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King-Devick Performance following Moderate and High Exercise Intensity Bouts

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ABSTRACT

International Journal of Exercise Science 10(4): 619-628, 2017. The King-Devick (K-D) test is a concise, noninvasive assessment of oculomotor and cognitive function that has been shown to detect sub-optimal brain performance following sports head trauma. Used in a number of sports as a sideline concussion assessment tool, the K-D test can be administered by non-medical personnel. However, the issue regarding the effect of exercise on K-D performance has not been fully explored. Using a randomized crossover design, this study aimed to compare the effect of two intensities of exercise on K-D performance. Twenty males (21.2 ± 1.9 years) completed the K-D test prior to and after 15 min of either moderate (65% of age-predicted maximal heart rate) and high intensity (80% of age-predicted maximal heart rate) exercise bouts, separated by one week. Significant differences were found in working heart rate and ratings of perceived exertion consistent with exercise intensities. K-D performance did not change after moderate exercise, however a significant improvement (5.4%) was observed after high intensity exercise. Based upon these findings, it appears that high intensity exercise can influence test performance and administrators of the test need to be aware of the arousal state a player is prior to K-D test administration to ensure objective measurement.

KEY WORDS: King-Devick, exercise, ocular-motor performance

INTRODUCTION

There has been increased attention in sport-related concussion across the community in recent years (13). Despite greater awareness, sports-related concussion remains one of the most difficult injuries to diagnose (15); specifically with regards to sideline detection of concussive signs and indicators (19) reflecting neurophysiological alterations in the brain (2, 25). Obvious symptoms include headache, blurred vision, dizziness, nausea, balance problems, fatigue and feeling 'not quite right' (27). Other less common features include confusion, memory loss and reduced ability to think clearly and process information. Loss of consciousness occurs in 10-20% of cases (6).

In response to the growing concern, many national sporting organizations have implemented policies to address concussion, particularly at the elite/professional levels. When a player is suspected of sustaining a concussion, they are required to complete a sideline concussion assessment. There are a number of different sideline assessments with the best utilized of these being the Sports Concussion Assessment Tool Version 3 or SCAT3 (21, 30). However a number of sports, for example the combative sports of boxing and mixed martial arts (7), ice hockey (10), rugby league and rugby union (13, 14), employ a sideline cognitive assessment tool known as the King-Devick (K-D) test.

Originally developed as a reading tool to assess the relationship between oculomotor function and reading ability (11, 23), the K-D involves saccadic eye and other eye movements, reading random single-digit numbers out loud from left-to-right, down the 15.2 x 20.3 cm (6 x 8 inch) page. There are three cards (called trials) of increasing difficulty. The time for each card is recorded and the K-D summary score for the three cards is based upon the total time plus any errors made during the reading of the tasks (7). The complete test, takes no more than two minutes to finish.

The test-retest reliability of the K-D test has been presented in multiple studies (9). The systematic review by Galletta et al (8) has reported high levels of reliability across a range of sports, where the K-D has been tested in the absence of head trauma, with an intraclass correlation coefficient (ICC) of pooled studies of 0.92). The systematic review by Galetta et al (8) also demonstrated the reliability of the K-D to be delivered by both medical personnel and laypersons. For example, in fighting sports (boxing and MMA) intraclass correlation coefficient (ICC) values have ranged from 0.95 to 0.97. Similarly, high levels of test-retest data have been observed when parents administered the K-D test in boxers (ICC: 0.90).

With high reliability and the ability of the test to be delivered by non-medically trained personnel, the K-D assessment is becoming a popular sideline assessment tool for concussion. However, the issues regarding learning effects and the effect of exercise influencing K-D performance, are questions that are continually asked about the test. Whilst mild learning effects is acknowledged to occur and forms part of the familiarization protocol (see review [8]), the effect of exercise on K-D outcomes require further exploration. To date, limited studies have reported an improvement in K-D performance after 'vigorous' or 'intense' exercise (8, 12, 17). However, whilst these studies showed improvements in the K-D test, they were essentially field-based studies, lacking comparative exercise intensity as well as quantifying the levels of exertion. Apart from the study by King et al (12) that reported perceived exertion, previous studies did not control the level of exercise performed.

