions diagnosed at schools during 2013-2014 school year as the dependent variable. The ENTER method was used, meaning that predictors were entered simultaneously and not in any particular order. The multiple correlation, R, was .568 with an R square of .322 meaning that 32% of the variability in total concussions diagnosed at the school was attributable to the combination of the predictors. The adjusted R square is a value that indicates what the explained variance would be had the population been used instead of using a sample. There appears to be some shrinkage in predictability (.322-.269) in this instance meaning that the proportion of variability being accounted for is about 27%. The R square change that was .322 is significant F (5, 63) = 5.993, P <.001. The Durbin-Watson statistic was 1.910. According to Field (2009) Durbin-Watson is “a test for serial correlations between errors in regression models. Specifically, it tests whether adjacent residuals are correlated which is useful in assessing the assumption of independent errors… as a very conservative rule of thumb values less than one or greater three are definitely cause for concern...” The Durbin-Watson suggests that the adjacent residuals are not correlated, indicating that the assumption of independent errors has been met. This is shown in Table 5.

Table 5

Regression model summary for the independent variables and total diagnosed concussions during 2013-2014 school year (N = 69)

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate	R Square change	Durbin-Watson
1	.568	.322	.269	9.538	.322	1.910

In Table 6 the overall regression equation is significant as shown by a significant F (5, 63) = 5.993, p < .001.

Table 6

ANOVA for the independent variables and total diagnosed concussions during 2013-2014 school year (N = 69)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	2725.889	5	545.180	5.993	.000
Residual	5731.173	63	90.971		
Total	8457.072	68			

As shown in Table 7, the t-tests of the regression coefficients reveal that one of the predictor variables makes a significant contribution to the prediction of total number of concussions diagnosed, which is number of years that concussion legislation has been in place. This is a positive correlation suggesting that as the number of years that concussion legislation has been in place increases so does the total number of concussions diagnosed. The Tolerance statistics and the VIF suggest that multicollinearity is not a problem. The distribution is normally distributed and the PP plot suggests there is no evidence of heteroscedasticity. The results suggest that the number of years concussion legislation has been in place is a significant predictor of the total number concussions diagnosed at the school during the 2013-2014 school year.

Table 7

Multiple regression analysis summary for the independent variables and total diagnosed concussions during 2013-2014 school year (N = 69)

Variable	B	SEB	β	T	p
Constant	7.641	8.028		.952	.345
total number of educational hours to all participants (student-athlete, coach, parent, athletic trainer)	.014	.009	.181	1.523	.133
number of required participants in training	1.759	1.090	.199	1.614	.112
utilization of baseline cognitive testing	-3.744	2.547	-.163	-1.470	.147
number of years concussion legislation has been in place	2.688	1.236	.230	2.174	.033*
presence of a certified athletic trainer	-4.418	3.302	-.156	-1.338	.186

$p<.05$

Chapter 5: Discussion

The responses from a total of 72 surveys were determined to be eligible for inclusion in the current study. Based upon demographic information obtained from the surveys, notable findings were obtained. First, of the schools that responded, 81.9% reported that they do employ an athletic trainer. This is a significant finding because prior research has shown that only 42% of American schools employ a certified athletic trainer (Chrisman et al. 2013) and the fact that there is a trainer in place may indicate a higher likelihood to respond to the current survey. Additionally, among the schools that responded, 63.9% reported that they required their student-athletes to take baseline neurocognitive testing prior to participating in a sport. Given the fact that no state law required schools to do so at the time of the study, this finding is important and noteworthy and shows a proactive approach by the participating districts. Finally, the data showed that 94% of schools that responded had a return-to-play protocol in place; however, only 55.6% had a protocol in place in regard to academic accommodations or a return-to-school protocol following a concussion. Given the fact that cognitive and physical rest have been identified as the most critical aspects to decrease the risk for complications and lengthier recovery times in concussion patients (Waryasz, & Tambone, 2013), this finding illustrates the need for further awareness and implementation of return-to-school protocols in high schools.

