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King Devick computerized neurocognitive test scores in professional football players with learning and attentional disabilities

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ABSTRACT

Objective: This study examined outcomes from the King Devick (K-D) in athletes with Learning Disabilities (LD) and attention disorders (ADHD).
Methods: A total of 574 professional football players from the Canadian Football League (CFL) completed baseline evaluations with computerized neurocognitive testing (CNT) prior to the 2016 competitive season. Player age, education, history of concussion, LD, and ADHD were analyzed for K-D and Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) performance. A series of analyses of co-variance (ANCOVA's) were used to compare participants with a history of LD and ADHD with history of concussion as a co-variate.
Results: Approximately 5% of participants reported a diagnosed history of LD and 13% with ADHD. Performance on the K-D test was not significantly correlated with age, education, or history of concussion but was significantly correlated with history of LD and ADHD. Participants with LD performed approximately 6.9 s slower on the K-D test ($t[563] = 4.70$, $p. = 0.0003$) and participants with ADHD were approximately 2 s slower ($t[572] = 2.04$, $p. = 0.04$).
Conclusions: Results indicated that players with a history of diagnosed LD and ADHD performed slower on the K-D test in comparison to athletes with no history of diagnoses. The results of this study underscore the importance of recognizing individualized outcomes when using the K-D.

1. Introduction

Over the past 2 decades, experts in concussion have advocated for the use of empirically based validated measures for the diagnosis and management of sport-related concussions [17]. Computerized neurocognitive testing (CNT) is one component to manage sport-related concussion (SRC) with recent consensus statements suggesting the use of CNT as part of a comprehensive concussion evaluation. Many sport organizations have adopted baseline assessments that include CNT which allow a clinician to make comparisons between a player's pre-injury and post-concussion performance when deriving a concussion diagnosis.

There are factors that are known to impact baseline CNT performance including age, sex, and culture. Furthermore, a history of learning disabilities (LD) and attention deficit hyperactivity disorder (ADHD) have also been identified as moderating variables. The diagnosis of LD and ADHD typically occurs during childhood. Prevalence rates for ADHD in adults range from 1 to 6%; the National Comorbidity Survey Replication study found an estimated 4.4% of adults aged 18–44 experienced symptoms and some associated disability [11]. The prevalence rates in high school and collegiate athletes are assumed to reflect those in the general population although recent studies suggest the incidence of ADHD in athletes may be much higher in college age samples [2]. Iverson et al., [10] identified 12.4% of a sample of over 32,000 high school aged athletes to have a history of either learning difficulties or diagnosed ADHD.

Collins et al. [5] first identified that collegiate football players with a history of LD and ADHD performed more poorly than aged-matched peers on baseline neurocognitive tests. Solomon and Haase [26] reported significant correlations (poorer performances) in NFL football players with LD/ADHD on the verbal and visual memory domains from ImPACT testing. Subsequent studies have indicated that individuals

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with LD and ADHD are more likely to have invalid baseline scores on CNT [24]. Merritt et al. [18] also identified differential outcomes on ImPACT scores in college athletes with a history of ADHD/LD. Elbin et al., [7] drew from a large a sample of high school and collegiate athletes (N = 23, 089) who had undergone baseline ImPACT testing. Comparisons between participants with self-reported LD/ADHD (n = 2377) with controls revealed significant differences between groups, leading the authors to highlight the need for separate normative data for athletes with LD and ADHD. Similar findings were identified in a study by Zuckerman et al., [29] where 6636 high school athletes with self-reported diagnoses of ADHD and LD had poorer scores on most composite scores of ImPACT testing. Taken together, individuals diagnosed with ADHD and/or LD should be carefully considered when comparing CNT outcomes to normative values to ensure valid interpretations of testing results.

The K-D is a test of rapid number naming that measures eye movements, attention, and language function [9]. Better performance on the K-D test has been correlated with higher reading fluency scores ([13,23]. Conversely, children with reading difficulties have poorer performances on the K-D test because of these hypothesized deficits in saccadic eye movements. Several studies with young children that targeted saccadic training demonstrated improved reading comprehension coupled with improved results on the K-D test [6,15].

