

Article ▶ The Effect of Relaxation Techniques and Visual Training on Peripheral Vision in U.S. Collegiate Soccer Players

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ABSTRACT

Background: Injuries are common among soccer players in the United States. A possible causative factor is stress-induced peripheral vision narrowing, causing reduced awareness of other players on the field. This pilot study sought to measure peripheral visual attentive fields during non-stress and stress conditions in healthy young collegiate soccer players before and after training techniques (stress reduction or vision training).

Methods: Single-blind, randomized pilot study. Athletes were recruited from soccer teams at a National Association of Intercollegiate Athletes (NAIA) Division 1 school. Athletes were randomized into two groups for one month of training in relaxation (n=9) or peripheral vision exercises (n=8). Peripheral visual attentive fields were measured using Bernell Color Campimetry (white, red, green, and blue) under stress and non-stress conditions.

Results: 16 athletes (14 male) completed the study. Athletes initially had a statistically significant stress-induced reduction in visual attentive fields for certain colors, including both colors white and blue ($p < 0.05$). After training, a statistically significant decrease in narrowing was shown for the color white for the combined results of both training groups ($p < 0.05$).

Conclusions: Color campimetry was effective for measuring baseline peripheral visual attentive fields, with no significant learning effect. Participants demonstrated stress-induced peripheral field narrowing in the laboratory setting, which was reduced after intervention.

Keywords: athletic performance, soccer, sports vision, sports injury prevention

Background

The popularity of soccer is on the rise in the United States; the Federation Internationale de Football Association (FIFA) reports that over 24 million Americans currently play this sport.¹ In addition, soccer was ranked in a 2011 Entertainment and Sports Programming Network (ESPN) sports poll as the second most popular sport in the country for 12-24 year-olds.² Unfortunately, this increase in popularity carries an increase in the injury rate, with 22% of athletes ages 5-14 years are injured while playing the sport.³ Soccer injuries vary from orthopedic injuries, such as sprains and strains, to more serious neurologic injuries, including concussion.^{4,5} Concussions range from mild to severe and can cause athletes serious health problems.⁶ Additionally, injuries can cause athletes to be out of play for weeks or longer, depending on the severity. In a 10-year prospective study of collegiate soccer players, head-to-head contact was the primary cause of concussion, with authors speculating that injury severity could be mediated by contact anticipation, allowing for muscle contraction to reduce cranial acceleration and shearing forces.³ Determining the mechanism of injuries is an essential first step towards prevention of injuries in soccer players.

As the role of vision in sports performance is becoming appreciated,⁷ and the concept of sports vision is better defined,^{8,9} visual training is becoming more common in athletics.¹⁰⁻¹² Peripheral vision is motion sensitive, warning of potential contact with other players on the field.¹³ Athletes have increased peripheral retinal sensitivity as compared to non-athletes, which aids in the motion detection of both teammates and obstacles.¹⁴ With impaired peripheral vision, athletes may not see the incoming object or person in time to respond, and therefore, they may sustain injury from avoidable contact.¹⁵ Peripheral vision is reduced in stressful situations.¹⁶ This visual attentive field narrowing may contribute to injuries during the game.¹⁷

Injuries are higher among athletes with greater perceived life stress, with possible factors including reduced attention, decreased peripheral vision awareness, increased muscle tension, and fatigue.¹⁸⁻²⁰ Relaxation techniques have been used effectively to reduce the stress response.²¹ Relaxation techniques address the physiologic response to stress by decreasing oxygen consumption, decreasing heart rate and blood pressure, improving attention, decreasing muscle tension, and decreasing peripheral narrowing.²² Techniques shown to reduce stress

