

Evaluation of visual skills in sedentary and active work environments

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Abstract

The two fundamental categories of vision include visual-perceptual and visual-motor skills. Visual-motor skills encompass three essential ocular motor skills, namely focusing, eye-hand coordination and tracking. The aspects of the visual perceptual process include visual memory and visualization. This study aims to determine whether there is a difference in the visual performance of individuals exposed to a sedentary work environment and those exposed to an active work environment. The participants consisted of military recruits, who underwent a 12 week intense training regimen, and second year university students, who were subjected to a battery of vision testing to determine their visual performance. It was hypothesized that training recruits will possess superior visual skills in comparison to university students. The results indicate that training recruits possess superior skills in eye-hand coordination and visualization, while students showed enhanced tracking and sequencing skills. Cardio stress indices and blood pressures were tested to determine the heart health of the subjects and whether these factors influence visual attributes. Although not significant, the results indicate a decrease in cardio stress index in training recruits although their blood pressures were higher than those of students. The results concur with previous studies, which have shown that individuals exposed to physical activity, even for a short period of time, tend to acquire superior visual skills. However, the skills are honed according to the field of expertise due to the transfer effect that occurs in the brain. The findings of the study support as well as contradict evidence regarding sports vision testing and training, thus further investigation is required to elucidate the controversy regarding vision testing.

Keywords: Sports vision, visual skills, physical activity, visual motor skills, visual perceptual skills.

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Introduction

The eyes form the basis of what may be considered one of the most essential special senses - vision. The visual system serves to acquire information from one's

surroundings and acts as the basis for the execution of appropriate motor tasks (Babu, Lillakas & Irving, 2005). Maintaining optimal visual clarity is imperative in several areas, especially if one leads a dynamic lifestyle. The eyes, therefore, should be able to sustain the demands made on them and function accordingly (Despopoulos & Silbernagl, 2003). Figure 1 details the structures involved in generating an image, as well as the path of light from the time it enters the eye to the formation of the image.

Although optimal functioning of the eyes is essential for visual clarity, it is also imperative that the eyes and brain operate in synergy. This enables humans to see while moving, as the brain compensates for motion of the head by turning the eyes (Scanlon & Sanders, 2007).

From a physiological perspective, this ensures that the image falls on the fovea, making it necessary for visual perception and clarity. It has been established that to complete a task successfully, the visual system has to operate concurrently with the skeleto-muscular system as well as the environment (Mann, Ho, De Souza, Watson & Taylor, 2007). Thus, eye movements, which serve to “...locate visual targets and stabilize images on the retina” (Babu *et al.*, 2005: 1060), performs a crucial function in attaining optimal visual clarity. This can especially be seen in sports such as tennis, volleyball and basketball that require saccadic eye movements, which entail rapid changes of fixation from one target to another to ensure that the image falls on the fovea (Despopoulos & Silbernagl, 2003; Mann *et al.*, 2007).

It has been established that ocular activities (such as the lens changing shape, work of the ciliary muscles and increased complexity of electrochemical reactions conducted by the retina) can be subjected to exertion during exercise, thus implying that entrainment of vision is possible through interaction with the environment (Helveston, 2005; Verhagen, Dijkerman, Grol & Toni, 2008). Studies have shown that by simply participating in physical activity, one naturally improves one’s visual awareness as well as visual processing skills and visual-motor integration, thus implying that through Sports Vision training one can considerably improve performance and skill (Abernethy & Neal, 1999; Babu *et al.*, 2005; du Toit, Krüger, de Wet, van Vuuren, van Heerden & Janse van Rensburg, 2006b; CIGNA Medical Coverage Policy, 2008). However, Abernethy and Neal (1999) proved that it is not only physical attributes that influence visual excellence, but rather the manner in which visual information is processed.

