

The effects of vision training, neck musculature strength, and reaction time on concussions in an athletic population

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A concussion is a major concern across the athletic population. Prevention of concussions can lead to a decrease of 3.8 million concussions that occur annually in the United States. Vision training, increasing neck musculature strength and quick reaction times are thought to be ways to prevent concussions. The purpose of this study is to review the literature on vision training, neck musculature, and reaction time, and how these interventions can prevent concussions. Upon review of the literature, vision training is proven to prevent concussions in a collegiate football setting, but there is no literature on different levels or sports. There are inconclusive results on whether neck musculature strength prevents concussions. There are substantial results conclud-


ing reaction time does prevent concussions by allowing the athlete to protect and anticipate head impact lessening the severity of the blow to the head. More research needs to be done for all three interventions to prove across all ages and levels of every sport that vision training, neck musculature strength, and reaction time prevent concussions in an athletic population. If proven true, practitioners in an athletic setting can use vision training, increasing neck musculature strength, and increasing reaction time as interventions to help prevent concussions in an athletic population.

Keywords: Concussion, Vision training, Neck strength, Reaction time

INTRODUCTION

Over the past decade, concussions have been a rising concern within the athletic population for all ages. Concussions are a type of injury where practitioners cannot see with their eyes like a joint dislocation or an open wound. Concussions are diagnosed through tests and a history on the athlete's signs and symptoms. If a concussion is misdiagnosed, this injury can lead to detrimental effects. A concussion is a complex pathophysiological injury affecting the brain caused by traumatic biomechanical forces resulting in an impairment of neurological functions caused by both direct and indirect head impacts (Harpham et al., 2014). Some clinical signs and symptoms of a concussion includes headache, dizziness, visual disturbances, amnesia, fatigue, sluggishness, nausea, impaired postural stability, disturbances in equilibrium, and cognitive or

mental status changes (Eckner et al., 2011). Currently, there is an incidence rate of 3.8 million concussions annually in the United States (Gutierrez et al., 2014). This does not include the amount of concussions going undiagnosed. Of these 3.8 million concussions, ten to twenty five percent of them go on to develop into prolonged symptoms causing adverse neurological health problems in the future (Eckner et al., 2014). Concussions are a concern across all ages of athletes with children younger than fifteen years old representing up to forty percent of the 1.1 million concussions resulting in an emergency room department visit each year. Children less than eighteen years of age are also more prone to second impact syndrome. Second impact syndrome is a rare but potentially fatal condition resulting in immediate brain swelling when an athlete sustains a head impact when the initial concussion is not fully resolved (Mihalik et al., 2010).

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There is a major problem with concussions occurring in athletes not only in the United States, but in the World as well. To protect the athletic population from adverse effects related to concussions, medical professionals need to be able to diagnose concussions as soon as they occur. Medical professionals also need to remove the athlete from play until the concussion resolves, which could take anywhere from days to years. Research is coming out constantly about how to diagnose and treat concussions as well as how to try and prevent concussions. Injury prevention is important to keep athletes playing their sport. This includes preventing concussions from occurring. Preventing concussions in an athletic population will keep the athlete healthy and playing. Concussion prevention will also save money from all of the diagnostic assessments and physician visits that occur when an athlete sustains a concussion. The purpose of this literature review is to explore the preventative interventions and tools used in research to prevent concussions from occurring. Over the past decade, researchers considered vision training, neck musculature strength, and reaction time training as interventions to prevent concussions in athletic populations.

VISION TRAINING

Vision training is conserved as a viable way to help prevent concussions. According to Clark et al. (2015b), great vision allows football players to use their eyes and brain to obtain the information in their peripheral vision allowing the athlete to react faster to their environment to avoid injury causing collisions. In this study, there was significant evidence stating the incidence rate of concussions with this cohort decreased from 5.1 cases per 100 player seasons from 2006 to 2013 to 1.4 cases per 100 player seasons. Clark et al. (2015a) also find similar results illustrating vision training decreasing the incidence of concussions in players who receive vision training compared to those who do not receive vision training. Harpham et al. (2014) suggest the same findings. Harpham et al. (2014) found division I football players with higher visual and sensory skills lead to less head impact during hits. The athlete's visual and sensory performance allows the athlete to anticipate the hit on the field. Anticipating the hit allows for the athlete to either move out of the way or brace their head for the hit. All of these studies explain preseason and in season vision training does need to occur to see maintained benefits in their vision.

