

Relationship of Cervical Neck Strength and Head Impacts in Youth Soccer

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Précis

Concussions are a prevalent issue in the world of sports medicine, and have been receiving increased publicity at all levels of athletic competition. The debilitating effects of brain injuries have been widely discussed as they relate to professional athletics, but little has been researched concerning adolescent athletes. The purpose of this study was to investigate a potential predisposing factor of concussions, utilizing software that quantifies the magnitude of head impacts. Youth soccer participation is of particular concern, as concussion incidence has been shown to be near that of collision sports such as football and ice hockey.

As an Athletic Training Student, concussions have always interested me, particularly due to the involved difficulties in quantifying and measuring their severity. Head injuries are nearing epidemic levels, with Athletic Trainers heavily involved in the diagnosis and management of concussions. With our field of healthcare so closely tied with these concussions, I wanted to focus on investigating potential ways to prevent or limit these debilitating injuries.

Related to potential predispositions of head injuries, neck strength has been theorized to be a factor in the severity of concussions. Initially it was believed that with stronger neck muscles, the likelihood of brain injury would decrease. However, recent literature has been inconclusive when investigating athletes in a variety of sports and ages of competition. These studies looked at strength related to the number of contacts with the head, without an ability to apply a measurement to the severity of the impacts. My research expanded upon previous works by combining neck strength measurements and innovative impact software.

In order to address the relation between neck strength and head impacts, local youth soccer players were recruited as subjects for the study. Each player's isometric strength was recorded using a device that measures force output from a stationary position. Participants were

also fitted with a headband manufactured by X2Impact, a software company that specializes in equipment related to head impacts. The headbands measure rapid changes in head movement, and are able to quantify the head contacts that occur during practices and competitions. Once the data was collected, the results were analyzed to investigate relations between neck strength in various directions and the magnitude of the impacts for each individual player.

It was discovered that an increase in neck strength was related to higher impact measurements in youth soccer players. The results were encouraging, as three different relationships between directional strength and the magnitude of head contact were found to be significant. The findings of the research dispel intuitive belief that an increase in strength is more beneficial for an athlete. Further studies need to investigate dynamic strength, body height and weight influences, gender differences, and the relation of neck flexibility (as opposed to neck weakness) to concussion occurrence.

Concussions remain a serious issue in the health of active individuals. Identifying possible factors leading to head injuries could help in preventing long-term damage, and may assist in providing individuals with a safer athletic environment. I feel as if my study adds further discourse to this important issue, and will hopefully inspire additional research in the future.

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INTRODUCTION / LITERATURE REVIEW

Concussions are an increasingly prevalent injury involved with sport participation, particularly among youth athletes. Relatively recent developments at both professional and amateur levels of athletics have expanded the national discourse on the issue, with an increased demand for research on the underlying causes of these potentially catastrophic injuries. Brain injuries are present among all stages of competition, with certain participants at a higher risk for severe damage. The goal of this research was to examine the relationship between cervical neck strength and the magnitude of the forces placed upon the head in youth soccer participants, in order to further isolate an important potential predisposing factor in a population vulnerable to serious injury. Many studies have investigated the long-term effects of concussions on an individual's cognitive abilities, yet little has been done exploring specific mechanisms or the discrepancies that exist between levels of competition and development. Head impacts and traumatic brain injury (TBI) can be extremely dangerous to an individual's overall health and function, but much is still unknown of the underlying causes and contributing factors.

Definition and Evaluation

In providing a definition, the American Academy of Neurology states, "A concussion is a trauma-induced alteration in mental status that may or may not involve loss of consciousness" (Broglio et al., 2010). The third International Conference on Concussion in Sport, widely regarded as establishing the standards for concussion definition and treatment, defines concussion as "a complex pathophysiological process affecting the brain, induced by traumatic

biomechanical forces” (McCrory et al., 2009). Mechanisms of injuries may be presented through violent, high-impact collisions, or through minor contact that causes brain disruption. Although the main area of concern is the skull, the specific blow may not necessarily be to the head; rather, the force can be to a separate aspect of the body that causes the head to move in a way that elicits brain impact. The specific contact of the brain is categorized as either “coup” or “contrecoup” depending on the site of contact with the skull. Coup injury occurs when the tissue strikes the skull at the location of the direct blow, while contrecoup damage involves the force of the brain against the opposite aspect of the skull, due to the rapid changes in acceleration from the original mechanism. Additionally, trauma to the brain may not present itself with one outstanding impact. Subconcussive forces can accumulate from multiple, regularly occurring incidents of contact summing to cognitive and physical impairments. Smaller magnitude forces may not exhibit typical symptoms at an acute onset, but may result in serious brain injury long after activity has been discontinued.

