# Effect of Playing Soccer on the Level of Visual Attention in High School Students

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Soccer is a great example of a sport that requires a high performing set of cognitive processes. Though it may vary depending on position, each player must be acutely aware of many players on the opposition and friendly sides at once, as well as the ball. This is why soccer players and players of other similarly interactive sports have been found to score higher on executive function tests. However, these tests, especially those for visual attention, are not standardized. Indeed, there seems to be countless ways to test for visual attention, many of which are not considered very objective. The aim of this study was to optimize the involuntary optokinetic nystagmus (OKN) response as a means to objectively compare visual attention between a group of high school soccer players and a control group that did not play a team sport, meaning one that involves interacting with more than one other person during play. Ten participants for each group were recruited and viewed three different speeds of an OKN square grating at 60, 90, and 120°/sec. It was hypothesized that the soccer-playing group would have a significantly greater OKN frequency and therefore visual attention than the control group. Each participant was instructed to "follow the lines across the screen" and did so three times for each of the three speeds. Each trial lasted for 15 seconds. After all recordings were collected, each trial was cut into a 10 second section, and the completed OKN eye movements of each were then manually counted and the data was analyzed. The null hypothesis that the soccer-playing group did not have a significantly higher OKN frequency was not able to be rejected for the 60°/sec and 90°/sec speeds but was rejected for the 120°/sec speed. This study supports findings that soccer players have significantly greater visual attention than people who do not play team sports.

## Introduction

Sport science is a large field that is constantly expanding. Understanding the variables that affect performance in sports is important to better understanding the sport itself and the athletes' relationship with the sport. Sports can be studied in multiple fields of science, including physiology, biomechanics, and psychology. Physiology is the study of how the health of one's body is impacted by sports, while biomechanics deals with how one physically operates one's body affects sport performance. Psychology, on the other hand, is the study of how playing sports impacts one's mind. Most researchers observing the relationship between sports and psychology do so through the field of cognitive psychology, which describes mental processes, such as reasoning and memory. There is cognitive psychology testing in nearly every sport from volleyball (Fortin-Guichard et al., 2020) and basketball (Xu et al., 2022) to cricket (Khan & Mitra, 2022) and water polo (Kovačević et al., 2023). There is great significance derived from the findings of sports science testing, especially the psychological aspect of it; for example, if a sport is found to have a large percentage of participants with superior reasoning skills, participation in the sport should be encouraged. Therefore, not only does researching how sports impact the mind help to better understand benefits associated with sports, it can also allow people to be better informed when it comes to encouraging participation in a specific sport or sports in general.

In the sports science field, the game of soccer has been extensively researched. Research examining the benefits of soccer has led to an increase in participation in the sport. One of such benefits frequently studied is an increase in performance in executive functioning tests. Researchers at the German Sport University Cologne, for example, found that youth soccer players who could perform better at technical dribbling and skills tests also performed better at cognitive tests (Scharfen & Memmert, 2019). Furthermore, Vestberg et al. found that both high division and lower division players scored significantly higher on an executive function test when compared to the general population (2012). Soccer research is conducted in a number of ways. Research addressing cognitive psychology in soccer often concerns eyesight performance. This is accomplished through the testing of several optical processes. One such process is smooth pursuit eye movements, which is when one's eyes follow a moving target. The evaluation of the efficacy of these movements is also quite diversified. Some researchers use moving dots to stimulate voluntary smooth pursuit eye movement and use recording software to analyze the results. Involuntary eye movements can also be stimulated using processes such as optokinetic nystagmus (OKN).

OKN is an oscillation of the eyes stimulated in response to a full field visual motion. The underlying processes behind this involuntary movement are the same processes that allow a person's perception to remain clear when the object being tracked is in motion or when the person tracking the object is in motion. An example of the OKN response in everyday life is how one's eyes will track and then re-track trees as they are viewed while the person is in a moving vehicle. These distinct movements are due to the slow phase and quick phase movements associated with a complete OKN movement. A slow phase (SP) is first stimulated in response to and following the moving stimulus, which is followed by a quick phase (QP) of the eye darting back to the original starting position. In context, the tracking of the stimulus itself—the tree—represents the SP movement of the OKN response, while the rapid, unfocused movement back across the visual field represents the QP movement. In the medical field, optokinetic drums are used to test for the presence of eyesight. OKN is stimulated in the lab through a variety of ways. Some researchers have constructed large vertical cylinders in which colored bars are projected (Garbutta et al., 2001); others have created virtual reality systems for participants to view (Kovalev et al., 2020). The most common form of stimulation by far is the presentation of moving images across a computer screen; typically, these are horizontal sinusoidal or square gratings with vertical black and white bars. Sinusoidal gratings are gratings where the luminance of the image changes at the rate of a sine function. Square gratings have distinct boundaries between the black and white bars and the luminance is either black or white with no colors between. In most studies, advanced eye tracking systems are used to analyze corresponding eye movements and assess for variables like OKN velocity and OKN gain (a fraction of OKN velocity over the actual velocity of the stimuli) in real time as participants view the stimuli.

