EFFECT OF HISTORY OF CONCUSSION ON KING-DEVICK TEST PERFORMANCE

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The King-Devick Test (KDT) is a concussion assessment tool that requires individuals to read single-digit numbers from left to right as fast and as accurately as possible. Although sufficient research has been conducted on the KDT as a whole, little research has analyzed the effect of concussion history on KDT performance. The purpose of this study is to determine if history of concussion will predict worse performance on the KDT. Ten participants were recruited to this study with inclusion criteria being 1) between the ages of 18 and 26 and 2) enrolled as a student at Indiana University. Exclusion criteria included 1) visual, ocular, or brain injury within the past 12 months, 2) history of an eye movement disorder, 3) noncorrected visual impairment, and 4) diagnosis of attention deficit/hyperactivity disorder, dyslexia, dyscalculia, or a language processing disorder. Based on self-reported concussion history, participants were sorted into one of two groups: no concussion history (NoHx) or a history of concussion (ConHx). The participants completed the KDT twice, completion time and number of errors were recorded, and the two times were averaged to attain the participant's overall time score. An independent t-test was used to examine the effect of concussion history on KDT performance. For all tests, significance was set to $\alpha = 0.05$. The average time for the NoHx group to complete the KDT was 42.71 seconds ± 3.62 and the average time for the ConHx group was 44.15 seconds ± 6.71. There was no significant difference between the groups when comparing performance (p value =0.687). Although not significant, the study showed promising results regarding those with concussion history producing slower KDT times than those without concussion history. Further research is needed with a larger sample size to better determine the effect of concussion history on KDT performance.

THESIS MANUSCRIPT

INTRODUCTION

Concussions are a mild form of traumatic brain injury that occur from biomechanical forces, which typically lead to a rapid onset of neurological symptoms.[1-4] There are an estimated 1.6-3.8 million concussions that occur each year within the United States accounting for 6% of high school athletic injuries and 9% of collegiate athletic injuries.[5] The Center for Disease Control and Prevention interviewed 800 high school athletes and found that 69% of these athletes have played with a possible concussion without reporting their symptoms to coaches and sports medicine staffs.[6] This alarming observation is partly because the majority of the diagnostic tests available are based on subjective reporting and only test a few signs and symptoms. Common sideline diagnostic tools include Sports Concussion Assessment Tool version 5 (SCAT5), Balance Error Scoring System (BESS) and the King-Devick test (KDT).[2]

The KDT is a portable, vision-based, rapid number naming task that captures afferent and efferent visual signals that derive from saccadic eye movements and their interleaved fixations, along with aspects of cognition.[4] The KDT requires the individuals to read single-digit numbers from left to right as fast and as accurately as possible on either test cards or a tablet.[7] The KDT challenges individuals with rapid saccadic movements while simultaneously processing, verbalizing, and initiating eye movement to the next number. These visual and oculomotor pathways, which travel from the eyes to the visual cortex are often vulnerable to impairment after sustaining a concussion. This makes oculomotor testing, one of the few objective concussion tests. It has been found that there is a five times greater likelihood of worsening KDT times from baseline to time of injury if the individual has a concussion.[7] Although there has been ample research conducted on the KDT, it remains uncertain whether the KDT can differentiate between individuals with a history of concussion from ones without.

Diagnostic accuracy is often driven by the effectiveness of a test. In other words, if the test is easy and less stimulating, individuals with a history of concussion can perform to the level similar to their control counterparts who have no history. We hypothesize that a history of concussion will be associated with worse KDT performance. The purpose of this study is to determine if a history of concussion will predict worse performance on the KDT and therefore show that the KDT can differentiate between those with a history of concussion and those with no history of concussion.

METHODS

Subjects

Ten subjects were recruited to participate in this study. One subject had a history of multiple concussions, two had a history of one concussion, and seven subjects had no history of concussion. Additional inclusion criteria included 1) being between the ages of 18 and 26 and 2) being enrolled as a student at Indiana University. Exclusion criteria included 1) any visual, ocular, or brain injury within the past 12 months, 2) any history of an eye movement disorder, 3) any noncorrected visual impairment, and 4) a diagnosis of attention deficit/hyperactivity disorder, attention deficit disorder, dyslexia, dyscalculia, or a language processing disorder.

Study Design

This study is a case controlled clinical trial. Based on their self-reported concussion history, participants were assigned into one of two groups: no concussion history (NoHx) or a history of concussion (ConHx).

Experimental Procedures

Subjects were first asked to complete a questionnaire to confirm eligibility and collect demographic data (age, sex, years of education, native language and other languages spoken) and other pertinent data (vision correction, concussion history, ocular/visual injury and disorder history, learning disability diagnoses, Karolinska sleepiness scale). The questionnaire took approximately 3 minutes to complete.

Based on the concussion history provided in the questionnaire, the subject was assigned to either Group NoHx (no concussion history) or Group ConHx (history of concussion). The researcher explained the KDT procedure by saying, “This test evaluates your saccadic eye movements, or rapid eye movements from one fixation point to the next. This test is comprised of three test cards. Each test card has eight lines of several digits (numbers). Please read the digits aloud as quickly but as accurately as possible from left to right and top to bottom. If you make a mistake, correct it if you can and continue on. This is a timed test--tapping the tablet screen starts and stops the stopwatch. You will have a brief break in between cards to catch your breath. Each test card will get progressively harder. The horizontal lines guiding you from digit to digit on each line on Test Card 1 disappear on Test Card 2. The lines of digits on Test Card 3 are closer together than they were on Test Card 2. Do you have any questions?”

The researcher provided the subject the paper demonstration card. The demonstration card directed the subject to read aloud digits from left-to-right using arrows pointing from left-to-right throughout the series of digits. (See **Figure** 1.) Subjects completed the demonstration card twice. Subjects were reminded to “read the digits as quickly but accurately as possible” before starting the test. The researcher silently counted any errors while the subject completed each test card one at a time, taking a brief (1-2s) pause after tapping the screen to stop the timer, and tapping again to start the timer and bringing up the next test card. At the conclusion of the test, the researcher recorded the total time and number of errors on the subject data collection sheet. The subject completed the test a second time, following the same instructions. The total time and number of errors for the second attempt were recorded. This portion of the data collection took approximately 6 minutes. The total duration of the data collection took approximately 10 minutes.

Instrumentation

We used the King-Devick Test (King-Devick technologies, Inc, Downers Grove, IL) on an electronic tablet to standardize the individual's performance. This test records the amount of time, in seconds, it takes the individual to read aloud the three test cards of the KDT and the researcher counted the number of errors the individual made during the test.

Statistical analysis

Demographic variables were compared between groups using an independent t-test for continuous variables and chi-square for categorical variables. The effect of concussion history on KDT performance (duration in seconds) was examined using an independent sample t-test for continuous variables. Statistical analysis was conducted using SPSS version 25 and the level of significance was set at $p < 0.5$. For all tests, significance was set a priori to $\alpha = 0.05$.

RESULTS

Demographics

A total of 10 college-aged subjects ranging from ages 20 to 26 years old participated in the study. The control group with no history of concussion (NoHx) included 7 subjects and the group with a history of one or more concussions (ConHx) included 3 subjects. 2 subjects had a history or 1 concussion and 1 subject had a history of 2 concussions. Details of subject demographics can be seen in ***Table** 1*.

King-Devick Test

All subjects completed the Kind-Devick Test (KDT). The average time for the NoHx group to complete the KDT was 42.71 seconds ± 3.62 and the mean time for the ConHx group was 44.15 seconds ± 6.71. There was no significant difference between the groups when comparing the mean scores (p value = 0.687), see ***Table 2.*** The NoHx group made an average of

0.75 errors ± 1.39 and the ConHx group made an average of 0.67 errors ± 0.47. There was no significant difference between the groups when comparing the mean errors made (p value = 0.96), see ***Table 3.***

DISCUSSION

Previous research has found that the KDT is an effective assessment tool to determine the presence of concussion in an individual by comparing the individual's baseline KDT score with their score during a suspected concussion. However, it is unknown whether the KDT can differentiate between those with no history of concussion and those with a history of one or more concussions. Although the results of this study did not show a significant difference, the study showed promising results regarding those with a history of concussion performing slower on the KDT than those without a history of concussion.

