

Article ► An Exploratory Study of the Potential Effects of Vision Training on Concussion Incidence in Football

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ABSTRACT

Background: Vision training has become a component of sports enhancement training; however, quantifiable and validated improvement in visual performance has not been clearly demonstrated. In addition, there is minimal literature related to the effects of vision training on sports performance and injury risk reduction. The purpose of the current investigation was to determine the effects of vision training on peripheral vision and concussion incidence.

Methods: Vision training was initiated among the University of Cincinnati football team at the beginning of the 2010 season and continued for four years (2010 to 2013). The sports vision enhancement was conducted during the two weeks of preseason camp. Typical vision training consisted of Dynavision D2 light board training, Nike strobe glasses, and tracking drills. Nike Strobe glasses and tracking drills were done with pairs of pitch-and-catch drills using footballs and tennis balls, with instructions to vary arc, speed, and trajectory. For skilled players, "high ball" drills were the focus, whereas for linemen, bounce passes and low pitch drills were stressed. Reaction time data was recorded for each athlete during every Dynavision D2 training session. We monitored the incidence of concussion during the four consecutive seasons of vision training, as well as the previous four consecutive seasons, and compared incidence of concussions (2006 to 2009 referent seasons v. 2010 to 2013 vision training seasons).

Results: During the 2006-2013 pre- and regular football seasons, there were 41 sustained concussion events reported. The overall concussion incidence rate for the entire cohort was 5.1 cases per 100 player seasons. When the data were evaluated relative to vision trained versus referent untrained player seasons, a statistically significant lower rate of concussion was noted in player season in the vision training cohort (1.4 concussions per 100 player seasons) compared to players who did not receive the vision training (9.2 concussions per 100 player seasons; $p < 0.001$). The decrease in injury frequency in competitive seasons with vision training was also associated with a concomitant decrease in missed play time.

Discussion: The current data indicates an association of a decreased incidence of concussion among football players during the competitive seasons where vision training was performed as part of the preseason training. We suggest that better field awareness gained from vision training may assist in preparatory awareness to avoid concussion-causing injuries. Future large scale clinical trials are warranted to confirm the effects noted in this preliminary report.

Keywords: athletic training, concussion, Dynavision, football, injury, injury prevention, peripheral vision, vision, vision training

Introduction

Football is a complex skilled sport with the need to integrate sensory input to be successful; vision plays a key component.¹ There are 22 players on the field of play, and players need to see, to track, and to identify multiple targets for successful performance, as well as to avoid injuries. Success in football requires robust vision tracking, the substantial intake of visual information, and rapid analysis of this information.^{2,3} This requires processing of information in the central and peripheral visual fields. Since rule changes in the 1970s, the concept of “see what you hit” has reduced the risk of catastrophic injury, yet the number of concussions remains high.⁴

In recent years, the management of traumatic brain injury (TBI) in sports has come under scrutiny from academia and media, both noting the short- and long-term outcomes associated with concussions. Athletic concussions have been in the forefront of the public’s focus due to the high-profile injuries, deaths, and lawsuits concerning long-term consequences from concussion.^{5,6} Recently, the reported incidence rate for TBI, which includes concussions,

went from 1.75 million annually to 3.6 million annually.⁷ This likely reflects, in part, increased awareness by both the athletes and support personnel, as well as an increase in the reporting of TBIs. This apparent doubling of reported concussions is supported by recent media reports concerning the burden and seriousness of concussions in sports such as football, with some teams reporting 20 concussions per year, up from 10 per year.⁷

Over the last 10 years, the volume of literature that defines or describes the process of injury, assessment processes, and rehab strategies has expanded. The primary emphasis has been on neuro-psychological tools, balance systems, and posture. Although multiple organizations associated with sports have published recommendations, a gold standard still does not exist in terms of post traumatic management and pre-participation assessment.^{1,8,9} In 2004, the National Athletic Trainers Association (NATA) published a position statement based on the available research and clinical practice trends at that time. The position statement included recommendations to its association

membership for concussions; however, research is evolving at a pace that often overshadows many recommendations. NATA outlines multiple sections in its 2004 position statement,⁹ from defining, to pre-participation evaluation, to assessment, to post-concussion management, to return to play. The primary emphasis is on the management of post-TBI and recommended pre-participation assessment tools.

