Correlating the King-Devick Test With Vestibular/Ocular Motor Screening in Adolescent Patients With Concussion: A Pilot Study

Shira Russell-Giller, BA,*† Diana Toto, MS,‡ Mike Heitzman, PT, DPT,‡ Mustafa Naematullah, BS,‡ and John Shumko, MD, PhD‡

Background: The King-Devick (K-D) test is a rapid number-naming task that has been well validated as a sensitive sideline performance measure for concussion detection. Patients with concussion take significantly longer to complete the K-D test than healthy controls. Previous research suggests that ocular motor deficits, specifically saccadic abnormalities, may be an underlying factor for the prolonged time. However, these findings have not been studied at length.

Hypothesis: K-D testing time of concussed adolescents at the initial clinical concussion visit will positively correlate with vestibular/ocular motor screening (VOMS) total scores.

Study Design: Case series.

Level of Evidence: Level 3.

Methods: A total of 71 patient charts were retrospectively analyzed between October 1, 2016, and January 31, 2017. Included charts consisted of patients between the ages of 10 and 18 years with a diagnosis of concussion and who had completed K-D testing and VOMS assessment at the initial physician visit. Univariate correlation between K-D testing time and the 7 VOMS items was assessed using Pearson correlation coefficients.

Results: K-D testing time strongly correlated with all 7 VOMS items ($r(69) = 0.325$-0.585, $P < 0.01$). In a linear regression model that accounted for each VOMS item, the convergence (near point) item and the visual motion sensitivity item significantly predicted K-D testing time ($\beta = 0.387$, $t(63) = 2.81$, $P < 0.01$ and $\beta = 0.375$, $t(63) = 2.35$, $P = 0.02$, respectively). Additionally, 37.5% of the 24 patients with worsening symptoms after K-D testing freely reported increased visual problems.

Conclusion: Our study suggests that prolonged K-D testing times in adolescents with concussion may be related to subtypes of vestibular/ocular motor impairment that extend beyond saccadic abnormalities.

Clinical Relevance: Poor K-D testing performance of adolescents with concussion may indicate a range of vestibular/ocular motor deficits that need to be further identified and addressed to maximize recovery.

Keywords: King-Devick test; vestibular/ocular motor screening; concussion

Concussion is a major public health problem resulting from a change in brain physiology after a blow to the head or body.[3] Concussions often produce symptoms such as blurred vision, dizziness, imbalance, and headaches, as well as measurable neurologic impairments in cognition, reaction time, balance, and behavior.[15] More often, concussion symptoms occur immediately after the impact and resolve spontaneously; however, sometimes symptoms will develop over a longer period of time.[15] Since concussion diagnosis and prognosis are determined by functional impairment rather than

From †Multiple Sclerosis Comprehensive Care Center, RWJBarnabas Health, Livingston, New Jersey, and ‡Matthew J. Morahan III Health Assessment Center for Athletes, RWJBarnabas Health, Livingston, New Jersey

*Address correspondence to Shira Russell-Giller, BA, Multiple Sclerosis Comprehensive Care Center, RWJBarnabas Health, Matthew J. Morahan III Health Assessment Center for Athletes & The Center for Health and Wellness, Barnabas Health Ambulatory Care Center, 200 South Orange Avenue, Livingston, NJ 07039 (email: shirarussell26@gmail.com) (Twitter: @RWJBarnabas).

The authors report no potential conflicts of interest in the development and publication of this article.
DOI: 10.1177/1941738118765450

structural brain injury,[15] it is challenging to capture a comprehensive picture of the various physical and behavioral elements that may have been impaired by concussion.[18]

Recently, researchers have studied eye movement abnormalities as an indication for impaired function in concussed patients.[4,11] Although eye movement abnormalities are often combined with or interpreted as other related symptoms such as balance and/or dizziness, the vestibular/ocular motor system is also uniquely affected by concussion.[23] A pediatric sports study showed that 81% of the adolescents diagnosed with concussion demonstrated vestibular deficits that were separate from other symptoms.[5] Additionally, studies have shown that concussed adolescents with indicated visual impairments have worse neurocognitive performance,[6,10,22] and concussed adolescents with vestibular abnormalities take longer to return to school and play.[5] Therefore, it is important to evaluate the vestibular and ocular motor systems after concussion using standardized clinical assessments.

