ABSTRACT

Background: Disruption of the visual and vestibular systems is commonly observed following concussion. Researchers have explored the utility of screening tools to identify deficits in these systems in concussed patients, but it is unclear if these tests are measuring similar or distinct phenomena.

Purpose: To determine the relationships between common vestibular tests including the King-Devick (K-D) test, Sensory Organization Test (SOT), Head Shake-Sensory Organization Test (HS-SOT), and Dynamic Visual Acuity (DVA) test, when administered contiguously, to healthy recreational athletes aged 14 to 24 years.

Study Design: This study used a prospective design to evaluate relationships between the K-D, SOT, HS-SOT, and DVA tests in 60 healthy individuals.

Methods: Sixty participants (30 males, 30 females; mean age, 19.9 ± 3.74 years) completed the four tests in a single testing session.

Results: Results did not support a relationship between any pair of the K-D, SOT, HS-SOT, and DVA tests. Pearson correlations between tests were poor, ranging from 0.14 to 0.20. As expected the relationship between condition 2 of the SOT and HS-SOT fixed was strong (ICC = 0.81) as well as condition 5 of the SOT with HS-SOT sway (ICC = 0.78). The test-retest reliability of all 4 tests was evaluated to ensure the relationships of the 4 tests were consistent between test trials and reliability was excellent with intraclass correlations ranging from 0.79 to 0.97.

Conclusions: The lack of relationships in these tests is clinically important because it suggests that the tests evaluate different aspects of visual and vestibular function. Further, these results suggest that a comprehensive assessment of visual and vestibular deficits following concussion may require a multifaceted approach.

Level of Evidence: 2b: Individual Cohort Study.

Key words: Dynamic visual acuity, saccades, vestibulo-ocular reflex

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INTRODUCTION
The functional damage to the brain parenchyma from concussion commonly manifest as deficits in several domains including cognitive, postural stability, autonomic dysfunction, and behavioral. Evaluation of patients with a suspected concussion should address all these domains. The most frequently documented complaint following concussion is headache; but dizziness, postural instability, and balance dysfunction are also common. Although researchers have assessed the efficacy of screening tools to detect postural instability such as the Sensory Organization Test, the contributions of the visual and vestibular systems to postural instability in the concussed athlete have not been thoroughly investigated and are frequently studied independently of other clinical measures.

Visual system disruption is frequently observed following concussion, and 65% to 90% of patients show oculomotor dysfunction, which may impair postural stability. Visual and vestibular system disorders have both been implicated as causes of postural instability. An easily administered screening tool, the King Devick (K-D) test, assesses both the visual and vestibular systems. This test also incorporates the cognitive domain because it identifies impairment of eye movements, attention, language, and other symptoms that are associated with suboptimal brain function. Researchers have suggested that the K-D test may be useful in the acute assessment of concussion.

Coordination of the three peripheral sensory systems (visual, vestibular, and somatosensory) is required to function normally and maintain postural stability. Concussion disrupts the integration of postural responses from these systems and results in postural instability. Several studies evaluated the usefulness of postural stability tests in concussed athletes. The Sensory Organization Test (SOT) is commonly used to assess postural stability. The Head Shake-Sensory Organization Test (HS-SOT) modifies two of the standard SOT conditions by including dynamic head motions that stimulate the semicircular canals within the vestibular system. The Dynamic Visual Acuity (DVA) test is used to assess different aspects of vestibular function including the vestibulo-ocular reflex. Although there are multiple means of assessing vestibular and oculomotor function, it is unclear whether these tests are assessing the same or different components of vestibular and oculomotor function. In a recent report, results from the DVA differed from those of other oculomotor tests, such as gaze stability tests, suggesting that these tests assess different constructs.

Each of these tests (K-D, SOT, HS-SOT, and DVA) evaluates components of vestibular and oculomotor function but the degree to which they measure common deficits (or attributes) is not known. The purpose of the current study was to assess the relationships between common vestibular tests, including the K-D, SOT, HS-SOT, and DVA tests, when administered contiguously, to healthy recreational athletes aged 14 to 24 years. Additionally, a secondary purpose was to conduct a test-retest reliability evaluation of the four tests.

METHODS
Statistical Methods
This study used a prospective design to evaluate relationships between the K-D, SOT, HS-SOT, and DVA tests in 60 healthy individuals. The reliability of all four tests was evaluated to ensure the relationships of the four tests were consistent across individual test trials.

