Vision and sports: A review of the literature

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Abstract
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Vision and Sports:
A Review of the Literature

by

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ABSTRACT

The basis for training visual abilities to enhance sports performance is explored. Optometric intervention in sports assumes the following statements to be true: 1 Athletes have better visual abilities than non-athletes and better athletes have better visual abilities than the poorer athletes, 2 Visual abilities are trainable, and 3 Visual training is transferable to the performance of the athlete. The literature demonstrates that athletes have better visual abilities than non-athletes. Studies have shown this to be true in the following areas of vision: Larger extent of visual fields, larger fields of recognition (peripheral acuity), larger motion perception fields, lower amounts of heterophoria at near and far, more consistent simultaneous vision, more accurate depth perception, better dynamic visual acuity, and better ocular motilities. The literature also shows that all of the above skills are trainable. Two studies are cited that support the belief that visual training is transferable to athletic performance but they suffer from inadequate experimental design.
INTRODUCTION

There is a rising optometric interest in sports vision. Articles describing the value of visual abilities in athletic performance are common.1,2,3,4,5,6,7 Many of these articles propose measurement and training techniques but cite few or no references on which the proposals are based.3,5,6,7,8,9,10 The reader must therefore assume that the proposals and assertions made are opinions of the authors rather than proven facts. The need to establish a foundation of facts on which to base optometric intervention is obvious. The purpose of this study is to explore the scientific foundations of sports vision.

The role of visual abilities in sports can be investigated by reviewing the following assumptions:

1. That athletes have better visual abilities than non-athletes and that the better athletes have better visual abilities than the poorer athletes.

2. That visual abilities are trainable.

3. That visual training of visual abilities is transferable to the performance of the athlete.

DO ATHLETES HAVE BETTER VISUAL ABILITIES THAN NON-ATHLETES AND DO THE BETTER ATHLETES HAVE BETTER VISUAL ABILITIES THAN THE PoORER ATHLETES?

Winograd11 compared certain visual measurements, as measured by the Keystone Telebinocular Instrument, of college varsity athletes,
college non-athletes, and rejected candidate athletes. All the athletes were baseball players and the rejected candidates were those athletes that failed to make the college team. The data shows significant differences between the varsity players and the rejected candidates in simultaneous vision and in far point lateral imbalance. In comparing the varsity and the non-athletic groups, significant differences were found at the far point setting in the tests of stereopsis and simultaneous vision. Significant differences were also found at the near point in the fusion and lateral imbalance tests.

Graybiel et al\textsuperscript{12} reported on Russian studies of vision and reports which compare twenty-five champion tennis players to one hundred and ninety-four untrained students. The tennis champions had significantly lower amounts of heterophoria than the non-athletes, both at near (25cm) and at far (5m). In another experiment the subjects performed a fatiguing task consisting of crossing out certain letters in a text of medium size print for fifteen minutes. Sixty percent of the athletes and forty-one point two percent of the non-athletes showed no change in the distance phoria. At near, fifteen point five percent of the athletes and four point eight percent of the non-athletes showed no change in their phorias. Graybiel does not state the direction of the changes in phoria that did occur. In the same article, Graybiel also reports on studies that show that thirty tennis players had "considerably" better depth perception than one hundred and twenty-two football players. Also "a correlation"
was found to exist between the athletes' depth perception and "athletic efficiency" of tennis and soccer players. "As a group, more skillful players perceived depth more accurately." In another Russian study, also reported by Graybiel, when the peripheral vision of javelin and discuss throwers was blocked, the distances thrown were significantly shorter in both groups. The author further reports that their "movements became clumsy."

Hobson and Henderson found that, of the basketball players at Grinnel College, the best pass-concealer (as rated by the coaches) had a visual field fifteen degree larger than the other players, all of whom had fields larger than normal as indicated by the American Optical Company's charts.

Johnson postulated that if perception in the peripheral field is an important factor in team sports with widespread function that athletes in these sports would possess a larger "perceptual field" (better peripheral acuity), either because the sport selected individuals with such ability or the sport provided experience which tended to develop a larger form field. The study used a modified arc perimeter and Landolt C's to measure peripheral visual acuity. The results showed the average peripheral form field in a sample of twenty-six football and basketball players to be significantly superior to a group of non-athletes with equal mean foveal acuity. The study further showed that the acuity in the peripheral field, as measured by a Landolt C, significantly (p<.01) improved with practice.