Functional magnetic resonance imaging (fMRI) of former athletes has shown neurocognitive deficits in individuals with no documented incidence of a concussion, highlighting the potential risk for subconcussive damage (Johnson, 2012). These blows occur in acceptedly violent sports such as American football, boxing, and ice hockey, but also in sports not necessarily deemed “high-contact,” particularly soccer. Regardless of the source of the brain injury, the severity of the damage and cognitive and physiological symptoms are dependent on a variety of factors that vary given the individual’s own specific predispositions.

Both acute and chronic damage should be taken into consideration with suspected brain injuries. Both high-intensity and subconcussive blows may contribute to neurocognitive impairments beyond the initial concussion (Johnson, 2012). Internal bleeding of the brain, either

arterial or venous, may lead to epidural or subdural hematomas respectively. With a traumatic incidence, bleeding can cause internal hemorrhaging placing an overwhelming amount of swelling on the brain, and is considered a medical emergency. Another risk is Second Impact Syndrome, which causes extensive cerebral swelling when a second bout of trauma occurs without the proper healing of a previous concussion. The youth sporting population is especially at risk, as younger individuals are more susceptible to Second Impact Syndrome given prolonged healing times with concussions (McCroory, 2001). In terms of long-term damage, chronic traumatic encephalopathy (CTE) is another very real danger. CTE presents itself with symptoms similar to dementia, Alzheimer's, and Amyotrophic Lateral Sclerosis (ALS or Lou Gehrig's Disease), but with indicators emerging at earlier ages for those involved with sports in which TBIs commonly occur (Cearnal, 2012). Diagnostic imaging shows severely altered brain tissue in those with CTE, making the danger very real for the millions of athletes involved in contact and collision sports. The potential for intracranial damage should always be considered, as permanent neurological damage or death can be a direct result (Yi, Padalino, Chin, Montenegro, & Cantu, 2013).

Diagnoses of concussions are typically performed by a Certified Athletic Trainer (ATC), physician, or a specialized neurologist, in accordance with varying legislature determined by individual state governments. Symptoms of a concussion include, but are not limited to, headache, confusion, disruption of neurocognitive function, memory loss, balance disruption, temporary loss of consciousness, lack of or difficulty sleeping, sensitivity to light (photophobia), changes in personality, altered behaviors or emotions, and drowsiness or fatigue (Table 1). Symptoms may be exacerbated by physical or mental activity, changes in one's environment, or stress. The severity and duration of symptoms are dynamic and variable, and difficult to predict

depending on the individual affected. Diagnostic imaging can be utilized to assess damage done to brain structures, either to evaluate cranial bleeding or to view damage accumulated by long-term trauma. Although fMRI and computed tomography (CT) scanning may exhibit large-scale destruction of brain tissues, symptom recognition remains the greatest determinate of neurocognitive impairment (Yi et al., 2013).

TABLE 1. Concussion symptoms (McCrory et al., 2009).

Cognitive Symptoms	Physical Symptoms	Emotional Symptoms
Disorientation	Headache	Irritability
Confusion	Intracranial pressure	Increase in emotion
“Feeling in a fog”	Neck pain	Sadness
Loss of consciousness	Nausea or vomiting	Nervousness
Retrograde amnesia	Dizziness	Anxiousness
Anterograde amnesia	Vision disturbances	Changes in behavior
Inability to focus	Balance Issues	
Delayed verbal response	Sensitivity to light	
Drowsiness	Sensitivity to noise	
Slurred speech	Delayed coordination	
	Difficulty sleeping	

