Article ▸ # Sports Vision Evaluation Findings in an Elite Athlete Population

Navjit K. Sanghera, OD, Illinois College of Optometry, Chicago, Illinois
Eric A. Baas, OD, Illinois College of Optometry, Chicago, Illinois
Barclay W. Bakkum, DC, PhD, Illinois College of Optometry, Chicago, Illinois
Katie Foreman, OD, Illinois College of Optometry, Chicago, Illinois
Stephen Beckerman, OD, Illinois College of Optometry, Chicago, Illinois

ABSTRACT

Background: Epidemiological studies suggest that the athletic population has a significant need for vision care. Recently, there has been an increased awareness and discussion of sports-related concussion, which can have a negative impact on athletic performance. The goal of this investigation is to characterize baseline performance of a cohort of elite athletes on a battery of sports vision tests. This information can: 1) serve as a baseline for comparison after an athlete is concussed, 2) help evaluate the effects of concussion on the visual system as it relates to athletic performance, and 3) help establish vision-related criteria for determining if and when an athlete is ready to return to play and perform at pre-concussive levels.

Methods: Twenty-one male Major League Soccer athletes ages 18-35 were tested on 20 sports vision-related tests.

Results: Eighteen of 21 subjects (86%) demonstrated one or more clinically significant problems with visual acuity, ocular health, binocular vision, and/or exhibited visual symptoms. The screening results indicate that 17% failed visual acuity, 26% displayed abnormal ocular health findings, 6% exhibited binocular vision problems, and 29% complained of at least one visual symptom related to a previous incident involving head trauma or concussion.

Conclusion: This visual performance testing characterized baseline findings for this population and may help determine how deficits may interfere with optimum athletic performance at the elite level. The baseline testing could also serve as an indicator of recovery in acute vs. chronic stages and help determine if and when a concussed athlete is ready to return to play.

Keywords: binocular vision disorder, concussion, sports vision, traumatic brain injury

Introduction

Several epidemiological studies suggest that the athletic population has a significant need for vision care.[1-3] In order to help address this need, a standard protocol of optometric sports vision testing has been developed that can help assess an athlete's visual profile for his/her particular sport and also determine areas of weakness or strength.[2] Recently, there has been an increased awareness and discussion of sports-related concussion.[2,3] A concussion is defined as an insult to the brain caused by an external physical force that may produce a diminished or altered state of consciousness that results in impairment of cognitive abilities or physical functioning and/or a disturbance of behavioral or emotional functioning.[4] Concussion can result in a multitude of symptoms, including but not limited to headache, dizziness, decreased ability to concentrate, memory problems, irritability, judgment problems, and anxiety.[5] A concussion can result in damage to any part of the visual system, including the visual pathway, visual cortex, and visuomotor system.[6] As a result, patients who present with a history of concussion commonly have a wide array of visual complications, the most common being accommodative, oculomotor, and binocular dysfunctions, as well as photosensitivity and visual field loss.[6-8]

Visual skills are essential in many sports, and visual sensory input may account for over 85%-90% of the sensory input an athlete receives.[9] Therefore, the types of deficits that can occur as the result of concussion may have a negative impact on athletic performance, even though the specific relationship between visual skills and athletic performance has not been well established. In some cases, the performance of some concussed athletes, especially those in elite levels of competition, continues for long periods of time to be below the levels of those athletes before the injury occurred.[3] Therefore, the goal of this investigation was to establish the normal values of the performance of a cohort of elite athletes on a battery of sports vision tests. This information can: 1) serve as a baseline for comparison after an athlete is concussed, 2) be used to evaluate the effects of concussion on the visual system as it relates to athletic performance, and 3) help establish vision-related criteria for determining if and when an athlete is ready to return to play and perform at pre-concussive levels.

Methods

Twenty-one male Major League Soccer players, ages 18-35 (mean: 26.5, standard deviation: +/-8.5), participated in

Table 1. Tests Performed as Part of the Battery

Test Performed
History
Visual Acuity
Pupil Testing
Colvard Pupillometer (Pupil size)
Hess-Lancaster
Distance Cover Test
Near Cover Test
Near Point of Convergence
HRR Pseudoisochromatic Plates
Near Randot Stereopsis
Retinoscopy
Autorefraction
Distance Accommodation Amplitudes
Howard Dolman Depth Perception
Tachistoscope
Vision and Balance eyes open
Vision and Balance eyes closed
Vision and Balance target
WSF Proaction first trial
WSF Proaction second trial
WSF Hand Release first trial
WSF Hand Release second trial
WSF Locate first trial
WSF Locate second trial
FDT Visual Field Defect
Ocular Health Assessment