Participants
Participants were recruited through flyers distributed to public and private school systems in a metropolitan community between May and September 2014. Participants were required to be 14 to 24 years old and possess sufficient English language skills to complete questionnaires. Exclusion criteria were lower extremity musculoskeletal injuries in the prior three months; history of a head injury in the past year; or diagnosis of a visual, vestibular, or balance disorder.

Telephone screening was used to ascertain eligibility. Participants meeting study criteria were provided information about the purpose of the research and the potential risks. Participants provided written informed consent or the parent/guardian provided written permission and the child assented. Experimental procedures were approved by the institutional review boards associated with the study. Participants completed a personal/medical history form prior to testing to ensure there were no reasons for exclusion (Appendix 1).
INSTRUMENTATION

King-Devick test
The K-D test is a screening tool that identifies impairments of eye movements, attention, and language through measurement of the speed of rapid number naming. Participants read aloud a series of single-digit numbers from left to right on one practice card and three test cards. Standardized instructions were followed. The sum of the time to complete the three test cards constitutes the summary score, known as the K-D composite score. The number of errors is recorded as the K-D error score.

Sensory Organization Test
The SOT was performed using the NeuroCom Equitest BalanceMaster. The SOT uses a computerized system with a servo-controlled dual force plate and visual surround to determine whether an individual can effectively use inputs from visual, somatosensory, and vestibular systems to maintain balance while suppressing inaccurate sensory information. The SOT evaluates sensory interactions during six conditions that alter visual, somatosensory, or vestibular systems with the participant attempting to maintain steady state standing balance while wearing a harness within the NeuroCom Equitest BalanceMaster. The conditions are the following: (1) eyes open standing on a firm surface; (2) eyes closed while standing on a firm surface; (3) sway-referenced vision standing on a firm surface; (4) eyes open standing on a sway-referenced surface; (5) eyes closed standing on a sway-referenced surface; and (6) eyes open, sway-referenced vision standing on a sway-referenced surface. Three trials are performed for each condition to generate a composite equilibrium score. The SOT has good-to-moderate test-retest reliability and has assessed sensory contributions to balance control in children, young adults, older adults, and individuals with neurological disorders. It has also been used to evaluate the effectiveness of interventions targeted at improving balance.

Head Shake Sensory-Organization Test
The HS-SOT was performed using the NeuroCom Equitest BalanceMaster. The HS-SOT is an enhancement of the SOT and was developed to improve the delineation of balance performance. Unlike the SOT where the head is static, the HS-SOT requires active head movements in the horizontal plane, as if saying no repeatedly, to correspond with visual and auditory feedback while maintaining a fixed head velocity at approximately 100° per second as measured by an accelerometer. In addition to assessing the possible influence of head movements on postural stability, the HS-SOT also stimulates the semicircular canals. This stimulation creates additional vestibular input that must be integrated during the balance task. Therefore, the HS-SOT may quantify subtle balance deficits and enhance the clinical standard use of the SOT. The HS-SOT has been shown to have excellent test-retest reliability in healthy, younger adults and moderate-to-good test-retest reliability in healthy, older adults. At least five trials of the HS-SOT are required to calculate composite fixed (condition 2) and sway (condition 5) scores.

Dynamic Visual Acuity test
The DV A test was performed using the NeuroCom Equitest BalanceMaster. The DV A test assesses the ability to use the peripheral vestibular system for appropriate visual target capture during head movements and quantifies decrements in visual acuity during dynamic head tasks. In the computerized DV A test, individuals report the orientation of an optotype E (which way the open legs of the E point) displayed on the computer while their head is in motion at a fixed velocity of approximately 100° per second. The DV A test varies the size of the E to identify the smallest E that can be accurately recognized at least 60% of the time when the head is in motion. The DV A software uses logMAR units (log of the minimum angle of resolution) to quantify the ability to accurately identify the orientation of the E. The computerized DV A test has been reported to detect peripheral vestibular dysfunction in adults and children and has been verified as a sensitive and specific assessment for detecting peripheral vestibular impairments.

