NeuroRegulation

The Effect of Passive Infrared Hemoencephalography on Athlete Performance

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Abstract

This single case study explores the effects of a specific form of biofeedback on sports enhancement. Three college athletes from three different sports (baseball, volleyball, and basketball) were each subjected to five weekly sessions of passive infrared hemoencephalography (pIR HEG) from a licensed psychotherapist who had been trained in this form of biofeedback. Sports data were collected prior to the session, during the sessions, and after the sessions. In addition, card sorting and thermal imaging were done by the therapist during each of the five brain-training sessions. The results were mixed. The baseball and volleyball players demonstrated modest gains in their specific sports measures and in the card-sorting process, whereas the basketball player's measures were flat. The thermal imaging was also inconclusive. However, two out of three subjects reported subjective improvements in focus and concentration on the field and in their daily lives. In addition, two of the subjects reported improvements in their rate and intensity of headaches, which was not a specific goal of the treatment, but one which is routinely seen from pIR HEG treatment. There are significant limitations to this study that make it impossible to generalize. Further studies with longer treatment times and larger numbers of subjects are recommended.

Keywords: sports enhancement; hemoencephalography (HEG); EEG biofeedback; neurofeedback (NF); passive infrared hemoencephalography (pIR HEG)

Citation: Barry, L., & Nooney, G. L. (2018). The effect of passive infrared hemoencephalography on athlete performance. *NeuroRegulation*, *5*(4), 129–136. http://dx.doi.org/10.15540/nr.5.4.129

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The human brain is only 2% of one's body mass (Wang et al., 2014). The study of the brain is difficult for many reasons. One main reason is that we cannot manipulate someone's brain. The brain is so intriguing, and everyone thinks very differently, but we cannot cut open a healthy human to conduct research. That leaves all of the research up to people who have had a head trauma, stroke, mood disorders, headaches, and neurodegenerative disorders (Wang et al., 2014). From laboratory studies, researchers have found that almost all of the brain's processes are sensitive to temperature (Wang et al., 2014). To study the brain of brain-injured participants we need to be aware of the brain temperature to keep them safe and effective for the trial (Wang et al., 2014). If researchers fail to do so, the functional activity and energy efficiency of the brain will go down remarkably for the participant (Wang et al., 2014).

Biofeedback

Wouldn't it be useful to have instant feedback regarding aches and pains that go on in our brains without having to cut open one's head? Dr. Antoine Remond discovered that electroencephalography (EEG) helped to identify those with attention-deficit disorder (ADD) or people with minimal brain dysfunction (Siever, 2008). Hershel Toomim's research led him to develop instruments to measure brain temperature and galvanic skin response (now known as electrodermal response; Siever, 2008). In 1984, Toomim and Chuck Davis created the world's first wireless biofeedback system (Siever, 2008). Biofeedback is a procedure that provides a person feedback over a bodily function that allows that individual to develop more control over that function to treat the medical problem (Siever, 2008). Toomim, however, found a further connection between cerebral blood flow and EEG (Siever, 2008), which led him to build the first ever blood oxygenation biofeedback device, which he named nIR hemoencephalography (HEG; Siever, 2008).

EEG Biofeedback

EEG biofeedback (hereafter referred to as neurofeedback or NF) training specifically looks at brain waves and how a participant receives instant results (Hammond, 2007). This type of training is very specific to the temporal, occipital, and parietal regions of the brain. Depending on where the electrodes are placed determines which skill the training is focusing on: balance, concentration, anxiety, etc. (Hammond, 2007). A study looked at performance enhancement in golfers using EEG profiles (Arns, Kleinnijenhuis, Fallahpour, & Breteler, 2008). They specifically looked at the central-temporal parietal areas and found that if the left-temporal alpha increased, the athlete's performance decreased, but if the right-temporal alpha increased, the athlete's performance increased (Arns et al., 2008). The results showed that each athlete performed differently even though they were completing the same task (Arns et al., 2008). Another study looked at performance in dancers by using EEG slow wave heart rate coherence training (Thompson, Steffert, Ros, Leach, & Gruzelier, 2008). Results showed that EEG slow wave training increased confidence, well-being, energy, respiratory control, and pitch (Thompson et al., 2008). Thompson and colleagues (2008) found the same results in singers and musicians. EEG slow wave training is great for relaxation therapy, but EEG fast wave training involves more visuomotor activities (Thompson et al., 2008). Another study conducted by Vernon in NF training found that, if experimenters made one hemisphere more active, then the other hemisphere becomes dominant (2005). By reducing the verbalizations in the left-temporal lobe, it increases the visual-spatial process in the right-temporal lobe, which raises the question: can shifting more positivity or negativity on a specific lobe improve performance (Vernon, 2005)? Vernon (2005) looked at pre-elite archers and found that the use of NF does enhance performance.