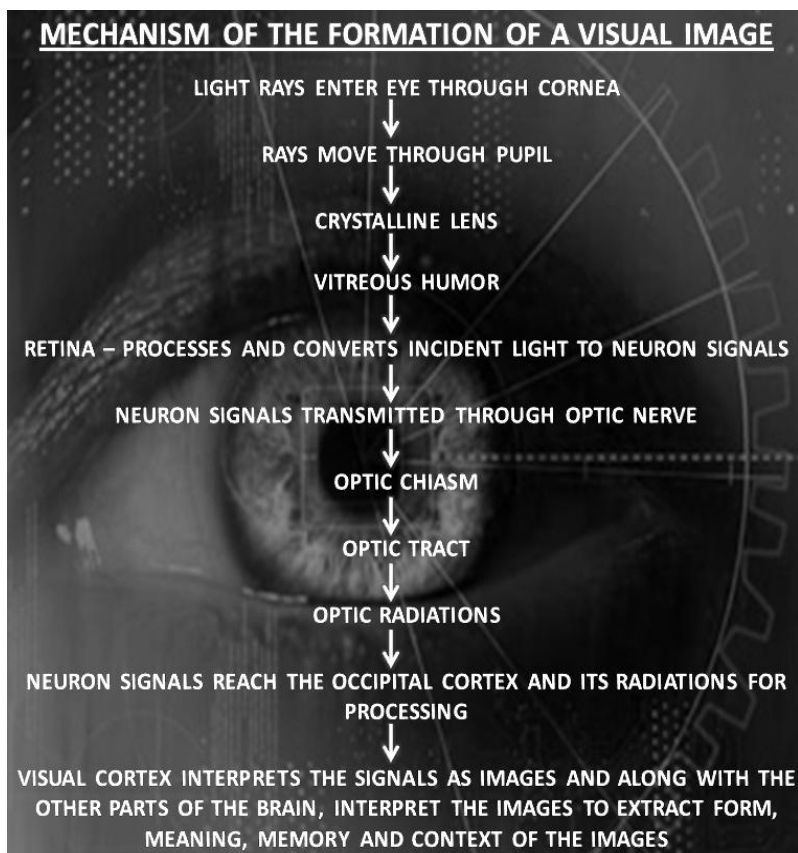


Figure 1: Flow diagram summarizing the mechanism of vision, tracing the path of light from the time it enters the eye to the formation of the image (Meyer, Meij & Meyer, 1997; Purves, Augustine, Fitzpatrick, Hall, LaMantia, McNamara & Williams, 2004; Scanlon & Sanders, 2007).

Sports Vision

Sports Vision is essential as it does not focus on a specific aspect of the body, but on the body as an entire entity. The basis of Sport Vision encompasses three processing stages: perception, decision making and response, that is, the execution of movement (Silverthorn, 2004; Barrett, 2009). Perception involves conveying information to the central nervous system. Decision making may be influenced by perceptual information, confidence levels, previous successes or failures stored in memory, the feedback system surrounding the individual, as well as the subject's current situation. With regard to response, one has to focus on the imminent situation as a whole, not just on subject's task, and base decisions accordingly. Motor functions are used to act on these decisions as they employ peripheral neurons to carry impulses to structures (Silverthorn, 2004; du Toit, Kruger, Chamane, Campher & Crafford, 2009). From a neurological stance, studies have shown that participating in physical activity altered neural activities through visual pathways (Nakata, Yoshie, Miura, & Kudo, 2010).

Skills besides eye movements that are necessary to attain visual excellence include sequencing, which assesses how individuals interpret, organize and process visual sequences and are used to improve sequential processing (Wilson & Falkel, 2004). Visualization refers to the ability to concentrate as well as visualize and recall sequential arrangements. Athletes and recruits are often trained in visualization to improve concentration and attention for longer periods of time (Wilson & Falkel, 2004).

Coordination occurs when the motor system composes complex actions by combining simpler sub-movements. The process involves sharing information about the progress of the sub-movement with the centres controlling another sub-movement, to ensure that the second occurs in appropriate relation to the first (Wilson & Falkel, 2004). Eye-hand coordination refers to the ability of the hands, eyes and body to operate as a single constituent, thereby ensuring an effective response to visual stimuli (du Toit, Kruger, Joubert & Lunskey, 2007). Eye-hand coordination is assessed to improve fine motor control, eye movement speed and accuracy.

Peripheral awareness refers to the ability to focus on a single image while maintaining awareness of one's surroundings and is a vital component of one's efficiency in sporting performance (du Toit et al., 2006b). Vision testing and training can improve peripheral awareness, enabling one to focus on one's task whilst making skilled anticipation judgments, thus giving one the advantage over the opposition and ensuring success (Wilson & Falkel, 2004; Williams, 2009). As confirmed by Memmert, Simons and Grimme (2009: 146), vision and attention are associated in the sense that "...attention is closely linked to the capacity of visual memory; basic differences in attention might well predict differences in performance".