The development of sideline screening tools such as the K-D test has become important to quick real-time decision making in professional sports [9]. Poor performance on the K-D test is indicated by a longer time to complete the task. The K-D test has demonstrated high test retest reliability (ICC's between 0.86 and 0.97) in a variety of athletic adolescent and adult samples ([1,8,12,14,16]. In a recent meta-analysis, the K-D test demonstrated adequate sensitivity (86% detected a concussion on the sidelines) and specificity (90%) when assessing sport concussions in various contact sports in youth and college samples [9], with lower results found in professional football [20] and rugby [19]. Lower (faster) K-D times are associated with increased age in different athletic samples. For instance, Alsalaheen et al. [1] noted that participants between the ages of 16–18 had median speeds that were 2.91 s faster than 13–15 year-olds. Furthermore, Weise et al. [28] noted that participants in high school had K-D times up to 6 s faster compared to those in junior high school. Another study of children ages 6 to 17 reported a K-D speed increase of 3.7 s per year for children until the age of 17 [25]. In contrast, in a sample of male professional ice hockey players (mean age = 23.8 years) there was no significant correlation with age and K-D performance, suggesting the effect of age is negligible once players have reached cognitive maturity [27]. Additionally, test characteristics suggest no significant differences in performance between genders [25] and no significant correlations between K-D test performance with level of education attainment or number of self-reported previous concussions [27].

To date, there have been no empirical studies using the K-D test with professional football players with a history of LD and/or ADHD. The purpose of this study was to examine outcomes of the K-D test in athletes with a history of LD and/or ADHD in conjunction with another well standardized concussion assessment tool (ImPACT). We hypothesized that athletes with ADHD/LD would perform poorer on measures of CNT and the K-D test in comparison to other athletes without these diagnoses.

2. Materials and methods

Approval was granted by the University of Alberta Institutional Review Board. Informed consent by athletes was waived with IRB approval, and health-screening data was retrieved in a de-identified manner.

The K-D test was piloted as a component of baseline assessments in the Canadian Football League (CFL). In 2016, players from all 9 teams (n = 917) underwent standardized pre-season medical evaluations adhering to regulations outlined by the CFL which included player reports of concussion history. Participants were individually administered the K-D test by team athletic trainers or graduate students (who underwent standardized training for the administration with the K-D). All participants were administered the K-D electronically by iPads to ensure standardized administration. Participants were required to complete 2 error free trials with the K-D and the best score without errors was used as the participants baseline score. For ImPACT testing, players completed the online version of ImPACT ® (version 3.2.2) individually at team sites.

The CFL concussion assessment protocol required new players or those medically diagnosed with a concussion in the previous years to complete ImPACT testing at the start of each competitive season. This subset of players (n = 574) was used in the analysis to ensure simultaneous baseline testing with K-D and ImPACT. There were no significant differences in the demographic variables (age, years of education, history of LD, history of ADHD, history of concussion) between the players who only completed the K-D test (n = 917) with the 574 players who completed ImPACT and K-D testing.

Statistical analyses were performed by using SPSS 24.0 (Chicago Illinois). Our study approached analyses of this data using different statistical techniques including 1) correlations between age, education, history of learning disability (LD), Attention Deficit Hyperactivity Disorder (ADHD), history of concussions, and K-D time; 2) before analyzing ImPACT and K-D scores for players with LD and ADHD, a comparison of history of concussion (IV) across K-D and ImPACT composite scores (DV's) was conducted using analysis of variance (ANOVA); 3) Because of the significant differences between history of concussion on several ImPACT composite scores, a series of analysis of co-variance (ANCOVA's) were used to compare subjects with a history of LD and ADHD with history of concussion entered as a co-variate; and 4) partial correlations between the K-D test with the 5 domains of ImPACT testing using LD and ADHD as co-variates. Significance for analyses was set *a priori* at $p < .05$. Cohen's *d* effect sizes [4] were also computed to complement interpretation of results, with effect sizes being interpreted as negligible/very small ($d < 0.20$), small ($d = 0.20–0.49$), medium ($d = 0.50–0.79$), or large ($d > 0.80$).

3. Results

The participants who completed baseline testing ranged in age from 20 to 41 years-old, with a mean age of 25.4 years (SD = 2.9). The majority of participants had several years of post-secondary schooling (mean years of education = 15.4, SD = 1.2). There were approximately 5% of participants who reported a history of a diagnosed learning disability, results generally consistent with other data for in adults. The percentage of participants diagnosed with ADHD (13.5%) was slightly higher than outpatient clinical samples but likely due to the medical requirements of the CFL in which players prescribed stimulant medication must have a confirmed diagnosis. There were 2 participants that reported being diagnosed with LD and ADHD and they were included in the analyses for each group. Based upon medical histories, groups were created using no history of concussion, (n = 340), one concussion, (n = 144), and two or more concussions (n = 90) (Table 1).