Hemoencephalography (HEG)

There are two approaches to HEG which is another form of biofeedback training but pertains more to the activation of the prefrontal cortex and its functions. Toomim et al. (2004) developed near infrared spectrophotometry (nIR HEG) and Carmen (2004) developed passive infrared hemoencephalography (pIR HEG).

One of Toomim's studies used "top down" training, which allows for the brain to shift from the damaged areas and activate different areas for problem solving. They used a spectrophotometer to access blood flow in the prefrontal cortex (Toomim et al., 2004). Toomim and colleagues (2004) specifically looked at attention, impulsivity, reaction time, and reaction time variability. Results showed that after nIR HEG training there was an increase in blood flow in the brain corresponding to the training sites (Toomim, 2004). The study was limited to specific brain dysfunctions due to the area of the brain researchers wanted to explore (Toomim, 2004).

Headaches and migraines have also been studied and treated with HEG. A migraine is a lingering persistent pain causing the individual to suffer (Walker & Lyle, 2016). In the United States 18% of women and 6% of men receive migraines daily (Stokes & Lappin, 2010). Each person's migraine can be different, but they are a frequent phenomenon that can be studied and treated. There is no cure for migraines but one common form of treatment for migraines is peripheral skin temperature biofeedback, blood volume pulse, and electromyography feedback (Stokes & Lappin, 2010). In a previous study conducted by Stokes and Lappin (2010), participants were interviewed for 30 min for every 10 sessions they completed. Participants were asked questions and were tested using different types of biofeedback treatments: thermal biofeedback devices such as the HEG machine and the hand warming units, blood volume pulse feedback, and electromyography feedback (Stokes & Lappin, 2010). The point of this study was that participants learned to control their headaches by simply warming their foreheads or raising their hand because the hand warmers were too hot (Stokes & Lappin, 2010). Stokes and Lappin (2010) found that even if none of the biofeedback treatments helped to reduce headaches, it did help participants to be able to control their headaches or even prevent them.

Another study conducted by Carmen utilized pIR HEG. Carmen (2004) had participants pick out a movie of their choice and wear a headset monitor to measure waste heat caused by increased blood flow to the prefrontal cortex. Once the participant got emotionally involved in the movie, their limbic system was activated and their prefrontal cortex went partially off-line. The headset monitor device picked up the decreased heat in the prefrontal cortex due to the reduced blood flow, and the computer paused the movie. The participant was then instructed to focus and relax at the same time. By doing so, the participant's limbic activation was reduced and the prefrontal cortex activation was increased which also increased the blood flow in that area and, once it reached a preset level, the movie began to play again. As the participants were able to handle longer pause times without getting fatigued, their brain learned to spontaneously strengthen the functioning of the prefrontal cortex and inhibit the limbic system more efficiently. This resulted in improvements in migraine headache frequency and intensity (Carmen, 2004). Results showed that this was a very useful and long-lasting way to treat migraines, but it would take at least six sessions to really get the training to stick (Carmen, 2004).

Athletes often get headaches due to the stress of their sport. There has been quite a bit of research conducted on athletes and concussions. A study conducted by Keightley and colleagues (2014) studied young children with concussions and their working memory. Working memory is tied into the prefrontal cortex because information only stays in our working memory for a few seconds. The prefrontal cortex deals with impulse decisions and personality. To be successful, athletes must be able to react quickly and efficiently to rapidly changing stimuli while maintaining a relaxed focus. Since pIR HEG is designed to improve prefrontal cortex efficiency, we became interested in whether this treatment would result in performance improvement for athletes.