Some of the tools used to measure and train vision are Dynavision, strobe glasses, tachistoscope, Brock's string, eyeport training, accommodative flippers, saccadic eye movement training, near far

training, and stereopsis. Dynavision is designed to train and test hand-eye coordination to improve visual motor skills (Clark et al., 2015a). Dynavision is a board with multiple small bulbs, and the goal is for the athlete to hit the lit bulb as fast as possible. Strobe glasses are LED lenses which block the light from coming to the eye (Clark et al., 2015a). Athletes will use these glasses to do skills like pitch and catch to train their field of vision. Tachistoscope has a picture flash- in front of the athletes quickly (Clark et al., 2015a). The athletes then answer the question on the next slide pertaining to the picture being flashed. The difficulty is increased by adding more questions or making the time they see the picture faster (Clark et al., 2015b). Brock's string uses five different colored beads attached to a string at varying intervals. The athlete will focus on one color at a time working from close to their face to further down the string training their vision. Eyeport training uses flashing lights the athlete focuses on. The flashing lights will move horizontally, vertically, in a circle, or depth depending on the exercises training the eye to focus in many different planes. Accommodative flippers are glasses with flippers on them. The athlete will start reading letters on an index card and then the practitioner will flip the flippers switching the eyes being covered. The athlete then adjusts as quickly as possible and continues reading, training the athlete to switch their focus. Saccadic eye movement puts two saccadic eye charts eight feet away from the center line (Clark et al., 2015b). The athlete stands eight feet back and reads both charts without moving his head testing and training their peripheral vision. Near far training uses two saccadic eye charts, one four inches away from the athlete and one ten feet away. The athlete switches back and forth reading from each saccadic eye chart training and testing both near and far vision. Stereopsis is where the athlete wears polarizing glasses and is asked to point where the wings of a fly are. The distance between the point and the wing is recorded (Clark et al., 2015a). All of these instruments are used to test and train vision in athletes.

Clark et al. (2017) also conducted the study to explain why female soccer players are at higher risk of sustaining a concussion than male soccer players. The reason suggested is female soccer players tend to have their eyes closed more often while heading the ball compared to male soccer players. With an athlete's eyes closed during a header, the athlete is more vulnerable to an injury, including a concussion, since they are not visually aware of the field and play. Having eyes closed may be the reason why there are more concussion rates in female soccer players compared to male soccer players, but more research needs to be done. Schmidt et al. (2015) completed a study looking at visual performances relating

to severity of head impact during hits in high school football players. They hypothesized those high school football players with greater visual performances will have reduced odds of sustaining a moderate to severe head impact compared to high school football players who had poor visual performances. However, the results of this study displays high school football players with greater visual performance did not have reduced odds of sustaining moderate to severe head impact compared to players with poor visual performances.

According to the studies illustrated above, there are only findings where greater vision performances and vision training work to prevent concussions in a collegiate football environment. Vision training also has to continue through the preseason and regular season to prevent concussions from occurring in collegiate football setting. Although vision training proves to be a viable option to prevent concussions in the college football setting, there are not any definitive findings of vision training working as a preventative tool in other sports or level. More research needs to be conducted in other levels of football as well as different sports in order to determine if vision training and performance is a viable option to help prevent concussions in the athletic population.

NECK MUSCULATURE STRENGTH

Another preventative concussion intervention researchers study includes neck musculature strength. Neck musculature strength is thought to prevent concussions since athletes weaker necks are more likely to experience greater head impacts while athletes with stronger necks are able to withstand the velocity of a head impact diffusing the hit through the muscles, not allowing much head displacement to occur (Eckner et al., 2014). The literature discussed below suggests as to whether or not greater neck musculature strength and girth prevents concussions.