this study. Each was administered a battery of sports vision tests based upon the standard protocol of optometric sports vision testing (Table 1).[2] Even though most of these are standard optometric procedures, several of the protocols were modified specifically for sports testing. Pupillary testing was performed using two methods, both the standard procedure with the Colvard pupillometer[10] and the modified protocol from the sports vision testing protocol.[2] It has been shown that testing distance and lighting are critical in using the Wayne Saccadic Fixator.[11] In this study, only two of the tests that use the Wayne Saccadic Fixator were performed.[12] For the eye-hand coordination test, the testing distance was 30 inches, and the illumination was 20 foot-candles incident on the instrument in a dimly lit room. For the hand speed test, the test distance was at subjects' optimal positioning, and the illumination was at 40-70 cd/M^2 incident on the instrument in a dim room.

Results obtained from the group of subjects were recorded on a standardized data collection form (Appendix 1; see online link). Descriptive statistics, including means, frequency counts, and percentages, were calculated as needed. All statistics were performed with the IBM SPSS Statistics 21 software package.

Table 2. Percentage of Athletes Failing the Tests

Test Performed	Percentage failed
History	24%
Visual Acuity	17%
Colvard Pupillometer (Pupil size)	0%
Hess-Lancaster	0%
Distance Cover Test	0%
Near Cover Test	38%
Near Point of Convergence	27%
HRR Pseudoisochromatic Plates	0%
Near Randot Stereopsis	0%
Retinoscopy	39%
Distance Accommodation Amplitudes	11%
Howard Dolman Depth Perception	11%
Tachistoscope	16%
Vision and Balance eyes open	0%
Vision and Balance eyes closed	5%
Vision and Balance target	21%
WSF Proaction first trial	15%
WSF Proaction second trial	20%
WSF Hand Release first trial	20%
WSF Hand Release second trial	21%
WSF Locate first trial	15%
WSF Locate second trial	15%
FDT Visual Field Defect	5%
Ocular Health Assessment	6%

When multiple comparisons were made using a paired t-test, a Bonferroni correction was applied. The purpose of the study and the testing protocol was explained to each subject, and informed consent was obtained prior to testing. The testing protocol conformed to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of the Illinois College of Optometry, and all participants engaged in an informed consent process.

Results

All of the subjects tested within normal limits for the following: pupillary responses, pupil size and symmetry, Hess-Lancaster testing, distance cover test, color vision, and Randot stereopsis (Table 2).

Of the 24% of subjects who failed the HELPS history (Table 2), complaints ranged from subjects being hit on the head (4), possible loss of consciousness and experiencing a period of being dazed and confused (4), significant sickness (1), and an evaluation in an emergency room, hospital, or by a doctor because of an injury to the head (3).[13] Amongst vision-specific concerns, one subject complained of difficulty seeing, sensitivity to lights, reduced peripheral vision, and blurred vision after close work. Two subjects also complained of dizziness, lack of consistency in play, difficulty judging speed, being easily distracted from the visual target, reduced

Table 3. Eye Movement Testing Results

Visagraph Test Results	Norms	Average	Standard Deviation
Eye Movement # Fixations	Undefined	3.85 fixations	5.11
Saccade Speed # Excursions	Undefined	39.05 excursions	9.80
Saccade Speed # Fixations	Undefined	52.00 fixations	15.67
Visagraph Reading 1 Average Fixations OD/OS	Undefined	116.05 number of fixations made	39.11
Visagraph Reading 2 Average Regressions OD/OS	Undefined	18.11 number of regressions made in a right-to-left direction	14.46
Visagraph Reading 3 Average Span of Recognition OD/OS	Undefined	0.95 number of words perceived during a fixation	0.49
Visagraph Reading 4 Average Duration of Fixation OD/OS	Undefined	0.355s per fixation	9.48
Fixations/100 words OD	Norm 114, Goal <77	115.88 number of fixations made	34.96
Fixations/100 words OS	Norm 114, Goal <77	116.65 number of fixations made	35.12
Regressions/100 words OD	Norm 23, Goal <11	18.06 number of regressions made in a right-to-left direction	13.93
Regressions/100 words OS	Norm 23, Goal <11	18.18 number of regressions made in a right-to-left direction	13.82
Average Span of Recognition OD	Norm 0.88, Goal >1.30	0.98 words per fixation	0.49
Average Span of Recognition OS	Norm 0.88, Goal >1.30	0.98 words per fixation	0.49
Average Duration of Fixation OD	Norm 0.27, Goal <0.23	0.26s per fixation	0.04
Average Duration of Fixation OS	Norm 0.27, Goal <0.23	0.26s per fixation	0.04
Reading Rate	Norm 195, Goal >312	233.65 words per minute	147.04
Directional Attack Difficulty (%)	Norm 20%, Goal <14%	14%	0.09
Grade Level Efficiency	7th grade level	8th grade level	4.68

performance as stress builds, and headaches. One subject also reported emotional concerns such as anxiety, depression, and difficulty concentrating.