A previous history of concussions does predispose an individual to further head trauma, with potentially cumulative effects (Savola & Hillborn, 2003). Those with 3 or more concussions have been shown to have long-term deficits in neurocognitive function, and have a greater risk for future re-injury and longer recovery times. Multiple incidents of traumatic brain injury also increase the likelihood of major disruptions such as anterograde and retrograde amnesia, dementia, and other debilitating brain injuries (Guskiewicz et al., 2003). Certain

populations have been shown to be at a higher risk for both impact occurrence and symptom severity, but findings are without consensus. Gender differences among individuals requires further comparison, as does concussion mechanism variations between adolescent athletes and those competing at elite/older levels. Examining the differences between the various types of competition may aid in discovering the underlying factors contributing to TBI within the different athlete groups. Many recent studies have been performed regarding incidence rates in various populations but little research has investigated impact mechanisms, particularly among youth soccer players, a population of increasing importance related to traumatic brain injuries.

Epidemiology

Despite the lack of publicity on concussion awareness compared to other sports, soccer has similar concussion incidence rates to those seen in American football and ice hockey, at both recreational and elite levels (Koutures et al., 2010). Investigation into the epidemiology of head trauma in youth soccer reveals varying data that expresses the dangers of player participation. According to recent research, about 15% of all acute damage occurs to the head, with concussions accounting for 1.65% of all sustained injuries (Giannotti, Al-Sahab, McFaull, & Tamim, 2010). In a 2010 survey of high school Certified Athletic Trainers, concussions accounted for 15.4% and 11.1% of all high school girls and boys soccer injuries respectively. In terms of specific mechanisms, heading the ball, or the attempt to head the ball, was the cause for 60.8% of all head injuries (Marar, McIlvain, Comstock, & Fields, 2012). Contact with other players has been found to be the most common source of impact (35-47%, depending on the

study). Contact with other surfaces and structures, as well as head strikes with the soccer ball, were also found to be significant causes (Gianotti et al., 2010; Koutures et al., 2010).

Concussions among Adolescents

Existing research highlights the very real dangers of concussions for the adolescent athlete. According to national emergency department admittance records, the 10- to 14-year-old population had the highest incidence of traumatic brain injury, followed closely by 15- to 19-year-olds. Soccer was listed as one of the activities that produced the largest amount of adolescent emergency room visits. Additionally, younger individuals generally recover at a slower rate from concussive symptoms than do older participants. Studies have established that “it is well accepted that high school aged athletes take longer to heal than older athletes”, with high school athletes usually requiring 10-14 days to fully recover neurocognitively, double that of collegiate averages (Grady, 2010). In pediatric individuals, those admitted to the emergency department presented symptoms 2-3 weeks post-injury in over 50% of documented cases (Blinman, Houseknecht, Snyder, Wiebe, & Nance, 2009). In younger individuals (10- to 14-year olds) research is unsubstantial and rarely focuses on sports-specific mechanisms, with a need for further examination in athletes below high school participation.

Gender Differences

Gender disparity is another often overlooked aspect of concussion research, particularly given that a discrepancy has proven to exist. Females have been shown to be at a greater risk for reported concussions and concussive symptoms when compared to those in the same sport, particularly in soccer (Covassin, Swanik, & Sachs, 2003; Powell & Barber-Foss, 1999). Women

exhibit decreased cognitive functions and higher reported symptoms than males in identical populations through concussion testing (Broshek et al., 2005). Further data shows that female soccer athletes have almost double the rate of concussion than their male counterparts, with 3.4 concussions per 10,000 athlete exposures (in this case, an exposure was deemed as one athlete competing in one practice or event). Player-to-surface and player-to-ball contact was a more significant source of head impacts in female soccer players at the high school level, while player collisions was the predominate source in the male athletes (Marar et al., 2012). Within the last five years, concussion incidence has increased by 3.2% in high school girl's soccer and 1.8% in boy's soccer (Yard et al, 2008; Marar et al, 2012). Although the higher rates of TBI could be due to a heightened awareness and recognition of head injuries and their symptoms, the gender disparity is still increasing at various rates. Several theories have been formulated to describe these gender discrepancies among soccer athletes, with many related to differences in body structure and biomechanical differences.