Visual attention has been defined as a cognitive process that allows one to effectively choose from the large amount of information in our environment (Lockhofen & Mulert, 2021). It allows one to know where to look and controls how much attention is paid to different stimuli. This is an important skill in which to have proficiency, especially in an environment where there are many distractions present, such as in the game of soccer. Paying attention to a moving person or object may seem straightforward, but the process of attention is not well understood. The generally accepted definition of visual attention is disregarding irrelevant information in one's sight in order to focus solely on certain sections; however, there is uncertainty concerning how our brains manage to attend to certain sections, as well as how different stimuli attract more attention than others (Carrasco, 2011). Therefore, it is useful to develop objective means of assessing visual attention to better understand the cognitive process, which is probably why there seem to be endless methods to do so—some involving reaction time, others concerning eye-tracking, and still others measuring electrical activity in the brain (Barone et al., 2023). Indeed, the accomplishment of this imperative goal is no easy feat, especially without expensive eye-tracking hardware or electroencephalograms. Despite this, a recent study may offer a simple yet objective method for comparing visual attention between people. Frattini and Wibble, researchers in the Department of Clinical Neuroscience at the Karolinska institute, investigated how OKN is impacted by the visual attention and alertness of adults (2021). A major finding was that the frequency of OKN observed in a participant is a good indicator of the level of visual attention present (Frattini & Wibble, 2021). Since these two variables are related, the level of visual attention present in participants may be assessed by comparing their OKN frequency.

There are various approaches to test for visual attention. In fact, new methods are regularly being proposed in order to better understand what visual attention is and to more easily facilitate the testing process. However, there exists a gap in optimizing OKN frequency to compare visual attention between test subjects. Therefore, the aim of this study was to determine if high school students who play soccer have greater visual attention than their non-team-sport-playing peers by comparing their OKN frequency, in order to assess if there is a significantly different level of visual attention between the groups based on Frattini & Wibble's findings (2021). High school students were chosen for this study because of their availability as test subjects and because the OKN response has been found to be fully developed by three years of age (Valmaggia et al., 2004). The non-team-sport-playing group had not played a sport requiring more than one person in the past five years. To conduct the study, first a group of soccer-playing and a group of non-team-sport-playing high school students were exposed to three different speeds of a black and white sinusoidal grating. The eye movements of the participants were analyzed following the viewing to determine OKN frequency, then the values from the two groups were compared to determine if there was a significant difference at any of the three speeds. It was hypothesized that the group of soccer players would have a significantly higher OKN frequency and therefore a greater level of visual attention due to the nature of soccer being an interactive game that requires participants to observe many details in the visual field, such as the position and movement of multiple players. In addition, soccer has been found to require strong cognitive skills (Knöbel & Lautenbach, 2023).

## Literature Review

Knöbel and Lautenbach developed a method capable of testing working memory in a "soccer-specific setting" in adjunct with the three core executive functions (2023). It was claimed that coaches want to identify certain abilities of players to recognize what areas to enhance as well as to identify talent (Knöbel & Lautenbach, 2023). In addition, evaluating solely cognitive abilities in a sports science environment was decided to have limitations, so it was chosen to relate the tasks to soccer. The test required the participants to view pictures of a soccer player's outline; once one of the pictures was repeated, the participants had to guess how many pictures separated it from the original picture. It was found that this test allowed researchers to successfully evaluate the level of cognitive function of the participant (Knöbel & Lautenbach, 2023). Before the experiment began, participants answered a visual analog scale concerning how motivated they were. This ensured that motivation was kept as a control variable. This experiment was focused on developing a lab dependent experiment, but one that was also specific toward the sport being tested.