Various studies have been conducted in the area of Sports Vision. However, the results are highly contrasting and no accurate deduction can be derived from the results. Though it would appear that in a comparison between athletes and non-athletes, the results were in favour of athletes, thus supporting the notion that athletes possess superior visual skills (Hazel, 1995; Babu et al., 2005; Mansingh, 2006). These results refer only to specific skills and not vision in a holistic sense. Studies by Memmert et al. (2009) and Akarsu, Çalışkan and Dane (2009) confirm that athletes do not differ from non-athletes in basic visual skills, such as "...visual acuity, colour vision, peripheral response time, depth perception and ocular muscle balance" (Memmert et al., 2009: 147), rather in tasks specific to their sporting context, namely "...saccades, visual reaction time, peripheral awareness and dynamic visual acuity" (Akarsu et al., 2009: 872).

A review by Hazel (1995), suggests that exercise enhances one's visual efficiency and increases the brain's reaction to stimuli so that a quicker response is elicited.

This is confirmed in a study that compared physical activity and visual attention which showed that even sub-maximal exercise enhances visual acuity and visual attention (Cereatti, Casella, Manganelli & Pesce, 2009). Exercise has also been shown to have a substantial influence on visual concentration, eye-hand coordination, proaction-reaction time, as well as visual response speed and accuracy (Tomprowski, 2003; du Toit, Krüger, de Wet, van Vuuren, Joubert, Lottering & van Wyk, 2006a; du Toit et al., 2007).

However, there is contrasting evidence that suggests that such regimens do not provoke significant changes in visual and motor performance and, while there may be an improvement in the battery, it does not result in an improvement in sporting performance (Wood & Abernethy, 1997; Abernethy & Wood, 2001). This can be seen in a study conducted on clay target shooters, where visual differences between expert shooters and novices were negligible. The only significant attribute was reaction time (Abernethy & Neal, 1999). Wood and Abernathy (1997), although producing results that implied the benefits of vision testing and training in their study, argue that other factors could contribute to the improvement, such as the placebo effect or an “illusory function of expectancy effects” (p. 658).

This present study covers various features of visual skill assessment and how it is influenced by exercise and various circumstances. The physical aspects of visual perception tested includes visual acuity, in which the ability to identify a stationary object is tested (Wilson & Falkel, 2004). Assessing eye movements is essential in determining visual excellence as it tests the ability of the eyes to focus at varying distances, conduct point-to-point movements and evaluate the speed and accuracy of saccades. Procedures that exemplify these aspects include focusing and tracking. These methods aim to enhance vision by improving the ability of the eyes to focus, as well as the accuracy of saccadic movements, and help the eyes to operate more accurately and efficiently for sustained periods of time.

Black and Garbutt (2002), as cited in Pettee Gabriel and Ainsworth (2009: 8S), define stress as “...a state of threatened homeostasis provoked by a psychological, environmental or physiological stressor”. It has been determined that physical activity has the potential to substantially reduce stress levels by influencing the release of the neurotransmitters dopamine, endorphins and serotonin (Pettee Gabriel & Ainsworth, 2009). Cañal-Bruland, Pijpers and Oudejans (2010) conducted a study which showed that in the sporting environment, a meagre level of anxiety experienced by players had a positive effect on performance. However, a considerable increase in stress levels reduces overall performance and thus it can be deduced that visual performance will also be affected. This study proposes that stress levels of recruits (cardio stress index) should fall following increased activity. Therefore, it is envisaged that the decline in stress levels should provide visual advantage.

The aim of this study was to compare the differences in visual skills and cardio stress index of sedentary and active individuals. It was hypothesised that active individuals would have superior visual skills and a lower cardio stress index (CSI) than sedentary individuals.

Methods and Material

Design

The study was a comparative and quantitative study.