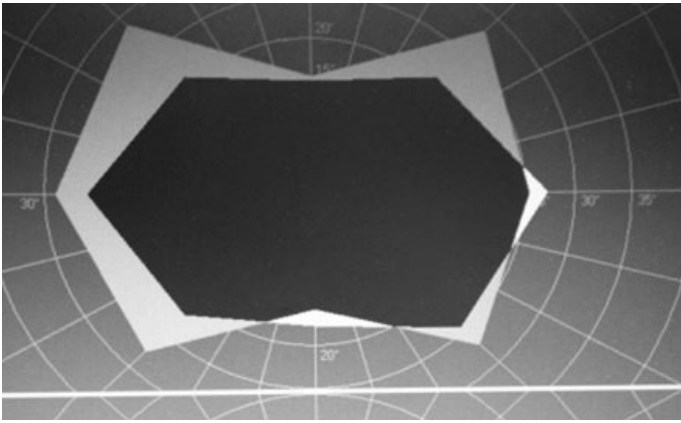


Figure 1. Color campimetry for left eye of subject 5, during pre-training initial testing, showing the reduction in peripheral field under stress (black area) compared with larger non-stress peripheral field (grey area).

and to increase relaxation include diaphragmatic breathing, biofeedback, and guided imagery.²³⁻²⁵ These commonly used techniques are considered safe and effective.^{26,27}

The purpose of this study was to examine peripheral vision narrowing from stress in soccer players and to determine whether it was possible to reduce peripheral narrowing through training in either visual strategies or stress reduction.

Methods

Seventeen intercollegiate soccer players (13 male and 4 female) were recruited from the men's and women's soccer teams at a National Association of Intercollegiate Athletes (NAIA) Division 1 school. All were pre-screened for visual defects, ocular disease, vestibular impairments, and recent concussion. Vision pre-screening was performed or supervised by a licensed clinical optometrist and included static visual acuity, cover test, near point of convergence, accommodative facility, binocular smooth pursuits, binocular saccadic movements, stereo acuity, retinoscopy, monocular visual attentive field screening using the HMP-200 (NovaVision, Inc), and contrast sensitivity. Vertigo pre-screening included the Vertigo Symptoms Scale in order to identify signs of vertigo dysfunction that could impair vision. Athletes were excluded if they had best-corrected visual acuity worse than 20/40, presence of strabismus, presence of phoria (worse than 5 exo, 4 eso, or any vertical), uncorrected refractive error (greater than -0.50 D or more than +2.00 D), visual field defects reducing the horizontal field to less than 40 degrees with each eye, convergence worse than 7 cm from the nose, accommodative facility worse than 8 cycles per minute binocularly and 11 cycles per minute monocularly, any abnormality in smooth pursuit or saccadic eye movements, stereoacuity worse than 40 seconds of arc, contrast sensitivity worse than 1.72 log, active pathology potentially affecting visual function (determined by subject interview), glasses worn during sports (athletes wearing contact lenses were included), vestibular impairments, or concussion in the previous 2 months. In addition, all potential participants completed the Depression-Anxiety-Stress scale to identify depression or anxiety symptoms and the Holmes and Rahe Stress Scale

screening for negative life events. Athletes who passed the pre-screening had the opportunity to participate in the study. Participants were randomly assigned to one of two groups and were free to leave the study at any time. This protocol was approved by the primary investigator's university Institutional Review Board, and the tenets of the Declaration of Helsinki were followed.

Visual Attentive Field Assessment

All participants completed color campimetry by a certified ophthalmic technician using the Computerized Functional Color Field Tester (Bernell; Figure 1) under both stressed and non-stressed conditions prior to beginning training and after training was completed. The examiner was blinded to the intervention group designation. The test incorporates 4 different-colored targets that are 1 mm in size. This test was chosen as a way to determine the difference in color perception in the periphery for athletes. Color perception is a result of the stimulation of three types of cone photoreceptors in the eye. Because these photoreceptors change in structure and function with increasing eccentricity from the fovea, color perception in the periphery is present but decreases in response, with a greater decrease in red/green sensitivity.²⁸ Each participant was seated comfortably, with neutral spine position, 23 centimeters from a 42.72cm flat-screen computer monitor (Acer) wearing either contact lenses or no correction if none was needed. In the non-stressed situation, each eye was tested separately across 8 different peripheral meridians for each of the following target colors: white, blue, red, green. During the testing, the athlete was instructed to identify the color of a target that moved from a peripheral area of non-seeing into an area of seeing while maintaining central fixation. To maintain central focus, participants had to call out a number that flashed in the center of the screen; the examiner also watched to ensure that they were maintaining continual focus on the central image during testing. Each trial was terminated by the examiner when the participant correctly identified the color. Next, each participant repeated the test under a stressful condition created with a cognitive task using the intermittently flashing numbers on the middle of the screen. Athletes were asked to take the original number, subtract 2 and then multiply by 3, and call this final number out loud during testing. Participants needed to process the mathematical problem accurately and quickly. This created the need for divided attention and presumably reduced peripheral visual awareness.