Concussion Education to the Student-Athlete

It was hypothesized that a relationship would be found between the amount of concussion education provided to the student-athlete and the average number of diagnosed concussions per student-athlete. This hypothesis was not supported during statistical analysis. This finding is not entirely surprising because recent research has found that education alone does little to mitigate non-reporting of concussion symptoms (Kroshus, Baugh, Hawrilenko, & Daneshvar, 2015; Kurowski, Pomerantz, Schaiper, Ho, & Gittelman, 2015). This study examined individuals from multiple sports, but findings have shown a discrepancy in the concussion management of student-athletes playing football as compared with other sports (i.e., boys and girls soccer) (Esquivel, Haque, Keating, Marsh, & Lemos, 2013); therefore, it may have been more prudent to examine specific sports, rather than a variety of sports.

Additionally, many of the high schools that completed the survey provided concussion education in the form of a document rather than in the form of a didactic presentation putting into question the quality of the concussion education provided. It is also important to note that only 40.3% of those that received education were required to take an assessment to ensure that they retained that information. The use of the investigator-created variable (total concussions diagnosed ÷ number of student-athletes) may have also contributed to the lack of findings because it had a restricted range and therefore would likely reveal only significant findings with a larger *n* due to the expectation of a small effect size. These factors, along with the low response rate and a lack of the optimal number of participants may have contributed to the lack of a significant finding.

Concussion Education to Coach, Parent, and Athletic Trainer

It was also hypothesized that there would be a relationship between the required amount of concussion education to all other participants (measured by cumulative time of education to coach, parent, and athletic trainer in minutes) and the average number of diagnosed concussions per student-athlete. Again, this hypothesis was not supported during statistical analysis. This finding was more surprising because research has linked social supports, and pressure from these supports, as important factors when examining the accurate reporting of concussion symptoms (Register-Mihalik et al., 2013). Additionally, one study found favorable changes in the attitudes and prevention/management practices of concussions in coaches subsequent to being provided with extensive concussion education (Sarmiento, 2010). As discussed in the previous hypothesis, it is likely that the quality of education provided, the restricted range of the investigator-created dependent variable, and the low response rate were contributing factors to the absence of statistically significant results.

Baseline Neurocognitive Testing

It was hypothesized that a relationship would be found between the average number of diagnosed concussions per student-athlete reported (number of diagnosed concussions ÷ number of student-athletes) and whether or not a school requires baseline neurocognitive testing prior to beginning a high school sport. Again, this hypothesis was not supported by statistical analysis. This finding was unanticipated, given the probability that one would expect there to be a relationship between average number of concussions and baseline neurocognitive testing if it were an effective practice. In addition to the previously described limitations, improper administration of baseline neurocognitive testing by untrained individuals is a regular practice in many schools (Moser, Schatz, & Lichtenstein, 2013) and is not something that could be assessed through the current survey. It is certainly possible that improper administration and interpretation of baseline neurocognitive testing contributed to the absence of significant findings.

Number of Participants Receiving Concussion Education

It was also posited that the number of required participants mandated to receive concussion education according to a school concussion management protocol would positively correlate with the average number of diagnosed concussions per student-athlete. Again, this hypothesis was not supported during statistical analysis. Given the fact that research has provided evidence that the culture of a sports program and social supports of a student-athlete are such important factors in the accurate reporting of concussion symptoms (Kroshus, Garnett, Hawrilenko, Baugh, & Calzo, 2015), it was unexpected that there was no relationship found among these variables. As previously mentioned, low response rate, the restricted range of the investigator-created dependent variable, and quality of education provided may have contributed to the lack of a significant finding.

Predictive Variables of Concussions

Finally, it was hypothesized that the total amount of education in minutes provided to all participants (student-athlete, coach, parent, athletic trainer), the number of required participants in training, the utilization of baseline neurocognitive testing, the number of years that concussion legislation has been in place, and the presence of a certified athletic trainer would predict, significantly, the average number of diagnosed concussions per student-athlete (number of diagnosed concussions ÷ number of student-athletes) in high school athletics. The statistical analysis did support this hypothesis. Specifically, 18% of the variability in the average number of concussions per student-athlete was attributable to the combination of the predictors, with the number of years that concussion legislation has been in place being identified as the lone significant predictor variable. This is a positive correlation suggesting that as the number of years that concussion legislation has been in place increases, so does the average number of concussions per student-athlete. This finding was consistent with the findings from past research (Bompadre et al., 2014). Given the fact that prior research has pointed to many of the other predictor variables as integral factors in the accurate reporting of concussions (Moser et al., 2013; Kroshus et al., 2015; Register-Mihalik et al., 2013), it is believed that the quality of education, the restricted range of the investigator-created dependent variable, and low response rate may have contributed to those variables not reaching significance.