It has been found that there is a five times greater likelihood of worsening KDT times from baseline to time of injury if the individual has a concussion.[7] The KDT challenges individuals with rapid saccadic movements while simultaneously processing, verbalizing, initiating the eye movement to the next number. These visual and oculomotor pathways, which travel from the eyes to the visual cortex are often vulnerable to impairment after sustaining a concussion. This makes oculomotor testing, one of the few objective concussion tests. Specifically, it has been shown that longer KDT performance times have been associated with ISI, larger number of saccades produced, and larger deviations of saccade endpoints in those with concussion history compared to healthy controls. Therefore, it can be interpreted that chronic concussion may negatively affect the neurocognitive systems that control visual function and lead to deficits in spatial target selection and coordination of eye movements.[4] Although this study did not produce significant results, the results are leaning toward this same conclusion that those with a history of concussion will perform worse on the KDT compared to those without concussion history. These findings also contribute to previous findings that concussion can have long lasting, detrimental effects on the brain and cognitive processing.

LIMITATIONS

The limited sample size of this study likely contributed to the insignificant results. Future studies should include a larger sample size as well as similarity in all demographics. Also, future studies should ensure totally controlled environments with no visual or audible distractions while the subject is completing the KDT. Due to some time constraints and accommodating of schedules, there were few instances where data collection could not be conducted in a private room. Researchers attempted to make the environment as quiet as possible but at times there were others in the vicinity and background noises where occurring. These kinds of distractions could impact a subject’s performance. Lastly, the demographics of the subjects were not very diverse in this study. Future research should include subjects with wider range of ages and different races.

CONCLUSION

Although not significant, the study showed promising results regarding those with a history of concussions performing slower KDT performance times than those without a history of concussion which aligns with previous research. Further research is needed with a larger sample size to better determine the effect of concussion history on KDT performance.

TABLES AND FIGURES

Table 1. Demographic Variables

Variables	**NoHx**	**ConHx**
n	7	3
Sex	1M, 6F	1M, 2F
Age, y	22.71	23.33
Race	1 Black, 6 White	3 White
Hours of Sleep	7.64	8.0

Table 2. King-Devick Performance

Control	**History of Concussion**	**P-value**
42.71 ± 3.62	44.15 ± 6.71	.687

Table 3. King-Devick Errors

Control	**History of Concussion**	**P-value**
0.75 ± 1.39	0.67 ± 0.47	.960

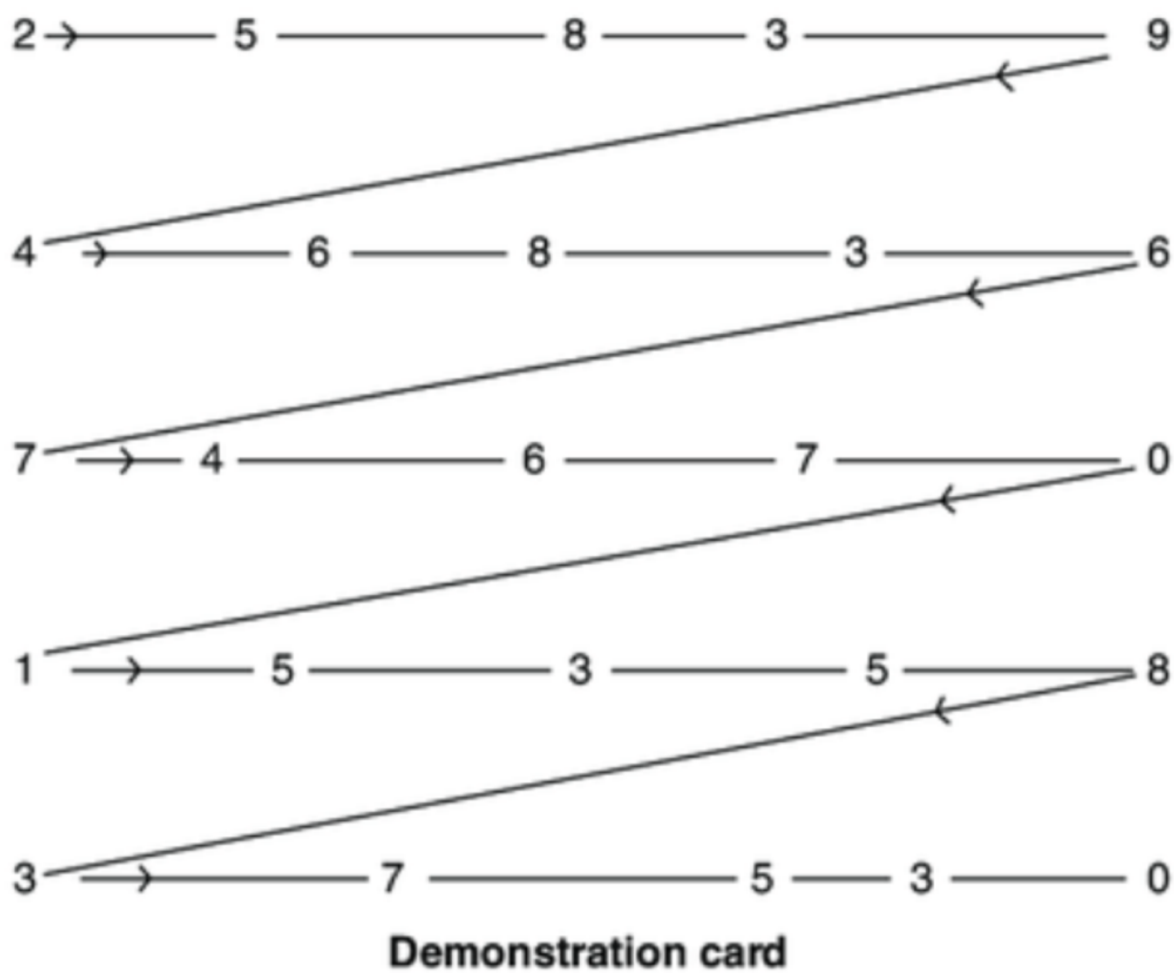

Figure 1: KDT Demonstration Card

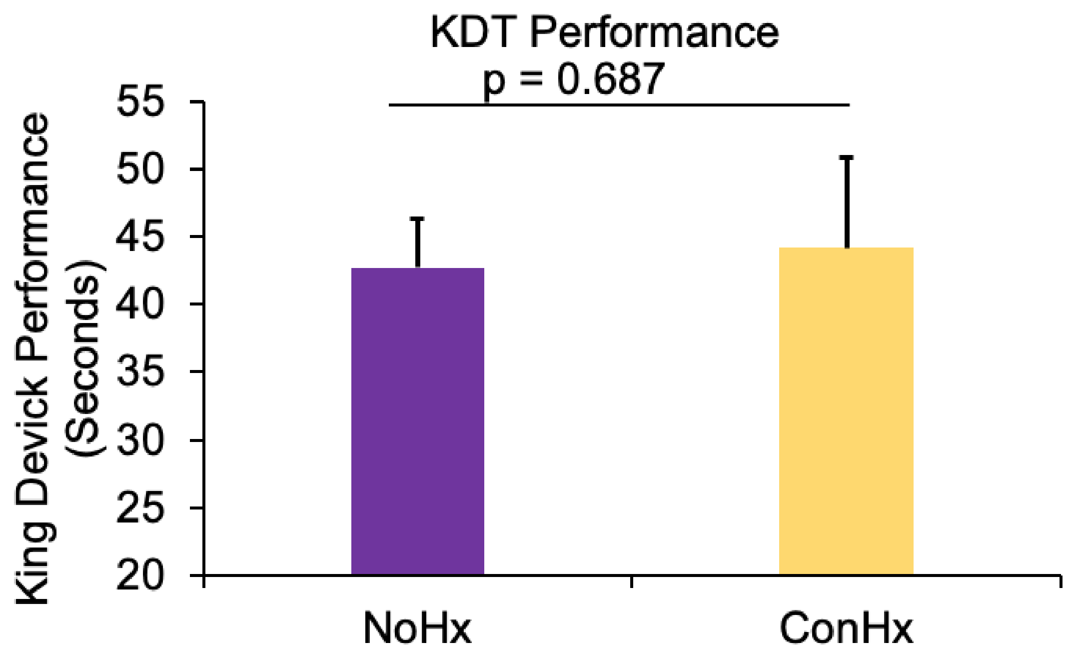

Figure 2: Effect of history of concussion on KDT performance.