The aim of this study was to extend on these initial findings (8, 12, 17), as well as test Davey's model of exercise-arousal-cognition (5) that suggests moderate intensity exercise (~60-70% of heart rate max), inducing an optimal level of arousal, would improve cognitive performance compared to low (<60% of heart rate max) and high intensity (>70% of heart rate exercise). The objective of this study was to compare two levels of exercise (moderate vs high), using heart rate intensity and Borg rating of perceived exertion (RPE) (3), and its influence on post-exercise K-D test performance. Whilst Galetta et al suggested that 'vigorous' exercise is associated with mild learning effects (9), based upon Davey's model (5) and a meta-analysis of cognitive performance following exercise (22), we hypothesized that comparing K-D test performance with two different levels of exertion, would improve following moderate but not high intensity exercise bouts.

METHODS

Participants

Twenty male athletes from one elite Australian Rules football club (21.2 ± 1.9 years; 184.5 ± 6.6 cm; 79.5 ± 5.8 kg) were recruited to participate. Inclusion criteria required participants to be currently listed Australian football players, who were regularly training on a daily basis as part of their professional contractual arrangements and no limitations including, cardio-vascular, eye-sight or neurological issues; injury (including concussion with the previous 6 months) or illness that would impede exercise or K-D performance. Prior to testing, participants signed an informed consent, approved by the Institutional Human Research Ethics, and all testing protocols followed procedures in accordance with the Declaration of Helsinki.

Protocol

Using a randomized counterbalanced-crossover design, participants completed an initial K-D test, along with recording of resting heart rate and RPE. The participant was then randomly assigned to exercise for 15 min at either a moderate intensity (65% of age-predicted maximal heart rate) or high intensity (80% of age-predicted maximal heart rate) exercise bout using the calculation of (220-age) x 0.65 or (220-age) x 0.85 as per the American College of Sports Medicine guidelines (1). The exercise bouts were completed at the same time, prior to the players' afternoon training session, on the same day, one week apart. Players were instructed to maintain their normal dietary intake, as prescribed by their team dietician, between testing sessions.

Exercise bouts were completed on a cycle ergometer (M3 Indoor Cycle, Keiser Corporation, USA) whilst participants wore a heart rate monitor (Polar Electro Oy, Finland). Participants were not fasted, and euhydrated (>1.015 $g.ml^{-1}$) by hand–held urine refractometry (Atago Co. Japan) (24, 29), and instructed to wear normal exercise clothing. Players were instructed to use the first five minutes to 'warm-up' with gradual increase of heart rate to the targeted heart rate by the 5^{th} minute (26). The following 10 minutes, participants where instructed to maintain a steady-state heart rate at their calculated intensity (either being moderate intensity at 65% of predicted heart rate maximum (HR_{max}), or high intensity of80% HR_{max} (1). At each 5^{th} minute, player's heart rate and RPE was collected. Players were permitted to drink water during the exercise bouts, and at the completion of the exercise, players were re-tested on the K-D test.

Statistical Analysis
All data was pre-screened using Shapiro–Wilk tests, and found to be normally distributed. Levene's test for all variables was found to be non-significant. A two-way ANOVA with repeated measures was used to compare the effect of exercise intensity over time. When ANOVA detected differences, paired comparisons (with Bonferroni adjustment) and Cohen's d effect sizes (4) between groups at each time point were undertaken (trivial [>0.2], small [0.21–0.5] medium [0.51–0.8] and large [>0.8]). Alpha was set at $p<0.05$, and all data is presented as group mean (±SD).

RESULTS

All participants completed both testing sessions without incident. Differences in working heart rate between the two exercise intensities were observed with significant condition by time interaction between the moderate and high exercise bouts ($F_{3,114}$=56.74, $p<0.001$; figure 1).

