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ORIGINAL RESEARCH

ESTABLISHING NORMATIVE CHANGE VALUES IN VISUAL ACUITY LOSS DURING THE DYNAMIC VISUAL ACUITY TEST

Chris Marquez, MS, AT[1]
Monica Lininger, PhD, LAT, AT[1]
Scot Raab, PhD, LAT, AT, CCD[1]

ABSTRACT

Background: Baseline visual acuity (VA) loss from static to dynamic head conditions assessed using the Dynamic Visual Acuity Testing (DVAT) have not been established in NCAA football players. DVAT assesses the Vestibulo-Ocular Reflex (VOR) which is measured in Logarithm of the Minimum Angle of Resolution (logMAR). Decreased VA beyond baseline measures may detect VOR impairment and impact treatment protocols and assist in return to play decisions post-concussion.

Hypothesis/Purpose: To establish normative VA mean scores during a static head posture as well as dynamically during the DVAT with a head speed of 150 deg/s in the pitch (vertical) and yaw (horizontal) planes rotating 20 degrees in each direction.

Study Design: Descriptive study, Diagnostic Tests.

Methods: Sixty-seven, NCAA Division I College football players (age = 19.68 $\pm$ 1.53) completed static VA and DVAT assessment in the pitch and yaw planes during baseline concussion testing at the beginning of the 2014 regular football season. Comparison of VA was evaluated by calculating the difference in players' static and dynamic VA values using the DVAT.

Results: Static VA for all participants (n = 67) was -0.232 $\pm$ 0.109 logMAR. Dynamic VA for participants (n = 67) was 0.0845 $\pm$ 0.159 in pitch and -0.007 $\pm$ 0.141 in yaw at 150 deg/sec. Mean losses in VA during pitch and yaw at 150 deg/sec were 0.317 $\pm$ 0.140 and 0.227 $\pm$ 0.133, respectively.

Conclusions: VA diminishes during head movement at 150 degrees/sec. Loss of acuity beyond established normative values from baseline may be indicative of VOR dysfunction, especially secondary to head trauma. The assessment of visual acuity function with head movements of 150 deg/sec can potentially identify concussion and subsequent sequelae. Further research is recommended.

Level of Evidence: 2b

Key words: Concussion, oculomotor measures, Vestibulo-ocular reflex

CORRESPONDING AUTHOR
Scot Raab
Northern Arizona University
Athletic Training Education Program
PO Box 15094
Flagstaff, AZ 86011
928-523-9059 / 928-523-4315 fax
E-mail: scot.raab@nau.edu

[1] Northern Arizona University, Flagstaff, AZ, USA

INTRODUCTION

The methods to assess potential sequelae from concussion should include the higher brain centers that control eye reflexes. Football exposes participants to concussion risk secondary to violent high-speed impacts; it also has the highest incident of concussion compared to other collegiate sports.[1] The occurrences of concussion may be higher than the documented rates due to under reporting by players because of a perceived need or desire to continuing play and the misinterpretation of the variety of symptoms that are associated with concussions.[2] A plethora of symptoms are associated with concussions and fall in the general domains of cognitive, physical, or behavioral symptoms. This research focuses on the symptoms that are associated with the physical domain, specifically to vestibular related impairments. It is estimated that when assessing symptoms associated with the vestibular system and involvement, 78.8% of football players at the high school and college level reported dizziness and 55.8% reported balance problems secondary to concussion.[3] The vestibular system is comprised of sensory organs in the ear, the ocular system, postural muscles of the body and areas of the brain responsible for balance and coordination. The vestibular system has two functions, visually tracking and focusing on objects during head movement, and managing posture. Visual tracking is specific to the vestibular-ocular system while maintenance of balance is specific to the vestibulospinal system. These distinctive functions of the system allow for individual assessment. Assessments used in Athletic Training settings such as the Balance Error Scoring System (BESS) or other stationary balance tests assess the vestibulospinal component, however such assessments fail to assess the vestibular-ocular component of the vestibular system.[4,5]