Biomechanical Factors

Recent research has been performed in an effort to quantify predispositions or biomechanical factors relating to concussion incidence. Neck musculature (specifically the sternocleidomastoid and trapezius muscles) has been found to stabilize and propel the head during the heading motion performed in soccer, in addition to bracing for potential contact with an object or individual (Bauer, Thomas, Cauraugh, Kaminski, & Hass, 2001). Because of its role in the stabilization of the skull, neck strength has been hypothesized as being a significant factor in concussion occurrence. Investigations on cervical muscle strength in youth sports have

yielded mixed results, with no relation found between youth ice hockey cervical muscle strength and decreased head impact occurrence (Mihalik et al., 2011). Previous studies have relied solely on neurocognitive testing in the assessment of concussion and impact severity, including the studying of heading incidence and concussion in youth soccer (Kontos, Dolese, Elbin, Covassin, & Warren, 2011). Gender discrepancies in head-neck stabilization do exist, with females exhibiting greater peak head angular acceleration measurements in ages 20-28 (Tierney et al., 2005). However, these findings only investigated “physically-active” individuals, not specifically athletes involved in sports with high concussion incidence. Conclusions on neck-strength as a factor describing differences in gender outcomes has been inconclusive, with studies contradictory on whether increased neck musculature prevents or predisposes an individual to traumatic brain injury (Grady, 2010). Other research has examined neck strength and differences related to traumatic brain injury, but not in conjuncture with impact data on the same subject cohort. Software to better measure head trauma has been recently developed, enabling researchers the utilization of additional tools with which to quantify impacts related to biomechanical factors. Impact data and neck strength measurements were used for this specific study of youth soccer, as further investigation is necessary into this seldom researched subset of the athletic population.

Diagnostic Testing and Measurements

In the professional and collegiate setting (and increasingly among high schools), baselines of cognitive ability are established using both the ImPACT computerized program and the Sport Concussion Assessment Tool 2 (SCAT 2). ImPACT testing is the most scientifically

evaluated concussion evaluation program, in which participants complete a 20-minute neurocognitive test. Response variability, working memory, attention span, and problem solving are evaluated through several different types of interactive modules (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). Results from this testing are used for pre-and post injury comparison, and to determine the extent of post-concussion cognitive deficits. The SCAT 2, typically in paper form, utilizes subjective symptom scoring, anterograde and retrograde memory evaluation, and balance testing to establish a baseline from which to compare concussion-like symptoms in the case of TBI. Its efficacy has been established by the International Conference on Concussion in Sport (McCroy et al., 2009). Testing is typically performed by Certified Athletic Trainers or physicians immediately following incidence at a practice or event, with symptom scoring used as a quantifiable measurement of concussion effects during the recovery of the athlete in the following days, weeks, or months. It is strongly recommended that these neurocognitive assessment tools be used by medical practitioners as an additional form of evaluation in measuring an athlete's concussion recovery, and not as an exclusive determinate of whether an individual may return to sport participation (Yi et al., 2013).

As previously stated, neck strength measurements may be utilized in an effort to quantify biomechanical predispositions to TBI. Cervical strength can be determined using isometric testing that isolates the trapezius and sternocleidomastoid (SCM) muscles from other large-scale accessory movers. An isometric contraction is muscle activation in which the muscle does not change length, but a force output is still being produced. This is typically performed with the head secured in a stable position and the patient pushing against a stable force. Neck strength is then measured at various angles and directions in order to best represent the dynamic movements of an athlete's head during active participation.

In terms of investigating the specific force impacts on athletes, recent technological advancements now provide researchers with further data on head trauma. Headbands designed for the investigation of concussion mechanisms are able to be implemented for the study of soccer athletes in particular. The headbands have a built-in system for detecting and recording changes in linear and angular acceleration of an individual's skull, specifically calibrated to distinguish ordinary movements from collisions and contacts to the head. Data is documented on built-in recording software, and uploaded to a specified data collection database. Utilization of impact findings and neck strength recordings may provide an excellent assessment in the event that an athlete suffers concussive trauma, as objective and descriptive data would then be able to be compared with unaffected individuals.