The National Collegiate Athletic Association (NCAA) guidelines, also in 2013,¹⁰ focused on the assessment process and recommended that member institutions formulate a concussion management plan with recommendations for baseline testing, neuropsychological evaluation, and a return-to-play pathway. Minimal to no information contained in either policy reflects vision assessment or the role of vision in return-to-play. On an annual basis, the NCAA publishes a guideline on sports-related concussions, which the membership holds as the standard set by the organization.

Overall, little to no emphasis is placed on prevention or training to reduce the risk of traumatic brain injury. Primary work occurs in the area of equipment alteration, by way of either adding a layer for load absorption or in the direction of monitoring impact size and location. However, efforts to use performance training as a tool to reduce injury risk have received minimal attention in the literature. There remains the question, "Is there a viable option to provide the athlete the opportunity to train neuro-cognitive function to avoid and/or assist the brain in the recovery process?"

The prevention of TBI in football up to this point has received minimal attention,¹¹ and primary emphasis has been on rule changes and interpretation, equipment evolution, and baseline neurological assessment testing. Studies designed to reduce the risk by way of performance training the athlete directly have received negligible attention. Since the equation for injury involves both intrinsic and

extrinsic factors, at some point intrinsic factors must be addressed. With that as a direction, our group assessed available techniques and training modalities to address this issue.

Unfortunately, helmets and concussion mitigation strategies reported to date have been ineffective.¹¹ What is needed is a strategy that can decrease the risk of injury from collisions and concussive injuries that is easily adoptable by coaches and medical practitioners. The purpose of this study was to evaluate the potential for vision training to decrease the incidence of concussive injury in elite football players. We hypothesized that preseason vision training would significantly reduce both practice and competition concussion incidence in football.

Methods

Human Subjects

Vision training was incorporated into the preseason football camp training schedule of all University of Cincinnati football team members from the 2010 to the 2013 seasons. The testing and training was a team-wide activity. No informed consents were signed as this was implemented as part of the standard evaluation for concussions, and training was integrated into the performance enhancement segment of the athletes' program. The University of Cincinnati Institutional Review Board (IRB) reviewed the project and determined that it did not meet the criteria for research involving human subjects, and therefore IRB oversight was not required.

Dynavision

The Dynavision is a device designed to evaluate and to train eye-hand coordination to improve visual motor skills.^{7,8} Training typically consists of two one-minute sessions with the athletes. The reason for doing multiple sessions is to demonstrate consistency and improvement with the tasks. The staged and progressive

nature of the tasks also helps keep the athletes engaged.

The off-the-shelf “*A” training session is an established Dynavision protocol.¹²⁻¹⁵ “*A” is the program name that comes as part of the package for the Dynavision and is a one-minute task of hitting lights on the board as quickly as possible. It uses traditional eye-hand reaction training to challenge an individual’s eye-hand coordination in multiple visual fields. The resultant output provides the athlete with feedback relative to the number of hits in one minute, as well as the average reaction time for each hit. Targeted programs were written to improve the perception of the regions of interest and eye-hand performance and precision. For example, quarterbacks focused on their blind side, while linemen focused on central visual fields.



In this video we see a University of Cincinnati athlete participating in one of our vision training exercises. Around him are multiple athletes going through similar exercises. In this particular exercise the athlete is doing the Dynavision reaction time task, where he holds a button, waits for a light to light up and hits that light with that same hand. It is a one handed visual reaction time task. Added to that task is a catch drill. Immediately after the light goes on the proctor to his side gently tosses a ball to him, which he must turn and catch. The drill trains visual reaction times, eye hand coordination, and sequential visual processing. After doing the drill with the right hand, the athlete switches to his left hand and the ball is tossed from his right side. This way they are trained to react to their left and right visual fields.