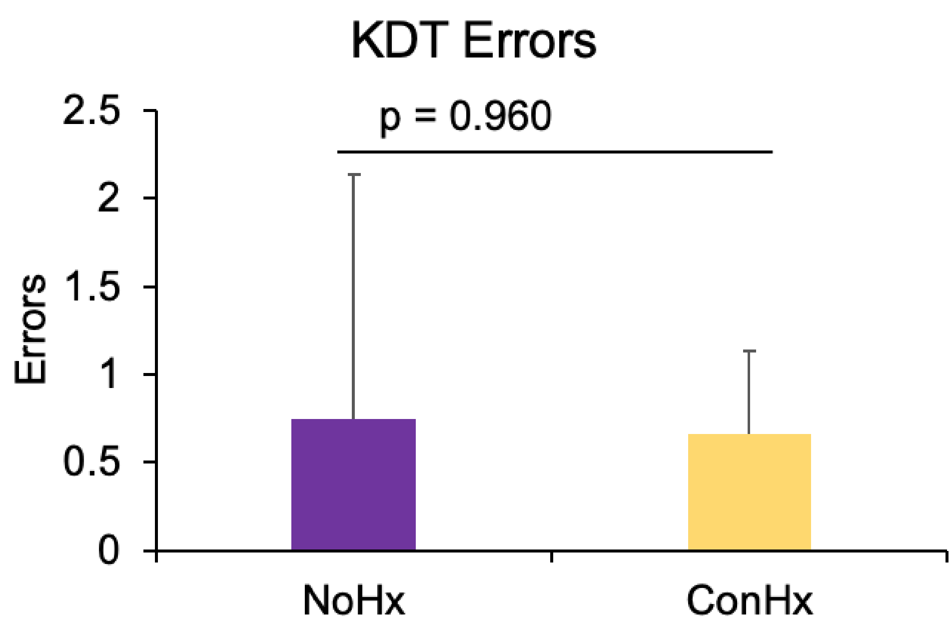

Figure 3: Effect of history of concussion on KDT errors.

REFERENCES

1. Barkhoudarian GMD, Hovda DAP, Giza CCMD. The Molecular Pathophysiology of Concussive Brain Injury. *Clinics in Sports Medicine.* 2011;30(1):33-48.
2. McCrory P, Feddermann-Demont N, Dvořák J, et al. What is the definition of sports-related concussion: a systematic review. *British Journal of Sports Medicine.* 2017;51(11):877-887.
3. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport-the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine.* 2017;51(11):838.
4. Rizzo JR, Hudson TE, Dai W, et al. Rapid number naming in chronic concussion: eye movements in the King–Devick test. *Annals of Clinical and Translational Neurology.* 2016;3(10):801-811.
5. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006;21(5):375-378.
6. Centers for Disease Control and Prevention NCfIPaC. HEADS UP Concussion in Youth Sports Online Training Transcript. U.S. Department of Health and Human Services. https://www.cdc.gov/headsup/youthsports/training/index.html. Updated October 3, 2019. Accessed November 14, 2019.
7. Galetta KM, Liu M, Leong DF, Ventura RE, Galetta SL, Balcer LJ. The King-Devick test of rapid number naming for concussion detection: meta-analysis and systematic review of the literature. *Concussion.* 2016;1(2):Cnc8.
8. Rizzo JR, Hudson TE, Amorapanth PX, et al. The effect of linguistic background on rapid number naming: implications for native versus non-native English speakers on sideline-focused concussion assessments. *Brain Inj.* 2018;32(13-14):1690-1699.
9. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport—the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *PM&R.* 2013;5(4):255-279.
10. Halstead ME, Walter KD, Council on Sports M, Fitness. American Academy of Pediatrics. Clinical report--sport-related concussion in children and adolescents. *Pediatrics.* 2010;126(3):597-615.

11. Diagnostic and Statistical Manual of Mental Disorders. In: Fifth ed. Washington (D.C.): American Psychiatric Publishing; 2013.
12. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine.* 2017;51(11):838-847.
13. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc.* 2007;39(6):903-909.
14. DePadilla L, Miller GF, Jones SE, Peterson AB, Breiding MJ. Self-Reported Concussions from Playing a Sport or Being Physically Active Among High School Students - United States, 2017. *MMWR Morb Mortal Wkly Rep.* 2018;67(24):682-685.
15. Cantu RC. Recurrent athletic head injury: risks and when to retire. *Clinics in Sports Medicine.* 2003;22(3):593-603.
16. Meaney DF, Smith DH. Biomechanics of concussion. *Clin Sports Med.* 2011;30(1):19-31, vii.
17. Ahmadzadeh H, Smith DH, Shenoy VB. Viscoelasticity of tau proteins leads to strain rate-dependent breaking of microtubules during axonal stretch injury: predictions from a mathematical model. *Biophys J.* 2014;106(5):1123-1133.
18. Kraus MF, Susmaras T, Caughlin BP, Walker CJ, Sweeney JA, Little DM. White matter integrity and cognition in chronic traumatic brain injury: a diffusion tensor imaging study. *Brain.* 2007;130(Pt 10):2508-2519.
19. Heitger MH, Anderson TJ, Jones RD. Saccade sequences as markers for cerebral dysfunction following mild closed head injury. *Prog Brain Res.* 2002;140:433-448.
20. Heitger MH, Jones RD, Macleod AD, Snell DL, Frampton CM, Anderson TJ. Impaired eye movements in post-concussion syndrome indicate suboptimal brain function beyond the influence of depression, malingering or intellectual ability. *Brain.* 2009;132(Pt 10):2850-2870.

APPENDICES

APPENDIX A

STATEMENT OF PROBLEM

Although there has been a lot of research done on the KDT as a whole, there has been little research on the effects of history of concussion on KDT performance.

SPECIFIC AIMS AND HYPOTHESES

Specific Aim: To determine the influence of a history of concussion on KDT performance.

Hypothesis H_0: History of concussion has no influence on KDT performance.

Hypothesis H_A: History of concussion will be associated with worse KDT performance.

OPERATIONAL DEFINITIONS

Concussion: traumatic brain injury that occur from biomechanical forces, which typically lead to a rapid onset of neurological symptoms

Multiple concussions: having sustained 2 or more concussions that were diagnosed by an athletic trainer or physician

***King-Devick Test (KDT)*:** a portable, vision-based rapid number naming task that captures afferent and efferent vision, including saccadic eye movements and their interleaved fixations, along with aspects of cognition.

KDT Error*:* Any time a number is misread aloud as directed.