There are clinical screening techniques to assess the health and function of the vestibular-ocular system. These screenings include the King-Devick and the Vestibular Ocular Motor Screening (VOMS) assessment, that are meant to replicate concussion symptoms by challenging components of the vestibular ocular system.[4,6] The King Devick requires an athlete to read a series of numbers from left to right and top to bottom on a series of three cards without errors. On each subsequent card the numbers are more challenging to visually sequence into lines. A concussed individual will find it more challenging to discern the lines and will make errors in the number sequencing. The King Devick requires rapid saccadic eye movement but zero head movement.[4,6] One component that is tested during the VOMS assessment is the vestibulo-ocular reflex (VOR). The VOR is a mechanism of the vestibular ocular system that allows the eyes to remain stabilized on an object during high-speed head movements.[7] The VOR is malleable through the continued actions of focusing on images of varying distances during head movements.[8] These actions can be trained though activities that require high velocity head movements such as specialized tests that identify the changes and integrity of visual acuity. The two tests that are performed to isolate the integrity of the VOR are the gaze stabilization test (GST) and the dynamic visual acuity test (DVAT). The GST and DVAT both analyze changes in visual acuity during head movement but have very distinct testing protocols. The GST quantifies changes in visual acuity through varying the velocities of head movement while DVAT is done at a constant velocity. Both measures have acceptable sensitivity ranges (0.64-0.83) published in the literature, especially in individuals who have vestibular dysfunctions and a previous history of mild traumatic brain injury (mTBI).[9-17] The GST and DVAT can differentiate between individuals that have vestibular dysfunctions and those with normal function.[18] The utilization of GST and DVAT may also assist in determining quantifiable measurements of VA during sessions of vestibular rehabilitation.[14,15] The ability to numerically identify changes in VA during rehabilitation is important because it could quantify improvements in vestibular function achieved after concussion using vestibular rehabilitation rather than rest.[14,15] The relationship between concussions and vestibular dysfunction supports the need for more research on the function of the vestibular system post-concussion.

While the quantitative numbers from GST and DVAT have been suggested to be reliable in determining visual acuity changes during high-speed head movements, there are no normative values established for the differences in visual acuity compared to baseline static visual acuity during testing in NCAA Division I football players. The purpose of this study was to establish normative VA mean scores during a static head posture as well as during the DVAT with a head speed of 150 deg/s in the pitch (vertical) and yaw (horizontal) planes rotating 20 degrees in each direction.

METHODS

This was a descriptive study using data from sixty-seven Division 1 football players (age = 19.68 $\pm$ 1.53) at two institutions that completed initial baseline concussion assessment prior to the 2014 regular football season. The data were collected during baseline testing by the universities sports medicine staff. The research team retrospectively reviewed the de-identified data to answer the research objective. The data points were from each football player completing the screening in accordance with the guidelines for DVAT assessment. Furthermore, each player also self-reported a prior history of mTBI, head or neck injury, nystagmus, or any other diagnosed vestibular dysfunctions during pre-participation exams.

Measures

The InVision System developed by Neurocom (Neurocom, Clackamas, Oregon, USA) was used to assess both static visual acuity (SVA) and dynamic visual acuity (DVA). Measurements of SVA were collected as comparative values of visual acuity with a stationary head posture and during DVAT with head movement. All measurements of visual acuity, both in static and dynamic conditions were described using the Logarithm of the Minimum Angle of Resolution (logMAR). LogMAR is considered the gold standard during clinical trials and interventions that involve visual acuity.[19] Lower values of logMAR indicate clearer visual acuity compared to higher values, for example, a logMAR of 0 is equal to 20/20 vision while a logMAR of -0.0187 is equal to 20/13 on a Snellen eye chart.[20] Instruments used for the data collection included the InVision program that was installed on a 15 inch laptop combined with a head mounted accelerometer and gyroscope to accurately report head movement speed and amount of motion. (Figure 1)

Figure 1. *NeuroCom inVision System. 2017 Natus Medical Incorporated, Pleasanton, CA*