Sports Enhancement

NF has been proven to improve sports performance by maximizing optimal brain function (Ross, 2015). Specifically, NF can improve an athlete's attention, focus, and emotional control, slow cognitive decline, improve sleep, and help to restore brain function after a traumatic injury (Ross, 2015). NF in general has made sports psychology very cutting edge and up to date. With more advanced technology we can target individual sports and explore specific effects on the individual athlete (Hammond, 2007).

Athletes must master the skills of stepping back and analyzing multiple sources of input in a short period of time and of having enough focus and concentration to act quickly and definitively. These skills primarily involve prefrontal cortex brain activities. In this study we focused on pIR HEG as developed by Jeffrey Carmen (2004), which targets the prefrontal cortex and its variety of functions, such as impulse control, organization of emotional reactions, personality, prioritizing, competing, and complex planning (McKinley, O'Loughlin, Pennefather-O'Brien, & Harris, 2015). Since pIR HEG improves prefrontal cortex efficiency, we are hypothesizing that this treatment will result in an improvement in these athletes functioning in their particular sport.

Method

Participants

Participants included one male undergraduate student athlete from each of the following teams: basketball, volleyball, and baseball at Briar Cliff University (n = 3). The average age of participants was 21 years old. The study was approved by the Internal Review Board (IRB) of Briar Cliff University where the first author was a student in the Psychology department.

Setting

The training took place in the second author's office. The remaining pieces of the experiment took place in practice (gym, field, or course, depending on the sport) and at different locations based on competition.

Materials

Materials included an ordinary deck of cards, a DVD movie (of the participant's choice), the EZPIR system (Jeff Carmen; Manlius, NY), and an infrared camera. The EZPIR system has two major components: the headset with a heat sensor connected to a computer through a hardware encoder and BioEra software (Proatech LLC, www.proatech.com). The camera utilized was the Seek Compact Pro made by Seek Thermal. This instrument was designed to connect to an iPhone and utilizes the internal computer power of the iPhone in order to process the images, thus producing a false color image that distinguishes between different levels of heat. The pIR HEG headband heat sensor picks up waste heat which is distributed through the forehead and thus indirectly measures increased blood flow to the prefrontal cortex.

Procedure

The experimenter recruited participants by asking permission from the coach and asking the athletes to participate in the study. The researcher told the athletes that the study would be measuring their athletic performance while they completed pIR HEG training.

Each participant signed the informed consent form before training began. Individually each participant completed training once a week. Training included sorting a deck of cards, by suit and then numerical order, while being timed. The participant was instructed to complete the task as fast as possible. The researcher explained how sorting, impulse control, and speed correlated to the prefrontal cortex. Then the researcher took a picture of the subject's face with special attention to the forehead utilizing the Seek Compact Pro. The researcher then explained what the picture meant; the darker (cooler) parts could mean fatigue or slight depression and the lighter (warmer) parts are how engaged your prefrontal cortex is at that moment. The goal was that by the end of the training the whole prefrontal cortex would be warm and evenly distributed across the forehead.

Next, the participant was instructed to choose a movie that they could become emotionally invested in. After the movie was selected the participant was guided to put on a headband with the heat sensor. The researcher helped to place the detector just above the eyebrows but not too far in the hairline and ensured that no hair was underneath the sensor on the forehead. The participant was then instructed to watch the movie and wait for further instruction. The computer software is programmed to pause the movie when the subject becomes emotionally activated, causing a less active prefrontal cortex blood flow. Once the movie paused, a bar graph would appear on the left side of the screen. After the bar appeared on the screen the participant was instructed to relax their body and concentrate on the bar graph. If the bar did not move up or continuously went down, the researcher instructed the participant to relax and concentrate specifically on the neck and shoulder muscles while continuing to focus on the bar graph. When the subject was successful in this endeavor, there would be increased blood flow in the prefrontal cortex; the sensor would pick up the increased waste heat; and the bar on the graph would rise. Once the bar reached the yellow line at the top of the graph, the movie would resume, which was a tangible reward for the subject. If at any point the participant felt tired or exhausted, they were instructed to tell the researcher immediately. After approximately 30 minutes of watching the movie, the researcher took another picture using the Seek Compact Pro. Then the researcher explained what the picture meant to the participant. The participant then scheduled another meeting for training.