The other off-the-shelf training program that was also completed on the Dynavision was the reaction test. The reaction test is a task where the subject uses one hand at a time to hold down one button, and when a light illuminates, the subject hits that light. The subject is required to scan an area or region of interest in preparation for the light to be

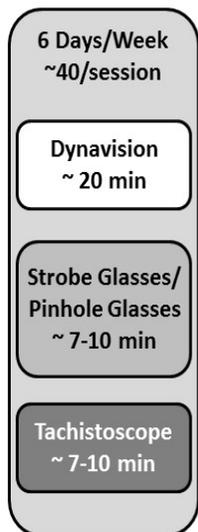
hit. A computer records how long it takes for the subject to initiate a response to the light: moving their hand from the button they were holding. Then the subject hits the newly lit light, and the task is completed. So, two tasks in one are performed: seeing the light and responding and hitting the light.¹⁵ The Dynavision assesses visual and motor reaction times for the left and right hands. The lights are arranged horizontally, vertically (with an arc), and a single light. The subject is told to scan the area where the lights could illuminate and respond when lit. Alternately, the subject is told to keep his eyes on one point and to use peripheral vision to see and to respond to the lights. Thus, the training enhances scanning practices and peripheral vision response times.

Peripheral vision reaction time ratio is a calculation to determine an athlete’s speed of reaction to what they see in their peripheral vision. We used the data collected during the Dynavision program “*A” session during the 2013 preseason football camp for each athlete and calculated the average reaction time for the buttons hit in the outer two rings of the vision board compared to the inner three rings. We compared every athlete’s peripheral vision reaction time ratio from the first training session of football camp to their last training session of football camp. The ratio was calculated by taking the mean of the reaction times for the outer two rings divided by the mean of the reaction times for the inner two rings. A higher ratio means it takes longer to see and to hit the buttons in the periphery compared to the center of the visual field.

Strobe Glasses

Strobe glasses (Nike SPARQ Vapor Strobe) are LED lenses that flash and block the light signal to the eyes.¹⁴ They are set to flash more rapidly in the initial training stages and are gradually slowed as the athlete adapts to the training. The slower the interval, the more difficult the task becomes because of the reduced visual input.

Pre-Season Camp (~2.5 weeks)



During Season (~14 weeks)

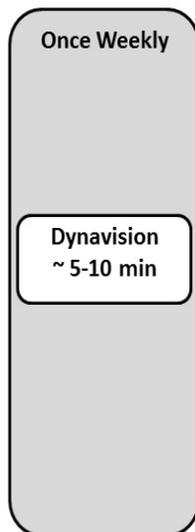


Figure 1: In this figure we see the scheme for vision training of University of Cincinnati football players' during the preseason, where there is very regular and intense training. During these two-plus weeks, the complexity and demands of the vision training are escalated as the training proceeds. During the season, no new drills are added, and a maintenance phase is initiated where subjects perform exclusively the Dynavision once weekly in approximately ten-minute sessions.

The Vision Training Procedure

Vision training was divided by position, with targeted drills for each position. This included Dynavision, strobe glasses, pitch and catch, and tachistoscope. Typically, this training occurred once per day during preseason training camp. Vision training was considered part of conditioning, and groups of players rotated through the vision training stations. We typically ran three main vision training stations during the football camp, and subjects did the training daily as part of their preseason conditioning (Figure 1).

Dynavision Methods

During football camp, typically 2.5 weeks immediately prior to the start of camp, players had approximately 40 minutes of structured vision training per day, 6 or 7 days per week. The vision training typically included 20 minutes of Dynavision. The Dynavision training programs performed on the light board were purpose-built programs that were structured to be appropriate to the players' positions. For

example, receivers and defensive backs would do training requiring the subjects to see and to hit lights over their head. Linemen would have specific tasks but with less reaching over their heads, as their positions do not require many overhead actions like catching high balls.