Saccade: rapid, ballistic movements of the eyes that abruptly change the point of fixation

Inter-saccadic interval (ISI): is measured as the time between saccades and is an indicator of complicated processes involved with saccadic planning as well as number recognition and language retrieval.[9]

Second impact syndrome (SIS): describes a condition in which individual experiences a second head injury before complete recovery from an initial head injury.[10]

Karolinska Sleepiness Scale (KSS): measures the subjective level of sleepiness at a particular time during the day

Corrected vision: Use of vision aid (Ex. glasses or contact lenses) to improve visual acuity

Learning disability: Neurodevelopmental Disorder3 that impedes the ability to learn or use specific academic skills (e.g., reading, writing, or arithmetic), which are the foundation for other academic learning[11]

Dyslexia: difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities[11]

Dyscalculia: difficulty in learning or comprehending arithmetic, such as difficulty in understanding numbers, learning how to manipulate numbers, performing mathematical calculations, and learning facts in mathematics[11]

ASSUMPTIONS

- Health history questionnaire is reliable
- Tablet used for testing will be reliable
- Subjects will be truthful and follow directions
- Subjects answer all questions honestly and perform tests to best of their ability

LIMITATIONS

- Participants will only be college students and therefore will not be applicable to the general public.

DELIMITATIONS

- Participants will not have any learning disabilities (e.g. ADD/ADHD, Dyslexia, Dyscalculia etc.)
- Participants will not have a history of visual or ocular injury
- Participants will not have any visual or ocular disorders.
- Participants will not consume stimulants prior to participation.
- Testing environment will be consistent amongst participants.

APPENDIX B: REVIEW OF LITERATURE

Concussion

A concussion has been defined as a traumatic brain injury induced by biomechanical forces typically involving a quick onset of neurological symptoms. [1,2,4,12] However, in some cases signs and symptoms may begin to exhibit themselves minutes or hours after the initial incidence.[1,2,4,12] Neuroimaging typically does not show signs of concussions due to the fact that acutely sport-related concussions (SRCs) demonstrate themselves as functional impairments rather than structural injuries in the brain.[12]

Epidemiology

It is estimated that 1.6-3.8 million sports-related concussions occur each year in the United States.[5] This amounts to 6% of high school athletic injuries and 9% of collegiate athletic injuries; however, this estimate may not be accurate as concussions are often underreported.[5] While single concussion can affect a wide array of neurological function including vestibular, cognitive, ocular-motor functions, and proprioception (include some REFs), emerging evidence suggests that neurological defects can be multiplied with multiple concussions. A history of multiple concussions are linked to greater severity of symptoms, longer recovery times, increased risk of developing depression, as well as an earlier onset of age-related memory loss and dementia.[1,13] Fifteen percent of students reported having at least one concussion during the past year, with 6% (1 million) reporting having suffered two or more concussions.[14] 69% of those athletes with a possible concussion reported playing with concussion symptoms and 40% of those athletes reported that neither they reported concussion symptoms nor their coach was not aware that had a possible concussion.[6] The likelihood of additional concussions increases three times following the first concussive incident, highlighting the importance of early recognition and proper recovery.[4,15]

Mechanisms of Injury

Evidence has shown that the primary cause of concussion is the inertial, or acceleration, loading occurring to the brain due to the motions experienced by the head and neck during a direct impact to the cranium, neck, and body, as well as head impacts to the ground.[16] The brain is resistant to changing its shape when experiencing slow or transient pressures; however, the tissue deforms easily when shearing forces are applied. [16] For example, a study from Ahmadzadeh et al. investigated the dynamic actions of Tau protein (an important neuronal axon's structural protein) in the context of mechanical strain force. In this study, high and low strain rates were applied to a viscoelastic micromechanical model of the axon with microtubules cross-linked by Tau proteins. Interestingly, at a lower strain rate, the viscoelasticity of the Tau mitigated mechanical force by extension of Tau, which allowed microtubules to slide relative to one another; hence no damage in axonal structure was observed. On the contrary, a higher strain rate disrupted Tau and transferred mechanical load directly to microtubules, resulting in break down and dissociation of microtubules.[17]

During a concussive impact, linear and rotational accelerations create shear forces in the brain tissue.[16] This can lead to tissue damage and diffuse axonal injury, which can then disrupt cortical and subcortical pathways resulting in neurobehavioral dysfunction.[16,18] After concussion, cerebral physiologic conditions are disturbed thereby decreasing brain function and increasing vulnerability to further injury. Namely, an acutely concussed brain experiences alterations in ionic balance, neurotransmitter activation, axonal integrity, and energy metabolism.[1]

The pathways for visual processing travel from the eyes to the visual cortex with connections to a multitude of areas in the frontal, parietal, and temporal lobes.[7] The cortical areas supporting saccadic function include the frontal eye fields, dorsolateral prefrontal cortex

(DLPFC), supplementary motor area, posterior parietal cortex, middle temporal area, and striate cortex.[19-26] These areas are responsible for planning, initiating, and executing coordinated saccades like those needed for reading and rapid number naming.[19,25]

Signs and Symptoms

Concussions are one of the most complex injuries to diagnose due to the wide variety of signs and symptoms that can occur, and majority of concussions occur without loss of consciousness[12]. Currently, there is no diagnostic tool that can accurately identify a concussion, and much of concussion diagnosis rely on subjective symptom reporting.[12] Typical symptoms of concussion can include headache, confusion, fatigue, dizziness, photophobia, irritability, and difficulty concentrating, among others.[27] Some athletes may feel pressure to underreport their subjective symptoms and due to the lack of clear, objective signs of concussion in some patients, they are at risk to return to activity with a brain injury.[28] The primary danger of returning to play too early is second-impact syndrome (SIS), which is a second concussive event that occurs before symptoms of the initial concussion are resolved and can be fatal.[29]

In the long-term, concussion has been linked to several physical, cognitive, psychosocial, and neurodegenerative disabilities including dementia, Alzheimer disease, Parkinson’s disease, and lifelong depression. [30].[13] During a concussive impact, damage and loss of neurons occur and can lead to structural changes that coincide with major depression and additional concussions could multiply this effect.[13] Guskiewicz, et al. (2007) found that retired football players with a history of two or more concussions were 1.5 times more likely to be clinically diagnosed with depression compared to players with no concussion history, and this prevalence ratio doubled in players who reported a history of three or more concussions.[13]

Risk Factors

There are multiple risk factors for concussions including previous history of concussion, gender, and age. Previous history of concussion is the most predictive factor of subsequent injury.[31] One study demonstrated that if a football player had previously suffered a concussion, they were three times more likely to experience another one within the same season.[32] Another study found that if loss of consciousness occurred during a concussion, the athlete was six time more likely to sustain another concussion than those who withstood a concussion without loss of consciousness.[33] Recovery time also begins to increase with each additional concussion sustained suggesting that a number of concussions has incremental deleterious effects in the brain.[31]

Females have shown to be more susceptible to concussions compared to males within the same sports.[34] There is limited research defining why females are more likely to get concussions, but it has been postulated that this sex difference is related to relatively weaker neck strength, hormones, or biomechanical factors.[34,35] It has also been found that females are more likely to have more severe post-concussive symptoms than their male counterparts.[9] This means that not only are females more susceptible to concussions, but it will take them longer to recover from the concussions they have sustained[36].

Age is another risk factor which has demonstrated that the younger the athlete the more vulnerable they are to sustain a concussion.[9] This is due to their continuous brain development, which creates a vulnerable time window against mechanical stress, but there is no test that is specifically designed to measure concussion in pediatrics. This is why specific pediatric concussion tests need to be used when evaluating a child.[9] In particular symptom checklists are important for youth to understand the symptoms and how to score it accurately to determine how the they are recovering from their concussion[3,9,31,34]. When contact sports are played at a younger age, the adolescent is still learning their form and may tackle or make poor contact with their opponent making them more suspectable to getting a concussion[3,9,31,34]. Coaching proper techniques for tackling and checking becomes extremely important during these times.