Vision Training

Athletes in the vision training group were taught three vision therapy techniques to release central field focus and to expand peripheral visual perception: the modified MacDonald card, central-peripheral saccades, and central fixation release using the Padula Transformation Cube.²⁹

The McDonald card has a central red dot surrounded by letters at various distances across the card. The athlete was

instructed to affix the card to a wall at eye level and to stand about 3 feet away from the card with good posture. The athlete focused on the red dot while simultaneously reading letters in alphabetical order in expanding distance from the center.

Athletes performed the central-peripheral saccades both monocularly and binocularly. All were instructed to put a small target (Post-it® note) at eye level in the center of a wall, and then to put colored or numbered targets elsewhere on the board. Participants held a stick of about 3 feet in length with both hands and were instructed to look at the center target and to use the stick to tap the targets that they viewed with their peripheral vision. After they tapped a peripheral target, the participant would then look at the target to check for accuracy.

For the central fixation release task, participants were instructed to place four of the Padula Transformation Cubes directly in front of themselves in a vertical line: on the floor 3 feet in front of the standing position, on the floor at the edge of a wall 6 feet in front of the standing position, 3 feet up the wall, and 6 feet up the wall. The transformation cube is a green/red box, and the athlete practices either viewing the box as red or green. Participants were instructed to view the box as green, to begin to move their arms in a circle for 3 arm rotations, then to view the box as red. The athlete would then proceed by looking at the next of the four transformation cubes.

Relaxation Training

Athletes in the relaxation training group were instructed in relaxation techniques to be performed in a quiet area. These exercises included diaphragmatic breathing and guided imagery. Diaphragmatic breathing requires deep breaths through the abdomen, a slower respiratory rate, and results in decreased stress on the system.³⁰ Guided imagery involves visualizing a positive, safe environment in which the individual performs at his/her optimal level.^{21,23} Participants were instructed to visualize doing exceptionally well on the soccer field.

Athletes in both intervention groups were issued a calendar to track compliance and were instructed to perform the exercises for 10 minutes daily, as well as before practice and games for the most benefit. After two weeks, athletes participated in separate group review sessions in order to ensure that they were performing techniques correctly, to answer any questions, and to promote compliance. After a total of 4 weeks of intervention, athletes returned to complete post-intervention color campimetry under both stressed and non-stressed situations, as described above. In addition, the compliance calendars were reviewed.

All potential participants were given a thorough explanation of the study and the choice of whether or not to participate. Those who agreed read and signed informed consent forms prior to any testing.

Statistical Analysis

The Wilcoxon Signed Ranks Test was used to determine whether there were statistically significant differences in color

Table 1. Study Demographic Information

	Vision Training (n=8)	Relaxation Training (n=9)	All Subjects (n=17)
Age, mean (SD)			
Sex male	6	8	15
Ethnicity			
Caucasian	7	5	12
African American	0	2	2
Asian	0	0	0
Hispanic	1	1	1

campimetry for both the left and right eye of each individual. This test was used because data were not normally distributed. First, in order to evaluate whether changes in visual attentive field were due to repeated testing, learning effect was assessed by comparing the non-stressed condition pre- and post-intervention. Next, in order to determine whether a stressed condition was actually created, stressed and non-stressed conditions were assessed before and after intervention. Finally, assessing the stressed condition before and after an intervention was done to look for a training effect from the interventions. Data were analyzed for all four colors under all four conditions for each eye: stress/no stress pre, stress/no stress post, pre/post no stress, pre/post stress. Statistics were generated using the International Business Machine Statistical Package for the Social Sciences (IBM SPSS Statistics) 22.0 and are reported using the Z statistic.

