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ACUTE EFFECT OF A PHYSICAL EXERCISE SESSION ON COGNITIVE FUNCTIONING: MODERATELY ACTIVE SPORTSPERSONS VERSUS SEDENTARY INDIVIDUALS

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ABSTRACT

In sport, physical activity (PA) and life in general, cognitive functioning plays a very important role in decision-making and performance. This study investigated whether the relationship between acute exercise and cognitive performance was beneficial and if there was a difference in this relationship between moderately active individuals and sedentary individuals. The acute effect of exercise on cognitive function was measured by means of the Stroop Test. The male participants (N=30; Age= MEAN±SD & range=18-25yrs) completed: (1) a trial Stroop Test; (2) a baseline Stroop Test; (3) a repeated sprint test; and (4) a final Stroop Test. The moderately active sportspersons were significantly (p<0.05) fitter than the sedentary group as they covered a greater distance during the Repeated Sprint test. There were significant differences (p<0.05) within and between groups, regarding pre- and post-Stroop Test performance. The moderately active sportspersons performed significantly (p<0.05) better in reaction time (RT) and in accuracy compared to the sedentary group. There was a beneficial relationship between acute exercise and cognitive performance and this relationship differed between moderately active sportspersons and sedentary individuals.

***Key words*:** Physical exercise; Cognitive functioning; Stroop Test; Repeated sprint test; Sedentary individuals; Moderately active sportspersons.

INTRODUCTION

In sport, PA (Physical Activity) and life in general, cognitive functioning plays a very important role in decision making and performance. In many sport events, participants have to simultaneously perform mechanical work with great physical demand and accurately perform decisional or perceptual tasks (Chang *et al*., 2014). Optimal cognitive functioning is, therefore, very important in a sportsperson's ability to be the best that he/she can be. Cognition or cognitive functioning refers to how individuals process sensory information, such as reasoning and memory, which all individuals require for daily activities (Neisser, 1967; Puente *et al*., 2016). Therefore, optimal cognitive functioning and its importance is not only applicable in sport but in the daily lives of individuals (Fitzsimmons *et al*., 2014).

Accumulation of recent research has indicated that exercise induces neuroplasticity, memory acquisition and specifically motor cortex plasticity. Kleim (2011) defines neuroplasticity as the capacity of neurons to structurally and functionally adapt. Plasticity is, therefore, the strengthening of certain neural pathways. In a review on selected biomedical and clinical studies, Ploughman (2008) postulates that exercise increases brain volume in specific regions implicated in executive processing and functioning. In the study of Ploughman (2008), involving 59 adults (aged 60 to 79), there were specific increases in the volume of the frontal lobe involved in higher order processing, memory and attentional control due to moderate aerobic exercise participation. The participants were involved in a six-month aerobic intervention that took place three times a week for 60 minutes.

Executive functioning is an umbrella term used to describe cognitive processes that are goal-orientated and the ability to adapt to changes within the environment or changing situations (Huizinga *et al*., 2006; Koziol & Lutz, 2013). Executive functioning is a critical high-level processing system that is involved in the orchestration of human cognition and action (Hogan *et al*., 2013). Executive functioning also involves goal-directed behaviour and controls multiple aspects of basic cognitive processes (Chang *et al*., 2014).

On the other hand, PA refers to any bodily movement produced by skeletal muscle that requires energy expenditure (Fitzsimmons *et al*., 2014). Research has shown that regular PA has a beneficial effect on cognitive functioning in individuals (Hogan *et al*., 2013). According to Colcombe and Kramer (2003), the benefits of PA are largely observed in executive functioning. Research has shown that although PA has cognitive benefits, these benefits differ when it comes to acute and chronic exercise (Pesce *et al*., 2011; Tomporowski *et al*., 2015).