There are other risk factors that play a more minimal role in concussions, but include migraines, mental health disorders or learning disorders. All three of these factors play an impact during diagnostic concussion tests. [31] Migraines and mental health disorders both have overlapping symptoms with those of a concussion making it difficult to determine if the symptom derives from the concussion or the disorder.[31] Learning disorders also have a similar diagnostic dilemma. Learning disorders not only has overlapping symptoms with concussions, but also may have an effect on oculomotor function assessments. [31] This can affect what tests can be reliably used for individual participants and may make it difficult to determine whether they are concussed.

Diagnostic Tests

Currently there is no definitive diagnostic tests for concussions.[12]**.** Some diagnostic tools commonly utilized for concussion assessment include Sports Concussion Assessment Tool version 5(SCAT5), Balance Error Scoring System (BESS) and the King-Devick test (KDT).[12] The choice of test is dependent on multiple factors including financial cost, time, available resources, and clinical standards of care.[37] It has been shown that incorporating a vision-based performance test into cognitive and balance-based sideline test, such as the SCAT5 and BESS, can improve concussion detection in youth and collegiate athletics.[28,38]

Oculomotor diagnostic tests for concussions, in particular the KDT, are low-cost and effective.[39] The visual and eye movement pathways travel from the eyes to the visual cortex and make various connections throughout the brain along the way, making the visual system vulnerable to impairment during concussive impact and an important component to assess during concussion.[7] Saccadic testing can help determine impairment of these pathways as it requires rapid, congruent movement of the eyes between various fixation points.

King-Devick Test

The King-Devick Test (KDT) is a portable, vision-based rapid number naming task that captures afferent and efferent vision, including saccadic eye movements and their interleaved fixations, along with aspects of cognition.[4] The KDT requires the individual to accurately and quickly read aloud a series of single-digit numbers from left to right from a series of test cards on a tablet-based application.[7] The total time it takes the participant to read all the numbers in the test series is their score measured in seconds, indicating that a lower time score is equivalent to a better performance.[38] The test requires rapid and accurate saccadic movements coupled with simultaneous processing during each fixation for the subject to read, verbalize, initiate the motor movement, and then direct attention to the next number.[4] Studies have shown that KDT performance improves after multiple attempts in non-concussed participants, indicating a learning effect is present.[7,40,41] When examining a group of 112 athletes, on average, athletes with a concussion showed a worsening time of 4.8 seconds while non-concussed athletes have shown an average improved time of 1.9 seconds when comparing to baseline performances (mention the worsening and improvement at what point (compared to baseline). Is it post-concussion?).[7] In a different study involving 219 college athletes from multiple sports, those sustaining a concussion demonstrated an average worsening time of 5.9 seconds compared to their initial baseline time pre-concussion.[40] In the same study, those that did not sustain a concussion demonstrated an average improved time of 0.72 seconds when comparing preseason and post-season KDT performance, exhibiting the KDT ability to indicate the possibility of concussion when any worsening score is observed.[40] In fact, it was found that if there is any worsening of KDT time from baseline to the time of injury, there is a five-times greater likelihood that the participant is concussed versus a control athlete.[7]

Factors that Influence KDT Performance

The King-Devick test has been shown to be a reliable tool to use on the sidelines of athletic events, where concussion evaluations often take place. It has been demonstrated that environment has no significant impact on KDT performance when comparing testing in quiet and noisy environments, suggesting that the KDT performance is not dependent on testing environment.[40] The effect of exercise on KDT performance has shown that the learning effect is still present after exercise, indicating that KDT performance is not affected by physical fatigue or recent exercise.[40] Specifically, college athletes that were tested after a two-hour basketball scrimmage demonstrated a 3.6 second improvement on average compared to their baseline and did not have any worsening performance.[40] Therefore, the KDT can be a viable option for sideline testing at athletic events in a loud environment where rapid concussion evaluation is needed to determine if an athlete is safe to return to play.

However, it has been found that KDT is sensitive to sleep deprivation due to the effects on cognitive functioning. [41] Reduced improvement of KDT performance from baseline was noted in those that experienced less quality sleep compared to those that felt better rested as assessed using the Karolinska Sleepiness Scale (KSS).[41] This same study did not find any significant correlation between KDT performance and time since caffeine intake or duration of sleep the night before.[41] Those that felt better rested exhibited an average improvement of 3.8 seconds on the KDT, similar to the learning effect typically seen with K-D testing, while those feeling less rested showed an average slowing of .23 seconds. [41] This study highlights the ability of the KDT to detect altered eye movements in those sleep deprived.[41] These results can be corroborated by previous research that found participants reporting higher levels of sleepiness demonstrated slower peak eye saccade velocities.[41,42] Therefore the amount of sleep should be considered when administering the KDT, more importantly, the subjective alertness of the participant during pre- and post-concussion testing.[41]

Lastly, in several studies, KDT baseline times have also been shown to improve with increasing of age in participants.[7,28,43] Total test times were shown to decrease with age in those 18 and younger, then remain unchanged until the around fifty years old where a decrease in performance was noted again.[7] In a particular study of 332 total athletes aged between 5 and 23 years old, there was a noted age effect at baseline with scores improving with age.[28] This age effect is thought to be associated with changes in saccadic eye movement and cognition during development.[28] White matter and gray matter changes have been shown to continually change in the frontal lobes throughout aging, especially throughout childhood. Also, eye movement tasks, which require frontal lobe activation, begin to reach stabilization during late childhood years.[44] Therefore, KDT baselines should be administered regularly, especially in the younger population, to negate the effects of aging.

Cognitive Processes Involved

Rizzo and colleagues aimed to determine if native English speakers perform differently on the KDT compared to non-native English speakers and they observed that KDT times and inter-saccadic intervals (ISI) were significantly longer in non-native English speakers.[8] ISI is measured as the time between saccades and is an indicator of complicated processes involved with saccadic planning as well as number recognition and language retrieval.[8] Dickson and colleagues observed a significant difference in KDT performance between English and non-native English speakers.[45] However, saccadic velocities were similar between the two groups so the difference in performance was suggested to be due to a longer verbal response processing time in non-native English speakers.[45]

Performance on the KDT has been found to correlate with the number of correct words on the Stroop test independent of patient history of head trauma, such that faster KDT times were associated with increased accuracy on the Stroop test, which suggests that the KDT can serve as a proxy for tests that examine complex cognitive process, cerebral functions, such as selective attention and response inhibition.[46] Specifically, it has been shown that longer KDT performance times have been associated with ISI, larger number of saccades produced, and larger deviations of saccade endpoints in those with concussion history compared to healthy controls. Therefore, it can be interpreted that chronic concussion may negatively affect the neurocognitive systems that control visual function and lead to deficits in spatial target selection and coordination of eye movements.[4] Those that speak a language that read from right-to-left may have an impairment when processing the KDT that requires reading of numbers from left-to-right due to lateralization preferences for right-to-left stimuli. Therefore, language of the participant should be accounted for when administering the King-Devick test.[8]

REFERENCES FOR REVIEW OF LITERATURE

1. Barkhoudarian GMD, Hovda DAP, Giza CCMD. The Molecular Pathophysiology of Concussive Brain Injury. *Clinics in Sports Medicine.* 2011;30(1):33-48.
2. McCrory P, Feddermann-Demont N, Dvořák J, et al. What is the definition of sports-related concussion: a systematic review. *British Journal of Sports Medicine.* 2017;51(11):877-887.
3. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport-the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine.* 2017;51(11):838.
4. Rizzo JR, Hudson TE, Dai W, et al. Rapid number naming in chronic concussion: eye movements in the King–Devick test. *Annals of Clinical and Translational Neurology.* 2016;3(10):801-811.
5. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006;21(5):375-378.
6. Centers for Disease Control and Prevention NCfIPaC. HEADS UP Concussion in Youth Sports Online Training Transcript. U.S. Department of Health and Human Services. https://www.cdc.gov/headsup/youthsports/training/index.html. Updated October 3, 2019. Accessed November 14, 2019.
7. Galetta KM, Liu M, Leong DF, Ventura RE, Galetta SL, Balcer LJ. The King-Devick test of rapid number naming for concussion detection: meta-analysis and systematic review of the literature. *Concussion.* 2016;1(2):Cnc8.
8. Rizzo JR, Hudson TE, Amorapanth PX, et al. The effect of linguistic background on rapid number naming: implications for native versus non-native English speakers on sideline-focused concussion assessments. *Brain Inj.* 2018;32(13-14):1690-1699.
9. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport—the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *PM&R.* 2013;5(4):255-279.
10. Halstead ME, Walter KD, Council on Sports M, Fitness. American Academy of Pediatrics. Clinical report--sport-related concussion in children and adolescents. *Pediatrics.* 2010;126(3):597-615.