Data Analysis

A multiple-baseline design was used to show the effects of treatment of performance in athletes. Due to the fact there were a variety of sports in this study, we could not begin each treatment at the same time. To demonstrate a treatment effect, we collected data during practice and not solely at competition. We collected three practice baseline points and one game point (depending on the team's games schedule) before starting treatment. Data was then collected once a week in practice, treatment, and then games in between treatment.

Results

Baseball

The results for the baseball player's stats were broken down into balls and strikes over a series of 20 pitches. During baseline he averaged 13 strikes and 7 balls in practice, as seen in Figure 1. He did not pitch in any games during baseline. Once treatment began, he averaged 14 strikes and 6 balls in practice and 15 strikes and 5 balls in games. Figure 1 shows the rise a steady trend of the practice strikes decreasing and the practice balls increasing. His card-sorting time did decrease steadily throughout treatment indicating a significant trend. Figure 2 shows the before and after of the infrared images.

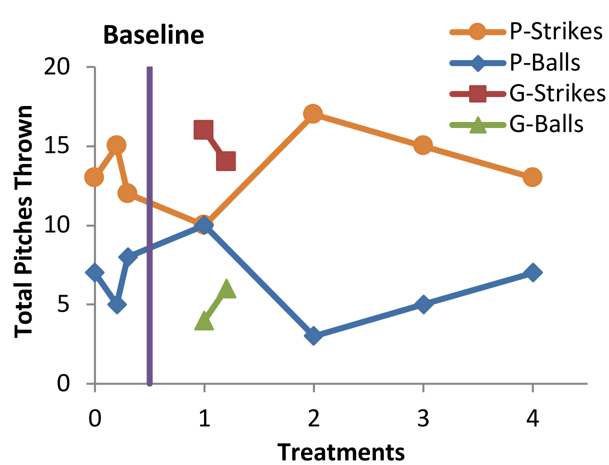

Figure 1. Baseball participant results during practice (P) and games (G) before and after treatments.