Buchellew in a follow-up study using the same methodology, agreed with the findings of Johnson. He also showed that the mean peripheral visual reaction time, that is, reaction time to a
stimulus presented in the peripheral field, is faster in each of the five athletic groups studies as compared to a non-athletic group. The apparatus used to measure peripheral and central visual reaction times was a group of lights mounted at different horizontal angles in the subject's periphery. The time between light presentation and subject's response was measured in hundredths of a second.

Olson\textsuperscript{16} compared depth perception and span of recognition in varsity college athletes, intramural athletes, and non-athletes. Using the Howard-Dolman apparatus for measuring depth perception, he found that both the varsity and intramural athletes had better depth perception than the non-athletes, significant at the .001 level of confidence. While the datum show that the varsity athletes had better depth perception than the intramural athletes, the datum are not significant at the pre-determined .02 level of confidence. The span of recognition was measured by tachistoscopically presenting two hundred slides containing from four to thirteen black dots randomly arranged. The subject watched a fixation point in the middle of the screen and recorded the number of dots that he saw after each presentation. The data show that both the varsity and intramural athletes had a higher span of recognition score than the non-athletes (p<.01). The varsity athletes had higher span of recognition scores than the intramural athletes though again not significant at the .02 level of confidence.

Stroup\textsuperscript{17} compared the field of motion perception of twenty aspirants to the varsity basketball team and twenty enrollees of a sports class who had never played on their high school basketball teams. The instrument used to measure the field of motion perception stabilized the subject's head while measuring the binocular field,
similar in principle to a perimeter. The initial test results show a significant difference (p<.01) in the field of motion perception between the two groups. Retested two months later, the results showed no significant differences in motion perception; but, a significant difference did exist between the first and second readings of the non-basketball players. The author does not state what activities the non-basketball players had been doing for the two months between the tests and attributes the increase in the field of motion perception of the non-basketball players to "training while taking a test."

Both Montebello\textsuperscript{18} and Miller\textsuperscript{19} report better depth perception among baseball players than non-athletes. Miller further found that depth perception statistically differentiated the outstanding and low skilled players in various sports activities.

Ridini\textsuperscript{20} measured depth perception by means of a Howard-Dolman apparatus and peripheral fields by means of a McClure Perimeter of one hundred and eighty-one eighth grade boys. The boys were broken into two groups; ninety-one athletes and ninety non-athletes. The athletes were defined as those boys who had not participated on an organized team in or out of school except as required in physical education classes. The results show a significant difference between the athletic and non-athletic groups in both depth perception and extent of peripheral field at the .01 level of confidence.

Beals et al\textsuperscript{21} studied the degree of correlation between shooting accuracy of basketball players and the visual attributes of static visual acuity (Snellen about at 6 meters), dynamic visual acuity (DVA), depth perception and size constancy. Dynamic visual acuity is "visual acuity as determined for targets in motion."\textsuperscript{22}
Dynamic acuity was measured by having the subject identify 1 3/4 inch letters as they were moved across a screen by a 35mm automatic slide projector which oscillated through a thirty-degree arc at a linear velocity of 8.83 miles per hour. They found a correlation of 0.76 between field shooting accuracy and DVA. Dippner questioned the statistical analysis used by Beals but states that there "may be a relationship between dynamic visual acuity and shooting ability."

Morris and Kreighbaum, in the discussion of their results, agree with the findings of Beals et al. Their study compares the dynamic visual acuity of high and low accuracy female basketball players. Dynamic visual acuity was measured by projecting a moving checkerboard pattern on a 180° cylindrical screen. The projected checkerboard contained a dot in one of four positions, up, down, left or right.) The subject attempted to identify the location of the dot under varying velocities and pattern size. Morris and Kreighbaum's data did not show a statistically significant difference in the mean dynamic visual acuity of the high and low percentage shooters but the data does show that the high percentage shooters have better dynamic acuity rates. The small sample size of eleven female players, five high accuracy and six low accuracy, makes statistical differentiation difficult.