All players were required to do dual task drills with their vision. This required tasks that had the subjects call numbers, words, or characters flashed on the tachistoscope while hitting buttons. The instructions for these drills were to use eye discipline and to keep their eyes on the scope while using peripheral vision to see the buttons and to hit the buttons. This, we believe, helps train functional peripheral vision. Peripheral vision reaction training was also done with the Dynavision, where subjects had to react to flashing lights in their peripheral visual fields while focusing on the tachistoscope or another light.

Tachistoscope

Typically, several players could work on the projected tachistoscope training simultaneously. Using football photos from the University of Cincinnati games, a timed power point program was developed where flashed pictures (still photos) of the games were projected. The subjects were to watch the timed power point and make note of one or two specific bits of information based on questions posed after the flash. The flashed pictures had numbers and/or letters randomly distributed throughout, and the players had to note the numbers/letters. Additional questions were asked of the players such as player numbers from the photos, teams being played, etc. This tachistoscope training was made progressively more complicated during the training camp by making the flash time shorter and the information to be obtained more complicated. Subjects were tasked to do the tachistoscope training for approximately 7-10 minutes per session.

Pinhole glasses, strobe glasses, and pitch and catch

Groups of players, typically 2 to 6 players, were given balls, pinhole glasses, and strobe glasses and were advised to throw the ball(s) around. This was done for approximately 7-10 minutes per session. Subjects rotated strobes and pinhole glasses every minute or two. The pitch-and-catch tasks were progressed throughout camp by varying the speed of the flash with the strobes, narrowing the visual field of the pinhole glasses, etc. Also, pitch-and-catch routines were made progressively more complicated by having subjects turn away from their partner and then perform a turn-and-catch.

In-Season Training – Maintenance Phase

During football season, a maintenance phase of vision training was initiated exclusively using the Dynavision. Subjects could use the Dynavision at any time on their own, but there was also one weekly structured training, typically 10 minutes in length, where subjects were run through the series of Dynavision routines that they had done at camp. No new routines were initiated during the season. In-season training sessions were expanded and contracted based on practice and game schedules.

Definition of a Concussion

The concussion management team for the University of Cincinnati sports medicine division uses the American Association of Neurological Surgeons (AANS) definition of concussion at its core: a trauma-induced alteration in brain function that is documentable.¹⁶ The documentable component to the definition can come from a change in brain function from baseline or an abnormal parameter in the absence of baseline.

For the University of Cincinnati, the process for identifying a concussion starts on the field.

- A big hit of concern or the athlete going down triggers an athletic trainer to assess the athlete.
- If the athlete has a suspected concussion, the athletic trainer pulls the athlete from play for a further evaluation by other members of the concussion management team.
- Typical sideline concussion assessment test (SCAT) II, SCAT III, and question-and-answer are performed.
- If the initial concussion suspicion is not founded, the player may return to play.
- If the suspicion of concussion remains, the athlete is pulled from all play that day and referred to be evaluated by a physician or physician designate such as a sports neuro specialist.
- The final diagnosis of concussion is made by the team physician based in part on the report of the neuro specialist, the trainers, and his/her observations.
- The treatment, rehab, and return-to-play pathway is initiated for the athlete.

For this study, the past concussions were confirmed based upon retrospective review of injury logs generated by the athletic trainer, the concussion management team member's report, and the team physician's final diagnosis based on the two reports in combination with his/her assessment. Currently the diagnosis is unchanged, but the records were being kept as part of an IRB-approved concussion protocol, so a historical analysis was not needed as they were directly entered into the system.

Helmets

All team members for each season used the same helmet models from the same two manufactures (Ridell and Schutte). All helmets were properly fitted by individuals well-trained in proper helmet fitting and maintenance.