Chang *et al*. (2014) argues that in various studies the effect of acute exercise on the cognitive performance of individuals has been well documented. In fact, from 1930 up to 1999, more than 200 studies have been executed on the influence of acute physical exercise on cognitive processes (Brisswalter *et al*., 2002). In the study by Pesce *et al*. (2011), in which 16, 60- to 80-year-old cyclists and 32 age-matched non-cyclists (16 endurance athletes and 16 sedentary individuals) performed a go/no-go reaction time task, it was found that with acute bouts of exercise, reaction time (RT=the time elapsing between a stimulus (visual or auditory) and the beginning of the reaction to that stimulus), improved in those individuals who took part in the exercise, compared to those who did not. Tomporowski *et al*. (2015) report similar results that were conducted on children. According to Hogan *et al*. (2013), cognitive performance was enhanced during, immediately after and after a delay of up to 20 minutes of acute bouts of exercise, once again showing the positive effect of acute exercise on cognitive performance. According to Cȯrdova *et al*. (2009), both executive functioning and alertness are directly and simultaneously enhanced by acute exercise.

The reason for this improvement in cognitive performance, according to Yanagisawa *et al*. (2010), is due to the acute bout of moderate exercise, which corresponds with increased activation in the left dorsolateral prefrontal cortex. It should be noted that increased serum levels of the brain-derived neurotrophic factor, neuro-electrical activation following acute exercise, were found in individuals who ranged in fitness from sedentary to highly trained adults. This study was conducted in Taiwan with 36 (25 males and 11 women) college-aged adults (Chang *et al*., 2014).

According to McMorris and Graydon (1996), sportspersons process information and make decisions at a faster rate during moderate or vigorous PA. They stated that sportspersons can perform more cognitive functions under great physical demands efficiently. Therefore, this, suggests that sportspersons have better cognitive functioning. It seems as if fitness levels are directly linked to the level of executive functioning. In a study performed on 28 males in Spain (14 students; age range=17 to 23 years) with low fitness and 14 young male adults with high fitness levels (age range=18 to 29 years), Luque-Casado *et al*. (2013) found that highly-fit individuals possessed faster RT in a psychomotor task, as well as greater heart rate changeability, therefore, attributing their better executive functioning to their higher fitness levels. This raises interest in whether it is indeed the case that regular aerobic exercise increases executive functioning (Luque-Casado *et al*., 2013).

According to Córdova *et al*. (2009), many studies using animal models and the effects of chronic aerobic exercise on the brain, have suggested that taking part in regular chronic aerobic exercise may also stimulate neurogenesis and synaptogenesis and, therefore, improve cognitive function and learning in individuals. In addition to this, it also leads to an increased amount of cortical capillaries and levels of the brain-derived neurotrophic factor (Córdova *et al*., 2009). Other studies on animal models highlight possible mechanisms through which exercise may influence neurological development, increase neurological efficiency and enhance cognitive performance (Hogan *et al*., 2013). The processes of neural adaptation induced by exercise comprise an increase in regional blood flow, promotion of brain vascularisation, a rise in levels of brain-derived neurotrophic factor, as well as up-regulation of genes associated with cellular plasticity (Hogan *et al*., 2013). As a result of these neuro-plastic changes, Hogan *et al*. (2013) argues that brain function is more efficient and adaptive, thereby, supporting better learning and performance in animals. The findings of Hogan *et al*. (2013) are not only found in animals and have been widely confirmed in human studies and also highlight the benefits of chronic aerobic exercise (Hogan *et al*., 2013).

The study by Hogan *et al*. (2013) indicate the importance of the physical fitness levels of adolescents as it relates directly to executive functioning (Hogan *et al*., 2013). It has been suggested that higher levels of physical fitness coincide with higher levels of executive functioning (Chaddock *et al*., 2011). This suggests that the promotion of participation in regular PA, leading to higher levels of physical fitness, can improve executive functioning and cognitive processing (Chang *et al*., 2014).