METHODS

The goal of this specific research was to investigate the relation of cervical neck strength to head impact values in youth soccer. Subjects for this study were recruited through a local soccer team participating in matches and tournaments not associated with interscholastic athletics. Once a feasible amount of interested was received, consent and Institutional Review Board forms were drafted and approved prior to implementation of the study. Subjects and their parent/guardian(s) were informed of the purpose, procedures, and risks involved with participation in the study. The impact-detecting headbands were described and shown to the individuals prior to acceptance, so as to give the athletes a greater understanding of their involvement.

Once the proper documentation was completed, each athlete underwent neurocognitive baseline testing using the imPACT computerized program. Testing was performed by a local

Physical Therapist/Athletic Trainer, who printed and delivered the results for further interpretation. Scores were observed and documented in a spreadsheet database in the event that a concussion was sustained while participating in the study. Those who were unable to be present at the original testing completed the test at a later date under supervision of an accompanying athletic trainer.

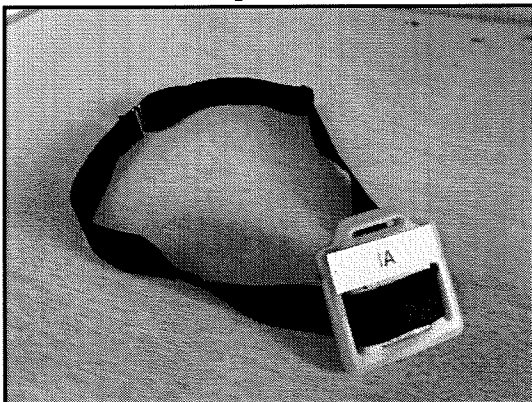
Neck strength measurements were recorded in a research lab on the campus of Washington State University. A Multi-Cervical Unit (MCU) isometric neck strength machine (designed by BTE Technologies) was utilized for the purposes of strength measurements (Figure 1). Basic information was recorded including the height, weight, age, grade, sex, and soccer position of the individual. The participants were instructed on proper positioning and technique when using the neck testing machine, and were asked follow instructions outlined by the automated system. Sensors for the machine were placed on either the forehead an inch above the eyebrows, above the occipital protuberance posteriorly, or on the lateral aspect of the skull for flexion, extension, and lateral rotation respectively. Shoulder and neck restraints were used to ensure of isolation of the cervical musculature. The patients were directed to exert a maximal force against the pads using only their neck muscles. Subjects held an isometric contraction for 3 seconds at maximum output until instructed to rest. A 10 second period of relaxation was observed before testing continued. Neck flexion, extension, and lateral rotation were recorded at 0, 25, and 45 degrees of rotation related to the individual's forward facing position. If any of the three measurements within each direction differed by a variation greater than a 10% value, the trials were repeated until consistent measurements were produced for ensured accuracy. Water was provided in the event of fatigue, and the participants were continuously questioned on the presence of any discomfort or pain elicited due to the testing apparatus.

At the conclusion of the cervical neck testing, a neurocognitive assessment was conducted utilizing the Standardized Concussion Assessment Tool (SCAT 2). The format of the SCAT 2 was slightly adjusted to fit the format of a tablet application for accessibility and documentation purposes.

FIGURE 1. MCU isometric neck strength tester (BTE Technologies)



FIGURE 2. X2Impact headband



After baseline neurocognitive and cervical neck strength was established, the participants were able to use the impact-detecting headbands during practice and competition. The headbands, provided by Seattle-based software company X2Impact, were at the final prototype stages when used for this study (Figure 2). The bands were fitted to each player's head, with proper orientation and operating procedures instructed to each individual. The power switch was triggered prior to the start of the practice or event, and turned off immediately after play was discontinued. Headbands were labeled with the initials of the participant, to ensure that each player wore the same equipment at every practice and game. Headbands were distributed and collected at practices and games by either those directly involved in the study or by research assistants volunteering through the Washington State University Athletic Training Program. Practices took place at Pullman High School and Lincoln Middle School, with weekend matches occurring in a variety of towns throughout Eastern Washington and Idaho.