SVA and DVAT

Measurements of SVA were taken at the beginning of the baseline testing protocol to determine visual acuity of the subject while their head was stationary. The SVA test required the subject to state the orientation of the optotype "E" on the center of the computer screen to the clinician. The optotype would appear on the computer screen for the duration of one second. The optotype would change its orientation (up, down, right, left) and would decrease in size until the subject could no longer correctly state the orientation of the optotype. The program provided a quantifiable measurement of SVA in the form of both a Snellen fraction and logMAR. The study used measurements of SVA in logMAR for all calculations. The measurements of visual acuity while the head was stationary established a value to compare to during the DVAT when the head was moving at 150 deg/sec.

The DVAT measures the difference between an established SVA and the dynamic visual acuity values determined by yaw (horizontal), pitch (vertical), and roll (ear to shoulder) motions of the head.[10,13] During the yaw motions, subjects rotated their heads from left to right as if shaking their head 'no' to approximately 20° in each direction with a target head velocity of at least 150 degrees/second. Subjects were allowed to practice the motions before actual DVA testing began to familiarize themselves with the testing parameters. The InVision program provided visual cues to the subjects on both head velocities and how far they were turning their head. Once actual testing started, there would be visual cues given to the subject until they reached the target head position and speed. It was required that the subject would have to maintain both head speed and the targeted range of motion prior to the optotype briefly being shown on the computer screen. Once an optotype appeared on the screen, the subject was to state its orientation to the clinician. The size of the optotype would decrease in size until the subject could no longer correctly state its orientation. The same procedure was followed while testing head motion in the pitch axis. The pitch motion simulates a 'yes' head nod, and moves the head 20° up and down from neutral. Due to time constraints during baseline testing, assessments about the roll axis were not completed.

Procedures

Players underwent baseline concussion testing during the off-season when their workouts included weight training and skills practice without the use of any kind of pads or helmet. Zero contact was taking place and subjects were expected to have been free from previous head trauma for the preceding six months. All subjects participated in preparticipation exams in coordination with questions about their medical history, physical exams by team physicians, and screening for diseases. Clinicians included questions from the SCAT-3 to establish dominant handedness, self-reported prior history of concussion, current symptoms, and memory recall.

At the time of testing, all subjects were taken into a well-lit room and seated ten feet away from the testing computer screen that was adjusted to their individual eye-level. Subjects requiring corrective lenses were instructed to wear them during the assessment. Subjects then began the SVA test to establish a quantifiable number for their respective static acuity prior to starting the DVAT. Subjects were monitored for any signs of dizziness or nausea during the testing period. If the subjects did become either dizzy or nauseous as a result of testing protocol, they were allowed a small rest break until their symptoms subsided. There were no complications during testing and all the subjects were able to fully complete the protocol.

Statistical Analysis

All statistical data points were placed into an Excel spreadsheet (Office 2007, Microsoft Corp., Redmond, WA) by the clinicians at the respective universities prior to being de-identified and transferred to SPSS (version 19, SPSS Inc., Chicago, IL). The research team then analyzed the SPSS file. Descriptive data was calculated using SPSS to report all collected measures of visual acuity in static and dynamic conditions. All measurements of visual acuity were analyzed in logMAR. Ninety-Five Percent Confidence Intervals where calculated to estimate meaningful ranges of acuity values to be expected in similar populations.

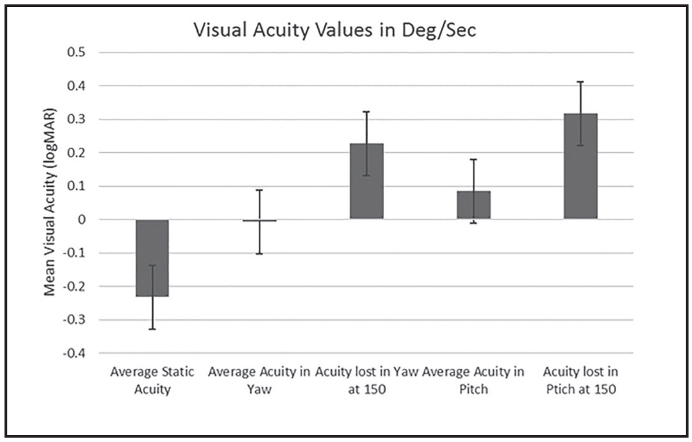

Figure 2. *Visual Acuity Values deg/sec. logMAR =Logarithm of the Minimum Angle of Resolution.*

