The missing piece of the concussion discussion: primary prevention of mild traumatic brain injury in student athletes

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Abstract: The majority of concussion research has focused on timely diagnosis and treatment, yet little has been reported on primary prevention. The goal of this study is to examine the use of core training as a preventative tool. We performed a non-randomized prospective study involving high school athletes. They participated in a 10-week training session with exercises focused on increasing core strength [mobility, agility, stability, strength and flexibility (MASSf)]. Logs were kept of all concussions diagnosed using ImPACT concussion testing. Statistical analysis was done using Chi-square to calculate expected/observed frequency and Chi-squared test statistic, χ^2. Test significance was accepted at a $P<0.01$. One hundred and nineteen athletes participated in the 2014 pre-season MASSf training sessions. Utilizing 2010–2013 concussion data the calculated expected number of concussions for 2014 was 10.87. With the addition of the MASSf program the incidence of concussions was reduced to 2. Using a Chi-squared contingency test, our calculated test statistic, $\chi^2=9.84$, corresponds to a P value of 0.0017. The MASSf program was repeated in the 2015 season with 2 concussions in 121 participants. Our study showed a statistically significant decrease in concussion rates after participating in MASSf training. This program shows a promise as a primary prevention method to reduce sports related concussions.

Keywords: Traumatic brain injury (TBI); trauma; head trauma; concussion; prevention

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Introduction

Over the last decade sports related concussions have been a topic of extensive debate. The estimated incidence of concussion in the US is 1.6–3.8 million per year and about 65% of these are in the 5–18 age group (1,2). Not only are there clinical ramifications, but they also bear a high economic burden (3,4). While many recover without sequelae, complications can include cumulative neuropsychological deficits, intracranial bleeding, cerebral edema, and post-concussion syndrome (5-7). We know that repeated concussions can cause delayed recovery times, long term neurologic deficits, a decline in cognitive performance, and even premature dementia (8-12).

Much of the emphasis of research has focused on timely diagnosis and treatment as opposed to prevention. One area of prevention that has been studied extensively is the use of helmets. Unfortunately, studies have failed to show that helmets reduce concussions (13-15).

Many risk factors are not able to be altered, however there have been a number of studies that have looked at the correlation between neck strength and concussion risk and found that neck strength may indeed be a modifiable risk factor (16-18). A strong association between whiplash induced injuries and concussion exists so in theory if you can decrease the whiplash effect by increasing neck and core strength you can decrease the risk of concussion (19). There are tools that are currently being used to measure neck strength in order to predict those at higher risk for concussions (18,20). There have been studies that looked at neck strengthening programs in athletes and found the program does improve isometric neck strength (21). However, to our knowledge, there have been no studies to test the hypothesis that strengthening programs do reduce the incidence of concussions.

We sought to examine this concept further by implementing a training module to increase neck and core strength in high school athletes and examine its effect on documented concussions.

The goal of this study is to examine the use of core training as a preventative tool for concussions in the high school athlete. We hypothesize that with increased neck and core strength, an athlete will have more control of their body mechanics and the movement of their head and neck during a fall or collision, allowing them to reduce the whiplash mechanism that is often the cause of a concussion.

Methods

We performed a non-randomized prospective pilot study involving high school athletes participating in football, soccer, and volleyball. During the fall of 2014, student athletes in grades 9–12 at a local high school participated in a pre-season ten-week training session with exercises in the following areas: mobility, agility, stability, strength and flexibility (MASSf).

MASSf was created specifically for this study by personal athletic trainers and a collegiate strength and conditioning coach. The program was designed to prepare the student athlete for safe participation in any sport, not simply those being studied in this pilot program. Each targeted area (mobility, agility, strength, stability and flexibility) consisted of a variety of exercises specifically designed to enhance that particular area. The program spanned 10 weeks during preseason training in 2014, with a maximum of over 70 sessions. Coaches picked one exercise from a list for each of the targeted areas to be carried out during that day's session. In other words, student athletes would do five exercises each day: one from each of the targeted areas. Each session would last approximately 20 minutes in addition to the sport specific practice time. We initially collected data from other schools in the region but factors such as socio-economics, size of programs, disparities of MASSf implementation, and a lack of standardized concussion diagnosis criteria between schools would only serve to compound the factors leading to meaningful results. Thus we chose to use a single school for homogeneity of the subjects in despite of a smaller sample size.