Wester et al. (2007) tested if OKN could be used to assess functionality of an impaired patient's eyesight. The reasoning for using OKN was justified because OKN is mostly objective since it is an involuntary response (Wester et al., 2007). Each participant was exposed to stimuli through the use of a curtain and projected bars. When analyzing, the researchers evaluated the efficacy of using OKN. This was accomplished by measuring the max velocity value of the viewing of the stimulus. The velocity was then compared with values of each subject received from the logMAR VA and Goldmann visual field test. Interestingly, an equation was derived from these findings:

$$V\text{max} = 14.2 \cdot \log(\text{VA}) - 6.20 \cdot \log(\text{SF}) + 0.22 \cdot \text{VF} + 25.0.$$

This source is a good example of the uses of OKN, how aspects of OKN are tested, and how these ideas are implemented to craft methods for research.

The purpose of the study, "Alertness and Visual Attention Impact Different Aspects of the Optokinetic Reflex," was to investigate how OKN is impacted by varying levels of visual attention in adults. It was hypothesized that tasks that require increased visual attention would lead to lower performing OKN responses. In their study, Davide Frattini and Tobias Wibble observe characteristics of the participants' OKN responses while eliciting varying levels of visual attention (2021). For the methods, participants wore eye-tracking glasses and were exposed to different rotating visual scenes that required different levels of visual attention. This study is significant because it highlights the connection between visual attention and OKN frequency. It is stated that "OKN frequency is adaptive to a viewer's level of visual attention" (Frattini & Wibble, 2021, p. 1), indicating that the observed OKN frequency is directly related to visual attention. Consequently, visual attention can be compared between participants by comparing the values of OKN frequency exhibited when exposed to the same stimulus.

## Methods

For the methods, human participants were selected due to the nature of the study needing to be applicable to human eye function. All data used was from participants that met all requirements of the study. The requirements included having either played soccer frequently (two times per week) for the previous five years or not having played a sport that requires playing with more than one other person in the past five years. The non-team-sport-playing group was implemented to act as a control with which to compare the results of the soccer players to. Requirements for the study also made sure that no participant could have uncorrected problematic abnormalities affecting their eyesight. There were twenty people who participated in the study in total, ten in each group. The number chosen was due to a similar quantity for group sizes in similar research (Garbutta et al., 2001; Frattini & Wibble, 2021) who used 10 participants and 12 participants respectively. Each participant filled out two forms—one informational form to ensure the participants either had been playing soccer frequently or had not recently played any team sports and to ensure the participants did not have any eyesight abnormalities, and one asking for consent from both the participant and a parent, which warned about eye strain while viewing stimuli as a particular risk of study. A computer was used to display the stimuli because it was the most feasible way to do so while recording the eye movements that were stimulated. A Lenovo ThinkPad E580 computer was chosen because it is capable of running the PsychoPY software and is also equipped with an HD720p camera, which allowed the participants' eyes to be recorded while they viewed the stimuli. A square grating was selected as the type of stimulus because of its standard use in other literature, such as by Turuwhenua et al. (2014) and Fujiwara et al. (2017). This grating stimulus was generated through PsychoPY, a software package for psychology and neurology written using python. Pertaining to the stimulus, the grating involved vertical black and white stripes that moved horizontally across the computer screen. A relatively low spatial frequency of 0.1 cycles/° was used because lower frequencies have been found to increase the amplitude, or length, of the eye movements stimulated (Waddington & Harris, 2015). Higher OKN amplitude was optimal because the recordings of the eye movements had to be analyzed manually and the footage being analyzed was not very high quality because it was from the computer camera. The dimensions of the computer were 33.75 cm by 19.4 cm. The distance from the participants' eyes to the screen was 0.0305 m. Using these values, the degrees of visual field were calculated to be ±34.2° horizontally by ±19.3° vertically. Three speeds of the stimuli were generated using the software, 60, 90, and 120 degrees of visual angle per second (°/sec). These speeds are supported by similar research, where using speeds from 5°/s to 120°/s is standardized in the field based on an experiment run by Holm-Jensen & Peitersen (1979). The upper extremity of this range was selected to augment the difference in OKN frequency between participants with higher visual attention to those with lower visual attention in an attempt to garner significant results. The participants were seated at a table in a room with the distance to the computer screen controlled and their chins placed on a chin rest consisting of cardboard atop textbooks measured to control the resting point of each participants' eyes in the middle of the screen and to hold the head steady. The computer was placed inside a cardboard box, and a blanket was placed on top of the box and over the head of the participant to help eliminate any distractions. Participants were then asked to confirm that there was no visible light apart from the computer screen before the instructions were read. Within the script read to the participant was the instruction for the participant to "follow the lines across the screen." This instruction was read to promote "look OKN," similarly to a study by Whalen where the phrase "count the stripes like train cars going by" was found to elicit the look OKN response while "watch the stripes go by" was found to elicit "stare OKN" (2006). These two types of OKN were first identified by Ter Braak, who described stare OKN as a quick, fluttering movement of the eye back and forth where the iris moves a small, almost imperceptible distance, and described look OKN as more of a bouncing movement where the iris moves back and forth all the way across the eye (1936). Look OKN was chosen to be elicited in this study because of these characteristic large amplitude movements. Larger amplitude movements were preferred to ease the quantification of eye movements as the videos of the participants' eyes had to be analyzed manually. Each participant viewed each of the three speeds on the computer screen three times, for nine trials viewed by each participant. During each viewing, the camera of the same computer simultaneously recorded the eye movements over a period of 15 seconds for each trial. An optional rest was given to the participants between each trial to prevent eye strain. When quantifying the eye movements, the trial lengths of 15 seconds were cut to 10 seconds of video, which was initiated with the second or third SP movement—the slower movement of the eye during OKN which follows the stimulus—to give the participant time to adjust to the speed of the stimulus speed. Manipulation of the videos were accomplished by importing each of the nine videos for each of the twenty participants into the video-editing software Filmora, and then using tools in the software to cut the videos and prepare for analysis by slowing the speed of the videos down. Subsequently, while viewing the participants' eyes using the slow feature, each QP movement, the quick right to left eye movements made against the left to right rotation of the stimuli, was quantified over the 10 second interval. After all data values of OKN frequency for each speed were quantified, an independent one-tailed two-sample t-test with an alpha value of 0.05 was performed on each speed to determine if there was a significant difference in value of OKN frequency between the soccer-playing group and the non-team-sports playing group. The participants were given a name from P1-P20 to maintain anonymity.