Results

Sixteen of the original 17 enrolled athletes completed the study, ranging in age from 18 to 23 years (20.53 ± 1.41 years). Vision therapy group (n=8) data is presented parenthetically. Fourteen (6) of the athletes were male; 12 (7) were Caucasian, 2 (0) were African American, and 2 (1) were Hispanic. See Table 1 for demographic information.

Our first aim was to measure athletes' peripheral vision in a laboratory setting, in both non-stressed and stressed conditions, in order to create stress-induced peripheral visual attentive field narrowing. To determine whether there were practice effects from repeated testing, we compared the pre-intervention non-stressed color campimetry to the post-intervention non-stressed color campimetry results for all participants. Analysis showed no significant changes between pre- and post-training sessions for any color, indicating no significant learning effect from testing (results ranged from $Z=-1.706$, $p=0.088$ to $Z=-0.220$, $p=0.826$).

Next, we wanted to create a stressful condition through dual cognitive task- and time-urgency and to measure the stress response in peripheral vision. We determined that participants initially had a statistically significant reduction in visual attentive field for certain colors (white right eye $Z= -3.413$,

Table 2. Z-score and p values for the right eye and left eye pre-intervention stress condition versus pre-intervention non-stress condition for each peripheral vision stimulus color, indicating that the stressed task does create peripheral narrowing in all but 2 scenarios. Asterisk (*) indicates statistically significant p value.

	Right Eye Z-score, p value	Left Eye Z-score, p value
Red	-3.129, 0.002*	-1.035, 0.301
Blue	-3.471, 0.001*	-2.432, 0.015*
Green	-1.590, 0.112	-2.485, 0.013*
White	-3.413, 0.001*	-2.379, 0.017*

Table 3. Z-score and p values for the right eye and left eye post-intervention stress condition versus pre-intervention stress condition for each peripheral vision stimulus color, indicating a decrease in peripheral narrowing after training during the stressed condition for the color white. Asterisk (*) indicates statistically significant p value.

	Right Eye Z-score, p value	Left Eye Z-score, p value
Red	-2.484, 0.013*	-1.193, 0.233
Blue	-1.965, 0.049*	-0.569, 0.569
Green	-0.085, 0.932	-0.259, 0.796
White	-2.586, 0.01*	-2.096, 0.036*

p=0.001; white left eye Z=-2.379, p=0.017; blue right eye Z=-3.471, p=0.001; blue left eye Z=-2.432, p=0.015; red right eye Z=-3.129, p=0.002; green left eye Z=-2.485, p=0.013), but no significance was found for other colors (red left eye Z=-1.035, p=0.301; green right eye Z=-1.590, p=0.112). Only white and blue had statistically significant reduction in visual attentive fields for both eyes (Table 2).

Our final aim was to determine whether the stress-induced peripheral narrowing could be changed with training, using either relaxation or visual training techniques. All colors for each eye of the post-training stressed visual attentive fields were compared to the same color and same eye of the pre-training stressed visual attentive fields for the relaxation group, and there was no significant change found (p=0.898 left eye, p= 0.166 right eye). This comparison was also done for the vision therapy group, and no significant change was found. The two groups had similar averages, so in order to increase power, we pooled the data. For example, Figure 2 shows findings of both intervention groups for left eye, white, stressed post-intervention average visual attentive field size. When the relaxation and vision therapy groups were pooled, there was a significant difference in the white post-training stressed visual attentive fields as compared to the white pre-training stressed visual attentive fields (Z=-2.586, p=0.01 right eye; Z=-2.096, p=0.036 left eye), indicating a treatment effect for the stressed condition. No difference was found for any of the other colors (Table 3).