Visual acuity testing revealed that 17% of all eyes tested had acuities worse than 20/20, which is considered to be clinically significant. Visual acuities ranged from 20/25 to 20/40.

Only 18 subjects completed the near cover test. Of these, 38% had abnormal results: 6 had greater than 6 exophoria, and 1 subject had esophoria.

For near point of convergence testing, only 11 out of the 21 subjects were tested. Of the 11 subjects who were tested, 27% had abnormal findings.

Retinoscopy was performed on 19 subjects. Thirty-nine percent of the subjects' eyes (15 eyes) had abnormal findings. Of these, 11 eyes had greater than +/-1.00 diopters (D) of sphere, and 4 had greater than +/-1.00 D of cylinder.

For accommodative amplitude testing, the average score for the right eye (OD) was 4.50 D +/-2.78, and in the left eye (OS), the average score was 4.95 D +/-2.70. Eleven percent of the subjects had clinically significant scores of less than 2 D of accommodative amplitude OS, while none had a score of less than 2 D OD. The differences in the scores between the eyes was statistically insignificant (t=0.33, p=0.75).

For the Howard Dolman depth perception test, the average score was 6.70 +/-4.21 seconds of arc. Eleven percent of the subjects had scores of greater than 11 seconds of arc, which is considered reduced stereopsis.

Of the 18 subjects tested for eye-hand dominance, only one subject was non-established (did not exhibit dominance of right or left). Seven subjects exhibited left dominance, while 10 subjects exhibited right dominance.

For eye movement testing, the average fixations/100 words OD and OS were at a 7th grade level, with a range between 4th and 13th grades. The average regressions/100 words OD and OS were at an 11th grade level, with a range between 2nd and 14th grades. The average span of recognition OD and OS was at a 10th grade performance level, with a range between 1st and 14th grades. The average duration of fixation OD and OS was at a 10th grade performance level, with a range between 2nd and 18th grades. The reading rate (words per minute) was at a 10th grade performance level, with a range between 2nd and 14th grades. The overall grade level efficiency average was at an 8th grade level of performance (Table 3).

The mean Tachistoscope score was 14 numbers correct out of 18, with a standard deviation of 3. Ten of the athletes scored poorly enough to be considered clinically significant.

For vision and balance with the eyes open, all subjects scored the maximum score of 5 and therefore passed. The mean for the vision and balance test with the eyes closed was a score of 3.84 +/-1.01. Five percent of the athletes scored one standard deviation below the mean and therefore failed this test. The mean for the vision and balance test while following a target was 4.16 +/-0.90. Twenty-one percent of the athletes scored one standard deviation below the mean and therefore failed this test.

For the eye-hand coordination test, two separate trials were performed. The average for the first trial was a score of 35.75 +/-4.14 buttons touched. Fifteen percent of subjects were one standard deviation below the mean, therefore failing in the first trial. The average for the second trial was a score of 39.67 +/-3.97. Twenty percent of subjects were one standard deviation below the mean and therefore failed in the second trial. There was a significant difference between OD and OS (t=3.34, p=0.005). This is probably indicative of a practice effect between Trial 1 and Trial 2.

The hand speed release test also had two trials that were performed; the average in the first trial was 215.70+/-84.73 milliseconds. Twenty percent of subjects failed this test in the first trial. In the second trial, the average was 204.11+/-52.64 milliseconds. Twenty-one percent of subjects failed the second trial. The average score in the first trial for the locate test was 573.30+/-173.97 seconds. Fifteen percent of subjects failed in the first trial. In the second trial of the locate test, the average score was 454.20+/-115.00 milliseconds. Fifteen percent of subjects failed in the second trial.

Of the 19 subjects whose visual fields were tested with frequency doubling technology (FDT), one subject failed, testing with a monocular superior defect. Even though it is not considered clinically significant, there was a statistically significant difference between eyes (t=2.9, p=0.009).

The average intraocular pressure (IOP) OD was 16mmHg +/-3.85. The average IOP OS was 17mmHg +/-4.03. Only five subjects had IOPs that were elevated to clinically significant levels. The upper limit for either eye was 20mmHg. There was no statistically significant difference between eyes (t=1.86, p=0.08).