## Results

Table 1 shows the raw data of the number of completed OKN movements over the three sets of 10 second intervals by each participant for each speed. There were thirty trials for each group at each stimulus velocity. There are some notable outliers in this data set, including the 38 eye movements by P14 at 60°/s as well as very low values, such as 1 or 2 eye movements achieved by a few of the participants. These outliers may have been caused by misunderstood instructions or an inability to properly quantify the eye movements. Though the best possible 10 second segment was taken from the 15 second videos, some analyzed recordings had videos frozen for longer than 5 seconds, possibly causing some quantifications of eye movements to be incorrect. It may be observed from Table 1 alone that the soccer-playing group performed better than the non-team-sport-playing group on average; however, Table 2 displays this finding much clearer. The data shows that the difference in means from the two groups for each respective speed never went below half an eye movement. Interestingly, the same is not true for the medians collected. Referring to Figure 2, while the soccer-playing group displays higher medians for the 60°/s and 120°/s trials, the median between the two groups is actually the same for the 90°/s trial. Furthermore, the soccer-playing group has a considerably higher standard deviation for the 60°/s and 90°/s trials at 6.384 and 4.976, respectively. The non-team-sport-playing group had a consistent standard deviation for these two trials at around 2.7 before having the higher standard deviation of the two groups for the 120°/s trial at 3.66, during which the soccer-playing group's standard deviation dropped to 3.019.

The means of the soccer-playing group are quite unexpected when compared to each other, as it was anticipated that the number of OKN completions would rise from the 60°/s trial to the 90°/s trial and then drop off, like the non-team-sport-playing group; however, that was not the case. Instead, the most OKN completions for the soccer players were observed in the 60°/s trial, followed by the 120°/s, with the 90°/s trial having the least completions.

An independent one tailed 2 sample t-test was conducted at an alpha value of 0.05 to compare the number of eye movements performed at each speed by each group. The results, as seen in Table 3 were not able to reject the null hypothesis for the 60°/s and 90°/s trials as the p-values were $p > 0.05$. However, there was a significant p-value of 0.029 in the 120°/s, meaning that there was enough evidence to reject the null hypothesis. This indicated that there was a significant difference between the two groups' values at this speed. The critical values for 60°/s, 90°/s, and 120°/s were 1.685, 1.679, and 1.673, respectively.