Collins et al. (2014) displays findings in high school basketball, soccer, and lacrosse athletes stating neck strength and girth does predict concussions. They note concussed athletes had smaller and weaker neck strength compared to uninjured athletes. They also note every one pound increase in neck strength leads to a decrease in five percent chance of sustaining a concussion. Eckner et al. (2014) also illustrate smaller and weaker necks lead to greater risk of concussions compared to athletes with big and strong necks. Their study looks at both male and female contact sport athletes across ages eight to thirty. The results display greater neck strength reduces the force of the head's dynamic response to the external forces in all planes of motion, across all age spectrums,

and across both genders. This study also concluded anticipating the external force through anticipatory neck musculature contraction acts independently from neck musculature strength to further reduce the external force acting on the head, thus preventing a concussive blow. Gutierrez et al. (2014) explored the impacts of headers on high school female soccer players and found similar results with greater neck strength being related to decreases in strength of impact of the soccer ball on the head during heading. They also found athletes with weaker necks cannot control their head movement when heading the ball and cannot physically tolerate headers as well as athletes with stronger necks can. High school female soccer players with weaker neck strength have a greater chance of sustaining a concussion compared to high school female soccer players who have stronger necks. Hrysmallis (2016) discussed studies regarding neck strength relating to concussions. Hrysmallis (2016) found increasing isometric neck strength is directly related to decreasing injuries. This may be useful as a screening tool for injury risk with athletes. If athletes have weak necks, then they may be targeted for neck strengthening programs to help reduce the risk of injury, including concussions.

Throughout the literature, there is also research disproving neck strength as an indicator of preventing concussions. Mihalik et al. (2011) conducted the research on youth hockey players measuring neck strength while looking at the hits sustained by these youth hockey players. The results of study found that increased static cervical neck strength in isolation was not enough to reduce the severity of head impacts sustained by youth hockey players. Mihalik et al. (2011) concluded there were no coherent differences in head acceleration among youth hockey players with weak, moderate, and strong cervical muscles. Schmidt et al. (2014) also conducted the study regarding high school and college football players measuring their neck strength and neck musculature girth. The study found that football players with stronger and weaker cervical musculature had equal odds of sustaining moderate to severe head impacts. They also found players with larger neck musculature had greater odds of sustaining both moderate and severe head impacts. However, players with greater neck stiffness during anticipated forces and less head displacement after contact displayed reduced odds of sustaining higher magnitude head impacts. This research article supports enhancing cervical musculature dynamic responses to head impact versus strengthening neck musculature as a way to prevent higher magnitude head impacts.

Throughout the literature of neck musculature strength, researchers used different measuring tools to measure cervical neck

musculature strength, girth, and head impacts. Collins et al. (2014) implemented a new Velcro tool to measure cervical neck strength proving to be reliable with the gold standard of using a hand-held dynamometer. The Velcro tool is a Velcro head strap attached with a D-ring and scale measuring in pounds. This device was able to accurately measure neck strength comparable with a hand held dynamometer and was used as the primary device in the high school setting to measure neck strength. Eckner et al.'s (2014) study used a similar device as above using a head-gear and pulley scale to measure peak force neck musculature strength. Mihalik et al.'s (2011) and Gutierrez et al.'s (2014) study used the hand held dynamometer while Schmidt et al.'s (2014) study used HUMAC NORM Testing & Rehabilitation System where the athlete lies on the table and a pad applies force to the head in which the athlete resists. All of these tools are proven to be used as viable methods to measure cervical neck musculature strength. The tools used to measure neck girth include cloth (Collins et al., 2014) and ultrasound (Schmidt et al., 2014) with both tools being a viable way to measure neck girth. In both Mihalik et al.'s (2011) and Schmidt et al.'s (2014) study, they used the Head Impact Telemetry System technology inside the helmets to measure impact forces. Gutierrez et al.'s (2014) study used a custom headband, which held a tri-axial accelerometer to measure header impact. Even though, all of these studies used different measuring tools, these studies used viable tools to allow their results to be sound.

According to the literature, there are inconclusive results for neck strength preventing concussions. In basketball, lacrosse, rugby and soccer, increased neck strength seems to lead to fewer concussions, but in hockey and football, neck strength does not seem to effect concussions. Researchers concluded anticipating a head impact and allowing the cervical neck musculature to brace for the impact reveals less head movement and acceleration following the head impact, which may lead to less concussions. A limitation in all of the neck musculature research is categorizing neck strength. There is no agreed upon scale as to what constitutes as strong, moderate, and weak neck strength. For example, football players will likely have stronger necks than soccer players, yet in their respective studies, they were broken down into strong, moderate, and weak necks. The question is there a threshold of neck strength to prevent concussions needs to be answered in future research. More research needs to be done in both neck cervical strength and anticipation of head impacts to see if these can be interventions practiced to prevent concussions.