Sanderson and Whiting studied the relationship between static visual acuity, dynamic visual acuity and performance in a catching task. The catching task required the subject to catch a mechanically tossed tennis ball. The trajectory of the tennis ball was exposed to the subject for only 80 msec of its flight, the first portion of
the flight was in total darkness, the 80 msec illumination period occurred, then the last portion of the flight ranging from 320 msec to 0 msec was in total darkness. The results show that the dynamic visual acuity and catching performance are significantly related. In the Sanderson and Whiting study, dynamic and static acuity scores were not significantly related. The relationship between dynamic and static acuity had been disputed in the literature.\textsuperscript{26,27,28} The apparent conflict was explained by Sanderson and Whiting by examining the role of exposure time. The studies showing a significant correlation between static visual acuity and dynamic visual acuity occurred when the methodology of the experiment allowed the exposure time of the moving target to be one second or more. This is an important finding when it is observed that many athletic tasks allow exposure times of less than one second, such as a baseball pitch which requires approximately one-half of a second to reach home plate.\textsuperscript{29}

Trachtman,\textsuperscript{30} in a study of thirty-six Little Leaguers aged ten to twelve, compared ocular motilities and batting averages. The quality of both pursuits and saccades were quantified by examiners who had no prior knowledge of the subject's batting skills. The pursuits were measured on a scale from one to six and the saccades on a scale from one to five. The results show a coefficient of correlation of +0.44, significant beyond the .01 level of confidence between ocular motilities (pursuits and saccades) and batting averages. Hubbard and Seng\textsuperscript{31} have demonstrated that the visual tracking of a pitched baseball is accomplished by pursuit movements. Trachtman's results agree with Hubbard and Seng, showing a +0.40 correlation between pursuits and batting average, significant to the .05 level.
Falkowitz and Mendel,\textsuperscript{32} in a study similar to Trachtman, screened fifty Little Leaguers aged eleven to thirteen with the following criteria: pursuits were scored as either smooth\textsuperscript{(s)} or jerky\textsuperscript{(j)}; near point convergence (NPC) was scored in categories of less than two inches (NPC<2), between two and four inches (2<NPC<4), between four and eight inches (4<NPC<8), and beyond eight inches (NPC>8); saccades were scaled as 'one', if accurate and no head movements, 'two', if accurate but slight head movement, and 'three', if slight under or over shooting or if head leads the eyes; and eye dominance was established by bilaterally sighting a hole card. The data can be seen in Figure 1. As shown in the data, the best hitters generally have the best saccadic pursuit, and convergence abilities and have uncrossed eye-hand dominance. The poorer hitters generally have the poorer ocular motilities and have crossed eye-hand dominance. The CNP data is nearly linear with respect to batting averages. This study also shows evidence to support Adams\textsuperscript{33} study that unilateral hand-eye dominance correlates with higher batting averages.

\begin{center}
\textbf{Insert Table 1 about here}
\end{center}

To summarize, the literature shows that various athletic groups demonstrate visual abilities that are superior to non-athletic groups. These superior visual abilities include: extent of visual motion field, extent of visual detection field, ocular motilities, peripheral acuity, dynamic visual acuity, depth perception, "span of recognition", consistent simultaneous vision and lower heterophorias.
ARE VISUAL ABILITIES TRAINABLE?

In a retrospective study by Wold, Pierce and Keddington, the authors show that all of the ten visual functions measured improved significantly at a .001 level of confidence as a result of visual therapy. These functions were:

1. Pursuits
2. Saccadic fixations
3. Accommodative amplitude flexibility
4. Convergence
5. Accommodative flexibility
6. Acuity
7. Binocular alignment
8. Focus alignment relationships
9. Fusion
10. Stereopsis/Suppression

The cases examined were one hundred consecutive binocular vision therapy cases from the office of the senior author. The strabismic and amblyopic cases were not included. All of the patients exhibited some learning dysfunction. In the thirty-four patients, for whom information was available, the word-recognition improvement was 1.0 grade level over the three month period of training, while the expected rate of word-recognition improvement, over the three months, is 0.3 grade levels. This finding indicates a positive transfer effect of the training to the performance of the patient in the environment.