Performance on the K-D test was not significantly correlated with age, education, handedness, or history of concussion (all p's > 0.05), but was significantly correlated with history of LD and ADHD (Table 2).

Results from the individual ANOVA's revealed that participants with a history of no concussions demonstrated *lower* (poorer) performances compared to those with one or two or more concussions on the Verbal Memory ($F[2, 569] = 5.16$, $p = .006$], Visual Motor Processing ($F[2, 569] = 8.28$, $p = .0003$], and Reaction time composite ($F[2, 569] = 4.45$, $p = .01$]. We believe this is likely a practice effect as participants with previous concussions were required to take the ImPACT testing multiple times before medical clearance. In contrast, there was no significant effect for history of concussion on K-D baseline

Table 1
ImPACT and King Devick tests descriptive statistics.

	Verbal memory	Visual memory	Visual motor	Reaction time	Impul. error	Symptom total	K-D score
Concussion history							
0 (n = 340)	84.0[a]	74.8	37.6[a]	0.64[a]	4.7	4.1[a]	44.1
1 (n = 144)	86.7[b]	76.5	39.4[b]	0.62[b]	5.3	5.0[b]	44.5
2+ (n = 90)	86.4[b]	76.6	40.4[b]	0.61[b]	4.7	4.5[b]	44.5

Note: [a,b]Those participants with a history of zero concussions were significantly lower on ImPACT composite scores than participants with a history of 1 or 2+ concussions. There were no significant differences between participants with 1 or 2+ concussions. Higher scores represent stronger (better) performances.

Table 2
Pearson correlations between demographic variables and King Devick test.

	LD	ADHD	History of concussion	Age	Education	Handedness
K-D	0.19**	0.09*	0.03	0.03	−0.03	0.02

Note: results are expressed as r values * denotes p = .046; ** p. = 0.00004.

score (F[2, 569] = 0.03, p = .97].

As noted in the statistical analyses, history of concussion was entered as a covariate for the ANOVA's comparing participants with LD and ADHD. There was a significant main effect for history of concussion (F[10, 1132] = 2.57, p = .005] suggesting a multi-variate effect. Players with a history of LD demonstrated poorer performances on all ImPACT domains, although results on the visual motor processing and reaction times domains did not reach statistical significance (see Table 3). Pairwise comparisons revealed that participants with a history of LD performed approximately 6.9 s slower on the K-D test (t [563] = 4.70, p. = 0.0003), a result consistent with findings of slower K-D scores in LD samples. In addition, players with a history of ADHD presented with statistically significantly slower performances (1.9 s slower) when compared to the non ADHD group (t[573] = 2.04, p. = 0.04).

Partial correlations (with LD and ADHD as covariates) revealed that the K-D test was significantly correlated with Visual Motor Processing, Visual Memory, and Reaction Time, although R-squared values were low (Table 4).

4. Discussion

This study was conducted to evaluate outcomes from K-D and ImPACT in professional football players with a history of LD and ADHD. Consistent with previous research, the K-D test demonstrated no significant effect for age, education, and previous history of concussion. In contrast, a history of LD and ADHD resulted in slower performance compared to athletes without disabilities. These findings have practical significance since, without knowledge that a player has ADHD or LD, a clinician may flag a baseline test as invalid or misdiagnose a concussion if no baseline CNT exists. Results from ANCOVA revealed small but significant differences for players with ADHD. The current findings determined the K-D is sensitive to underlying reading and attention difficulties and participants with these characteristics may be especially prone to poorer scores. Our results are consistent with a growing body of evidence that has consistently found differences in athlete samples for those who have a history of LD and ADHD with ImPACT testing ([7,26]. Thus, in the context of clinical sport concussion evaluations using the K-D test, players with a history of LD and ADHD require careful post-injury monitoring. Furthermore, it is important to interpret K-D results on an individualized basis, contextualized with an understanding of how a LD and/or ADHD diagnosis impact performance. This is especially important given that other research has linked propensity of players with a history of LD and ADHD to have increased risk of concussion (SRC) [21].