RESULTS

The participants had an average perception time of 20.09 $\pm$ 3.363 ms. The overall mean SVA for all sixty-seven subjects were -0.232 $\pm$ 0.109 logMAR (Figure 2). The average departure head speed from the target of 150 deg/sec was 183.439 $\pm$ 17.309 deg/sec in pitch and 184.621 $\pm$ 20.609 in yaw. The average DVA in pitch (combined value of moving the head up and down) was 0.0845 $\pm$ 0.159 logMAR. The average DVA in the yaw plane (combined head movements of left and right) was –0.007 $\pm$ 0.141 logMAR. There was an average loss of 0.316 $\pm$ 0.140 logMAR in pitch and 0.227 $\pm$ 0.133 logMAR in yaw. The 95% CI for acuity lost in pitch and yaw was [0.269, 0.358] and [0.191, 0.261] respectively. (Table 1)

Table 1. *Variable Descriptives*

Variable	Mean	SD
Age (years)	19.68	±1.53
Perception Time (ms)	20.09	±3.363
SVA (logMAR)	-0.232	±0.109
DVA in Pitch (logMAR)	0.085	±0.159
DVA in Yaw (logMAR)	-0.007	±0.141

logMAR =Logarithm of the Minimum Angle of Resolution

DISCUSSION

The results from this study support the assertion that a lower value of VA is expected in individuals when they undergo DVAT compared to VA in static conditions. The testing speed was set at 150 deg/sec; however, the average actual speed was higher despite the visual cues provided to the participants by the InVision program. It is plausible that with greater practice, participants could more accurately maintain the goal head speed of 150 deg/sec. The subjects increased speed may overestimate the loss of VA. However, accuracy of the assessment at speeds between 150-200 deg/sec is supported.[11,12] The ability of the DVAT to assess the function of the VOR could potentially aid clinicians in identifying vestibular dysfunction associated with head injuries missed by assessments not tailored to the vestibular-ocular system.[2] It is supported in the literature that horizontal movements in yaw are more reliable in determining vestibular impairments than in pitch when assessing DVA.[12] The values reported in this study found VA in the horizontal plane (yaw) did not drop as much as VA in the vertical plane (pitch). It is speculated that football players are more accustomed to scanning a field from left to right and not up and down. This supports the assertion that further research comparing head movements and post mTBI symptoms across sports and positions is warranted. It is possible that kickers or kick returners will perform better in pitch. The DVAT may also serve as an appropriate baseline tool to compare the integrity of the vestibular system in athletes when they suffer a concussion that can typically be completed as part of preparticipation examinations.[11] It is also noteworthy to remember that future studies could include measurements of DVAT in the roll movement, which is not a typical movement in athletes but may be sensitive to vestibulo-ocular deficits. Comparison of baseline DVA results may also influence clinicians regarding decisions related to return to play status of athletes who have suffered from vestibular dysfunctions secondary to mTBI.

This study has several limitations. This study only assessed healthy football players and excluded the motion of 'roll'. Future studies should include the 'roll' head movement, include other types of athletes, and measure the difference in VA from static and during dynamic head movements in athletes who are post-concussion.

CONCLUSION

The results of this study provide mean data regarding SVA and dynamic DVAT during head movements at 150 degrees/second. All conditions for DVAT demonstrated decreases in losses in VA as compared to SVA. Losses of VA during DVAT beyond an established norm or outside the currently reported confidence intervals may be indicative of VOR dysfunctions, potentially secondary to head trauma. There is a need for more research to be completed in order to establish definitive DVAT values and changes from SVA prior to its employment as a reliable tool to assess the vestibular function and return to play in multiple populations. With further research, the InVision system may become an important tool in assessing the VOR in athletes' pre and post-concussion assisting clinicians in return to play and long-term treatment plans.