## Discussion

The purpose of this study was to determine if there was a significant difference in visual attention between high school students that played soccer and those that did not play a "team sport," using a novel method concerning OKN frequency. It was hypothesized that the soccer-playing group would have a significantly higher level of visual attention due to higher executive function being found in soccer players (Vestberg et al., 2012) as well as team sport athletes outperforming non-athletes at cognitive function tasks (Meng et al., 2019). To test the hypothesis, descriptive and inferential statistics were run to determine if the soccer-playing group had significantly higher visual attention than the non-team-sport-playing group. This was accomplished by using values of OKN frequency to compare the groups, since OKN frequency has been found to be related to visual attention (Frattini & Wibble, 2021).

The results of this study suggest that high school students who play soccer have greater visual attention than those that do not play a team sport, which is supported in similar studies such as those by Jin et al. (2023) and Verburgh et al. (2014). The frequency of OKN was also variable in relation to the speed of the stimulus. The non-team-sport-playing group demonstrated its highest OKN frequency at 90°/s, followed by 120°/s, then 60°/s. This trend is consistent with findings by Holm-Jensen & Peitersen (1979), who found that OKN gain becomes lower than 1 at speeds after 90°/s, meaning that the SP movement of OKN is not able to keep up with the actual speed of the stimulus, which suggests that the OKN frequency will not continue to increase. Interestingly, the soccer-playing group contradicted these findings. The results showed greater OKN frequency at 60°/s, followed by 120°/s, then 90°/s. Perhaps the most important takeaway from this study, however, is the methodology developed—using the assessment of OKN frequency to offer a valuable means of assessing visual attention, though further research is necessary to support the efficacy of this methodology.

One possible source of error in this study was that some of the recordings were not continuous and instead had high latency at certain points, causing possible incorrect quantifications of OKN movements to be made. There could have also been errors from the participants misunderstanding instructions or not remaining as focused as possible. For example, some participants may not have put the chin rest all the way to the computer keyboard as instructed, causing the chin rest to be at different distances, which may have caused different results. In addition, the chin rest could have been used incorrectly by not placing the chin all the way down on the rest or not keeping the head vertical, which may have also caused different results. The instructions to “follow the lines across the screen” could also have been interpreted differently than intended.

Some procedural improvements that could be made include using an eye tracking device to prevent human error when recording the completed OKN movements. Also, a larger screen could help take up more of the participants’ field of view. The chin rest used could also be improved as it was a modified cardboard container. In addition, perhaps a more representative group for the control group could be found, such as using a population’s value with which to compare the soccer or other sport group’s value to.

Future research could compare assessments of visual attention found from this method to other, more accepted methods, such as behavioral assessments or other eye tracking methods used in the field. In addition, further research could repeat the study by comparing OKN frequencies from a non-team-sport-playing group or population value to a different sport, between two sports, or perhaps to different positions of the same sport.

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# Figures and Tables

**Figure 1.** *Experimental Design Diagram*

**Title of the Experiment**
Effect of Playing Soccer on the Level of Visual Attention in High School Students

**Hypothesis**
If a high school student who plays soccer is compared to one who does not play a team sport, then the one who plays soccer will display a greater OKN frequency.

**Independent Variable** Soccer player

| Levels of Independent Variable | Soccer-playing high school students | Non-team-sport-playing high school students |
|---|---|---|
| **Number of trials at 60°/s** | 30 | 30 |
| **Number of trials at 90°/s** | 30 | 30 |
| **Number of trials at 120°/s** | 30 | 30 |

**Dependent Variable**
The number of completed OKN movements within a 10 second period characterized by a SP movement tracking the lines followed by a QP movement resetting the eyes back to where they started the movement.

**Constants**
The general age of participants, general number of years playing soccer of participants, position of eyes relative to screen, same instructions read to each participant, no eye abnormalities/uncorrected vision