A well-validated tool for concussion detection is the King-Devick (K-D) test, a rapid number-naming task that requires a participant to correctly identify single digits that are variably spaced on 3 handheld cards.[6,7] The K-D test broadly captures visual function and saccadic eye movements as well as attention and language function.[6,7,9,10,13] While patients with concussion take a significantly longer time to complete the K-D test than healthy controls,[8] the underlying reason for this deficit has largely been unknown.[20] To this goal, a recent study observing 25 patients with concussion history who completed a computerized version of the K-D test under infrared-based video-oculography showed that the prolonged K-D test time may be due to saccadic abnormalities, specifically, prolonged intersaccadic intervals, greater number of saccades, and larger deviations of saccadic endpoints.[19] Additionally, a study of the handheld version of the K-D test administered on rugby players showed its ability to assess saccadic eye movements to better identify concussion.[12] However, the K-D test does not assess other areas of ocular motor function such as pursuit, convergence, or accommodation, all of which have shown to be valuable indicators of impairment from mild traumatic brain injury.[2,4]

A more recent assessment performed during concussion visits is vestibular/ocular motor screening (VOMS).[16] The VOMS is a comprehensive examination of various saccadic eye movements with the intention of provoking symptoms after each assessment.[16] The VOMS accurately differentiates between controls and athletes with concussion in the evaluation of smooth-pursuit eye movements, saccadic eye movements, near point of convergence (NPC), vestibular ocular reflex, and visual motion sensitivity.[17] Abnormal VOMS results delay recovery time of concussed adolescents, indicating that the VOMS may assist in more effective prognosis of concussion.[1] The VOMS captures the interaction of the vestibular and ocular motor systems in a comprehensive evaluation that involves both patient and clinician reporting.[17] A previous study indicated that the VOMS does not provoke symptoms in healthy controls, and with a mean score of zero, there was no significant correlation between VOMS items and K-D test scores.[23] However, correlation between the VOMS and K-D test scores of concussed patients has not been explored. Since the VOMS only provokes symptoms in impaired populations, it is important to determine whether a relationship exists between the VOMS and K-D test scores of concussed individuals. Comparing the VOMS scores of concussed patients with their K-D test performance will illuminate the potential range of vestibular and ocular motor deficits that may be associated with prolonged K-D testing time. To this aim, this study explores the relationship between K-D and VOMS testing and observes patient-reported visual symptoms before and after K-D testing to gain a more comprehensive understanding of the underlying vestibular/ocular motor impairments affecting the K-D test performance of concussed adolescents.

Table 1. Mean K-D and VOMS scores at initial physician visit (N = 71)[a]

	Mean	SD
K-D total time, s	64.75	33.88
VOMS		
Smooth pursuit score	0.63	1.08
Saccades (horizontal) score	0.96	1.38
Saccades (vertical) score	1.08	1.55
Convergence (near point) score	0.52	1.24
Vestibular-ocular reflect (horizontal) score	1.3	1.57
Vestibular-ocular reflect (vertical) score	1.25	1.49
Visual motion sensitivity score	1.79	1.82

K-D, King-Devick; VOMS, vestibular/ocular motor screening.
[a]VOMS scores are measured on a self-reported scale from 0 to 6, where 0 = no impairment and 6 = complete impairment.

METHODS

This study was approved by the institutional review board at Saint Barnabas Medical Center, RWJBarnabas Health. A total of 71 patient charts were retrospectively analyzed between October 1, 2016, and January 31, 2017 (mean patient age, 14 ± 2.1 years; mean symptom score at initial visit, 5.7/22 ± 5.7). A majority of patients (70.4%) sustained their concussion from sports, and 70.4% of patients had experienced first-time concussion at the time of testing. Included charts consisted of patients with a diagnosis of concussion who had completed K-D testing and VOMS assessment at their initial physician visit after their concussion (Table 1). The time from concussion to initial physician visit ranged from 1 to 49 days (mean, 11 days). Univariate correlation between K-D testing time and the 7 VOMS items was assessed

Table 2. Correlation of VOMS item total scores and K-D testing time scores of patients with a 1- to 49-day time span from concussion to initial testing[a]

VOMS Item		K-D Score
Smooth pursuits total score	Pearson correlation	0.422
	Significance (2-tailed)	0.000
	N	70
Saccades—horizontal total score	Pearson correlation	0.325
	Significance (2-tailed)	0.006
	N	70
Saccades—vertical total score	Pearson correlation	0.464
	Significance (2-tailed)	0.000
	N	71
Convergence (near point) total score	Pearson correlation	0.573
	Significance (2-tailed)	0.000
	N	71
Vestibular-ocular reflex—horizontal total score	Pearson correlation	0.481
	Significance (2-tailed)	0.000
	N	70
Vestibular-ocular reflex—vertical total score	Pearson correlation	0.515
	Significance (2-tailed)	0.000
	N	71
Visual motion sensitivity total score	Pearson correlation	0.585
	Significance (2-tailed)	0.000
	N	68
King-Devick score	Pearson correlation	1
	N	71