UCLA Dizziness Questionnaire 2
The University of California, Los Angeles Dizziness Questionnaire 2 (UCLA-DQ2) is a subjective measure of a participant’s dizziness. The UCLA-DQ2 uses a six-point Likert visual analogue scale that
quantifies any symptoms associated with dizziness, from 0 (no symptoms) to 5 (severe symptoms). The Questionnaire is presented in Appendix 2.43,45

Procedures
All testing was conducted at a university research laboratory and collected repeated measurements in a single visit. Participants were permitted to use glasses or contact lenses and encouraged to report any visual disorders that would affect their ability to participate. They completed a personal/medical history form and the UCLA DQ-2. Instructions were provided before each test was performed, and participants were asked to demonstrate their understanding of the test before proceeding. Participants were offered water and rest breaks between tests to ensure hydration and adequate rest. Participants were asked to rate their dizziness or any symptoms associated with dizziness using the UCLA DQ-2 between each test and during testing because of the repeated cervical motions required by the HS-SOT and DVA tests.

To analyze for order effect of the four tests, two predetermined testing orders were used and participants flipped a coin to determine the order (Figure 1). The SOT and HS-SOT were considered a single test because the SOT is required to initiate the HS-SOT. The K-D test was completed in a seated position at a self-selected distance for reading, following procedures used in recent studies,8,7,16,18 for each of 3 trials (trial = 1 complete test). The time required to complete each trial was measured by a stopwatch to the nearest tenth of a second, and the number of errors was recorded.

The SOT was performed following a standardized procedure in the literature.46 Next, participants were returned to the BalanceMaster for the HS-SOT. Per manufacturer recommendations, participants were placed in an appropriately sized harness that did not restrict sway, and their malleoli were aligned with the axis of rotation based on their height. Participants were told to stand as steadily as possible during the six conditions. Three trials of the SOT were performed for each condition to calculate a composite score, ranging from 0 to 100. The score was more heavily weighted for the more difficult balance conditions (5 and 6), and a score of 0 was given to participants who required the harness to prevent a fall.

After completing the SOT, participants were disen-gaged from the BalanceMaster and offered a seated rest break. Next, participants were returned to the BalanceMaster for the HS-SOT. Participants were assisted in donning the head accelerometer and instructed to move their head in the horizontal axis at a velocity of approximately 100° per second.

![Figure 1. Randomly Selected Testing Order (A or B) Used in the Study. Abbreviations: DVA = Dynamic Visual Acuity test; HS-SOT = Head Shake-Sensory Organization Test; KD = King-Devick test; SOT = Sensory Organization Test.](image-url)
that corresponded with an auditory tone and visual feedback on the computer monitor. Participants practiced maintaining the horizontal motion at the appropriate velocity using the visual feedback until they were able to maintain the motion with their eyes closed and using the auditory feedback. Five trials of the HS-SOT were performed to calculate the composite fixed and sway scores. After completing the HS-SOT, participants were offered a seated rest break before continuing with the K-D test.

For the DVA test, participants stood eight feet from the Neurocom BalanceMaster computer screen following standard procedures recommended by the manufacturer, and the screen was adjusted so that the center of the screen was at the participant’s eye level. Participants who wore glasses or contacts were asked to wear them. Participants were provided two practice trials of at least two minutes for the horizontal motion and the visual acuity component of the DVA. Head motion velocity and appropriate horizontal motion were indicated with visual feedback from the computer. When the participant verbalized the direction of the optotype E to the investigator, the investigator clicked a handheld mouse-like device to indicate the direction (i.e., up, down, left, or right). Time to complete the DVA test was done for three conditions: static, left, and right. The DVA acuity score represents a difference between the static DVA score and the score achieved during the dynamic components (left and right) of this test.

**Statistical Analyses**

A sample size calculation was performed to estimate modest relationships between the K-D, SOT, HS-SOT, and DVA tests using PASS version 12 software (NCSS Statistical Software, Kaysville, UT). A sample of 56 participants was used to detect an intraclass correlation coefficient (ICC) as low as 0.35 with an α of 0.05. Sixty participants were recruited to allow for possible dropouts.

Test-retest reliabilities of the SOT composite, HS-SOT fixed composite, HS-SOT sway composite, and DVA scores were calculated by comparison of each trial within each test. The reliability of the K-D test was estimated using the K-D composite score averaged across the 3 trials. The ICCs were calculated using a 2-way, random-effects model. Reliability was defined in terms of consistency, and the average agreement was reported. An ICC less than 0.40 indicated poor reliability, 0.40 to 0.74 indicated moderate-to-good reliability, and greater than 0.75 indicated excellent reliability.45

The strength of relationships between the tests was estimated using Pearson correlation coefficients because distributions were approximately normal. The relationship between the SOT conditions 2 and 5 and the HS-SOT fixed and sway composites was also tested. Pearson correlations less than 0.50 were considered poor, between 0.50 and 0.75 were considered moderate, and greater than 0.75 were considered good. A p-value of less than .05 (2-tailed) was considered statistically significant. SPSS version 23.0 (IBM Corp., Armonk, NY) was used to analyze the data.