Results also found the K-D was significantly correlated with select domains from ImPACT but R-squared values were low suggesting little overlap between the cognitive abilities assessed by each test. Thus far the K-D test has been suggested to uniquely contribute to assessing clinical outcomes in athlete samples compared with other sideline testing tools. While it is not recommended as a standalone tool [20], results from this study suggested that it did not overlap significantly with the cognitive domains assessed by ImPACT. Due to the limited overlap between K-D and ImPACT cognitive domains, the K-D test may add unique information to the clinical outcomes associated with concussion.

Participants with a history of one or more concussions had higher scores on the verbal memory, visual motor processing, and reaction time indexes of ImPACT. These findings suggest likely practice effects with ImPACT testing given that players who had experienced a concussion were required to undergo post-injury testing and re-baselines the next year. In contrast, the K-D was introduced to only 4 teams in CFL in 2015 and most players had no previous exposure to the K-D test. Evaluation of practice effects would be helpful in the establishment of reliability of the K-D in athlete samples. While the K-D has been established as a measure that can discriminate individuals with LD from non LD, practice effects in athletes have not been well documented in the literature. It would be recommended that players with a history of LD and ADHD undergo multiple baseline tests to ensure adequate reliability consistent with other recommendations of CNT [3].

Participants with ADHD and LD reported significantly higher baseline symptoms of nervousness and feeling more emotional compared to other participants. Review of frequency counts suggested 5% of the ADHD sample reported feeling increased nervousness (compared with 1.4% in the other sample) and almost 8% of the ADHD sample reported feeling more emotional) compared with 2.4% in the other sample. In addition, participants with ADHD also reported significantly higher levels of concentration difficulties, with frequency counts suggesting 10% of the ADHD sample reported symptoms of greater than one for difficulties compared with 3.2% in the other sample but the

Table 3
ImPACT and King Devick tests descriptive statistics.

	Verbal memory	Visual memory	Visual motor	Reaction time	Impul. error	Symptom total	K-D score
Non LD (n = 546)	85.3[a]	75.7[a]	38.6	0.63	4.8[a]	2.0	43.9[a]
LD (n = 28)	79.5[a]	70.6[a]	36.5	0.63	6.3[a]	1.7	50.8[a]
Non ADHD (n = 497)	85.5[b]	76.1[b]	38.6	0.62	4.7[b]	1.8	44.0[b]
ADHD (n = 77)	82.2[b]	71.2[b]	37.7	0.64	5.9[b]	2.8	45.9[b]

[a] Denotes statistically significant differences between LD and non LD groups with history of concussions entered as a co-variate.
[b] Denotes statistically significant differences between ADHD and non ADHD groups with history of concussions entered as a co-variate.

Table 4
Partial correlations between K-D and ImPACT composite scores.

	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulsive errors	Symptom total
K-D	−0.08	−0.13[a]	−0.24[a]	0.12[a]	−0.04	0.04

[a] Denotes statistically significant differences at the 0.05 level with LD and ADHD entered as co-variates.

result did not reach statistical significance. While participants with a diagnosis of ADHD reported problems with concentration, the main differentiating symptoms were increased nervousness and feeling more emotional. The reasons for this finding were speculative, but it's possible that test taking situations were more distressing for individuals with ADHD.

Our study has limitations. First, data collection was retrospective and therefore vulnerable to several potentially confounding variables including recall bias. We relied on player report of a previous diagnosis of a LD and ADHD but due to confidentiality of test results, we could not verify this information with players. In addition, players in the CFL with a history of ADHD must meet special compliance measures to be granted permission to take stimulant medication. Thus, the baseline testing of these individuals was rigorous, but it is possible some players with previously diagnosed ADHD may no longer report this. In addition, there was no way of identifying whether athletes were taking medication at the time of their baseline assessments and whether taking medication had affected results from ImPACT and K-D. Second, the generalizability of these findings is limited to professional male football players and may not apply to female athletes or to other sports. Third, we depended on athlete disclosure for a history of concussion. Past research with this sample suggests reservations in disclosing concussions which may have influenced our data [22]. A prospective research design with a broader sample of athletes and gender would help to support the finding of this study.

In summary, the results of our study revealed that samples with previous learning and attention disorders demonstrate different outcomes on baseline measures of concussions (SRC). These differences suggest that collecting this information is paramount as it may affect cognitive test results used in baseline and diagnosing concussions. Individuals with a diagnosis of LD and ADHD may be more anxious when it comes to test situations, so ensuring that participants are reassured and explained the process of test taking is important. Continued study of athletes with modifying variables like LD and ADHD is needed to advance the understanding of SRC in special samples.

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