Additional Analysis

Additional statistical analysis revealed multiple positive correlations. Rather than using the average number of concussions per student-athlete, total concussions diagnosed during the 2013-2014 school year was examined as the dependent variable. This decision was made, based on the belief that the investigator-created variable (total concussions diagnosed ÷ number of student-athletes) had a restricted range and therefore would reveal only significant findings with a larger *n*, due possibly to a small effect size. Given the fact that past studies have found significant results relating to many of the variables being examined, a decision was made to utilize raw data in terms of total concussions as a dependent variable.

Specifically, a positive correlation was found between the total number of concussions diagnosed and the concussion education provided to all other participants (measured by cumulative amount of concussion education in minutes to coach, parent, and athletic trainer), indicating that as one increases the amount of education to all other participants, one should also expect an increase in total number of concussions diagnosed. A positive correlation was also found between the total number of concussions diagnosed and the number of required participants in training, indicating that as the numbers of individuals required to receive concussion education increases, so too will the number of concussions diagnosed. A positive correlation was also found between the total number of concussions diagnosed and the number of years that concussion legislation has been in place, indicating that as the number of years that concussion legislation is in place increases, so too will the total number of diagnosed concussions.

Another positive correlation was found between the total number of concussions diagnosed and, whether or not a school requires baseline neurocognitive testing prior to beginning a sport, indicating that schools which required baseline neurocognitive testing will have a significantly greater number of total diagnosed concussions than those schools that do not require baseline neurocognitive testing. A positive correlation was found between total number of concussions diagnosed and whether or not a school employs an athletic trainer, indicating that those schools which employ an athletic trainer will have a significantly higher total number of concussions diagnosed. Total number of concussions diagnosed and total education provided to all participants in minutes (student-athlete, coach, parent, athletic trainer) also revealed a positive correlation indicating that as one increases the total amount of education to all participants, one should also expect an increase in total number of concussions diagnosed.

Taken together, these findings imply that the assumptions which the initial hypotheses were based upon hold some merit and provides further evidence that the use of the investigator-created variable, the average number of concussion per student-athlete (number of concussions ÷ number of student-athletes), as the dependent variable may have been a contributing factor in the lack of significant findings with regard to the original hypotheses. Given this belief, it may be prudent to conduct a similar study in the future utilizing total concussions as the dependent variable in an effort to explore, further, the relationship between non-reporting of concussions and education.

Furthermore, it was determined through statistical analysis that the variability in total concussions diagnosed at the schools was attributable to the following combination of predictor variables: whether or not an athletic trainer was employed, whether or not baseline neurocognitive testing was required, the total amount of education provided to participants, total number of years that concussion legislation has been in place, and the number of required participants in training. Specifically, number of years that concussion legislation was in place was identified as a significant predictor of the total number of concussions diagnosed. This was a positive correlation indicating that as the number of years that concussion legislation is in place increases so does the total number of concussions reported. This finding was consistent with the findings from past research (Bompadre et al., 2014).

Summary

Based on the statistical analyses conducted for this study, it appears that a relationship exists between the average number of concussions per student-athlete and only one of the variables from the original hypotheses. Specifically, a positive correlation was found between the number of years that concussion legislation has been in place and the average number of concussions per student-athlete, indicating that as the number of years that legislation is in place increases, so too will the average number of concussions per student-athlete.

Further analysis revealed that there are multiple factors that have positive correlations with the total number of diagnosed concussions. Among those variables that were found to have a positive correlation with the total number of diagnosed concussions during the 2013-2014 school year were concussion education provided to all other participants (measured by cumulative amount of education to coach, parent, and athletic trainer in minutes), the number of required participants in training, the numbers of years concussion legislation has been in place, whether or not a school requires baseline neurocognitive testing prior to beginning a sport, whether or not a school employs an athletic trainer, and the total amount education provided to all participants in minutes (student-athlete, coach, parent, athletic trainer).