**RESULTS**

Sixty healthy individuals (30 males, 30 females; mean [SD] age, 19.9 [3.74] years) participated in the current study (Table 1). There were no dropouts or excluded data.

Testing order showed no effect, so was not used in the analyses. Twelve participants reported symptoms of dizziness associated with the HS-SOT. No reports exceeded a 2 of 5 (mild) rating. There were 10 reports of dizziness during the SOT and HS-SOT tests, and nine reports of dizziness during the DVA

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### Table 1. Demographic Characteristics of the Participants (N = 60)

<table>
<thead>
<tr>
<th>Demographic Characteristic</th>
<th>No. (%) or Mean (SD)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>30 (50)</td>
</tr>
<tr>
<td>Female</td>
<td>30 (50)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>19.9 (3.74)</td>
</tr>
<tr>
<td>Glasses/contacts</td>
<td>23 (38.3)</td>
</tr>
<tr>
<td>Previous head injury</td>
<td>10 (16.6)</td>
</tr>
<tr>
<td>Sports history</td>
<td>57 (95.0)</td>
</tr>
<tr>
<td>Caffeine intake</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>21 (35.0)</td>
</tr>
<tr>
<td>1/day</td>
<td>25 (41.7)</td>
</tr>
<tr>
<td>Less than 3/day</td>
<td>9 (15.0)</td>
</tr>
<tr>
<td>More than 3/day</td>
<td>5 (8.3)</td>
</tr>
</tbody>
</table>

¹ Age is reported as mean (SD).
test. Dizziness symptoms subsided within two minutes of test completion.

Test-retest reliability for all tests was excellent (Table 2). Table 3 provides Pearson correlation coefficients and p-values for each pair of tests. The HS-SOT sway was significantly correlated with the SOT composite ($r = -0.344$). The only other correlations that exceeded $r = 0.25$ were those calculated between subtests of the DVA, which should be strongly correlated with one another because they are measuring similar attributes. The association between condition 2 of the SOT and the HS-SOT fixed was strong ($r = 0.81$) and the association between condition 5 and the HS-SOT sway was also strong ($r = 0.78$).

**DISCUSSION**

Although excellent reliability was found for the K-D, HS-SOT fixed, HS-SOT sway, and DVA tests, only weak correlations were found between these measures in healthy recreational athletes aged 14 to 24 years. While each of the tests assessed in the current study have been studied independently as concussion assessment tools, results of the current study suggest multiple concussion assessment tools may need to be used together to identify all areas of suboptimal brain function after a concussion. Even though concussion assessment should address symptoms, cognition, and postural stability, many researchers and clinicians categorize postural stability tests together. Results of the current study indicate that these vestibular tests are measuring different phenomena.

The results of the current study are clinically important because knowing that there are no relationships between the K-D, SOT, HS-SOT, and DVA tests may encourage healthcare professionals to appreciate the complexity of impairments to visual/vestibular function. Each of these tests seems to be measuring a specific, and seemingly independent, aspect of the visual or vestibular system. Specifically, the postural stability tests (SOT, HS-SOT, and DVA) measure the integration of distinct aspects of vision with the vestibular system, and the K-D test assesses saccadic accuracy and attention and identifies oculomotor deficits. The finding that tests seem to be measuring different attributes reinforces the notion that the K-D test should be incorporated with other visual and vestibular assessment tests as part of a multifaceted approach to identify the anatomical structures that are injured in a concussed patient and manifest as disruptions to the symptom, cognition, and postural stability domains.

![Table 2](https://example.com/table2.png)

**Table 2. Test-Retest Reliability of the King-Devick (K-D) Test, the Sensory Organization Test (SOT), Head Shake-Sensory Organization Test (HS-SOT), and the Dynamic Visual Acuity (DVA) Test in Healthy Individuals Aged 14 to 24 Years (N = 60)**

<table>
<thead>
<tr>
<th>Test</th>
<th>ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-D composite score for 3 trials</td>
<td>0.97 (0.96 to 0.98)</td>
</tr>
<tr>
<td>SOT composite</td>
<td>0.83 (0.75 to 0.88)</td>
</tr>
<tr>
<td>HS-SOT fixed</td>
<td>0.81 (0.73 to 0.88)</td>
</tr>
<tr>
<td>HS-SOT sway</td>
<td>0.79 (0.69 to 0.87)</td>
</tr>
<tr>
<td>DVA static</td>
<td>0.83 (0.74 to 0.89)</td>
</tr>
</tbody>
</table>

All tests had a $p<.001$.

**Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient.**

![Table 3](https://example.com/table3.png)

**Table 3. Pearson Correlation Coefficients (P values) Between the King-Devick Test (K-D), the Sensory Organization Test (SOT), the Head Shake-Sensory Organization Test (HS-SOT), and the Dynamic Visual Acuity (DVA) Test in Healthy Individuals Aged 14 to 24 Years (N = 60)**

<table>
<thead>
<tr>
<th>Test</th>
<th>HS-SOT Fixed</th>
<th>HS-SOT Sway</th>
<th>DVA Static</th>
<th>DVA Right</th>
<th>DVA Left</th>
<th>SOT Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-D</td>
<td>0.079 (0.550)</td>
<td>-0.169 (0.198)</td>
<td>0.117 (0.374)</td>
<td>0.114 (0.385)</td>
<td>0.243 (0.062)</td>
<td>0.35 (0.791)</td>
</tr>
<tr>
<td>HS-SOT fixed</td>
<td>1</td>
<td>0.084 (0.523)</td>
<td>0.173 (0.187)</td>
<td>-0.179 (0.170)</td>
<td>-0.116 (0.379)</td>
<td>-0.032 (0.807)</td>
</tr>
<tr>
<td>HS-SOT sway</td>
<td>1</td>
<td>0.194 (0.138)</td>
<td>0.126 (0.339)</td>
<td>0.017 (0.895)</td>
<td>-0.344 (0.007)</td>
<td></td>
</tr>
<tr>
<td>DVA static</td>
<td>1</td>
<td>0.645 (&lt;0.001)</td>
<td>0.521 (&lt;0.001)</td>
<td>-0.016 (0.901)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DVA right</td>
<td>1</td>
<td>0.726 (&lt;0.001)</td>
<td>-0.215 (0.099)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DVA left</td>
<td>1</td>
<td>-0.216 (0.097)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Data are presented as Pearson correlation coefficients with associated p-values (2-tailed).
Concussion assessment should be performed using a multifaceted approach with measures that have sound psychometric properties. While the SOT is a recommended post-concussion assessment tool for concussed athletes, it is not typically used in the clinic for baseline testing, most likely due to cost of the equipment. It is primarily used to detect postural instability post-concussion to determine which of the three sensory systems (visual, vestibular, and somatosensory) is impaired.

The HS-SOT has identified healthy young and older individuals with balance deficits. Pang et al found that the HS-SOT sway was a better indicator of postural instability than the HS-SOT fixed. The authors also noted a significant difference between HS-SOT fixed and sway compared with conditions 2 and 5 of the SOT. In the current study, the association between condition 2 of the SOT and the HS-SOT fixed was strong ($r = 0.81$).

Regarding reliabilities for the HS-SOT condition 2 and 5, results of the current study were slightly lower than those presented in the Pang et al study for younger healthy adults (ICC = 0.85) but higher than those presented for older adults (ICC = 0.64). A similar association for younger adults for the HS-SOT sway (ICC = 0.81) was found in the current study, but results were higher for younger healthy adults (ICC = 0.78) and older healthy adults (ICC = 0.55). These differences may be the result of fatigue. Participants in the current study performed all six conditions of the SOT (18 trials) prior to the HS-SOT as opposed to performing conditions 2 and 5 of the SOT (6 trials) prior to performing the HS-SOT. In the current study, performance of all trials of the SOT and HS-SOT was completed because that is how the tests are performed in the clinical setting.

The HS-SOT and DVA tests both use high-velocity, active head movements to assess the function of the semicircular canals and the vestibulo-ocular reflex. These high-velocity movements may dissuade clinicians from using these tests on a concussed athlete since they may make the athlete's symptoms worse because of the required active head motions.