As mentioned, there is a difference in the effect of chronic exercise bouts compared to acute bouts. The same could be said about the effect acute exercise has on trained as compared to untrained individuals. According to Chang *et al*. (2014), given the improvements in cognitive performance and the beneficial changes in the cerebral structure and function that have been shown to result from exercise, it is likely that individuals who are active may receive different benefits from an acute bout of exercise as compared to individuals who are less active. Pesce *et al*. (2011) agree with this and report that while favourable acute exercise effects were found in both trained and sedentary individuals, the greatest benefits were experienced by trained individuals.

According to a study conducted by Fontana (2007), the amount of experience in physical activity is a significant factor in explaining the better cognitive abilities, such as increased speed of decision-making and accuracy. Thirty-two subjects, 16 experienced (mean age=21.1yrs) and 16 inexperienced (mean age=19.5yrs) college male soccer players at a university in America participated in the study. Different exercise intensities were used and interestingly it was found that it had no significance in the relationship between the level of accuracy and the exercise intensity when accuracy and speed were not considered separately. When testing experienced and inexperienced soccer players, Fontana (2007) found that the experienced players, with a higher physical activity level, had faster and more accurate decision-making skills than the inexperienced players. Therefore, it is suggested that experienced sportspersons have increased and faster decision-making abilities than non-sportspersons.

A meta-analysis by Chang *et al*. (2012) examined moderator variables which were deemed particularly relevant to acute exercise. The authors included exercise intensity and duration, timing of the cognitive task administered, exercise mode and cognitive task type and came to the conclusion that these mediators will, therefore, have an effect on the results being measured. Mediators and the affect they have on cognitive functions should not be observed in isolation as each variable has the potential to influence another variable (Tomporowski *et al*., 2015). For example, brain-derived neurotrophic factor response to exercise (as is seen during high intensity exercise), is dependent on the level of training of the participant (high-fit versus low-fit), with the former having higher levels of brain-derived neurotrophic factors than the latter (Ferris *et al*., 2007).

Tomporowski (2003) suggests an inverted-U hypothesis, which states exercise intensity will influence the size of the effect. It suggests that moderate intensity exercise will have the greatest benefits. The drive theory, as mentioned by Chang *et al*. (2012), suggests that the greatest benefits will be observed with high intensity bouts which are contrary to Tomporowski (2003). Chang *et al*. (2012) postulates that exercise intensity did not have a significant effect on cognitive performance assessed during exercise, but when cognitive performance is assessed following exercise there is an effect depending on when it is taken after the bout. When performed immediately following exercise, lighter intensity exercise will more likely show a positive result, however, when performed following a delay of more than one-minute, more intense exercise will more likely show a positive result (Chang *et al*., 2012). According to the meta-analysis performed by Chang *et al*. (2012), durations of at least 20 minutes of exercise are necessary to observe positive effects on cognitive performance; this is contradictory to other studies, such as Brisswalter *et al*. (2002) and Chang and Etnier (2009), which state that shorter durations elicit benefits.

The timing of the cognitive test administered is another important variable especially when viewed alongside variables, such as intensity. In a test administered during high intensity work, scores will be lower as the participant needs to focus on performing the PA. This can also be seen when comparing low-fit individuals to high-fit individuals (Chang *et al*., 2012). Neural resources, which are used when performing PA, compete with the same resources used to perform cognitive processing (Chang *et al*., 2014). Lower-fit individuals require more resources when conducting PA and thus have fewer resources available for cognitive performance (Chang *et al*., 2014). According to Chang *et al*. (2012), the type of cognitive task used to assess the effect of an exercise bout should be considered. A large beneficial effect has been found on motor skills and academic achievements, whereas a negative effect was seen on tasks relating to reasoning and verbal skills.

From the literature it can be derived that more research is needed on cognitive functioning with regard to the influence of exercise and the fitness level of the individual.