REACTION TIME

There is a study that aster reaction times lead to fewer hits on the head as well as less magnitude of the hit sustained. The quicker reaction time an athlete has, the more time the athlete has to prepare for the hit or object coming toward their head. "Raising the upper limbs to protect the head and face is a vital protective strategy for avoiding head impacts with other potentially injurious objects encountered during sport participation including other athletes and various components of the playing surface" (Eckner et al., 2011). In the study of Harpham et al. (2014) with division I collegiate football players, they found the faster reaction times these football athletes had, the less severe head impacts they sustained. They concluded these athletes with faster reaction times also can anticipate and react to the impending head impacts on the field. Another study done by Mihalik et al. (2010) concluded with similar findings. They studied youth hockey players with a mean age of fourteen years old. They tracked the severity of the hit and whether the athlete anticipated the hit or not. They found unanticipated hits lead to greater rotational velocity of the head. Another important finding from this study includes "head impact severity is increased with decreasing anticipation of a collision" (Mihalik et al., 2010). If an athlete has faster reaction times, they are able to anticipate hits and protect their heads from severe impacts.

A study done by Eckner et al. (2011) conducted the study regarding a clinical reaction time test compared to a functional sport related head protective response. The results found that the clinical reaction time test is predictive of a functional sport related head protective response closely simulating an object being thrown at the head. Even though this study used a protective response one might see in baseball, softball, or cricket, this response is thought to have relevance in other sports as well. A practitioner can use this clinical test as a screening tool prior to the season to diagnose the likelihood of an athlete being at danger of a severe head impact. The clinician can use this information to help train athletes with poor reaction times to create faster reaction times.

An athlete with a concussion will display slower reaction times than they normally do. This information is important for practitioners to keep in mind when trying to diagnose an athlete who may have signs or symptoms of a concussion. Recently, there has been literature pertaining to studying reaction time and what tests can be used clinically and cheaply to measure an athlete's reaction time. One such tool is catching a vertical ruler being released. The practitioner will then record the measurement at

which the athlete caught the ruler to help determine reaction time. The study performed by Eckner et al. (2009) tested the reliability of this clinical reaction time test versus a computerized reaction time test. Their subjects consisted of adult volunteers with a mean age of forty five years old. They concluded the “initial data suggests reaction time clinical is a reliable and valid measure of reaction time” (Eckner et al., 2009). Another study done by Eckner et al. (2010) used the same clinical reaction time test with the ruler compared to a computerized reaction time test in collegiate football players. They found the vertical ruler drop test is a valid way to measure reaction time in the collegiate football population. With these findings, Eckner et al. (2010) concluded that clinical test of reaction time has potential clinical utility and may prove to be a valuable tool for practitioners.

Reaction time is an important indicator to prevent concussions. The faster reaction time an athlete has, the more likely they are able to protect their head from severe impacts. With a faster reaction time, they will be able to anticipate hits better, thus lessening the impact severity on their head. They are also able to see object coming at their head sooner, meaning they have more time to dodge or cover their head from the object. There is also a cheap and easy to operate a clinical test with dropping a vertical ruler. This test can help practitioners accurately measure a baseline for reaction time as well as a tool to use to help diagnose whether an athlete has a concussion. Knowing athletes with slower reaction times prior to the season can help practitioners identify athletes who will be more prone to greater head severity impacts. Practitioners can also train these athletes to produce faster reaction times, thus protecting their heads from severe impacts lessening

the chance of sustaining a concussion.

CONCLUSIONS

Vision training, neck musculature strength, and reaction time may all have an impact in preventing concussions in sports (Fig. 1). Vision training is only proven to prevent concussions in the collegiate football setting. Studies done by Clark et al. (2015a, 2015b) proved with vision training, collegiate football athletes decrease their chances of sustaining a concussion. However, there is no literature looking at other sports or level of football stating vision training can prevent concussions. Throughout the literature, there are many tools used to help train vision. Neck strength has inconclusive results throughout the literature. Studies conducted by Collins et al. (2014), Eckner et al. (2014), Gutierrez et al. (2014), and Hrysonmallis (2016) concluded greater neck strength and greater neck girth lead to decreased severity in blows to the head thus decreasing the number of concussions sustained. However, studies conducted by Mihalik et al. (2011) and Schmidt et al. (2014) concluded there is no correlation between neck strength and size in reducing the severity of head impact during contact. Reaction time is the only intervention agreed upon by the literature in helping prevent concussions. The literature states a faster reaction time will allow athletes to protect their head from severe impacts. Having a fast reaction time can also allow the athlete to anticipate the hit coming, so they have more time to protect and prepare their body and head for the impact. This will also decrease the impact severity and forces on the head. There is also a cheap and easy clinical test to measure reaction time, which can help