Hoffman, Cohen and Ferer retrospectively examined the cases of one hundred twenty-nine visual therapy patient of three types:

1. Accommodative anomalies
2. Convergence insufficiencies

3. General skill deficiencies (poor pursuits, restricted actions, suppression, or poor hand-eye coordination)

They found an overall success rate of ninety percent which agrees with Wold et al that visual anomalies can be remedied through visual training.

Wittenberg, Brock and Folsom\textsuperscript{36} have demonstrated that stereo-acuity is trainable. The subjects' stereo-acuity was tested with the Aviators Unit of the Keystone Diagnostic Unit. The experimental group was then trained on the M-2 Stereoscopic Trainer. Both the experimental and the control groups were again tested on the Aviator Unit. The experimental apparatus was designed such that manipulation of the targets was not one of the testing procedures. This eliminated the variable of improved manipulatory skills and allowed the authors to demonstrate that the visual training (which did allow manipulation of the targets) transferred to another task utilizing stereo-acuity and was responsible for the stereo-acuity improvement.

Barmack,\textsuperscript{37} in experiments with monkeys, summarizes that three factors probably determine dynamic visual acuity:

1. Foveal acuity
2. Oculomotor control
3. Parafoveal acuity

Fergenson and Suzansky\textsuperscript{38} state that visual resolving ability and tracking and timing abilities are the main factors affecting dynamic visual acuity, and that tracking and timing abilities determine the deterioration of dynamic visual acuity as angular speed increased and exposure time decreased. The experiment tested the dynamic visual acuity under sixteen conditions of varying
angular velocity and exposure times. Each subject was tested six times under all sixteen testing conditions. The authors found a significant improvement in dynamic visual acuity between the first test mean as compared to the last test mean in eight of sixteen test conditions. The improvement was primarily in the intermediate difficulty test conditions.

Slonim et al. studied the effect of training dynamic stereo-acuity in thirty male and thirty female college students. The dynamic stereo-acuity was measured and trained by a movable Howard-Dolman device. The baseline dynamic stereo-acuity was measured for all subjects at an angular rate of one hundred twenty degrees per second. The subjects were divided into three equal groups: 1. A control group with no training. 2. A group trained at an angular velocity of sixty degrees per second. 3. A group trained at an angular velocity of one hundred twenty degrees per second. The results show a significant difference (p<.005) in dynamic stereo-acuity between the control group and both training conditions. The dynamic stereo-acuity of the group trained at sixty degrees per second improved more than the group trained at one hundred twenty degree per second.

The literature supports the assumption that visual abilities are trainable. Visual skills such as pursuits, saccadic fixations, accommodative flexibility and amplitude, convergence, acuity, binocularity, stereopsis, accommodative-convergence relationships, dynamic visual acuity, stereo-acuity and dynamic stereo-acuity were found to improve with training.
improvement of the players who received visual training was significant to the .05 level of confidence compared to the players who received no visual training.

Revien reports on a study that he made on the effects of vision training on performance. His subjects were members of the New York Sandlot Baseball Club. Revien states "After administering the exercises, the findings were as follows: the trained group improved its collective batting average by 72 percentage points over the previous year's average, while the other players, with the same amount of batting practice but no eye training, increased their average by 29 percentage points. That's one half the improvement of the visually-trained players. As for strikeouts, the figures were even more telling. In 1974 the nontrained players struck out 22.2 percent of the time; and in 1975, 22.1 percent of the time - virtually no improvement. But the visually-trained players, who in 1974 struck out 17.2 percent of the time, ended up in 1975 striking out only 9.2 percent of the time." (From page 20 of his book.)