Participants

The participants consisted of 158 undergraduate university students and 230 training recruits. The recruits were selected based on compliance with the inclusion criterion, namely completing the informed consent, as the data has already been obtained as part of a greater study. The undergraduate students comprised those that enrolled for the second year physiology course at the University of Pretoria, South Africa who opted to participate in the study and completed the informed consent. The recruits comprise military trainees who underwent 12 weeks of intense training. The undergraduate students spend an average of eight hours a day in classes. None indicated participation in more than light physical activity [3-6 metabolic equivalents (METs)] during the previous three months (Lovelady *et al.*, 2000). The training recruits spent at least one hour a day engaging in vigorous (organised) physical activity (>6 METs). Informed consent was obtained from the participants and ethical clearance was granted by the Ethics Committee of the University of Pretoria, South Africa.

Vision Testing

The level of visual skills was tested by means of five visual tests (Wilson & Falkel, 2004), while the health risk assessment consisted of two tests. The same criteria and testing procedures were used for both subject groups.

The battery of vision tests was as follows (Wilson & Falkel, 2004):

- *Focusing* uses the near-far chart to assess the ability of the eyes to focus, as well as improvement in the ability to sustain clear vision at varying distances. The materials used were a small letter chart, a large letter chart and a stopwatch. The large letter chart was placed on a wall at a distance from the participant and the small letter chart was held at nose level, about four inches away from the participant's face. The letters had to be read from left to right, alternating each letter between the near

and far chart. The number of letters called out correctly were counted and recorded. This test was conducted twice and the average recorded as the final score.

- *Tracking* is practised to enhance the speed and accuracy of saccades and measures the ability of the eyes to conduct point-to-point movements. Three two-strip letter charts and a stopwatch were used for this test. The strips containing few letters on a chart progressing down to letters placed close together were placed a metre apart. . While standing approximately at an arm's length from the strips, the participant, had to read the letters from left to right down the column, alternating between strips. The number of letters read correctly in one minute was recorded. The test was repeated and the average of the two results was recorded.
- *Sequencing* aims to assess how individuals interpret, organize and process visual sequences. A hand sequencing sheet was used. The instructor sat opposite the table from the participant and showed a sequence consisting of three types of movements: palm faced down (P), hand placed on the side (S) or fist (F). The participant had to repeat the sequence to the instructor. As the participant successfully completed each sequence, the level of difficulty increased, that is, more movements were added to the sequence. The level at which the participant made the last correct sequence was recorded. The test was repeated twice to accommodate the learning effect of the brain and the average result was recorded.
- *Eye-Hand Coordination* was measured using the egg-carton catch method. This method tested motor control, speed and accuracy of eye movements. The materials required were a 12-pocket egg carton, a coin (preferably the size of a 10c coin), a marking pen and a stopwatch. The inside of each egg pocket was numbered sequentially, with number 1 at the uppermost left pocket and number 2 in the pocket below number 1, up to 12 in the lowest right pocket. The coin was placed in the pocket numbered 1 and the participant had to flip the coin, in succession, until he/she reached number 12. The time in which the participant completed the task was recorded.
- *Visualization* was tested using a deck of playing cards. The ace-to-seven method was employed to evaluate the subject's ability to concentrate as well as visualize and recall sequential arrangements. The participant sat at a table. The instructor shuffled seven cards and placed them in front of the participant. The subject had to memorize the order and indicate when he/she felt that the sequence was successfully memorized. The cards were then flipped over face down and then flipped back in order, from ace to seven. The time is recorded from the time the cards are revealed to the subject to the successful completion of the test.

Health Risk Assessments:

- *Cardio Stress Index* was measured using a Viport (manufactured by Energy-Lab Technologies GmbH) and tests cardio stress index (CSI), heart rate (HR), heart rhythm, and QRS duration (Energy-Lab Technologies GmbH, 2005). While in a seated position and maintaining an upright posture, subjects, had to place the top two electrodes of the Viport on the first intercostal space of the subject. Prior to placing the Viport on the participant, the electrodes had to be moistened with conducting gel. Caution was exercised to ensure that all three electrodes were in contact with skin and no metallic objects (such as jewellery) could interfere with electrode signalling. Once correctly placed on the participant, the Viport was started. While the reading was being taken for duration of two minutes, the subject was instructed to maintain natural breathing, and avoid sudden movements and speaking.
- *Blood Pressure* readings were measured using the protocol as stipulated by the American Heart Association (Pickering et al., 2004). The blood pressure cuff was placed slightly above the brachial artery (left arm) while the participant was sitting in a relaxed, upright position. A stethoscope was placed on the brachial artery. The bulb of the sphygmomanometer was then pumped continuously to constrict the artery and loosened gradually. The point at which Korotkoff sounds were heard marked the systolic pressure. The stage at which the Korotkoff sounds disappeared marked the diastolic pressure. The final blood pressure reading was recorded as systolic pressure/diastolic pressure in millimeters mercury (mmHg).