Furthermore, it appears that the most relevant variable when attempting to determine the efficacy of a concussion management protocol relates to the number of years that concussion legislation has been in place, because significant and positive relationships were found between this variable and both average number of concussions per student-athlete and the total concussions diagnosed during the 2013-2014 school year. Logically, this makes sense, because one would expect that the longer concussion legislation has been in place, the more vigilant and knowledgeable those involved in activities in which concussions are commonplace would be, leading to more accurate reporting/diagnosis of concussions. Taken together, these findings imply that the assumptions upon which the initial hypotheses were based upon hold some merit and that the use of the investigator-created variable, average number of concussion per student-athlete (number of concussions ÷ number of student-athletes), as the dependent variable may have been a contributing factor in the lack of significant findings, in addition to low response rate and the quality of education provided.

Benefits of the Study

With over 1.7 million incidents reported annually, concussion has become the most common class of TBI in the United States (Bazarian, Zhu, Blyth, Borrino, & Zhong, 2012). As staggering a statistic as this may be, many believe that this number may fail to represent the true number of concussions, given the fact that indications suggest non-reporting of symptoms is commonplace among athletes (Khurana & Kaye, 2012; Williamson & Goodman, 2006). Due to the difficult nature of determining how often concussive episodes go unreported, estimates of the number of athletes who fail to report concussive symptoms vary from 20% - 60% (Chrisman et al., 2013). Failure to report a concussion and incurring a second brain injury prior to the brain healing from a first injury can have devastating and life-long consequences.

The current study has demonstrated a positive relationship between the numbers of years that concussion legislation has been in place with the average number of diagnosed concussions per student-athlete. Additionally, a positive relationship was found between the total number of diagnosed concussions and a variety of other variables including the amount of concussion education, the number of individuals receiving concussion education, the utilization of baseline neurocognitive testing, the presence of an athletic trainer, and the number of years that concussion legislation has been in place. This may imply that these variables can serve as protective factors against environmental causes (e.g., attitudes, subjective norms, perceived behavioral control) that may influence an individual's willingness to report concussion symptoms as posited by the Theory of Planned Behavior. Furthermore, given these findings, it may be important for school boards to consider, and prepare for both financially and logistically, an increasing number of diagnosed concussions as awareness regarding this issue increases because of the length of time that legislation has been and will continue to be in place regarding concussions.

Implications

Findings from the current study provide evidence for the importance of concussion education and the involvement of multiple individuals in the prevention of non-reporting of concussion symptoms. Specifically, findings that demonstrate a relationship between more extensive concussion education and total number of diagnosed concussions imply that providing more education may increase the willingness to report concussion symptoms. Essentially, increasing the requisite amount of concussion education for those involved in high school athletics may serve to decrease the long lasting effects and possible consequences of incurring multiple concussions or a second concussion prior to healing from the first. Furthermore, findings from the current study support the importance of baseline neurocognitive testing and the presence of an athletic trainer with regard to decreasing the occurrence of non-reporting of concussion symptoms.

Additionally, results from this study support the importance and efficacy of concussion legislation. These findings could provide the impetus needed to bring awareness to the growing issues related to concussions and serve as a reason for school boards to begin preparing, both financially and logistically, for the likely increase in diagnosed concussions that will come in subsequent years as awareness regarding these matters increases due to the fact that legislation has been in place for a longer period of time.

Limitations

It is important to note the limitations of the current study. First, the optimal number of participants (n = 109) based on a power analysis was unable to be recruited, thus reducing the generalizability of the findings and the increasing the possibility of a Type I error. The low response rate may have been a result of the concern over negative consequences or negative perception of a school district should they not be compliant with state laws. It was hoped that this concern would be mitigated by the anonymous nature of the survey, although the overall response rate (7.84%) was considerably lower than anticipated at the outset of the study, given the fact that studies have shown an average response rate to online surveys to be approximately 33% (Nulty, 2008).

Moreover, given the low number of usable responses (2.43%), more lenient inclusion criteria may have allowed for a larger *n*.

Furthermore, not all schools are required to keep data on the number of diagnosed concussions per year. Therefore, schools that do not keep data were excluded from participation in the survey, thus limiting the pool of applicants. It is also likely that those schools who choose to keep concussion data are likely more vigilant in their concussion management policies. This may skew the pool of self-selected survey respondents to the current study, restricting it to those that already have what they perceive to be an efficient concussion protocol in place. This belief was also somewhat evidenced by the fact that 81.9% of the schools that responded also reported that they do employ an athletic trainer while prior research has shown that only 42% of American schools employ a certified athletic trainer (Chrisman et al. 2013).