Once the headbands were collected post-participation, the equipment was charged on a USB docking station. Data was collected and uploaded by using software provided by X2Impact on a remote laptop. Impacts were recorded and sorted by headband number, time of incidence, and by specific measurement quantification. The results were distributed to an independent statistician for analysis. Descriptive statistics were calculated and linear regression conducted to explore potentially significant differences between age, size, and gender within the impact values.

RESULTS

Cervical neck strength measurements were recorded on the associated computer software, with the measurements at varying degrees of rotation (0, 25, and 45) averaged for a comprehensive strength value. Mean cervical flexion was calculated to be 10.88lbf (pound force), with accompanying extension and lateral rotation averages of 15.49lbf and 11.27lbf respectively.

Specific impact values varied among participants in both linear and angular acceleration (Table 2). The mean linear acceleration experienced by each subject (n=15) for all practices and competitions, measured as a function of force per unit of mass (gravity-force, g), ranged from 17.80-35.09 g, with an observed mean value of 24.85g for all soccer players. Maximum linear acceleration measurements for each player were recorded within a range of 25.63 to 154.28g, with an average high impact of 80.4g. Rotational acceleration changes required different units of measurement given the separate plane of movement, with an average mean acceleration of 5995.34 rad/s/s and maximum rotational acceleration values of 7901.30 to 35066.42 rad/s/s.

TABLE 2. Mean cervical strength and linear and rotational acceleration measurements

	Mean Cervical Strength (lbf)	Avg Mean Linear Accel. (g)	Avg Max Linear Accel. (g)	Avg Mean Rot. Accel (rad/s/s)	Avg Max Rot. Accel (rad/s/s)
Flexion	10.88	24.85	80.46	5995.34	16474.16
Extension	15.49	24.85	80.46	5995.34	16474.16
Lateral Rot	11.27	24.85	80.46	5995.34	16474.16

An Alpha-value level of $p < 0.05$ was used for statistical significance, with linear regression utilized in the analysis of existing correlations. Mean linear and rotational

acceleration values were regressed against the number of impacts recorded for each subject to ensure that unequal representation of players within the data set was unlikely to bias results. A strong relationship was found with a comparison of neck strength and both mean and maximum acceleration values. Cervical flexion strength and mean linear acceleration were significantly related ($R^2 = 0.48, p < 0.01$; Figure 3), as was the association between flexion and mean rotational acceleration ($R^2 = 0.58, p < 0.01$; Table 3, Figure 4). Lateral rotation was also found to be significantly related to impact values, with mean lateral strength correlated with maximum rotational acceleration ($R^2 = 0.40, p < 0.05$; Table 4, Figure 5). No significant relationships were found between neck extension strength and impact measurements (Table 5).

TABLE 3. Correlation between impacts and flexion strength

	R ²	p Value
Max Lin	0.058286	0.386026
Mean Lin	0.47644	0.004396
Max Rot	0.072603	0.331467
Mean Rot	0.577823	0.001005