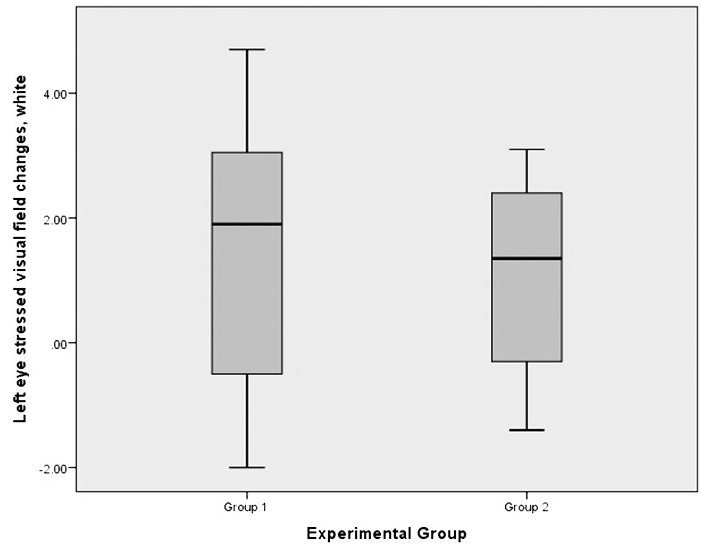


Figure 2. The post-intervention average visual attentive field size for the combined left eyes in the white, stressed condition for both the vision therapy group (group 1) and the relaxation therapy group (group 2), indicating that the two groups had similar averages, so to increase power we pooled the data.

Athletes were asked to perform the task daily for one month, for a total of 30 sessions. Their compliance with performing the techniques was poor, with average reported compliance of 13.25 ± 6.11 sessions for the relaxation group and 8.88 ± 3.44 sessions for the vision training group.

Discussion

This pilot study measured peripheral visual narrowing from stress in healthy athletes and demonstrated that reduced peripheral narrowing remained with stress. We were able to replicate prior studies of stress-induced peripheral vision narrowing using a lab-based campimetry task to create stress. Further, we found no significant learning effect with the campimetry upon repeated measure under calm conditions. The sample size in each of the two groups was too small to analyze separately, so the data was pooled together for analysis; the averages of each group were similar. The resulting analysis demonstrated that intervention led to a reduction in stress-induced peripheral narrowing on post-training measurement; however, we are unable to ascertain the reason.

Study limitations included a small number of participants, limiting the power of data analysis. In addition, compliance with training techniques was poor. Simply having the knowledge that peripheral narrowing could be reduced may have been enough to change the post-intervention performance, which could be controlled with an education-only group as well as a non-intervention control in the future.

A review of the literature did not show any other sports medicine studies using color campimetry. The tool is used by two of the authors (CG, JG) to measure peripheral vision and to track recovery after neurological injury, noting clinical changes (particularly expansion of fields) across all colors during rehabilitation. In the current study of healthy, normally sighted athletes, only the color white showed significance between pre- and post-measures of both eyes, while other

colors had varied responses, including visual attentive field expansion under stress, with no trend measured in our small sample.

Conclusion

The use of campimetry in this normally sighted, healthy population was effective in measuring peripheral vision, both for creating and measuring stress-induced peripheral visual attentive field narrowing for the color white. Participants demonstrated stress-induced peripheral field narrowing in the laboratory setting, which was reduced after training with either relaxation or peripheral vision techniques. The impact of training and education on reducing peripheral visual attentive field narrowing is unclear, possibly due to our small sample size with poor compliance in both training techniques. The prospect of reducing stress-induced peripheral vision narrowing is worthy of further study as a potential intervention to reduce injuries common among soccer players navigating a crowded field. We recommend further research using campimetry, with longer training periods and improved mechanisms for compliance, as well as control groups to establish ideal training techniques that may reduce stress-induced visual attentive field narrowing in healthy college soccer players.

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