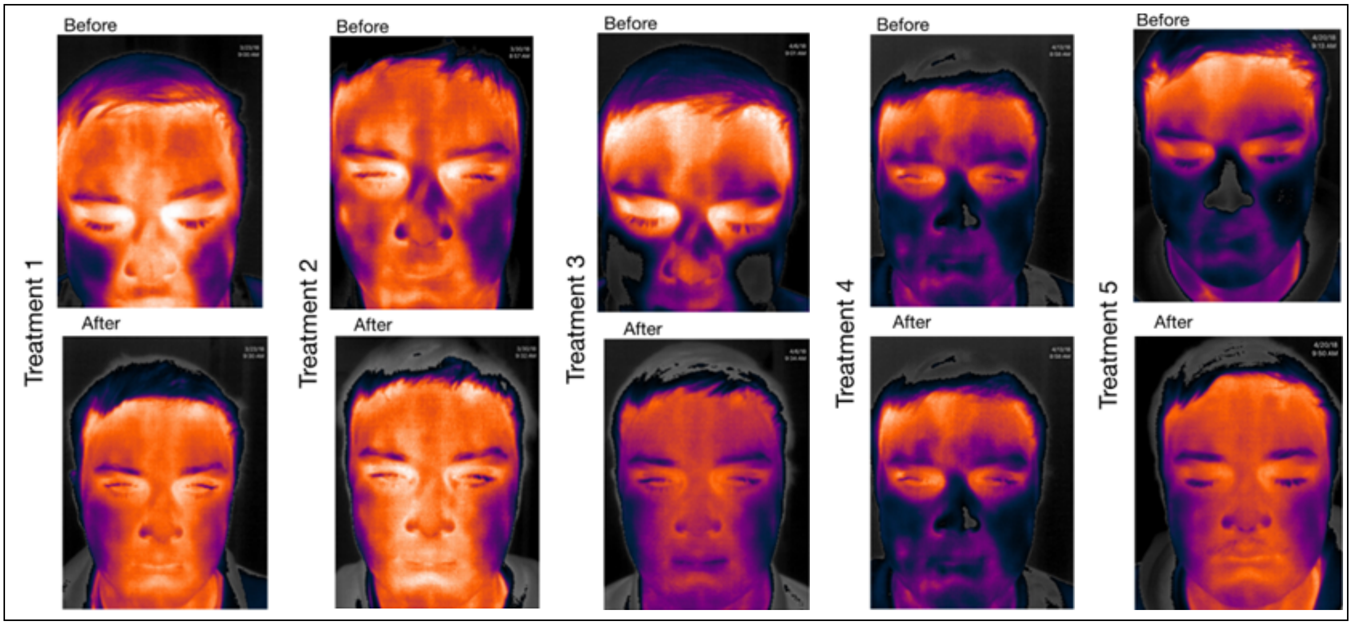

Figure 2. Baseball participant infrared images before and after treatments.

Volleyball

The results for the volleyball player's stats were broken down by passing rating, which is an average of all the passes he completed based on a 3-point rating scale. During baseline he averaged a 1.7 passing rate in practice and a 2.7 passing rate in a game, shown in Figure 3. Once treatment began, he averaged a 1.8 passing rate in practice and a 2.4 passing rate in a game. Figure 3 shows the consistency his passing became throughout treatment. His card-sorting time did steadily decrease causing a significant trend, meaning he steadily did improve throughout treatment; reasons will be discussed further in the Discussion. Figure 4 shows the before and after of the infrared images.

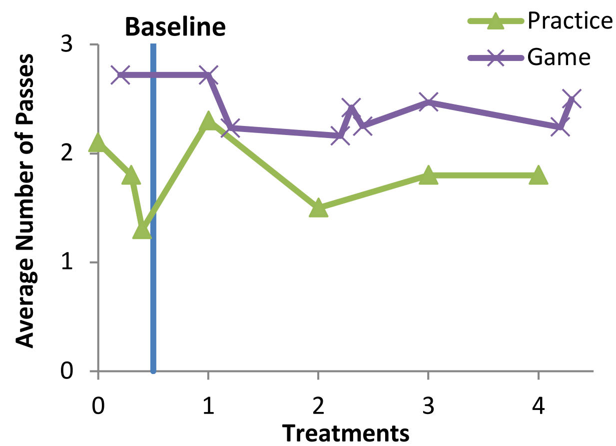

Figure 3. Volleyball participant results during practice (P) and games (G) before and after treatments.