Only one subject failed the ocular health portion of our screening due to the presence of a choroidal nevus in the posterior pole. This patient was advised to maintain yearly examinations for follow-up care and proper monitoring of the condition.

Discussion

Of the subjects who failed visual acuity testing, some of these same subjects had not had an eye examination within one year. As a result, they were not in their best correction at the time of testing. In addition, the use of a paper Snellen chart, which was not projected or backlit, could lead to poor resolution of letters and therefore inaccurate visual acuity assessment.

Colvard Pupillometer testing revealed pupil size symmetry between eyes for each subject tested. This could be due to light levels within the screening room not being lit at the suggested 4 cd/m^2, pupillary unrest, or not waiting at least 30 seconds before measurements were taken. The presence of physiologic anisocoria has been estimated at 20% of the normal population; therefore, some degree of pupil difference is expected.[14] Some studies report good test/retest reliability of the Colvard Pupillometer, while others suggest otherwise.[10,15-17] Due to symmetry in pupil size with all subjects within this study, we consider this to be outside of the normal amount as compared to the population. After further review, a more reliable test measure should be used for pupil size measurement or a more controlled light level for testing, since it is known that anisocoria is a measure of concussion[18] and in some cases a possible predictor for patient recovery and survival.

Near cover test was performed to obtain binocular posture. All subjects who were tested were tested with an isolated near target letter of the same size, regardless of visual acuity outcome for either eye. We do not believe that this information was reliable due to the use of an identical fixation target for all subjects. Two subjects had poorer visual acuity than 20/20 in at least one eye; therefore, they should have been tested with a near target that was two lines above the visual acuity in the worse-seeing eye.

Some of our subjects, as discussed earlier, had not had an eye examination within the past year. This could be a reason why some of our subjects failed. The subjects who had failed distance accommodation testing were not pre-presbyopic but instead were towards the younger age spectrum of this cohort. One of the subjects who failed this test most likely did so due to poor choice of a distance fixation target since he had compromised visual acuity. This patient should have been retested using a proper fixation target, and if this patient had failed again should have been reevaluated after a full eye examination.

Studies have found that accommodative dysfunction is amongst the most common visual problems following a concussion.[8] The average scores and standard deviations on the Howard Dolman Depth Perception tests both reflect poor distance stereoacuity findings.

Visagraph testing was developed on 7th grade level performance to compensate for any language barriers. It is difficult to determine why there was such a deviation in grade levels for our particular test results. Since our subjects ranged in age, the large variation in our results could have quite possibly been from diverse levels of educational backgrounds.

The Tachistoscope revealed that the majority of athletes performed within or above the standard deviation. This speed and span of recognition would be expected in an elite athletic population.

Vision and balance testing revealed what was expected. As the task requirements became more difficult, the percentage of athletes who failed also increased. We would surmise that this decrease in performance would be greater in a non-athletic population.

There was an improvement in the second trial of eye-hand coordination tests, implying that there is a possible learning curve, and therefore a second trial may be helpful in the true assessment of this test. In contrast, there was no real improvement in the second trial of the hand speed release or locate tests as compared to the first trial. This implies that one trial may suffice for both hand speed release and locate tests. This can likely be explained by the consistent target location in the hand speed release and locate tests that is variable in the eye-hand coordination tests.

FDT testing was performed on all subjects. One subject was advised to schedule a full eye examination for further evaluation and repeat visual field testing using a Humphrey Visual Field due to the presence of a superior defect. In a recent study published by Suchoff et al., it was found that 38.75% of subjects who had sustained a traumatic brain injury were found to have some type of visual field defect. Of these defects, most were nonspecific scattered defects.[8] This further supports our use of visual field testing as a possible indicator of traumatic brain injury for future baseline testing.

The subjects who failed tonometry testing were advised to schedule an eye examination for further evaluations and retesting of IOP using Goldman Applanation Tonometry, which is standard of care, since the I-care tonometer is considered merely a screening tool.[19]

This study has several weaknesses. A recent review by Zimmerman et al. states that the most reliable measure of visual acuity is with logMAR charts such as the Bailey-Lovie.[17] Unfortunately, this was not readily available for our vision screening but will be considered for future testing. This same article also mentions that contrast sensitivity is an important aspect of testing spatial visual acuity, which for the purpose of our screening was excluded due to the poor reliability found in most contrast sensitivity tests in a recent study by Kelly et al.[20] Another thought is to test athletes' baseline using dynamic visual acuity instead of static visual acuity.