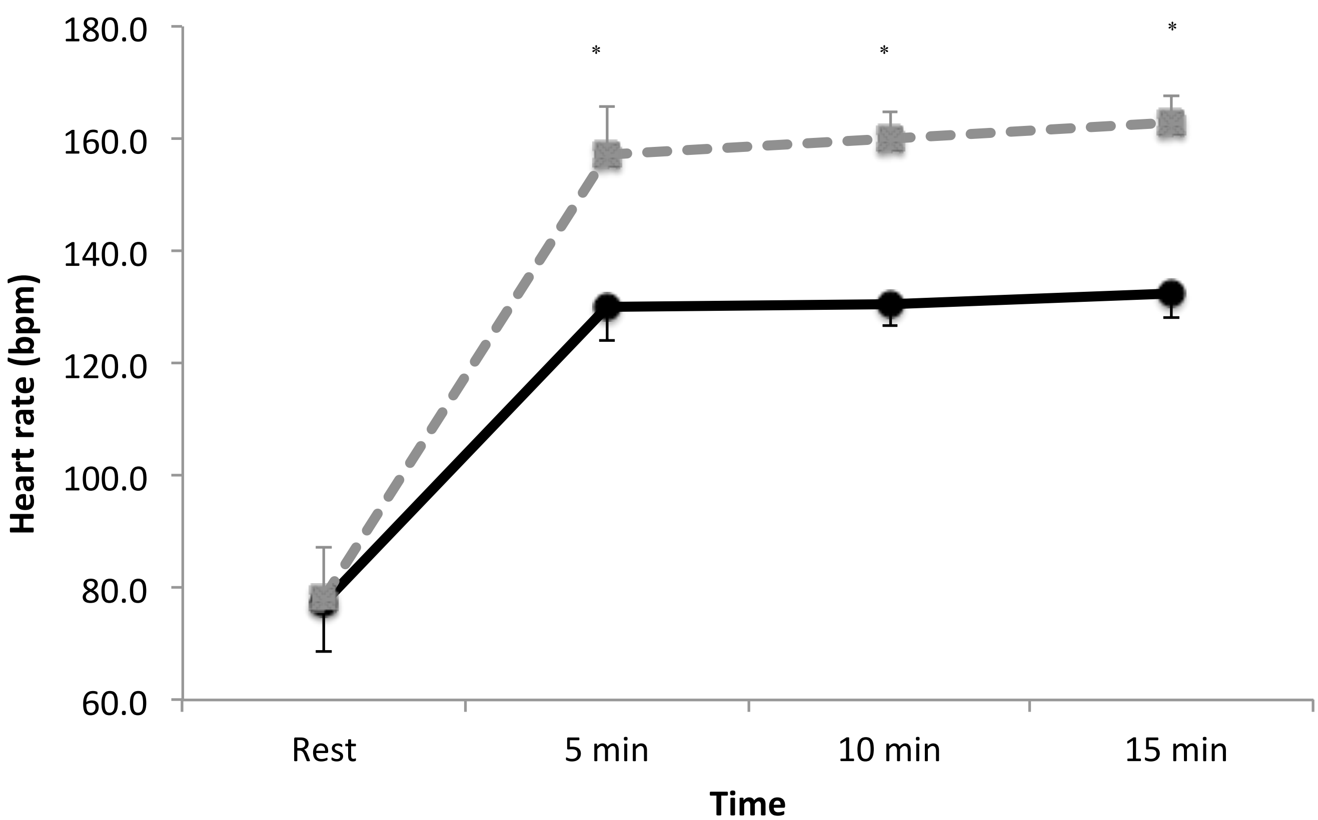

Figure 1. Mean (± SD) heart rate (HR) changes during the exercise intervention with the black line representing moderate intensity and the broken grey line the high intensity. Significant differences (represented by asterisk) in working HR were observed between the moderate and high intensities (p<0.001).