FIGURE 3. Flexion and mean linear acceleration

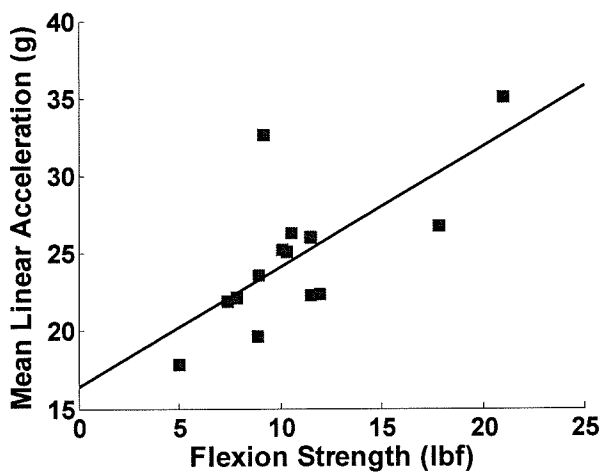


FIGURE 4. Flexion and mean rotational acceleration

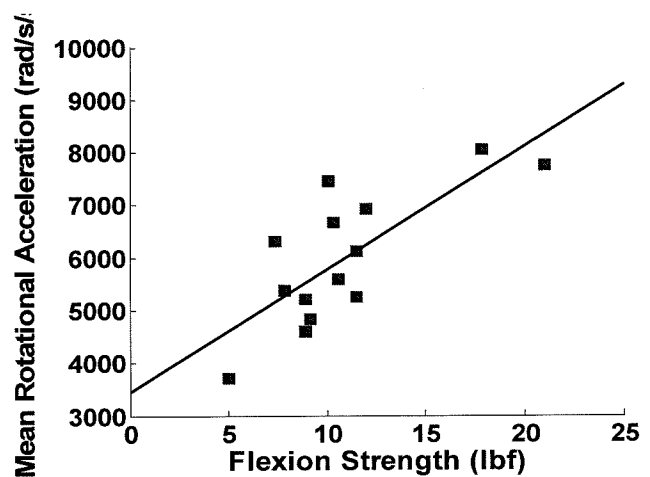


TABLE 4. Correlation of impacts and lateral strength FIGURE 5. Lateral strength and max rot. acceleration

	R ²	p Value
Max Lin	0.049315	0.42634
Mean Lin	0.086222	0.288131
Max Rot	0.399999	0.011404
Mean Rot	0.035065	0.503956

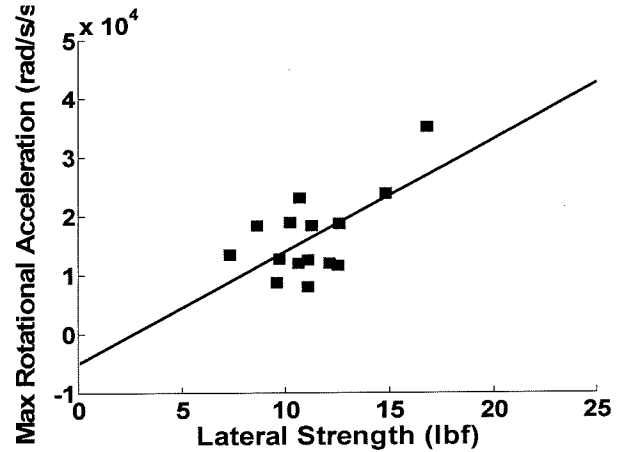


TABLE 5. Correlation between impacts and extension strength

	R ²	p Value
Max Lin	0.001043	0.909017
Mean Lin	0.001206	0.902224
Max Rot	0.032382	0.521031
Mean Rot	0.02422	0.579686

DISCUSSION

The findings related to neck strength and impact data in this study revealed statistically significant positive relationships between isometric strength at varying angles of measurement and higher head impact values, when measured through rapid changes in linear and angular acceleration. Increased neck flexion strength led to increased mean values in linear and rotational accelerations, with lateral rotation strength also shown to be correlated with maximum

rotational acceleration values. No significant relationship was observed between extension strength and either linear or rotational head impact measures.

Many physiological and experimental factors account for the data sets exhibited in this research. Isometric neck strength is a measurement of the contracting force of the cervical muscles without a change in length, giving an estimate of overall force output at a specific angle. With all of the angles regressed, the resulting value gives a reflection of the individual's overall neck strength in multiple directions, which translates to the body's functional use of the neck during soccer activities. It was shown that those with higher neck strength values in flexion and lateral rotation exhibited higher head impacts, which is consistent with previous literature related to concussions in athletes among various levels of participation. Previous studies have found a relationship between increased cervical neck strength and concussion incidence among youth hockey athletes, citing increased tone and decreased mobility as possible factors contributing to stronger forces placed on the skull of the participants (Mihalik et al., 2011). Additionally, Broglio et al. (2010) found linear and rotational acceleration to be among the strongest predictors of head impact values through biomechanical observations of high school football players. Although the population in this particular study of youth soccer athletes has been rarely investigated, the findings seem to support previously-held notions that neck strength plays a significant role in the determination of potential brain injuries.