A third limitation of the current study involves the sample recruitment methodology. The current study utilized a non-probability sample to obtain data, given that respondents self-selected to participate in the survey. Additionally, all those that participated needed to have a working email account and have kept concussion data for the 2013-2014 school year. Therefore, results from this study need to be interpreted carefully because the sample is probably not representative of the population from which it was derived.

Another possible limitation of the current study is that it does not take into account any education an individual may have received outside of what is required by a school. For instance, many coaches may be required to receive training if they coach sports beyond the school limits (e.g., recreational leagues). The amount of education received through these means could not be ascertained through the current study.

Finally, many schools require that individuals (student-athlete, coach, parent, athletic trainer) read a concussion information sheet and sign a waiver that they have read it; this serves as the required concussion education. In cases such as these, superintendents were asked to estimate the amount of time it would take to read this information sheet (in minutes) when responding to questions on the survey (Appendix A) regarding the amount of concussion education required. Considering that this was an estimate and not a standard amount of time, findings from this study should be interpreted with this in mind.

Future Directions

Although the current study provided equivocal evidence for the importance of concussion education, future research should be conducted to identify the specific and critical components of concussion education that provide the greatest impact in increasing concussion reports and decreasing the return to sports activity too early following a concussive injury.

One very important aspect of concussion education needing further inspection was discussed at the 4th International Conference on Concussion in Sport; this is the concept of knowledge-transfer (McCrory et al., 2013). Essentially, knowledge-transfer refers to the examination of the specific teaching practices utilized during concussion education, including the wish to determine the best practices with which to disseminate concussion education (Provvidenza & Johnston, 2009). There are a variety of concussion education resources available including those that are interactive (e.g., video games) and those that are passive (e.g., DVDs) materials. The most recent evidence points to the benefits of a multifaceted approach (Provvidenza et al., 2013). Specifically, an education presentation, case studies, peer interaction and discussion, and a concussion workbook were identified as an optimal knowledge-transfer strategy for athletes and parents (Provvidenza et al., 2013). Further investigation on the best methods with which to convey information related to concussions is important.

Research could also be conducted about the acquisition and retention of knowledge following concussion education to insure that the information was conveyed sufficiently well. Determining methods and practices with which to effectively disseminate concussion information to student-athletes is of utmost importance. Through more efficacious concussion education to the most critical members of the concussion management team (coach, athletic trainer, student, parent), it may be possible to further prevent the devastating consequences that can occur when athletes fail to report symptoms.

Further investigation regarding the environment in which the education is provided may also prove beneficial. Anecdotally, through conversations that took place during the research process for the current study, it was discovered that many students receive their education in a group setting which may be a less than optimal environment. Distractions, such as friends to talk with, may limit the attention which is paid to the information being offered. Additionally, the baseline neurocognitive testing environment should also be examined. During the course of researching for the current study it was discovered that this too may occur in a group setting which has been shown to lead to less than optimal results, thus limiting the effectiveness of the practice (Moser, Schatz, Neidzwski, & Ott, 2011; Lichtenstein, Moser, & Schatz, 2014).

A third area of future research should focus on discerning those individuals, besides that athlete, who receive concussion education; those individuals are most critical in lowering the occurrence on non-reporting of concussion symptoms. The design of the current study limited the ability to determine which of these individuals (coach, parent, etc.) were most critical to the decrease in non-reporting of concussion symptoms. By determining which individuals are most critical to target for concussion education, the focus of legislation regarding concussion education in schools can be geared more towards the most appropriate individuals.

Examination of education practices for specific sports (as compared with multiple sports) may also be beneficial to study. Given the fact that this study examined individuals from multiple sports and recent findings have shown a discrepancy in the concussion management of student-athletes playing football as compared with concussion management in other sports (i.e., boys and girls soccer) (Esquivel, Haque, Keating, Marsh, & Lemos, 2013) it may be prudent to examine specific sports, rather than a variety of sports.

Finally, a study that compares the length of recovery time for student-athletes from a school that has a specific return-to-learn protocol in place versus a school that does not have this protocol would provide critical information regarding the importance of return-to-school protocols to the well-being and recovery rate of the student-athlete. Cognitive rest is a vital component of the recovery process from a concussion and must be monitored by a concussion management team as was recommended in the most recent Consensus Statement on Concussion in Sport. Findings from a study such as this would provide evidence that could prove to be the impetus for developing legislation requiring return-to-school protocols to be implemented in schools across the country. Given the fact that this study found only 55.6% had a protocol in place with regard to academic accommodations or a return-to-school protocol following a concussion, this is an area that needs to be further explored.