**Table 1**. *Number of OKN completions during 10 second interval*

| | Non-team-sport-playing students | | | | | | | | | | Soccer-playing students | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60°/s | | | 90°/s | | | 120°/s | | | | 60°/s | | | 90°/s | | | 120°/s | | |
| P1 | 8 | 4 | 7 | 11 | 7 | 8 | 14 | 8 | 14 | P11 | 14 | 7 | 10 | 12 | 9 | 13 | 9 | 10 | 10 |
| P2 | 2 | 9 | 7 | 9 | 8 | 9 | 11 | 8 | 10 | P12 | 10 | 10 | 8 | 9 | 7 | 11 | 8 | 10 | 12 |
| P3 | 6 | 7 | 7 | 11 | 10 | 4 | 6 | 8 | 3 | P13 | 8 | 8 | 11 | 13 | 17 | 14 | 7 | 17 | 18 |
| P4 | 8 | 8 | 14 | 9 | 13 | 14 | 5 | 11 | 14 | P14 | 38 | 6 | 8 | 1 | 4 | 2 | 6 | 10 | 5 |
| P5 | 11 | 7 | 9 | 11 | 9 | 9 | 11 | 11 | 8 | P15 | 10 | 7 | 10 | 9 | 10 | 11 | 7 | 8 | 14 |
| P6 | 12 | 7 | 13 | 14 | 8 | 11 | 12 | 11 | 13 | P16 | 9 | 12 | 8 | 8 | 18 | 19 | 5 | 10 | 11 |
| P7 | 10 | 8 | 4 | 4 | 8 | 7 | 7 | 7 | 2 | P17 | 16 | 10 | 19 | 10 | 13 | 17 | 9 | 9 | 11 |
| P8 | 11 | 7 | 6 | 11 | 6 | 7 | 8 | 6 | 6 | P18 | 5 | 7 | 10 | 3 | 3 | 15 | 6 | 9 | 13 |
| P9 | 5 | 6 | 6 | 7 | 4 | 6 | 2 | 1 | 3 | P19 | 3 | 6 | 14 | 3 | 5 | 5 | 8 | 9 | 10 |
| P10 | 9 | 10 | 11 | 11 | 6 | 11 | 8 | 9 | 5 | P20 | 5 | 3 | 4 | 5 | 6 | 8 | 8 | 11 | 13 |

**Table 2**. *Descriptive statistics summary table of number of complete OKN*

| | Non-team-sport-playing students | | | Soccer-playing students | | |
|---|---|---|---|---|---|---|
| Statistic | Number of completed OKN movements within 10 sec time intervals | | | | | |
| | 60°/s | 90°/s | 120°/s | 60°/s | 90°/s | 120°/s |
| $n$ | 30 | 30 | 30 | 30 | 30 | 30 |
| $\bar{x}$ | 7.967 | 8.767 | 8.067 | 9.8 | 9.333 | 9.767 |
| $\sigma$ | 2.677 | 2.679 | 3.66 | 6.384 | 4.976 | 3.019 |
| Median | 7.5 | 9 | 8 | 8.5 | 9 | 9.5 |

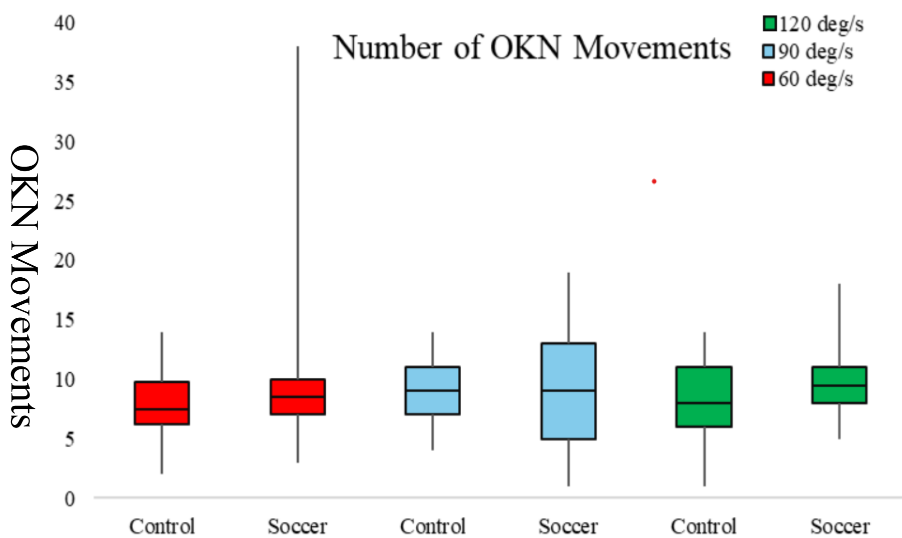


**Figure 2.** *Boxplot of number of completed OKN movements*

**Table 3.** *Inferential statistics t-Test comparing complete OKN movements between soccer-playing and non-team-sport-playing groups*

| Stimulus velocity | t-statistic | p-value | Null hypothesis decision |
|---|---|---|---|
| 60°/s | 1.426 | 0.081 | Fail to reject |
| 90°/s | 0.54 | 0.296 | Fail to reject |
| 120°/s | 1.93 | 0.029 | Reject |