Both of the above cited studies conclude that visual training is responsible for an increase in the athletes' performance but both studies have flaws. The Review study was not reported in any scientific journal (to our knowledge) but rather in a book by Revien and without the original data. The study's experimental group was already better than the control group at the beginning of the training. It could be argued that the experimental group had a greater potential for becoming good players and that just one more year of practice with or without the training is responsible for the greater improvement of the experimental group. Furthermore, no mention was made of what the control group experienced to compensate for the placebo effect of training.
In the Nishizawa study, the category "sc" (solid contact) shows that the increase in the batting ability of the trained individuals to be significant to the .05 level of confidence. Solid contact is defined by the experimenter as, "what is judged by the experimenter as a hard line drive or a hard hit ground ball." This is the same experimenter who knew all of the subjects and trained the experimental group for six weeks. This allows a definite possibility of experimenter bias. Also, there was no control group activity that paralleled the visual training sessions to reduce the possible placebo effect. Furthermore, no information was given as to any changes, positive or negative, in the visual abilities of the experimental group. These shortcomings still do not deny the improvement in batting ability in the experimental group and being one of the first of its kind, the study remains important as a base from which to more fully explore vision and athletic performance.

DISCUSSION

A certain amount of caution must be applied when stating to the scientific community that athletes have better visual skills than non-athletes. The reason for this is that the term "athlete" is a broad term. A statement that athletes have better visual abilities must be taken in the terms of the studies which support it. For example, the near point of convergence in the Falkowitz study is almost linearly related to batting average in Little League players between the ages of 10 and 12. This does not imply that the times for completion of the 1000 m. race for the U.S. Olympic team can be predicted on the basis of near point of convergence. Though both groups are "athletes", it is quite
apparent that the skills that are demanded by each athletic task are quite different. The visual testing, diagnosis and training of an athlete should be directed to the visual demands of his/her individual sport.

While the information offered in this paper lends partial documentation and validity to the optometric intervention in sports, there are many other factors that need to be addressed. For example, such topics as task analysis, performance, skills, the integration of skills, stress, visualization, the relationship of vision to balance, motion, movement, audition and touch are all related to sports vision.

An important aspect of this review of the sports vision literature is the delineation of the visual abilities that have been demonstrated by scientific method to be superior in athletes. A sports vision examination then would test skills such as ocular motility, saccades pursuits, convergence, peripheral acuity, extent of peripheral fields, stereo-localization, binocularity, eye-hand-body coordination, ocular dominancy, dynamic stereo-acuity, dynamic visual acuity, visual response time and quality, and integration and coordination of the other sense modalities. The sports vision exam must be defined in terms of the visual demands of the athletic task that the patient wishes to perform.
SUMMARY

The literature supports the concept that athletes have better visual abilities than non-athletes. Studies have shown this to be true in the following areas of vision:

1. Larger extent of visual field
2. Larger extent of field of recognition (peripheral acuity)
3. Larger extent of field of motion perception
4. Lower amounts of heterophoria, near and far
5. More consistent simultaneous vision as measured by the Keystone Telebinocular
6. More accurate depth perception
7. Better dynamic visual acuity
8. Closer near point of convergence
9. Better motilities, both pursuits and saccades

The literature also shows that the better athletes have better visual abilities than the poorer athlete in many visual functions.

The literature supports the concept that all the above visual abilities are trainable. A change in the visual fields can occur rapidly even as the testing procedure is being performed. Simultaneous vision, near point of convergence, and heterophoria both at near and at far have been shown to be alterable by optometric intervention. Depth perception, as detected by stereo-acuity, is trainable. Dynamic visual acuity and the motilities are eye movement qualities that can be improved. In summary, all of the visual abilities that have been demonstrated to be of superior quality in athletes are trainable.
That visual training enhances the athlete's ability to perform has not been conclusively demonstrated. The belief, that it makes no difference whether the visual training or something else (i.e. placebo effect) is responsible for the improvement in performance after visual training, so long as there is improvement, may be acceptable to the coach but to the optometric profession, it is unsatisfactory. To our knowledge, there are no valid, controlled studies that prove a positive relationship between visual training and athletic performance, nor are there any studies that disprove a relationship,
Table 1. The relationship between batting averages and visual skills of Little Leaguer baseball players (data from Falkowitz and Mendel 1977).

<table>
<thead>
<tr>
<th>Batting Average</th>
<th>Visual Skills</th>
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<tr>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
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Bibliography