To obtain parental and student informed consent to participate in the study, an information session was held during the spring of 2014. During this session, the program was explained to both students and parents and consent was obtained from each. Although the majority of the participants were present during this information session, those unable to attend but still interested in participating were given the opportunity after obtaining information from both the team coach and the athletic trainer who would be supervising the activities.

All students in grade 9–12 that participated in the designated sports were included in our study. Those students who sustained a concussion participating in activities other than those aforementioned sports were not included. All students had a physical completed prior to participation in the sport.

Athletic trainers and coaches kept logs of all concussions or potential concussions using the National Athletic Trainers Association (NATA) assessment tool during the fall sports season (*Figure 1*). Statistical analysis was done using Chi-square to calculate expected/observed frequency and Chi-squared test statistic, χ^2. Test significance was accepted at the $P<0.01$ level.

The MASSf program was then repeated in the 2015 season.

We also compared the concussion rate of surrounding schools not participating in MASSf to assess whether there was a change in the incidence rate.

Results

One hundred and nineteen student athletes participated in the 2014 pre-season MASSf training sessions and were subsequently monitored for concussions during the corresponding sports season (*Table 1*). There was one concussion that occurred while a soccer player involved in the program was dropped from a pyramid when performing cheerleading stunts at an outside facility. This was excluded because it was not one of the sports included in this study. A detailed spreadsheet was kept to log all concussions sustained during the season. We were able to use this log to compile a total for concussions during the fall sports season from 2010–2014 (*Table 2*). Utilizing 2010–2013 concussion data, or pre-MASSf data, the calculated expected number of concussions for 2014 was 10.87 (*Table 3*). With the addition of the MASSf program the observed incidence of concussions was reduced to 2.

To assess the results, we conducted a contingency analysis

Westmont Hilltop School District Criteria for Concussions

STEP 1. Identification and Recognition:

- confirming and establishing the presence of a sequence of signs and symptoms after an individual has sustained a hit to the head or body

STEP 2. Confirmed concussive hit:

- Sideline assessment tool used Standardized Assessment of Concussions (SAC testing) is a basic cognitive screening tool used to detect changes across multiple domains of cognitive functioning that are susceptible to the acute effects of concussions.
  SAC includes orientation, immediate memory recall, neurological functioning, exertional movement, delayed recall and verbal symptom intensity rating scale.
- Written assessment of signs and symptom intensity rating scale; tool used to initially post injury then again until athlete becomes asymptomatic.
  Written signs and symptoms assessment include rating the following: fogginess, difficulty concentrating, vomiting, dizziness, nausea, headache, showiness, balance problems, sensitivity to light, sensitivity to noise, numbness, trouble sleeping, visual problems, difficulty remembering, sleeping less, drowsiness, fatigue, emotional irritability, sadness, nervousness, sleeping more; rating scale to out of 10
- Head injury severity scale associated with the Glasgow Coma Scale; this is used to help determine the degree of head injury severity.
  Severity scale divided into 5 degrees: minimal, mild, moderate, severe and critical head injury.

STEP 3. Formal Clinical Evaluation:

- Vestibular Ocular Motor Screening for Concussions (VOMS) screening that includes smooth pursuits, saccades horizontal and vertical, convergence (near point), VOR horizontal and vertical and visual motor sensitivity.
- Neurological testing-ImPACT computerized based testing more specific testing used to help characterize cognitive functioning by testing memory, speed, and processing time as well as symptom assessment; testing improves diagnostic accuracy particularly in ruling out a concussion if the test results are normal when compared to athlete baseline; helps with understanding long term symptom severity of concussions as well as management of concussions and predicting when it is safe for an athlete to return to full physical activity; it gives result markers to establish academic accommodations necessary for a concussed athlete.

STEP 4. Clinical Impression:

- Once all steps are completed and information is assessed and evaluations are completed athlete will then be given an injury label of concussed athlete or non-concussed athlete. At this time decisions are made determining if the athlete needs further medical attention by a specialized physician/medial professionals.

Figure 1 Diagnosis and management of concussion.