The DVA test uses the same active head motions as the HS-SOT but identifies peripheral vestibular deficits by increasing retinal image slip during horizontal plane head motion. Retinal image slip occurs when the gain of the vestibulo-ocular reflex is decreased. Gain is analogous to controlling the volume of a radio; as the gain (volume) decreases, the vestibular-ocular reflex decreases. Therefore, the image on the retina is unstable and may manifest as blurred vision or oscillopsia. In a healthy individual without a vestibular deficit, the active head motion matches the eye motion during vestibulo-ocular reflex testing. When a vestibular lesion is present, such as in a concussion, the eye motion does not match the head motion. If retinal image slip velocity exceeds 2° to 4° per second, the visual acuity is reduced and can be measured by errors in DVA testing. In the current study, assessment was conducted on healthy young adults without known visual or vestibular deficits, such as retinal slip or complaints of blurred vision. Thirty-eight percent of participants wore corrective lenses for the DVA test. Although the K-D and DVA tests are not considered neurocognitive tests, both have components of cognitive measurement. Vital et al suggested that the DVA test should be performed passively because active horizontal plane motion relies on smooth pursuit and saccades, which may contribute to improved gaze stabilization, whereas passive horizontal plane motion is more sensitive. Future studies should investigate the use of the DVA test in a large sample of healthy young adults to determine if passive horizontal plane motion is more reliable than active horizontal plane motion. Such information would be useful before testing a concussed athlete since the active horizontal plane head motion of the DVA may increase the concussed athlete's dizziness.

The current study had several limitations. The participants were non-concussed healthy participants without vision or vestibular deficits, and participants were not required to be athletes. Therefore, it is unknown if the findings translate to concussed athletes. Further, the software used in the current study limited the number of trials that could be performed for the six conditions of the SOT. Future studies should consider extending the number of trials beyond the standard three trials for the K-D test and the SOT to determine if a performance plateau has been reached. Finally, the SOT has established normative values in healthy individuals for a variety
of age ranges, but no age-appropriate, normative values have been established for the K-D test, the HS-SOT, or the DVA test. Determining normative values for these tests would allow clinicians to identify unusual scores at baseline and post-concussion.

CONCLUSIONS
In the current study, the K-D test, the SOT, the HS-SOT, and the DVA test were investigated to determine if there were relationships between these tests in a sample of healthy recreational athletes aged 14 to 24 years. There were no significant relationships between the tests, which suggests that the tests are measuring different aspects of the visual and vestibular system. Based on the current study, each test measures a distinct anatomical structure’s ability to perform a specific function. It is not yet clear which tests or combination of tests are optimal to detect impairments following a concussion.

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**Appendix 1.** Personal History Form Used in the Current Study

Please provide us with the important background information on the following form. If you do not understand a question, leave it blank and we will assist you. Thank you!

**NAME:** ________________________________________________________________

Sports you have participated in: _____________________________________________

Occupation: ______________________________________________________________

Reading level: _____________________________________________________________

Have you EVER been diagnosed as having any of the following conditions? Circle the appropriate answer.

YES  NO Head injury  If yes, how many prior head injuries?________

When was your last head injury? ____________________________________________

YES  NO Learning disorder

YES  NO Attention Deficit Disorder

YES  NO Dyslexia

YES  NO Heart Problems

YES  NO High blood pressure

YES  NO Circulation problems

YES  NO Asthma

YES  NO Bronchitis

YES  NO Thyroid problems

YES  NO Diabetes

YES  NO Depression

YES  NO Epilepsy or seizures

YES  NO Upper extremity musculoskeletal condition

YES  NO Lower extremity musculoskeletal condition

YES  NO Vertigo

YES  NO Visual problems

Please describe if YES ______________________________________________________
Please list any surgeries or other conditions for which you have been hospitalized, including the approximate date and reason for the surgery or hospitalization:

<table>
<thead>
<tr>
<th>DATE</th>
<th>Reason for Surgery/hospitalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
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<tr>
<td>3.</td>
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<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
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<tr>
<td>6.</td>
<td></td>
</tr>
</tbody>
</table>

Please describe any significant injuries for which you have been medically treated (including fractures, dislocations, sprains) and the approximate date of injury:

<table>
<thead>
<tr>
<th>DATE</th>
<th>INJURY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Please list any PRESCRIPTION medication you are currently taking
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

How much caffeinated coffee or caffeine containing beverages do you drink per day?___________
Do you smoke?_________. How many packs of cigarettes do you smoke a day?___________________

### Appendix 2. Symptom Inventory Scale Adapted from the UCLA DQ.2: Intensity of Dizziness Symptom Scale

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>No symptoms</td>
<td>Very mild</td>
<td>Mild</td>
<td>Moderate</td>
<td>Moderately severe</td>
<td>Severe</td>
</tr>
</tbody>
</table>

To assess symptoms of dizziness, each participant was asked after each test to rate their symptoms of dizziness from 0 to 5.