Table 1: Results from the Individual Years

	No. of Concussions	No. of Players	Coach that year
2006	9	103	M. Dantonio
2007	8	102	B. Kelly
2008	7	103	B. Kelly
2009	11	109	B. Kelly
2010*	1	113	B. Jones
2011	3	110	B. Jones
2012	1	109	B. Jones
2013	1	105	T. Tuberville

*Vision training was initiated Aug 1, 2010

Table 2: The Average Time it Takes for Subjects to Hit the Different Rings When they Start the Vision Training Pre-season

Average Hit Time ± SD (time in seconds)	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Functional Peripheral Vision Ratio
Pre Season						
2010	0.56 ± 0.08	0.56 ± 0.06	0.69 ± 0.11	0.77 ± 0.12	0.98 ± 0.18	1.52
2011	0.62 ± 0.21	0.64 ± 0.19	0.72 ± 0.20	0.85 ± 0.26	1.02 ± 0.25	1.48
2012	0.55 ± 0.12	0.56 ± 0.12	0.64 ± 0.15	0.77 ± 0.20	0.91 ± 0.33	1.51
2013	0.52 ± 0.08	0.53 v 0.09	0.57 ± 0.07	0.67 ± 0.10	0.80 ± 0.19	1.40
Diameter of Rings (inches)	8.125	17.25	21.25	34.75	43.5	

Helmets were checked weekly for damage and were repaired or replaced as needed. The ratio of helmet type on the team was recorded annually.

Athlete Season Exposures

The relative rates reflect the reported concussions from the beginning of the fall training season (usually August) through the end of the season, including bowl games (except for the 2013-2014 season, which did not include the bowl).

Statistics

The initial statistical approach was to compare the pre-vision training years' incidence rates to the post-vision training years' rates using an unpaired Student's t-Test. The secondary approach for data analysis was an examination of rate of concussion for total player year exposure at the categorized grouping of vision training versus control year sample. Concussion rates were compared between vision training and referent untrained condition using a chi-square test with a Yates correction. Statistical significance was established a priori at $p < 0.05$.

RESULTS

Number of injuries

During the 2006-2013 pre- and regular football seasons, there were 41 sustained

concussion events reported. The concussion incidence rate for the entire cohort was 5.1 cases per 100 player seasons. When the data were evaluated relative to vision-trained versus referent untrained player seasons, a statistically significant lower rate of concussion was noted in players in the vision training cohort (1.4 concussions per 100 player seasons) compared to players who did not receive the vision training (9.2 concussions per 100 game exposures; $p < 0.001$).

The average number of diagnosed concussions per season for the four years prior to vision training was 8.75 ± 1.7 . This compares to 1.5 ± 1.0 concussions per season over the four years after initiation of vision training ($p < 0.001$). The periods of 2006 to 2009 and 2010 to 2013 each covered two different coaching staffs (Table 1).

Peripheral Vision

The average peripheral vision reaction time ratio calculated during the Dynavision "A" training session from the first vision training session of football camp in 2013 was 1.50 ± 0.23 . This improved to a ratio of 1.42 ± 0.15 following two weeks of vision training ($p < 0.01$; $N = 105$).

In Table 2, we see the reaction times taken to hit the Dynavision D2 buttons reported by year and broken down by ring to give a clearer indication of the functional peripheral vision

changes seen. What we see is the year-to-year improvement for the intake of upperclassmen who have had vision training.

A comparison of pre- and post-training functional peripheral ratios was made to assess the impact of the training program using data from the 2013 camp. Preseason athletes had an average ratio of 1.50 ± 0.23 . After vision training, these athletes had a ratio of 1.42 ± 0.15 ($p \leq 0.01$).

DISCUSSION

The concept of vision training to improve the athlete's on-field performance has evolved into a common practice for the University of Cincinnati sports teams.¹⁴ Multiple authors have suggested that training the visual field may improve several elements of competition.^{13,14,17} There is a growing body of evidence that vision training may have an added benefit of injury prevention.^{18,19} The objective of training would be to improve specific visual parameters, giving athletes in sports such as football and baseball an improved ability to focus on the field of play and to prepare for or to avoid injuries, including mild traumatic brain injury.