Neck strength and cervical muscle girth has been previously shown to increase joint and muscle stiffness in the primary stabilizing muscles of the head and neck (McNair, Hewson, Dombroski, & Stanley, 2002; Wittek, Ono, Kajzer, Ortengren, & Inami, 2001). These findings do not necessarily agree with long-held, intuitive beliefs of increased strength being directly related to injury prevention and preservation of muscle-joint complexes. In an activity such as

soccer, contact occurs primarily when attempting to strike the ball with the head, in which the athlete must stabilize the muscles of the neck prior to leaving the ground, proprioceptively while airborne, and again when making contact with the ball. Increased neck strength may lead to a tightening of the involved structures, allowing for less dynamic movement when coming in contact with another object or surface. This does not allow for sufficient dispersion of forces, leading to a higher impact upon direct contact and therefore a greater chance of brain injury. Future research should examine other methods of strength measurement besides isometric contractions in a hope to better represent dynamic sports movements.

The data collected in this study lends itself to further application among youth athletes. Concussion incidence has increased at the high school level among soccer players (Marar et al., 2012), and youth athletes are suffering head injuries at greater rates than previously witnessed (Jinguji, Satchell, & Krabak, 2011). Cervical neck strength has been postulated as a contributing factor in determining both the rate and magnitude of head injuries, and the findings of this research supports previous literature related to other population groups. Neck musculature could also be a contributing factor in discrepancies seen between genders in terms of concussion incidence, but further comparison between cervical strength of those affected and a normative baseline needs to be performed in order to classify the underlying determinants of head impacts. A decreased focus on building neck strength with a further emphasis on cervical flexibility (as opposed to neck weakness) could possibly reduce the forces sustained on the head during athletic competitions for all athletes, but particularly at adolescent ages. Allowing for greater dynamic movements, while preventing high-impact static forces, may decrease the damage sustained to the brain from an early age. More can be done from the onset of high-level athletic competition to prevent the potential for long-term damage, especially as more research surfaces about the

dangers of repeated head trauma. In soccer, an overwhelming majority of the impacts are at the subconcussive level, which has been shown to be related to an increased incidence of dementia-like symptoms and chronic traumatic encephalopathy (CTE) among athletes as they age (Yi et al., 2013). Neck strength appears to be an important factor in the determination of impact rates and forces, and the proper management and development of cervical muscle characteristics in young athletes may prove valuable in limiting long-term brain damage suffered during athletic competition. It is important to consider, however, that investigation into cervical strength only pertains to the domain of prevention; the prediction and management of concussion symptoms is extremely complex neurologically and greatly depends on the involved individual and their previous history of head injuries.

Several limitations of this study may have affected the outcomes in data collection throughout the research. A small sample of 15 youth soccer athletes was utilized given the resources available. Additionally, the participants were only male soccer players, allowing the possibility of confounding gender characteristics. The X2Impact software used to collect the linear and rotational acceleration figures were in their final prototype stages of development, and may have had some inaccuracies in the recording and transfer of the acceleration data, especially between the various student research assistants utilized in the collection process. Several biological and biomechanical characteristics could have also accounted for the variations in impact data. The variability in size among the pubescent athletes may have been a factor, as the taller players have easier access to headers and may be more physical while participating. Additionally, differences in style of play between competitors at various positions may account for alterations in aggressiveness between players. Research needs to be done to incorporate more subjects, measure muscle strength dynamically, examine differences between genders with

the use of the impact software, and to determine the efficacy of the software itself to further determine the relation of cervical neck strength and impact rates in youth soccer.

CONCLUSION

Concussions are a very real and widespread danger to the mental and physical health of athletic competitors. Youth athletes, particularly in soccer, have exhibited an increase in the incidence of traumatic brain injuries, but little is known pertaining to the underlying causes or predispositions associated with concussions. It was shown that there is a significant positive relationship between cervical neck strength and impact severity among youth soccer players, as calculated by rapid changes in head acceleration. The dynamic movements involved with sport participation require the use of neck musculature for stabilization of the head, and the strength characteristics may prove to be very influential on an individual's susceptibility to traumatic brain injury. Further research needs to be done to investigate sport-specific strength measurements, gender discrepancies, and differences between various sports and competition levels. The findings in this study highlight a possible predisposing factor, that when better understood, may decrease concussion incidence in a vulnerable athletic population.

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