Summary and Conclusion

Based on findings from the current study, it appears that concussion legislation is a critical factor in the reduction of non-reporting of concussion symptoms in high school athletics. Additionally, equivocal evidence was uncovered relating to the effects that concussion education, the utilization of neurocognitive baseline testing, and the presence of an athletic trainer have on the accurate reporting of concussions. Non-reporting of concussion symptoms can have serious immediate and long-term ramifications. Given the fact that completely eliminating concussions from sport is an unreasonable goal, further exploration regarding the reasons contributing to this phenomenon, as well as increasing knowledge of mitigating factors that may reduce the occurrence of non-reporting concussions is critical to the present and future well-being of student-athletes.

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Appendix A

Concussion Survey

Please provide all answers relating to the 2013-2014 school year and any time amounts given <u>in minutes.</u>

1. What state does your school reside in? ___________________________________
2. What grade levels were offered at your school during the 2013-2014 school year? **(7^{th}, 8^{th}, 9^{th}, 10^{th}, 11^{th}, 12^{th})**
3. What sports does your school offer to your students during the 2013-2014 school year? **(For this item a list of sports with boxes to check off will be provided)**
4. How many student athletes did you have in your school during the 2013-2014 school year? __________________________
5. Did your school employ an athletic trainer during the 2013-2014 school year?

   Yes No
6. In total, how many sports related concussions were diagnosed at your school during the 2013-2014 school year? _________________________
7. Did you require students to take a baseline neurocognitive assessment (i.e. ImPACT) prior to participating in any high school sport during the 2013-2014 school year?

   Yes No
8. Did you require students to obtain medical clearance prior to returning to play following a concussion during the 2013-2014 school year?

   Yes No

9. Did you require your students to attend workshops/lectures on concussions or receive concussion education in another manner during the 2013-2014 school year?

Yes **No**

If yes, how did you provide your concussion education (i.e. lecture, movie, information sheet) and how much total time **(total amount of education per student in minutes for the 2013-2014 school year)** was required? **(If you require student to sign off on a concussion information sheet please estimate the amount of time (in minutes) you believe it takes to read through the entire information sheet)**

____

10. How often did you require students to receive concussion education during the 2013-2014 school year?

once prior to starting any sport **annually** **biennially**

11. Did you require your coaches to attend workshops/lectures on concussions or receive concussion education in another manner during the 2013-2014 school year?

Yes **No**

If yes, how did you provide your concussion education (i.e. lecture, movie, information sheet) and how much total time **(total amount of education per coach in minutes for the 2013-2014 school year)** was required? **(If you require coaches to sign off on a concussion information sheet please estimate the amount of time (in minutes) you believe it takes to read through the entire**

information sheet)

____

12. How often did you require coaches to receive concussion education during the 2013-2014 school year?

    once prior to starting any sport annually biennially

13. Did you require your athletic trainers to attend workshops/lectures on concussions or receive concussion education in another manner during the 2013-2014 school year?

    Yes No Do not currently employ an athletic trainer

    If yes, how did you provide your concussion education (i.e. lecture, movie, information sheet) and how much total time **(total amount of education per athletic trainer in minutes for the 2013-2014 school year)** was required? **(If you require athletic trainers to sign off on a concussion information sheet please estimate the amount of time (in minutes) you believe it takes to read through the entire information sheet)**

    ____

    If you do not currently employ an athletic trainer please skip questions 14 & 15

14. How often did you require athletic trainers to receive concussion education during the 2013-2014 school year?

    once prior to starting any sport annually biennially

15. Did you require the parents of your student athletes to attend workshops/lectures on concussions or receive concussion education in another manner during the 2013-2014 school year?

Yes **No**

If yes, how did you provide your concussion education (i.e. lecture, movie, information sheet) and how much total time **(total amount of education per parent in minutes for the 2013-2014 school year)** was required? **(If you require parents to sign off on a concussion information sheet please estimate the amount of time (in minutes) you believe it takes to read through the entire information sheet)**

____

16. How often did you require parents to receive concussion education during the 2013-2014 school year?

once prior to starting any sport **annually** **biennially**

17. Were there any other individuals from your school required to receive concussion education during the 2013-2014 school year?