Statistical analysis

The sample mean (m) and standard deviation (SD) for the various parameters were calculated using Number Cruncher Statistical Software (NCSS). Between groups, differences were computed using the independent samples t – test. The level of significance was set at $p \leq 0.05$.

Results

The values obtained for recruits and university students in the Sports Vision battery were compared to establish whether physical activity affects visual abilities. The mean and standard deviation were calculated in visual skills, health risk assessments and population characteristics. Differences between male and female participants were also determined. Results that were significantly different are indicated by an asterisk.

In the visual skill assessments (Table 1), the recruits proved to be far superior in eye-hand coordination and visualisation. This implies that the recruits display a greater sense of fine motor control, eye movement speed and accuracy, ability to concentrate

for prolonged periods, and ability to visualise and recall sequential arrangements. However, students produced better results in tracking and sequencing. Therefore, the students are more proficient in conducting point-to-point eye movements and sequential processing. No significant results were obtained with regards to focusing, thus both groups appear to be equally proficient in their ability to maintain a clear vision at near and far distances.

Table 1: Comparitive results in Sports Vision testing battery between recruits and students

Mean visual skill difference		
Visual Test	University Students (n=158)	Training Recruits (n=230)
Focusing (# Letters/min)	41.42 ± 18.56	40.60 ± 20.13
Tracking (# Letters/min)*	56.95 ± 17.24	40.12 ± 18.72
Sequencing (Correct Sequences)	2.04 ± 0.92	1.56 ± 0.79
Eye-Hand Coordination (Sec)*	47.48 ± 31.18	25.66 ± 10.73
Visualization (Sec)*	52.61 ± 24.69	38.95 ± 22.03

*p ≤ 0.05.

Table 2: Cardio stress index comparison between training recruits and students

Mean differences in CSI statistics		
Characteristics	University Students (n=158)	Training Recruits (n=230)
Mean CSI Males	32.9 ± 25.37	24.39 ± 18.13
Mean CSI Females	36.92 ± 23.83	41.66 ± 22.28
Mean Group CSI	36.09 ± 24.13	31.9 ± 21.76
Total CSI Risk (%)	57.23	52.17

CSI ≥ 25 indicates risk; *p < 0.05.

Table 3: Population characteristics proposed to be influenced by vision

Mean differences in population characteristics		
Characteristics	University Students (n=158)	Training Recruits (n=230)
Age (Years)	20.4 ± 1.1	20.46 ± 1.2
Body Mass Index	23.3 ± 4.5	22.95 ± 3.18
Heart Rate (bpm)	83.1 ± 14.8	82.87 ± 13.06
Systolic Blood Pressure (mmHg)*	119.9 ± 12.6	127.16 ± 13.31
Diastolic Blood Pressure (mmHg)*	72.0 ± 9.9	77.08 ± 7.89

*p < 0.05

CSI readings (Table 2) indicate that training recruits exhibited lower results than students but the difference was not significant. This shows that recruits are able to

cope with physical stressors placed on the cardiovascular system and have a lower risk of developing lifestyle-induced cardiovascular diseases.

Blood pressure differences (Table 3) were significant as it was higher in recruits. Other factors, namely age, body mass index and heart rate were considered (Table 3) on the premise that these may influence visual attributes, but they all proved to be insignificant. This indicates that the visual system operates independent of these factors and that entrainment of the visual system is not reliant on these factors.

Discussion

It is a common belief that some visual abilities can be trained under controlled conditions and that it will be observed as an increase in performance (Hazel, 1995). This is in accordance with the results of this study, as in some areas, namely eye-hand coordination and visualisation, recruits obtained far superior results. These results confirm previous findings as studies conducted between experts and novices demonstrate an improvement in eye-hand coordination; reaction time and visio-spatial intelligence, indicating that exercise or physical activity intervention could significantly affect these specific visual attributes (Chapman, Underwood & Roberts, 2002; Akarsu *et al.*, 2009).