K-D, King-Devick; VOMS, vestibular/ocular motor screening.
[a]One participant did not complete smooth pursuits and horizontal saccades, so N = 70 for those items. Three participants did not complete visual motion sensitivity, so N = 68 for that item.

using Pearson correlation coefficients. Multiple linear regression was performed with each VOMS item as an independent variable and the overall K-D testing time as the dependent variable.

RESULTS

K-D testing time strongly correlated with all 7 VOMS items ($r(69) = 0.325\text{-}0.585$, $P < 0.01$) (Table 2). In a multiple linear regression model that accounted for each VOMS item, the NPC item and the visual motion sensitivity (VMS) item significantly predicted K-D testing time ($\beta = 0.387$, $t(63) = 2.81$, $P < 0.01$ and $\beta = 0.375$, $t(63) = 2.35$, $P = 0.02$, respectively) (Figures 1 and 2). Additionally, it is worth noting that 75.7% of patients reported positive on the VOMS test, and 37.5% of the 24 patients with worsening symptoms after the K-D testing freely reported increased visual problems.

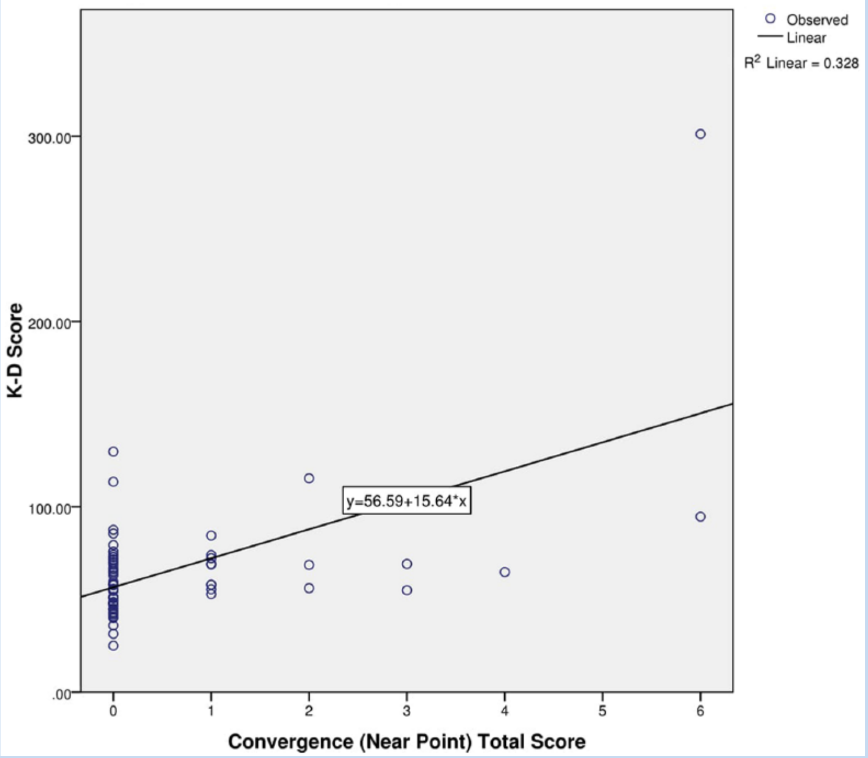

Figure 1. Regression model of convergence and King-Devick (K-D) test scores.