11. Diagnostic and Statistical Manual of Mental Disorders. In: Fifth ed. Washington (D.C.): American Psychiatric Publishing; 2013.
12. McCrory P, Meeuwisse W, Dvorak J, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine.* 2017;51(11):838-847.
13. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sports Exerc.* 2007;39(6):903-909.
14. DePadilla L, Miller GF, Jones SE, Peterson AB, Breiding MJ. Self-Reported Concussions from Playing a Sport or Being Physically Active Among High School Students - United States, 2017. *MMWR Morb Mortal Wkly Rep.* 2018;67(24):682-685.
15. Cantu RC. Recurrent athletic head injury: risks and when to retire. *Clinics in Sports Medicine.* 2003;22(3):593-603.
16. Meaney DF, Smith DH. Biomechanics of concussion. *Clin Sports Med.* 2011;30(1):19-31, vii.
17. Ahmadzadeh H, Smith DH, Shenoy VB. Viscoelasticity of tau proteins leads to strain rate-dependent breaking of microtubules during axonal stretch injury: predictions from a mathematical model. *Biophys J.* 2014;106(5):1123-1133.
18. Kraus MF, Susmaras T, Caughlin BP, Walker CJ, Sweeney JA, Little DM. White matter integrity and cognition in chronic traumatic brain injury: a diffusion tensor imaging study. *Brain.* 2007;130(Pt 10):2508-2519.
19. Heitger MH, Anderson TJ, Jones RD. Saccade sequences as markers for cerebral dysfunction following mild closed head injury. *Prog Brain Res.* 2002;140:433-448.
20. Heitger MH, Jones RD, Macleod AD, Snell DL, Frampton CM, Anderson TJ. Impaired eye movements in post-concussion syndrome indicate suboptimal brain function beyond the influence of depression, malingering or intellectual ability. *Brain.* 2009;132(Pt 10):2850-2870.
21. Pierrot-Deseilligny C, Rivaud S, Gaymard B, Agid Y. Cortical control of reflexive visually-guided saccades. *Brain.* 1991;114 (Pt 3):1473-1485.
22. Pierrot-Deseilligny C, Rivaud S, Gaymard B, Muri R, Vermersch AI. Cortical control of saccades. *Ann Neurol.* 1995;37(5):557-567.

23. Ploner CJ, Rivaud-Pechoux S, Gaymard BM, Agid Y, Pierrot-Deseilligny C. Errors of memory-guided saccades in humans with lesions of the frontal eye field and the dorsolateral prefrontal cortex. *J Neurophysiol.* 1999;82(2):1086-1090.
24. Rivaud S, Muri RM, Gaymard B, Vermersch AI, Pierrot-Deseilligny C. Eye movement disorders after frontal eye field lesions in humans. *Exp Brain Res.* 1994;102(1):110-120.
25. Sparks DL, Mays LE. Signal transformations required for the generation of saccadic eye movements. *Annu Rev Neurosci.* 1990;13:309-336.
26. White OB, Fielding J. Cognition and eye movements: assessment of cerebral dysfunction. *J Neuroophthalmol.* 2012;32(3):266-273.
27. Sport concussion assessment tool - 5th edition. *British Journal of Sports Medicine.* 2017;51(11):851-858.
28. Galetta KM, Morganroth J, Moehringer N, et al. Adding Vision to Concussion Testing: A Prospective Study of Sideline Testing in Youth and Collegiate Athletes. *J Neuroophthalmol.* 2015;35(3):235-241.
29. Wetjen NM, Pichelmann MA, Atkinson JL. Second impact syndrome: concussion and second injury brain complications. *J Am Coll Surg.* 2010;211(4):553-557.
30. Broshek DK, De Marco AP, Freeman JR. A review of post-concussion syndrome and psychological factors associated with concussion. *Brain injury.* 2015;29(2):228-237.
31. Kerr HA. Concussion risk factors and strategies for prevention. *Pediatric annals.* 2014;43(12):e309-e315.
32. Guskiewicz KM, Weaver NL, Padua DA, Garrett WE. Epidemiology of concussion in collegiate and high school football players. *The American journal of sports medicine.* 2000;28(5):643-650.
33. Delaney JS, Lacroix VJ, Leclerc S, Johnston KM. Concussions during the 1997 Canadian football league season. *Clinical Journal of Sport Medicine.* 2000;10(1):9-14.
34. Kutcher JS, Eckner JT. At-risk populations in sports-related concussion. *Current sports medicine reports.* 2010;9(1):16-20.
35. Tierney RT, Sitler MR, Swanik CB, Swanik KA, Higgins M, Torg J. Gender differences in head–neck segment dynamic stabilization during head acceleration. *Medicine & Science in Sports & Exercise.* 2005;37(2):272-279.

36. Gallagher V, Kramer N, Abbott K, et al. The effects of sex differences and hormonal contraception on outcomes after collegiate sports-related concussion. *Journal of neurotrauma.* 2018;35(11):1242-1247.
37. Association NCA. Interassociation consensus: diagnosis and management of sport-related concussion best practices. *National Collegiate Athletic Association, Indianapolis, IN.* 2017.
38. Marinides Z, Galetta KM, Andrews CN, et al. Vision testing is additive to the sideline assessment of sports-related concussion. *Neurol Clin Pract.* 2015;5(1):25-34.
39. Tjarks BJ, Dorman JC, Valentine VD, et al. Comparison and utility of King-Devick and ImPACT® composite scores in adolescent concussion patients. *Journal of the Neurological Sciences.* 2013;334(1):148-153.
40. Galetta KM, Brandes LE, Maki K, et al. The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort. *J Neurol Sci.* 2011;309(1-2):34-39.
41. Davies EC, Henderson S, Balcer LJ, Galetta SL. Residency training: the King-Devick test and sleep deprivation: study in pre- and post-call neurology residents. *Neurology.* 2012;78(17):e103-106.
42. Goldich Y, Barkana Y, Pras E, Zadok D, Hartstein M, Morad Y. The effects of sleep deprivation on oculomotor responses. *Curr Eye Res.* 2010;35(12):1135-1141.
43. Moran R, Covassin T. Risk factors associated with baseline King-Devick performance. *J Neurol Sci.* 2017;383:101-104.
44. Luna B, Velanova K, Geier CF. Development of eye-movement control. *Brain Cogn.* 2008;68(3):293-308.
45. Dickson TJ, Waddington G, Terwiel FA, Elkington L. The King–Devick test is not sensitive to self-reported history of concussion but is affected by English language skill. *Journal of science and medicine in sport.* 2019;22:S34-S38.
46. Subotic A, Ting WK, Cusimano MD. Characteristics of the King-Devick test in the assessment of concussed patients in the subacute and later stages after injury. *PLoS One.* 2017;12(8):e0183092.

APPENDIX C: INDIANA UNIVERSITY INFORMED CONSENT FORM

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR RESEARCH

Effects of reading direction and history of multiple concussions on King-Devick Test performance

ABOUT THIS RESEARCH

You are being asked to participate in a research study. Scientists do research to answer important questions which might help change or improve the way we do things in the future.