In this paper, we report that a comprehensive preseason vision training program is associated with a reduction in concussion incidence in elite football players. It would be easy to criticize the association of vision training to a decrease in injury rate if this were a one-year study. However, this trend was seen over multiple years and coaching regimes (four different coaches). Further, it might be suggested that the decrease in reported injuries was not a causal relationship to vision training, as vision training might have had no other demonstrable effects. However, we found that functional peripheral vision (defined by the peripheral vision reaction time ratio) was improved in the team following vision training (Table 2). The research team had previously used vision training methods to improve batting performance in baseball players, so there is familiarity with the initiation and implementation of vision training.¹⁴ A

main difference between the training regimen performed for baseball and football is that football was limited to the summer camp of about two and a half weeks, whereas baseball was six weeks. Finally, the decrease in concussions was seen at a time when most other universities were reporting a rise in concussions.⁷ Thus, we believe that there is a strong association between vision training and injury prevention.

The question remains as to how might vision training prevent injuries. We believe that the vision training we performed is broadening the athlete's field of awareness or functional peripheral vision. It may be that with training, the eyes and brain are able to use information obtained within the field of functional peripheral vision to react faster to their changing environment and to avoid injury-causing collisions. In a post hoc analysis, we attempted to assess whether the peripheral vision might have improved. To do this, we analyzed the Dynavision data from the University of Cincinnati football team at the beginning and end of the 2013 camp. The improvement from 1.50 ± 0.23 before training to 1.42 ± 0.15 ($p \leq 0.01$) after vision training suggests that the ability of the athletes to see and to respond to the lights in their peripheral vision improves with training, and by extension we posit that they may become better able to respond to situations and to avoid injuries. It should be recalled that the higher ratio means it takes longer to see and to hit the buttons in the periphery compared to the center of the visual field.

Rationale for Vision Training

The vision training was initiated in 2010 for baseline concussion testing and performance enhancement. Also, we published our results on the performance enhancement associated with vision training of baseball players where batting performance was enhanced.¹⁴ For football, the Dynavision and strobe glasses were the main

vision training methods used, as this was being done as part of concussion management and position-specific performance enhancement.

Empirical evidence indicates that the vision training, which included ocular motor and visual conditioning, led to an improvement in the control and fidelity of the extraocular and intraocular muscles of the eyes.^{12-14,17,20-24} This likely included an improvement in muscle memory for the arms to hit the buttons effectively. The eyes were able more precisely to “focus” on a point, to remain there, and to give the brain better input concerning information from peripheral visual fields. This, to an extent, may be what the athletes use during competition to increase awareness of where that point is in physical space.^{14,15,24}

Limitations

A limitation of this study is that it is a retrospective analysis of reported concussions after the initiation of vision training. There was no control group. The vision training was performed during the summer camp on all players and continued to a limited extent during the football season. This is in compliance with contact hour rules. This restricted vision training to once a week for less than 15 minutes per session. The vision training was always directed by the same person for all four years, and the focus of the vision training was for concussion management and was presented to the students as performance enhancement. Thus, there was a dual purpose for the vision training. We estimate that the average player had 20 minutes of vision training on the Dynavision during camp, which is two weeks. This includes all players and all positions. Plus, there was an additional 20 minutes doing other vision training-related activities. This training duration is similar to what we reported for the University of Cincinnati

baseball players of about twelve minutes of vision training per week.¹⁴ While the results of this study provide important preliminary data on the potential benefits of vision training to reduce sport-related concussion in football, the small sample size indicates that interpretation of these results should be taken with caution. Before applying these results to clinical applications, a prospective controlled study design is needed to confirm the finding of the current study.

CONCLUSION

Future prospective studies are needed to determine a causal relationship of vision training and injury prevention. Further, from this retrospective analysis, it is not clear what vision training method or methods are most beneficial to support concussion injury risk reduction. Future prospective randomized clinical trials are warranted to better assess the cause and effect of vision training and its potential to reduce concussion incidence in football players.

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Note

At the conclusion of the 2014 season (the 5th season of vision training), the University of Cincinnati football team had 3 diagnosed concussions. This makes it 5 years with 3 or fewer concussions per season since the initiation of vision training.

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