REFERENCES

1. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among united states high school and collegiate athletes. *J Athl Train*. 2007;42(4):495-503.
2. Mulligan I, Boland M, Payette J. Prevalence of neurocognitive and balance deficits in collegiate aged football players without clinically diagnosed concussion. *J Orthop Sports Phys Ther*. 2012;42(7):625-632.
3. Lovell MR, Iverson GL, Collins MW, et al. Measurement of symptoms following sports-related concussion: Reliability and normative data for the post-concussion scale. *Appl Neuropsychol*. 2006;13(3):166-174.
4. Mucha A, Collins MW, Elbin RJ, et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: Preliminary findings. *Am J Sports Med*. 2014;42(10):2479-2486.
5. Guskiewicz KM. Postural stability assessment following concussion: One piece of the puzzle. *Clin J Sport Med*. 2001;11:182-189.
6. Ventura R, Balcer L, Galetta S. The concussion toolbox: The role of vision in the assessment of concussion. *Semin Neurol*. 2015;35(5):599-606.
7. Khan S, Chang R. Anatomy of the vestibular system: A review. *NeuroRehabilitation*. 2013;32(3):437-443.
8. Bloomberg JJ, Merkle LA, Barry SR, et al. Effects of adaptation of vestibulo-ocular reflex function on manual target localization. *J Vestib Res*. 2000;10(2):75-86.
9. Mohammad MT, Whitney SL, Marchetti GF, Sparto PJ, Ward BK, Furman JM. The reliability and

response stability of dynamic testing of the vestibulo-ocular reflex in patients with vestibular disease. *J Vestib Res*. 2011;21(5):277-288.

10. Goebel JA, Tungsiripat N, Sinks B, Carmody J. Gaze stabilization test: A new clinical test of unilateral vestibular dysfunction. *Otol Neurotol*. 2007;28(1):68-73.
11. Kaufman DR, Puckett MJ, Smith MJ, Wilson KS, Cheema R, Landers MR. Test-retest reliability and responsiveness of gaze stability and dynamic visual acuity in high school and college football players. *Phys Ther Sport*. 2014;15(3):181-188.
12. Roberts RA, Gans RE. Comparison of horizontal and vertical dynamic visual acuity in patients with vestibular dysfunction and nonvestibular dizziness. *J Am Acad Audiol*. 2007;18(3):236-244.
13. Whitney SL, Marchetti GF, Pritcher M, Furman JM. Gaze stabilization and gait performance in vestibular dysfunction. *Gait Posture*. 2009;29(2):194-198.
14. Alsalaheen BA, Mucha A, Morris LO, et al. Vestibular rehabilitation for dizziness and balance disorders after concussion. *J Neurol Phys Ther*. 2010;34(2):87-93.
15. Gottshall K, Drake A, Gray N, McDonald E, Hoffer ME. Objective vestibular tests as outcome measures in head injury patients. *Laryngoscope*. 2003;113(10):1746-1750.
16. Schubert MC, Migliaccio AA, Clendaniel RA, Allak A, Carey JP. Mechanism of dynamic visual acuity recovery with vestibular rehabilitation. *Arch Phys Med Rehabil*. 2008;89(3):500-507.
17. Herdman SJ, Hall CD, Schubert MC, Das VE, Tusa RJ. Recovery of dynamic visual acuity in bilateral vestibular hypofunction. *Arch Otolaryngol Head Neck Surg*. 2007;133(4):383-389.
18. Herdman SJ, Tusa RJ, Blatt P, Suzuki A, Venuto PJ, Roberts D. Computerized dynamic visual acuity test in the assessment of vestibular deficits. *Am J Otol*. 1998;19(6):790-796.
19. Hazel CA, Elliott DB. The dependency of logMAR visual acuity measurements on chart design and scoring rule. *Optom Vis Sci*. 2002;79(12):788-792.