____

18. Do you require anyone who receives concussion education to complete an assessment to assure they learned the information during the 2013-2014 school year?

Yes **No**

If so, which of the individuals mentioned above were required to complete an assessment related to their concussion education? (please circle all that apply)

Student-Athlete **Coach** **Athletic Trainer** **Parent**

19. Did you have a return to play protocol your school followed before a student could return to sports following a concussion during the 2013-2014 school year?

Yes **No**

If yes, please provide a brief description of your return to play protocol.

____

____

20. Did you have a protocol in place in regard to academic accommodations or a return to school protocol following a concussion during the 2013-2014 school year?

Yes **No**

If yes, please provide a brief description of your return to school protocol.

____

____

Appendix B

RETURN TO PLAY PROTOCOL (CHART)

Adapted from the Consensus Statement on Concussion in Sport - The 4th International Conference on Concussion in Sport (McCrory et al., 2013)

Rehabilitation Stage	**Functional Exercise at Each Stage of Rehabilitation**	**Objective of Each Stage**
No activity	Complete physical and cognitive rest	Recovery
Light aerobic exercise	Walking, swimming, or stationary cycling keeping intensity <70% maximum predicted heart rate	Increase heart rate
Sport-specific exercise	Skating drills in ice hockey, running drills in soccer. No head impact activities	Add movement
Non-contact training drills	Progression to more complex training drills, e.g. passing drills in football and ice hockey	Exercise, coordination, and cognitive load
Full contact practice	Following medical clearance participate in normal training activities	Restore confidence and assess functional skills by coaching staff
Return to play	Normal game play	

Appendix C (Email Recruitment Letter)

Dear ___________________,

You are being asked to participate in a research study exploring the relationship between concussion education and incident rate of concussion. This survey will be used for Doctoral dissertation purposes at the Philadelphia College of Osteopathic Medicine (PCOM) by Michael Heptig. You will be asked to provide demographic information, quantitative data regarding concussion education provided at your school, quantitative data regarding the number of concussions that were diagnosed during the 2013-2014 school year, and respond to yes/no questions. This survey will take approximately 15-20 minutes to complete and all answers will remain anonymous and confidential.

Your participation is completely voluntary, and consent will be assumed if the questions have been answered. You may withdraw from the study at any time, without penalty. There are minimal risks involved with participation in this study. Potential benefits include gaining insight into the most effective concussion management protocols in an effort to better serve the physical, academic, and social well-being of the concussed child.

If you have already completed this survey, please disregard and do not respond a second time as this will skew the results. Additionally, if you are the superintendent to more than 1 high school, please fill out separate survey responses for each high school rather than a total for both. Also, if there is another superintendent whom you feel would be willing to fill out this survey please forward this email with the link so they may add to the current study.

Thank you in advance for your participation. Should you have any questions, or if you would like the results, please contact Michael Heptig at PCOM at michaelhep@pcom.edu. You may also contact the dissertation chair and principal investigator for this study, Donald Masey, Psy.D. at Donaldma@pcom.edu or 215-871-6623.

Sincerely,

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Table 8: Breakdown of Concussion Legislation by State

State	Has state legislation regarding concussion managemen t	Requires Coach to receive annual concussion training	Requires parent to receive concussion education	Requires athlete to receive concussion education	Removal from play required following actual or suspected concussion	Graduated Return to play protocol required before returning to play	Medical clearance required prior to returning to play	Year Legislation was passed	Baseline neuro-cognitive testing required	Return to School Policy
Alabama	X	X	SI	SI	X		X	Jun-11		
Alaska	X		SI	SI	X		X	May-11		
Arizona	X		SI	SI	X		X	Apr-11		
Arkansas	X							Apr-13		
California	X		SI	SI	X		X	Oct-11		
Colorado	X	X			X	mentioned in law but not required	X	Mar-11		
Connecticut	X	X			X		X	May-11		
Delaware	X	X (not officially annual)	SI	SI	X		X	11-Aug		
Florida	X	X (not officially annual)	SI	X (no formal guidelines)	X		X	Apr-12		
Georgia	X		Info		X	mentioned in law but not required	X	Apr-13		

<u>**Key**</u>: **Info** - Information sheet provided but does not need to be returned signed