This consent form will give you information about the study to help you decide whether you want to participate. Please read this form, and ask any questions you have, before agreeing to be in the study.

TAKING PART IN THIS STUDY IS VOLUNTARY

You may choose not to take part in the study or may choose to leave the study at any time. Deciding not to participate, or deciding to leave the study later, will not result in any penalty or loss of benefits to which you are entitled, and will not affect your relationship with Indiana University.

Please review the rest of this document for more details about this study and the things you should know before making a decision about whether to participate in this study.

WHY IS THIS STUDY BEING DONE?

The purpose of this study is to understand the effects of reading direction and a history of multiple concussions on King-Devick Test performance. The King-Devick Test is a quick, portable test that examines your rapid eye movements from one point to another by reading numbers off of a tablet screen as quickly and accurately as possible. The directions for the test instruct you to read the digits like you would read words on a page (that is, left-to-right and top-to-bottom). However, we do not know how reversing the reading direction would change test performance. Furthermore, we want to examine the effect of a history of multiple concussions on King-Devick Test performance, specifically between the normal left-to-right and the reverse right-to-left reading directions.

You were selected as a possible participant because you are an Indiana University – Bloomington student.

The study is being conducted by Dr. Keisuke Kawata (Assistant Professor, Department of Kinesiology, Indiana University School of Public Health—Bloomington).

HOW MANY PEOPLE WILL TAKE PART?

If you agree to participate, you will be one of up to 300 participants taking part in this research.

WHAT WILL HAPPEN DURING THE STUDY?

If you agree to be in the study, you will meet with the researcher in a conference room and do the following things:

Complete a questionnaire.

This questionnaire will ask about your age, years of completed schooling, and languages spoken, in addition to a brief medical history (vision correction, concussion history, ocular/visual injury and disorder history, learning disability diagnoses, etc).
We anticipate that this questionnaire will take approximately three minutes to complete.
Be randomized into a test condition group.
We will flip a coin to decide which test condition group you are assigned to: "heads" will indicate that you will complete the King-Devick Test in normal left-to-right reading direction; "tails" will indicate that you will complete the test in the reverse right-to-left reading direction.
We anticipate that this coin flip and group assignment step will take approximately 30 seconds to complete.
Complete the King-Devick test twice.
The researcher will provide the test instructions.
You will practice reading the demonstration card in the direction assigned to you by the coin flip.
You will complete the test twice.
We anticipate this step will take approximately six minutes to complete.

The total length of your participation is expected to be about ten minutes.

WHAT ARE THE RISKS OF TAKING PART IN THE STUDY?
While participating in the study, the risks, side effects, and/or discomforts include:

A risk of completing the questionnaire is being uncomfortable answering the questions.

The only known risk associated with the tablet form of the King-Devick Test is fatigue or headache from focusing on the tablet screen.

There is also a risk of possible loss of confidentiality.
The above risks will be minimized in the following ways:
While completing the questionnaire, you can tell the researcher that you feel uncomfortable or that you do not want to answer a particular question.
While completing the King-Devick Test, you may take a pause and/or look away between test cards and you can take a few moments between the first and second test attempts if you start to feel fatigued from focusing on the tablet screen.
You will be assigned a subject number which will be on your questionnaire and on your King-Devick Test results form. Your name and/or contact information will not be written on any study materials except your informed consent statement. Your subject number will never be stored in the same electronic or physical document as your name and/or contact information.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THE STUDY?
We don't expect you to receive any benefit from taking part in this study, but we hope to learn things which will help scientists in the future.

HOW WILL MY INFORMATION BE PROTECTED?
Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. No information which could identify you will be shared in publications about this study. You will be

assigned a subject number and all information collected about you during this study will be associated with your subject number, not your name or contact information. All physical paper files will be stored in a locked cabinet in a locked office, and all electronic copies of the de-identified data will be stored in a secure Box Health folder.
Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and any state or federal agencies who may need to access your research records (as allowed by law).

WILL MY INFORMATION BE USED FOR RESEARCH IN THE FUTURE?
Information collected from you for this study may be used for future research studies or shared with other researchers for future research. If this happens, information which could identify you will be removed before any information or specimens are shared. Since identifying information will be removed, we will not ask for your additional consent. Re-identification may be possible; however

WILL I BE PAID FOR PARTICIPATION?
You will not be paid for participating in this study.

WILL IT COST ME ANYTHING TO PARTICIPATE?
There is no cost to you for taking part in this study.

WHO SHOULD I CALL WITH QUESTIONS OR PROBLEMS?
For questions about the study, contact the researcher, Dr. Keisuke Kawata at 812-855-5244. After business hours, please call Dr. Keisuke Kawata at 870-210-9918.
For questions about your rights as a research participant, to discuss problems, complaints, or concerns about a research study, or to obtain information or to offer input, please contact the IU Human Subjects Office at 800-696-2949 or at irb@iu.edu.

CAN I WITHDRAW FROM THE STUDY?
If you decide to participate in this study, you can change your mind and decide to leave the study at any time in the future. The study team will help you withdraw from the study safely. If you decide to withdraw, please tell one of the researchers that you wish to withdraw. Your participation in the study will be immediately terminated.
Your participation may be terminated by the investigator without regard to your consent in the following circumstances: you indicate on the questionnaire that you meet one (or more) of the exclusion criteria or you are uncooperative, rude, or belligerent towards one of the research team. If possible, your participation will be rescheduled if the reason you meet an exclusion criterion is temporary (i.e. got less than 6 hours of sleep the night prior to the originally scheduled data collection). If rescheduling is not possible, your participation in the study will be terminated immediately.
By completing the questionnaire and taking the King-Devick Test you indicate your consent to taking part in this research study.

APPENDIX D: PREPARTICIPATION QUESTIONNAIRE

Subject Number_____________ **Date_____________**
Time______________

Demographics

Please answer the following questions honestly and to the best of your ability.

1. How old are you? _______ years
2. What is your gender? ___________________
3. YES NO Are you currently enrolled as a student at Indiana University Bloomington?
4. How many years of post-secondary education have you completed? ________________ years

   Note: If you are currently in your first year of college, then you have completed 0 years. If you are currently in your fourth year of college, then you have completed 3 years. Please ask if you need further clarification.

5. Which degree are you currently working towards?

- ☐ Bachelors
- ☐ Professional
- ☐ Masters
- ☐ Non-degree seeking
- ☐ Doctoral

6. Please list all languages that you speak and indicate your degree of proficiency with an X.

Note: "Native speaker" is defined as learning and using that language since childhood (your primary language or mother-tongue). "Fluent" is defined as a high level of proficiency (reading, writing, and speaking) in a learned language. "Proficient" is defined as being able to carry on a conversation, discuss current events, talk about beliefs/ideas, and comprehend written and verbal materials with relative ease. "Rudimentary" is defined as knowing some vocabulary or being able to participate in very simple conversations. Please ask if you need additional clarification.

Language:	*Native Speaker*	*Fluent*	*Proficient*	*Rudimentary*
______________________	☐	☐	☐	☐
______________________	☐	☐	☐	☐
______________________	☐	☐	☐	☐
______________________	☐	☐	☐	☐
______________________	☐	☐	☐	☐
______________________	☐	☐	☐	☐

7. YES NO Have you ever taken the King-Devick Test before?

   a) If YES, when? ____

8. I identify my ethnicity as:

   - ☐ Asian
   - ☐ Black/African
   - ☐ Hispanic/Latinx
   - ☐ Native American
   - ☐ Pacific Islander
   - ☐ White
   - ☐ Prefer not to say
   - ☐ Other: _______________

Health History

9. YES NO Have you performed any type of physical activity in the past 60 minutes?

10. How many hours of sleep did you get last night? ________ hours

11. YES NO Have you consumed any stimulants (e.g. caffeine, nicotine, Adderall, Ritalin, etc) in the past 12 hours?

12. Please indicate your current level of sleepiness by circling a number:

    1 *"Extremely alert"*

    2

    3 *"Alert"*

    4

    5 *"Neither alert nor sleepy"*

    6

    7 *"Sleepy—but no difficulty remaining awake"*

    8

    9 *"Extremely sleepy—fighting sleep"*

13. YES NO Have you ever been diagnosed with a concussion?

    a) If YES, approximately when did the concussion(s) occur, how long did signs and symptoms last, and who diagnosed it? Please list each concussion separately, use back of paper if necessary.