The reliability of pupillary testing could have been improved by incorporating five minutes of dark adaptation. This has been shown to be necessary for consistent pupillary measurement to control for accommodation and patient alertness.[14] Due to time- and space-related problems, we were unable to dark-adapt our patients.

When testing our patients' near cover test, a good consideration would be to incorporate an isolated Snellen letter 2 lines above best visual acuity for the athlete's poorer-seeing eye instead of using one target for all subjects.

Conclusion

Of the professional athletes in this study cohort, 18 of 21 subjects (86%) demonstrated one or more clinically significant problems with visual acuity, ocular health, or binocular vision and/or exhibited visual symptoms. This visual performance testing characterized baseline findings for this population and may help determine how deficits in these visual skills may interfere with optimal athletic performance at the elite level. The baseline testing could also serve as an indicator of recovery in acute vs. chronic stages. As the diagnosis and management of concussions in sports becomes more scrutinized, this battery of sports vision tests can serve as a baseline for comparison after an athlete is concussed to determine if and when he/she is ready to return to play and perform at pre-concussive levels.

References

1. Beckerman S, Hitzeman SA. Sports vision testing of selected athletic participants in the 1997 and 1998 AAU Junior Olympic Games. Optom 2003;74:502-16.
2. Erickson G. Sports Vision: Vision Care for the Enhancement of Sports Performance. St. Louis: Butterworth-Heinemann, 2007.
3. Beckerman SA, Hitzeman S. The ocular and visual characteristics of an athletic population. Optom 2001;72(8):498-509.
4. Goodrich GL, Kirby J, Cockerham G, Ingalla SP, Lew HL. Visual function in patients of polytrauma rehabilitation centre: A descriptive study. J Rehabil Res Dev 2007;44:929-36.
5. Ryan LM, Warden DL. Post-concussion syndrome. Int Rev Psych 2003;15:310-6.
6. Hellerstein LF, Freed S, Maples WC. Vision profile of patients with mild brain injury. J Am Optom Assoc 1995;66:634-9.
7. Suchoff IB, Kapoor N, Waxman R, Ference W. The occurrence of ocular and visual dysfunctions in an acquired brain-injured patient sample. J Am Optom Assoc 1999;70(5):301-8.
8. Suchoff IB, Kapoor N, Ciuffreda KJ, Rutner D, et al. The frequency of occurrence, types, and characteristics of visual field defects in acquired brain injury: a retrospective analysis. Optom 2008;79:259-65.
9. Knudson D, Kluka D. The impact of vision and vision training on sport performance. JOPERD 1997;68:17-27.
10. Colvard M. Preoperative measurement of scotopic pupil dilation using an office pupillometer. J Cataract Refract Surg 1998;24:1594-7.
11. Appler DV, Quimby CA. The effect of ambient room illumination upon Wayne Saccadic Fixator Performance. J Am Optom Assoc 1984;55:818-21.
12. Wayne Saccadic Fixator. Wayne Engineering. Skokie, Illinois. http://www.wayneengineering.com
13. Picard M, Scarisbrick R, Paluck R. International Center for the Disabled, TBI-NET, U.S. Department of Education, Rehabilitation Services Administration, Grant #H128A00022. 1991.
14. Lowenfeld IE. The Pupil. Anatomy, Physiology, and Clinical Application. Butterworth-Heinemann, 1993.
15. Rosen ES, Gore CL, Taylor D, Chitkara D, et al. Use of a digital infrared pupillometer to assess patient suitability for refractive surgery. J Cataract Refract Surg 2002;28:1433-8.
16. Wachler BS, Krueger RR. Agreement and repeatability of infrared pupillometry and the comparison method. Ophthalmol 1999;106:319-23.
17. Schnitzler EM, Baumeister M, Kohnen T. Scotopic measurement of normal pupils: Colvard versus Video Vision Analyzer pupillometer. J Cataract Refract Surg 2000;26:859-66.
18. Kelly JP, Nichols JS, Filley CM, Lillehei KO, et al. Concussion in sports: Guidelines for the prevention of catastrophic outcome. JAMA 1991;266:2867-9.
19. ICare Tonometer. ICare Tonometer USA. USA. http://icare-usa.com/
20. Kelly SA, Pang Y, Klemencic S. Reliability of the CSV-1000 in adults and children. Optom Vis Sci 2012;89:1172-81.

Correspondence regarding this article should be emailed to Eric A. Baas, OD, at ebaas@ico.edu.

Sanghera NK, Baas EA, Bakkum WB, Foreman K, Beckerman SA. Sports vision evaluation findings in an elite athlete population. Optom Vis Perf 2016;4(3):107-11.

The online version of this article contains digital enhancements.