SI - Signed Information sheet required

***** - must achieve passing score on assessment regarding concussion education

Table 8: Breakdown of Concussion Legislation by State

State	Has state legislation regarding concussion management	Requires Coach to receive annual concussion training	Requires parent to receive concussion education	Requires athlete to receive concussion education	Removal from play required following actual or suspected concussion	Graduated Return to play protocol required before returning to play	Medical clearance required prior to returning to play	Year Legislation was passed	Baseline neuro-cognitive testing required	Return to School Policy
Hawaii	X	X	X	X	X	X	X	Jul-12		X
Idaho	X		Info	Info	X		X	Apr-12		
Illinois	X		SI	SI	X		X	Jul-11		
Indiana	X	Info	SI	SI	X		X	May-11		
Iowa	X	Info	SI	SI	X		X	Apr-11		
Kansas	X	Info	SI	SI	X		X	May-11		
Kentucky	X	X*	SI	SI	X		X	Apr-12		
Louisiana	X	X	SI	SI	X	X	X	Jun-11		Academic accommo-dations mentioned in law
Maine	X	X (not annual)	SI	SI	X			May-12		

Key: **Info** - Information sheet provided but does not need to be returned signed
SI - Signed Information sheet required
***** - must achieve passing score on assessment regarding concussion education

Table 8: Breakdown of Concussion Legislation by State

State	Has state legislation regarding concussion managemen t	Requires Coach to receive annual concussion training	Requires parent to receive concussion education	Requires athlete to receive concussion education	Removal from play required following actual or suspected concussion	Graduated Return to play protocol required before returning to play	Medical clearance required prior to returning to play	Year Legislation was passed	Baseline neuro-cognitive testing required	Return to School Policy
Maryland	X	X	SI	SI	X		X	May-11		Academic accommo-dations mentioned in law
Massachusetts	X	X	X	X	X	X	X	Jul-10	head injury history required prior to start of each sports season	
Michigan		X	Info	Info	X		X	Oct-12	head injury history required prior to start of each sports season	

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Minnesota	X	X (every 3 years)	SI		X		X	May-11		
Mississippi	X		SI		X	X	X	Jan-14		
Missouri	X	Info	SI	SI	X		X	Jul-11		
Montana	X	X	SI	SI	X		X	Apr-13		
N. Carolina	X	SI	SI	SI	X		X	Jun-11		
N. Dakota	X	X (biennial)	SI	SI	X		X	Apr-11		
Nebraska	X	offered but not required/Is required by Nebraska School Activities Association	Info	Info	X		X	Apr-11		

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Nevada	X		SI	SI	X		X	May-11		
New Hampshire	X		strongly recommend-ed but not required	strongly recommend-ed but not required	X		X	Aug-12		
New Jersey	X	One-time training and annual information sheet provided	SI	SI	X		X	Dec-10		
New Mexico	X	One-time training and annual information sheet provided	SI	SI	X		X	Mar-10		

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New York	X	X (biennial)	Reco-mmended but not required	Reco-mmended but not required	X		X	Sep-11		
Ohio	X	X (every 3 years)	SI	SI	X		X	Dec-12		
Oklahoma	X	Info	Info	Info	X			May-10		
Oregon	X	X			X		X	Jun-09		
Pennsylvania	X	X	SI	SI	X		X	Nov-11		

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Rhode Island	X	X (only initial training required)	SI	SI	X		X	Jun-10	considering amending law to require ImPACT baseline testing	
South Carolina	X	Info	SI	Info	X		X	Jun-13		
South Dakota	X	X	SI		X		X	Mar-11		
Tennessee	X	X	SI	Info	X	X	X	Apr-13		
Texas	X	X (biennial)	SI	SI	X	X	X	Jun-11		
Utah	X	Info	SI		X		X	Mar-11		
Vermont	X	X (biennial)	SI	SI	X			Jun-13		
Virginia	X		SI	SI	X		X	Apr-10		

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Washington	X		SI	SI	X		X	May-09		
Washington DC	X	X (only initial training required)	SI	SI	X		X	Jul-11		
West Virginia	X	X	SI	SI	X		X	May-13		
Wisconsin	X	Info	SI	SI	X		X	Apr-12		
Wyoming	X	X (only initial training required)	Info	Info	X		X	Mar-11		

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