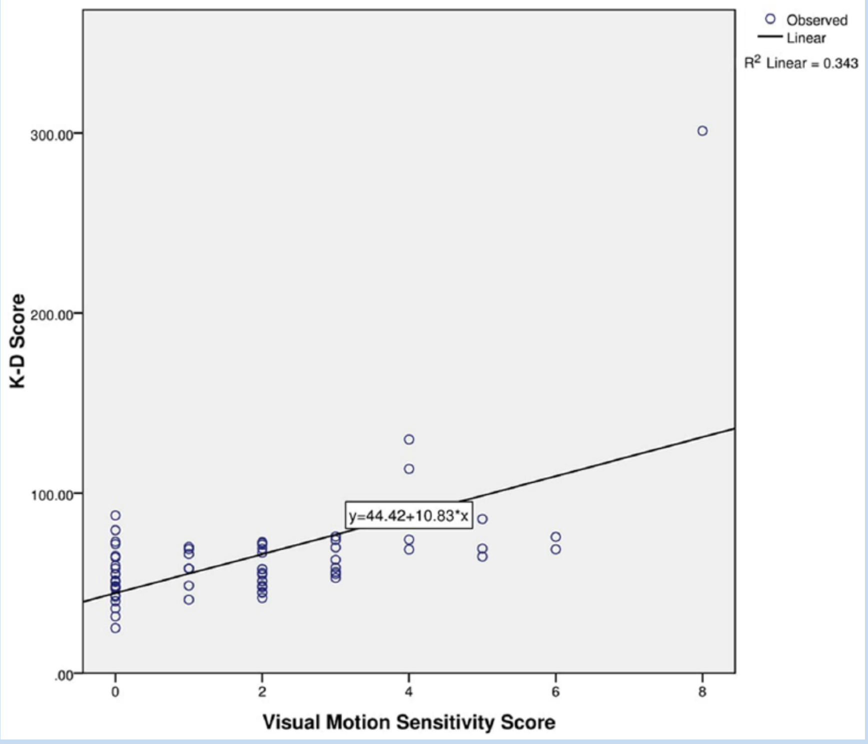

Figure 2. Regression model of visual motion sensitivity scores and King-Devick (K-D) test scores.

Table 3. Correlation of VOMS item total scores and K-D testing time scores of patients with a 1- to 5-day time span from concussion to initial testing[a]

VOMS Item		K-D Score
Smooth pursuits total score	Pearson correlation	0.521
	Significance (2-tailed)	0.013
	N	22
Saccades—horizontal total score	Pearson correlation	0.425
	Significance (2-tailed)	0.049
	N	22
Saccades—vertical total score	Pearson correlation	0.718
	Significance (2-tailed)	0.000
	N	22
Convergence (near point) total score	Pearson correlation	0.652
	Significance (2-tailed)	0.001
	N	22
Vestibular-ocular reflex—horizontal total score	Pearson correlation	0.76
	Significance (2-tailed)	0.000
	N	22
Vestibular-ocular reflex—vertical total score	Pearson correlation	0.743
	Significance (2-tailed)	0.000
	N	22
Visual motion sensitivity total score	Pearson correlation	0.727
	Significance (2-tailed)	0.000
	N	20
King-Devick score	Pearson correlation	1
	N	22

K-D, King-Devick; VOMS, vestibular/ocular motor screening.
[a]Two participants did not complete visual motion sensitivity, so N = 20 for that item.

To strengthen the validity of the relationship between K-D and VOMS scores, we limited our data set to consist of the patients with a time span of 1 to 5 days from concussion to initial physician visit (N = 22). Again, K-D testing time correlated with all 7 VOMS items ($r(20) = 0.425\text{-}0.760$, $P < 0.01\text{-}0.049$) (Table 3).

DISCUSSION

This pilot study found a significant relationship between the total scores of each VOMS item and overall K-D testing time in adolescents with concussion, supporting previous research that showed saccadic abnormalities affect K-D performance. As expected, the vertical and horizontal saccade items of the VOMS significantly correlated with prolonged K-D time. However, this study also suggests that prolonged K-D testing times may be related to vestibular/ocular motor impairment beyond saccadic abnormalities alone, as all the VOMS items correlated with K-D.

King-Devick Test

Specifically, this study showed that NPC and VMS uniquely predicted K-D performance. Additionally, while ocular motor deficits may be a contributor to the delay of completion in concussed patients, it is unknown whether attentional and/or cognitive deficits interact with ocular motor deficits during K-D performance.

Near Point of Convergence

While VOMS is becoming a more popular assessment for concussion, VOMS is rarely performed at baseline. This becomes particularly important when assessing NPC. Convergence insufficiency is present in 1 of every 20 children suggesting that, in a typical classroom, 1 to 2 children may have this condition.[21] NPC is often undiagnosed in school-aged children and could therefore mislead a clinician in a concussive setting to believe that the NPC insufficiency is a direct result of concussion rather than acknowledge the possibility of a preexisting condition.[14]

Limitations

It is important to note that this is only a pilot study using retrospective data. While significant correlations emerged, this study is limited because it does not describe a causal relationship.

CONCLUSION

This pilot study supports the previous research that prolonged K-D testing times in adolescents with concussion may be related to vestibular/ocular motor impairment, particularly saccadic abnormalities. However, this study also suggests that vestibular/ocular motor impairment affecting K-D testing may extend beyond saccadic abnormalities alone.

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