In their study, Cereatti *et al.* (2009: 137) contended that experienced athletes tended to have superior visual skills due to experience and that they “*show highest flexibility in the allocation of visual attention*”. They also maintain that by training the visual system, the eyes are able to better locate, focus centrally and functionally as a unit, which could result in reduced eye fatigue and improved consistency in performance (Hazel, 1995). The same explanation applies to recruits, as they are in the process of acquiring a wealth of experience in the physical demands of their field of expertise.

In a study conducted on soccer players, a correlation between vision and attention was established, confirming that experts on the field are able to fixate their attention on a specific area for a shorter period of time than amateurs and still absorb more information, which accounts for their improved performance (Memmert *et al.*, 2009). This suggests that the brain can be processed to a greater degree through experience following increased physical activity. The association between vision and attention can also be seen in saccadic movements. Babu *et al.* (2005) illustrated that attention revolves around the point of fixation, and with regard to saccades, athletes are better able to execute the saccadic movement as they possess a greater attention span.

In a study conducted on the effect of exercise on sporting performance, it was shown that visual acuity was advanced in more skilled players and the visual field is enhanced (Hazel, 1995). This can be construed as a transfer effect from physical activity to visual excellence. The transfer effect is explained as a gradual

development in visual performance due to increased stimulus processing by the brain, which can be observed as an improvement in overall performance.

Although some differences in visual skills between recruits and students are apparent, this study confirmed that students are more proficient in other skills. This is unrelated to their sedentary nature. These skills included pursuit tracking and sequencing. Literature advocates that the cause of these superior skills harnessed by students may be ascribed to environmental factors. In other words, the discipline students possess influences saccadic adaptation (Babu *et al.*, 2005). It is also suggested that training one's visual field has to be precise and specific in order for it to translate to overall performance in that specific field. This accounts for recruits being more proficient in some aspects of visual performance and students being more skilled in other visual aspects (Wood & Abernethy, 1997). Determining the extent to which visual attributes can be entrained will benefit the recruit by giving an indication of which attributes can be honed. This should result in optimal performance in that particular field.

While most evidence correlates with the results obtained in this study, there is also evidence that supports contradicting results, namely those obtained with the focusing, tracking and sequencing tests. This is confirmed in several studies, indicating that basic visual abilities and attention skills are not influenced by exercise, and some studies suggest that modifiable factors can affect the relationship between attention and exercise. This is further complicated by the modifiable factors that affect performance such as "...strength, technique, fitness, attitude and state of mind" (Hazel, 1995: 101). In other words, the extent to which these abilities affect performance may be determined, barring any external influences.

Stress has been implicated in various conditions such as cardiovascular disease. It has been established that increased stress levels tend to increase blood pressure. However, the results obtained in this study show that even though the recruits had higher blood pressures than students, their cardio stress index still proved to be lower than that of the students. This is postulated to be due to the increased level of physical activity conducted by recruits, which enables the recruits to handle the physical and visual stress associated with their job requirements. By overcoming these stressors, the recruit is able to deal with an enhanced level of physical and visual input efficiently.

From the neurological standpoint of Sports Vision testing and training, eye movements are programmed by the brain stem. However, horizontal rapid movements such as saccades and pursuit tracking are designed in the pons; vertical and torsion movements are programmed in the mesencephala. The cerebellum eventually provides modifiable enhancements to these movements to prevent errors (Scanlon & Sanders, 2007). An understanding of this complex physiology will make

it possible to understand the mechanisms of visual acuity and excellence so that one would be able to determine which specific components of the visual system can be trained or ‘fine tuned’.

Future studies should investigate other factors that influence visual performance in addition to physical activity. Perhaps the neurophysiologic changes in visual function to physical activity should be determined as it has been shown from an optometric perspective that “neurodevelopment” exercises such as body motion activities, improve visual abilities like saccadic movements and pursuit tracking (Helveston, 2005).

Conclusion

To a certain extent, participating in physical activity does influence one’s visual skills. This was evident in the superior visual skills possessed by the recruits. However, these skills are harnessed according to one’s field of expertise and the transfer develops accordingly, as indicated by the students’ proficiency in specific assessments. The objectives were achieved in that it was proven that physical activity does promote in an enhanced sense of Sports Vision. The results obtained favour both supporting and contradicting evidence with regard to Sports Vision testing and training, indicating that it is an area of study that requires further investigation.

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