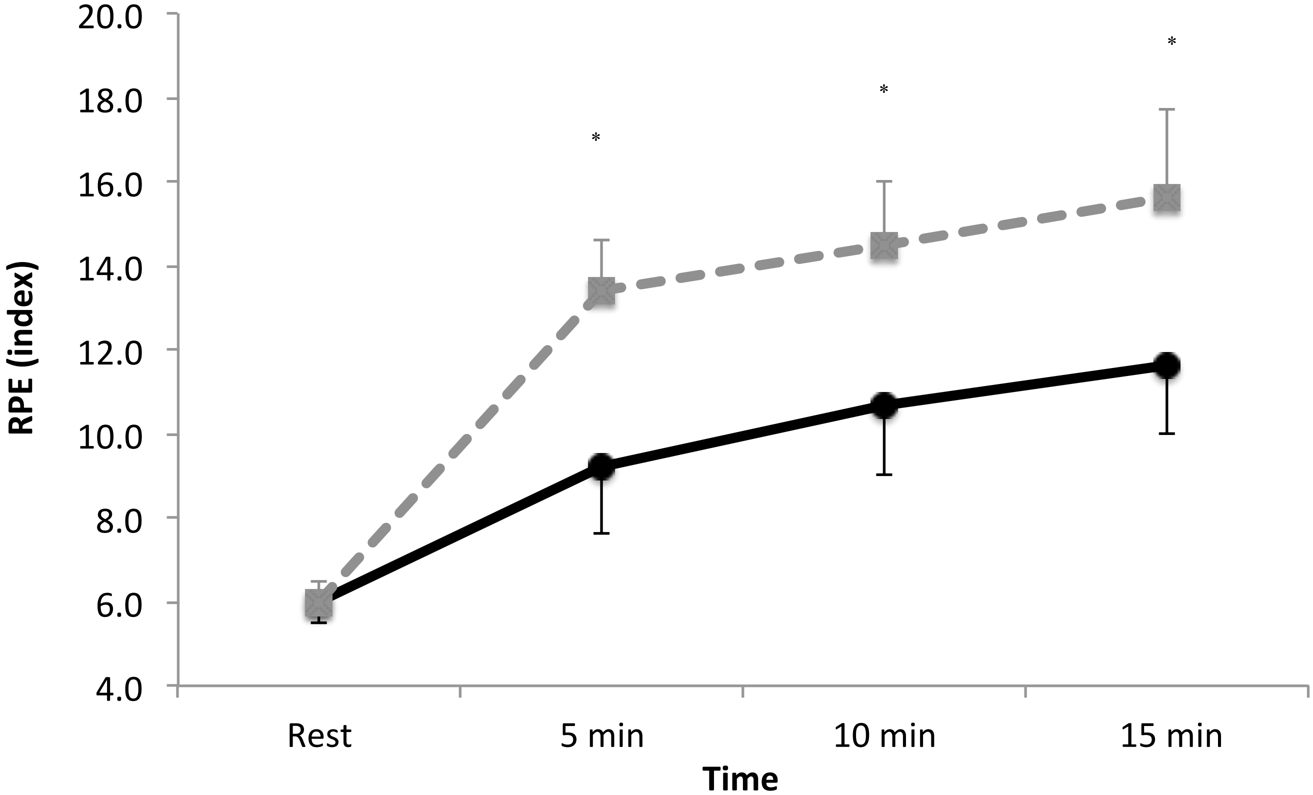

Figure 2. Mean (± SD) rate of perceived exertion (RPE) responses during the exercise intervention. Black line representing moderate intensity and the broken grey line the high intensity. Significant differences (represented by asterisk) in RPE were observed between the moderate and high intensities (P<0.001).

Similarly, differences in RPE responses (figure 2) were found with a significant condition by time interaction between the moderate and high exercise bouts ($F_{3,114}$=32.08, *p<0.001*; Figure 2).

K-D test performance is shown in table 1, which presents the summary score (total time) to complete the three trials. No errors were made by any of the players in any tests. There was a significant condition by time interaction between the moderate and high exercise bouts ($F_{1,38}$=8.71, *p=0.005*). Bonferroni adjusted post hoc comparisons showed no differences between K-D tests for moderate and high conditions in at baseline (t=1.71, *p=0.11, d=0.2*). A 0.5 s difference was observed in K-D performance following the moderate exercise intervention (t=1.31, *p=0.20, d=0.12*); however there was a significant improvement (2.2 ± 1.8 s) in K-D performance following the high intensity exercise bout (t=5.09, *p<0.001, d=0.44*).

Table 1. Mean (±SD) King-Devick score for moderate and high intensity exercise pre and post intervention.

Intensity	Pre score	Post score
Moderate	38.1 (±3.3)	37.7 (±4.6)
High	39.3 (±5.5)	37.1 (±4.7)*

* *p<0.001*

DISCUSSION

The aim of this study was to extend on the original work by Galetta et al. (8) by examining the effect of exercise intensity on K-D performance. Our finding that K-D performance was improved following 15 min of high intensity (80% of predicted maximal hear rate) exercise rather than moderate intensity (65% of predicted maximal heart rate) exercise did not support our hypothesis, but did support the original findings and data presented in a recent review by Galletta et al. (9) suggesting K-D performance is improved following intense exercise.

The improvement in K-D performance in the present study was slightly higher than reported in a recent systematic review that calculated from three field studies (8, 12, 17), a mean improvement of 1.4 s (95% CI: 2.1, 0.8) (9). Whilst their findings demonstrate improved K-D performance, these studies were single group cohorts exploring the effect of exercise without necessarily controlling for intensity. For example the original study by Galetta et al (8) showed an improvement of 3.6 s in median times between pre and post exercise K-D performance following an 'intense' two-hour basketball training session. Leong et al (17) reported in collegiate basketball athletes a median time improvement of 4.1 s following a 2.5 hour sprint training session. In both these studies the intensity of exercise was not documented. Conversely, King et al (12) found, in elite amateur rugby union players, a mean improvement of 1.2 s post exercise following a repeated high-intensity endurance protocol, that was quantified by a mean RPE group score of 16.6 ± 3.3.