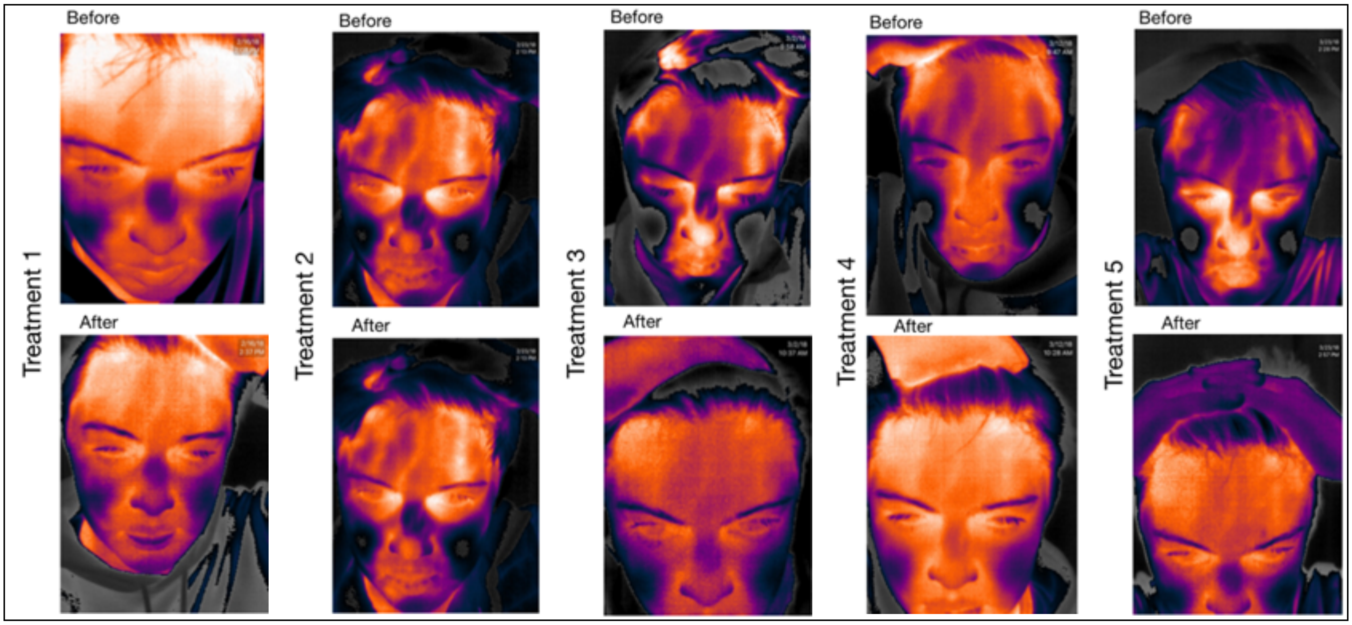

Figure 4. Volleyball participant infrared images before and after treatments.

Basketball

The results for the basketball player's stats were broken down by average free throws shot. During baseline he made 75.5% of shots in practice and 0% during the game, shown in Figure 5. The average percentage of shots made once treatment began was also 75% and average game percentage remained at 0. There was no change in percentage of shots made during games until two games posttreatment. His card-sorting time did decrease throughout treatment but not consistently enough to make a trend. Consequently, due to the lack of change in his statistics, treatment was not shown to be beneficial to this athlete in his game play. Figure 6 shows the before and after of the infrared images.

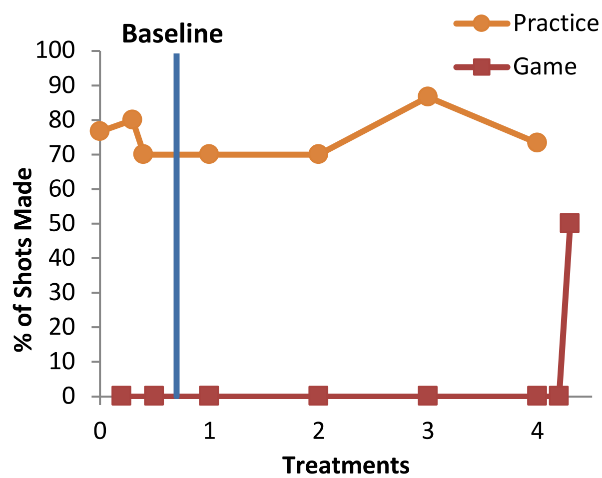

Figure 5. Basketball participant results during practice (P) and games (G) before and after treatments.