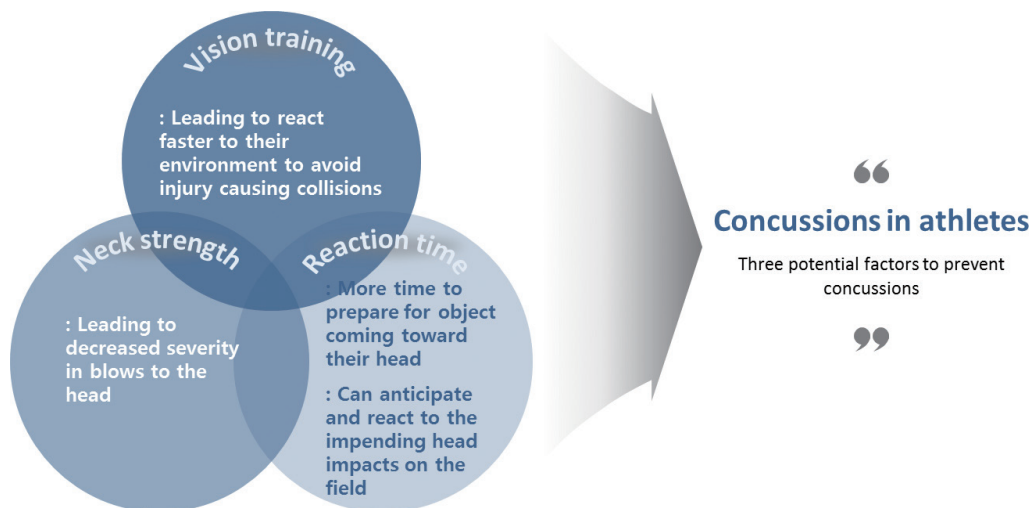


Fig. 1. Three factors to prevent concussions.

practitioners of all levels in sports prior to the season as well as a tool used to help diagnose a concussion. This test includes dropping a ruler and having the athlete catch it as quickly as possible and then measuring the distance from the end of the ruler (Eckner et al., 2009).

Another idea throughout the literature is anticipating hits may lead to preventing concussions in an athletic population. In order to anticipate a hit, the athlete must have good vision and fast reaction times. With the anticipation of the hit, they will be able to brace and activate their neck musculature to help keep their head stable. Throughout the literature of vision training, neck musculature strength, and reaction time, hit anticipation is an underlying factor. Hit anticipation decreases head impact severity while head impact severity is increased with decreasing anticipation of the hit (Mihalik et al., 2010). Since hit anticipation takes vision training, neck musculature strength, and reaction time into account, more research can create stronger arguments for vision training, musculature strength, and reaction as prevention interventions to decrease concussions in an athletic population.

In order for vision training and neck musculature strength to be considered as viable options in preventing concussions, more studies need to be conducted. Studies on vision training need to be conducted across different sports as well as different levels of football. If these studies concluded with vision training decreasing concussions across all of these sports and levels, then vision training can be considered to help prevent concussions as most researchers throughout the literature predict. Neck musculature and strength needs more studies as well. Since there is literature concluding both neck strength and size can lead to less concussions, but can also have no impact on the matter, research needs to continue in all ages and all sports to support both claims. The literature on reaction time proves reaction time prevents concussions, but more research may still be conducted throughout different sports and levels to create even more support for this finding. If any or all three of vision training, neck musculature strength, and reaction time are proven through the literature to help prevent concussions, practitioners, including athletic trainers and coaches, can use this knowledge to help prevent concussions in their athletes. They can implement vision training sessions, neck strengthening protocols, and reaction time training sessions to allow athletes to strengthen these areas to help athletes prevent against concussions. There are initial findings in the literature where vision training, neck musculature strength, and reaction time can help prevent concussions from occurring in an athletic population. However, more research needs to be done in all three

categories to create a more substantial argument in favor of vision training, neck musculature strength, and reaction time as interventions used to prevent concussions in an athletic population.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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