Table 1 Study participants by year, sport, and gender

Year	Football (Male)	Soccer (Male)	Soccer (Female)	Volleyball (Female)	Total
2010	42	38	36	21	137
2011	32	30	38	17	117
2012	35	39	33	18	125
2013	43	36	31	16	126
2014	34	36	28	21	119
Total	186	179	166	93	624

Note: 2010–2013 are pre-MASSf.

Table 2 Concussion injuries by sport and year

Injuries	Football	Soccer	Volleyball	Total
2010	12	2	0	14
2011	7	1	0	8
2012	9	5	0	14
2013	11	7	1	19
2014	0	2	0	2
Total	39	17	1	57

Table 3 Chi-squared contingency tables

	Injured	Not injured	Total
Observed			
Pre-MASSf	55	450	505
MASSf	2	117	119
Expected			
Pre-MASSf	46.13	458.87	505.00
MASSf	10.87	108.13	119.00
Total	57	567	624

Note: expected number of concussions = (row total × column total)/total.

Table 4 Chi-squared test statistic calculation

	Injured	Not injured	Total
Pre-MASSf	1.71	0.17	1.88
MASSf	7.24	0.73	7.97
Total			9.84

Note: using a Chi-square contingency test, our calculated test statistic, χ^2=9.84 which corresponds to a P value of 0.0017 which is highly significant.

using Pearson's Chi-squared test statistic to determine whether a relation between two variables MASSf training and concussion incidence reduction exists. The contingency tables were constructed using the collected data. We calculated the expected frequency of concussions using row and column totals from our observed frequency: expected number of concussions = (row total × column total)/total. Our expected number of concussions for 2014 was 10.87 or approximately 11. Our observed number of concussions after the implementation of MASSf training was only 2. Using a Chi-square contingency test, our calculated test statistic, χ^2=9.84 (*Table 4*) which corresponds to a P value of 0.0017 which is highly significant. We can therefore conclude that our MASSf training was statistically significant at reducing concussions.

The MASSf program was repeated in the 2015 season with almost identical results, 2 concussions in 121 participants. When looking at incidence rate, we compared the rates in surrounding schools and found no change.

Discussion

Concussions in our young athletes are a growing concern and continue to increase in number despite advances in research regarding equipment and other safety measures. A majority do well and recover within 1–3 weeks, but there are approximately 10–15% that do not return to baseline (6,7).

A consensus statement in 2011 stated that the initial step in caring for concussions in athletes is to develop an emergency action plan consisting of injury recognition, assessment, disposition, follow-up, return to play, and education (22). We argue that the initial step should aim at prevention as opposed to recognition. Despite the abundance of research related to concussions there has been a lack of evaluating preventative measures.

Interventions such as helmet use have been utilized as preventative strategies, however they have not correlated with a reduction in the either the incidence or severity of concussions (6,14). Padded headgear in Rugby players has also shown no reduction (23-25) and evidence that there is a risk reduction in football and hockey is also lacking (14,26).

In 2012, USA football instituted the Heads Up Football education program that consisted of training on proper equipment fitting, tackling techniques, reducing contact, and concussion awareness. This has been shown to decrease the number of head impacts during practices however has had no effect on those sustained during games (27).

When examining the biomechanics of head and neck strength and movement, there is evidence that head acceleration can be associated with brain injury (20,28). Dezman *et al.* looked at the effect of neck strength when heading a soccer ball and found that symmetrical strength in neck flexors and extensors reduces head acceleration, therefore decreasing risk of injury (29).

Collins *et al.* found that neck strength was a significant predictor of concussion, with the odds of concussion falling by 5% for every 1-pound increase in aggregate neck strength (18).

Geary *et al.* looked at the effects of a 5-week training program on isometric neck strength in rugby players. They found that the program did increase neck strength compared to their control group (30).

Given the findings that neck strength correlates to concussion risk we organized a pre-season core/neck strengthening and balance training program in high school athletes to attempt to decrease the number of concussions. After implementing this program, we found a subsequent significant decrease in the incidence of concussions in high school athletes.

Limitations to this study include small population size, short test period, as well as non-randomization.

Conclusions

Our study demonstrates a statistically significant decrease in concussion rates among high school athletes after participating in pre-season MASSf training. These results were then reproduced in the subsequent year. This supports the theory that strengthening core muscles correlates with a decreased risk of concussion. The MASSf program shows promise as a primary prevention method to reduce sports related concussion. Future larger studies are required for further validation.

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Footnote

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