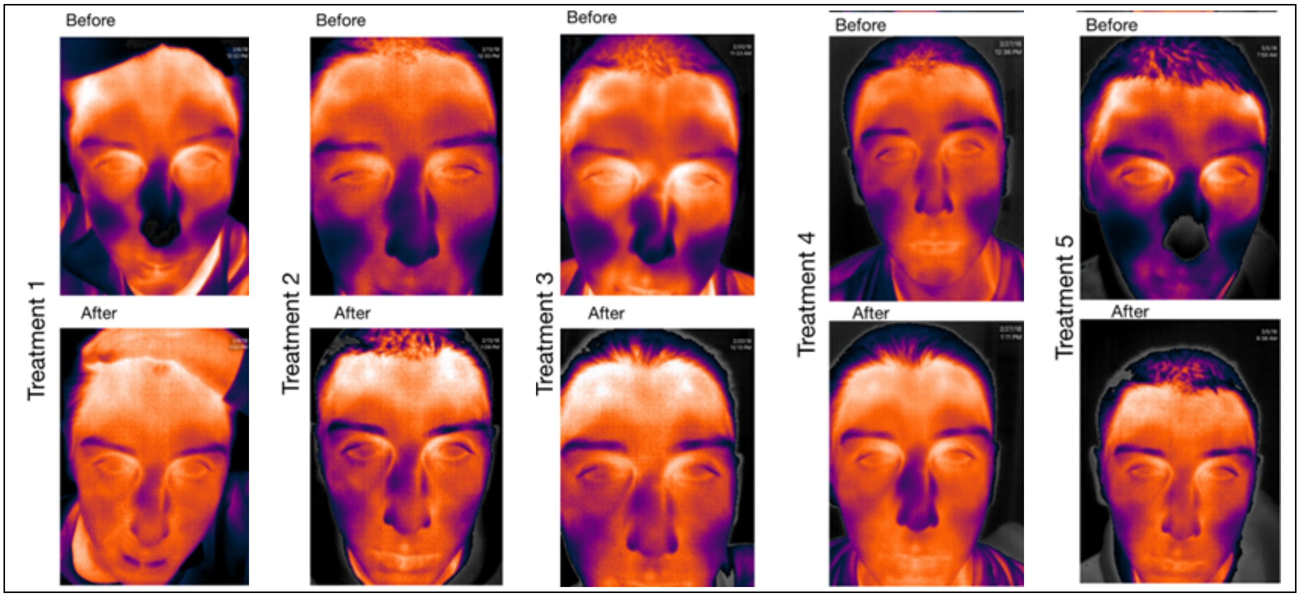

Figure 6. Basketball participant infrared images before and after treatments.

Social Validity

All three participants reported treatment had positively affected the way they see their game. The basketball player reported more concentration on how he shot the ball. The baseball player exclusively reported seeing an improvement in pitching strikes instead of balls. The volleyball player described an improved ability to "see the whole picture" during games and recalled a positive change in one specific game. All three did recall the mechanics of their sport improved. Along with their game play the baseball and volleyball player were able to concentrate on things outside of their game; e.g., homework, being more attentive in class, or demonstrating more initiative. Also, both the volleyball and baseball player reported to have had consistent migraines since grade school. Since beginning treatment, they have not had a migraine.

Discussion

In the current study we hypothesized that pIR HEG treatment will result in an improvement in these athletes' functioning in their particular sport. Our hypothesis was not fully supported. Participants were all chosen based on their playing time consistency, which allowed us to continuously collect data. Unfortunately, there is a lot of variability within a sport that did not allow us to generalize the sport overall. We did a nonconcurrent multiple baseline due to initial start date of the sport. Fortunately, we were able to have at least points of baseline before beginning treatment.

Secondly, we saw positive decreasing trends in the card-sorting task with the volleyball and baseball player. Both participants reported having consistent migraines since grade school and have reported they have decreased the frequency of them since beginning treatment. Additionally, they both reported to have carried the positive effects of this treatment into their everyday lives.

Unfortunately, there were quite a few limitations involved in this study and we are unable to generalize the results. There were consistent environment changes (e.g., weather, stress, gyms, etc.) that we could not control. Also, the length of study was a huge limitation. With the length of the semester and the initial starting times of each sport, we were forced to limit the study to 5 weeks. If the study would have been at least 8 weeks or longer we might have seen a stronger result. In addition, the measurement and interpretation of the infrared images was problematic (see Figures 2, 4, and 6). We needed a measurement that made it valid and reliable. The relatively inexpensive infrared camera used was capable of creating a false color spectrum, but it had limitations in being able to provide consistent images that could be compared.

We would recommend that future studies be conducted with longer periods of time, a larger number of subjects, and increased number of pIR HEG sessions, ideally at least 10 to 12 weekly sessions. We would also recommend that a more expensive, sensitive infrared camera be used that would provide for a more reliable comparison of images.

If future studies would focus on just one sport, it would make it more likely that some generalization of that specific sport could be drawn. For example, a study could conduct treatment on several different basketball players playing different positions. Since each position has unique challenges and different stress levels, the results could more readily generalize to the sport of basketball.

Due to the diverse functionality of the prefrontal cortex of the brain, we believe that there are many creative ways in which further studies of pIR HEG's effects on sports enhancement would be useful and would encourage others to design such studies.

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Received: November 11, 2018
Accepted: November 26, 2018
Published: December 7, 2018