Concussion	Date (month & year)	Duration of symptoms	Who diagnosed?
1			
2			
3			
4			
5			
6			

14. Vision:

    a) YES NO Do you have corrected vision (i.e. wear glasses or contacts)?

        i. If YES, what type of correction (i.e. nearsighted, farsighted, astigmatism, etc)?
        ____

        ii. YES NO Are you currently wearing your glasses/contacts?

b) YES NO Have you ever had an ocular or visual injury?

i. If YES, please explain and include date of injury. ____

c) YES NO Have you ever been diagnosed with a visual or ocular disorder?

i. If YES, please explain. ____

15. Learning disabilities:

a) YES NO Have you ever been diagnosed with ADHD/ADD?

b) YES NO Have you ever been diagnosed with dyslexia or dyscalculia?

c) YES NO Have you ever been diagnosed with a language processing disorder?

d) YES NO Have you ever been diagnosed with any other learning disabilities?

APPENDIX E: DATA COLLECTION SHEET

Subject number: _____________ Date: _______________

Attempt	Time (s)	Errors (count)
1		
2		

Administered by: ______________________________

RESUME

EDUCATION

INDIANA UNIVERSITY Bloomington, IN 2019 - 2021

- **Master of Science:** Kinesiology with concentration in Athletic Training
- CAATE Accredited Post-Professional Athletic Training Program
- Thesis: *"Effect of History of Concussions on King-Devick Test Performance"*
- Degree Awarded: June 2021

JAMES MADISON UNIVERSITY Harrisonburg, VA 2015 - 2019

- **Bachelor of Science**: Athletic Training, Magna cum laude
- CAATE Accredited Professional Athletic Training Program

CERTIFICATIONS AND MEMBERSHIPS

- Board of Certification 2019 - Present
- Indiana Professional Licensing Agency (IPLA), *Athletic Trainer* 2019 - Present
- National Provider Identification 2019
- Graston Technique M1 Provider 2019
- American Red Cross CPR/AED for Professional Rescuers 2015 - Present
- SafeSport Certification 2019
- National Athletic Trainers' Association (NATA) - Member 2017 - Present
- Eastern Athletic Trainers' Association (EATA) - Member 2017 - Present
- Pennsylvania Athletic Trainers' Society (PATS) - Member 2017 - Present

PROFESSIONAL ATHLETIC TRAINING CLINICAL EXPERIENCE

INDIANA UNIVERSITY CROSS COUNTRY / TRACK & FIELD Bloomington, IN 2020 - Present

Athletic Trainer

- Coordinated medical care, treatment schedules, and plans of care for student-athletes
- Implemented evidence-based return-to-running progressions including use of Alter-G treadmill and Hydroworx underwater treadmill
- Facilitated COVID-19 safety protocols during practices and events, including communication with pertinent staff and athletes regarding quarantine / isolation guidelines
- Conducted pre-participation examinations (PPE) for incoming freshmen and returning athletes
- Collaborated with IU sports medicine team including athletic trainers, physical therapists, physicians, strength & conditioning, and nutrition staff
- Created online home exercise programs for athlete rehabilitation
- Communicated with coaches and sports medicine staff regarding student-athlete status
- Supervised and mentored 1st year MSAT students

- Traveled with track & field team to various away meets, including 2021 Big Ten Indoor Track & Field Championships
- Documented medical information using Vivature (electronic medical record)

INDIANA UNIVERSITY BASEBALL Bloomington, IN 2020

Athletic Trainer

- Provided medical care at practices and home events, daily athletic training room coverage, and rehabilitation of acute, chronic, and post-op injuries
- Created and implemented several aquatic rehabilitation plans
- Collaborated with Head AT to provide consistent treatment and coordinate plans of care
- Utilized interventions such as cupping and Graston
- Preceptor and mentor to undergraduate athletic training student

BLOOMINGTON HIGH SCHOOL – SOUTH Bloomington, IN 2019

Athletic Trainer

- Indiana High School Athletic Association (IHSAA) – Class 4A
- Responsible for away-game coverage of JV / freshmen football, girls’ and boys’ soccer, girls’ basketball, and home swimming & diving meets
- Provided medical care during daily football practices
- Coverage of athletic training room for all school sports during the Fall and Winter seasons
- Coordinated care of student-athletes with 3 other staff ATs and supervising physicians
- Guided athletes, parents, and coaches through concussion return-to-play protocols from initial injury to final physician clearance, including graded exercise progression
- Preceptor and mentor to senior undergraduate athletic training student

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PRE-PROFESSIONAL ATHLETIC TRAINING CLINICAL EXPERIENCE

JAMES MADISON UNIVERSITY Harrisonburg, VA 2017 - 2019

Clinical experiences with the following:

- Eastern Mennonite University NCAA DIII, Harrisonburg, VA 2019
- James Madison University Women’s Lacrosse NCAA DI 2018
- Stuarts Draft High School, Stuarts Draft, VA 2018
- James Madison University Football NCAA DI 2017

PREVIOUS EMPLOYMENT

WOODWARD ACTION SPORTS CAMP Woodward, PA 2019

Athletic Trainer

- Responsible for evaluation, treatment, management, and documentation of injuries for over 800 action sports campers aged 8-18, as well as professional athletes, and staff
    - Sports: gymnastics, cheer, power tumbling, skateboarding, BMX, scooter, and parkour
- Implemented emergency action plans when needed
- Coordinated care with other medical and healthcare professionals staff
- Supervised athletic training students
- Communicated with parents of overnight campers regarding health status and plans of care

Athletic Training Student 2018

- Assisted Athletic Trainers with care of campers, professional athletes, and staff
- Rehearsed spinal immobilization techniques and plans of removal from various sites including trampolines, halfpipes, bowls, and spring floors

PROFESSIONAL DEVELOPMENT AND EXPERIENCE

National Athletic Trainers' Association Annual Meeting and Clinical Symposia

- 2020 Virtual (July 13-16)
- 2019 Las Vegas, NV (June 25-28)

Virginia Athletic Trainers' Annual Meeting and Clinical Symposium

- 2019 Williamsburg, VA (Jan 12)
    - Member of 1st place JMU Quiz Bowl Team
- 2017 Student Seminar, Liberty University (February 25)

Madison Athletic Training Students' Association 2015 - 2019

- Held position of Social Chair 2018 - 2019
    - Organized various team building activities to foster relationships between pre-professional and professional phase athletic training students

James Madison University Athletic Training Program Teaching Assistant 2018

- Courses: Acute Care, Therapeutic Modalities, and Lower Extremity Evaluation

Sports Medicine and Culture Study Abroad in Ireland 2018

- Attended lectures by sports medicine staff of Dublin City University, University College Dublin, the Gaelic Athletic Association, and of the Leinster Rugby Club

AWARDS AND HONORS

LUCILE M. SWIFT-MONA M. RUSSELL FELLOWSHIP, Indiana University 2020

- Awarded to a graduate student in the School of Public Health that "demonstrates initiative, character, need, and scholastic achievement."

SPORTS MEDICINE DIRECTOR'S AWARD, James Madison University 2019

- Awarded to one senior undergraduate athletic training student that "demonstrates strong leadership skills, professionalism, and the potential to make future contributions to the profession."

ACADEMIC HONORS, James Madison University 2015 - 2019

- Dean's List: Fall 2015 - Spring 2018
- President's List: Fall 2018