Whilst our results concur with previous research (9), our findings showing improved K-D performance after the intense exercise was nonetheless contrary to our hypothesis. Improvements in cognitive performance following moderate levels of exercise are a well-known phenomenon (16, 22). The meta-analysis by McMorris and Hale (22) revealed that exercise has a significant mean effect on cognition ($g = 0.14$, $p < 0.01$). Specifically, these authors found that speed of cognitive processing contributed towards significant improvement following moderate intensity exercise, compared to low and high intensities, which did not show significant improvement, supporting Davey's model of exercise-arousal-cognition (5).

In the present study, we wanted to not only extend on studies outlined in the review by Galetta et al (9), but also test the findings by McMoris and Hale (22) as well as Davey's model (5); therefore it was important to us to compare the effects of moderate and high intensity exercise on K-D performance.

A possible reason to account for improved K-D performance following high intensity exercise may be due to the simplicity of the task itself. Classic cognitive tests quantify processes such as inhibition, working memory, mental set shifting; or more complex tasks such as planning, abstract thinking, or cognitive flexibility (22). Conversely, the K-D tests measures oculomotor function with the primary measure is the speed of reading the digits, and a secondary measure being any errors in reading (9). In line with model of arousal-performance (5, 31) complex tasks require lower levels of arousal. Therefore, as more complex cognitive test performance would respond to moderate intensities of exercise, less complex tests, such as the K-D, would show improved outcomes following higher arousal levels with intense exercise. Further, it has been posited (22) that the level of exercise affects neurotransmitter activity influencing cognitive processing speed; lower intensities of exercise may not allow for enough neurotransmitter activity to facilitate improved processing, whilst optimal intensity exercise would lead to much greater release of neurotransmitters, creating excitation of cortical activity impacting on cognitive performance (22).

Whilst the present study, completed under controlled laboratory conditions, supports previous findings (8) and can be interpreted as not affecting the test (9), we suggest that the improvement in K-D scores, post exercise, could be misinterpreted by those naïve in administering the test as players 'sandbagging' (deliberately under-performing) their baseline performance (28). Given the SCAT3 that has an explicit instruction "…to be done in resting state. Best done 10 or more minutes post exercise" (20), we suggest that a similar rest period is undertaken to allow for any hyper-arousal state to diminish, prior to screening for concussion or subconcussion effects. Future research will explore the effect of a rest period following exercise on K-D performance.

Several limitations of the research should be acknowledged and inform future research designs. We used a crossover design with random allocation for the intensity of exercise to reduce between-participant variability (18). Whilst this design, where the individual completed the same test, may affect the K-D performance through familiarization (9), we ensured that it was not possible to learn the test by providing a one-week washout between testing sessions to reduce potential carry-over learning effects. We are confident that our findings accurately reflected the conditions being explored and not the design employed, as differences were not found in the pre-testing data between the two exercise intensities.

Another limitation of this study is the translation of the statistical improvement in K-D performance post high intensity exercise to clinical meaningfulness. In other words whilst being not statistically significant, we are unable to describe the difference in baseline scores between groups (1.2 s) in terms of clinical value, particularly when the high intensity condition showed a 2.2 s decrease in time, and the moderate intensity showed a decrease of 0.4 s. The systematic review and meta-analysis by Galetta et al. (9) revealed high sensitivity for the K-D to distinguish concussed versus non-concussed athletes and showed that the K-D demonstrated the ability to detect concussion when athletes *increased* their time (worse performance) compared to baseline. These authors suggested that the data from their pooled studies showed that worsening of K-D times (compared to baseline) is an accurate and sensitive indicator of concussion, but the variability of studies in their analysis emphasizes the importance of comparing an individual's data to their baseline and not to normative values.

Further suggestions for future research should also look at the effect of low intensity exercise (to compliment this study comparing moderate and high intensity), and longer durations of exercise, in simulating match conditions; but also the effect of intermittent exercise bouts, which would similarly create a more realistic environment in lab controlled conditions.

In conclusion, the K-D test is a reliable test sensitive to the detection of concussion injuries. However, our findings of improved K-D performance with high intensity but not moderate exercise, warrant further investigation in order to ensure that improvements in K-D test outcomes are not misinterpreted or disadvantage an athlete when being screened by the field of play.

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