PURPOSE OF THE STUDY

Numerous studies have shown that exercise and especially acute bouts of exercise has a beneficial effect on cognitive performance (Hogan *et al*., 2013). More recently, however, a study by Chang *et al*. (2014) has shown controversial results. They found that after an acute bout of exercise, individuals with high fitness levels had poorer executive functioning in comparison to those with low to moderate fitness levels. Therefore, this study set out to attempt to determine whether there indeed was a beneficial relationship between acute exercise and cognitive performance and if there was a difference in this relationship between moderately active sportspersons and sedentary individuals.

METHODOLOGY

Ethical clearance

This study was submitted to the Research Ethics Committee of the university in question for ethical clearance. Permission from the Division for Institutional Research and Planning and from the residing residence head were sought, with regard to whether or not the students living in the residence could volunteer to participate in the study. Permission was also granted by the Sport Bureau of the university in order to ask players of various sporting codes of the university's top sport teams to volunteer to be part of this study. Participants were informed that they could withdraw from the study at any time if they wish to do so without being penalised.

Research design

The current study used a one-time cross-sectional design, which made use of an acute test (independent variable) to determine whether a specific outcome (dependent variable) occurs as a result of the test being implemented.

Participants

Bona fide male university students (N=30) between the ages of 18 to 25 years were asked to volunteer. Male students from a selected residence at the university (sample of convenience for financial and other logistical reasons) served as resource. A sample (n=15) that did not participate in any form of physical activity was randomly selected from this residence to participate in the study. Moderately active male students (n=15) were randomly selected from the university sport teams from various sport codes. The students (n=15) recruited from the university residence were the 'sedentary' individuals. According to Pescatello (2014), sedentary individuals are classified as those who do not participate in at least 30 minutes of moderate intensity physical activity (40%-<60% VO2 R), on at least 3 days of the week for at least 3 months. The participants (n=15) from the various sport teams were sportspersons who played for a Maties First Team or any sport team affiliated with a Maties club and who trained >3 times a week for at least 60 minutes. Participants all had to have normal vision, corrected-vision and normal colour vision. This was specified in the informed consent form that each participant had to sign. Participants who had injuries were excluded from the study. The same applied to individuals claiming to be sedentary. Students with chronic illnesses and/or disability, including those diagnosed with dyslexia, those who did not have corrected-vision or normal colour vision were also excluded.

Procedures on testing days

Upon arrival, participants were given a brief explanation of what the Stroop Test consists of, as well as how it worked and what they must do to complete the test. They could complete the test in their mother tongue, namely English and/or Afrikaans. Participants meeting the inclusion criteria were asked to complete 3 trials of the Stroop Test, the first being a practice trial for familiarisation and the second being Test 1 (Baseline). After completing Test 1, participants performed the repeated anaerobic sprint test, as described in Figure 1. Participants underwent a warm-up before commencing the test. The repeated anaerobic sprint test consists of 6, 35m-sprints at maximum pace with a 10-second rest period to allow the participants the time to turn around and rest. Directly after completing the repeated anaerobic sprint test, participants were asked to complete the Stroop Test for the third and final time.

Measurement instruments

International Physical Activity Questionnaire (IPAQ)

The IPAQ was developed in 1998 with 2 versions, a short 9 items and a long 31 items, to determine PA patterns of healthy individuals. It has satisfactory reliability in determining the level of PA of healthy individuals (Hagströmer *et al*., 2005). The English long, self-administered questionnaire was used as it is feasible, acceptable and easy to complete by the participants. The long, self-administered questionnaire consists of 4 areas of PA: work-related activities; transportation; leisure time activities; and gardening/domestic activities. It also consists of questions related to time allocated to sitting, which contributes to sedentary activity and behaviour. The responses consist of scores which are categorised into low, moderate and high levels of PA. The IPAQ was used prior to classifying the participants into the respective groups namely, sedentary or active. This was done according to their PA level, as determined by the IPAQ.

Stroop Test

The Stroop Test that was used to measure cognitive performance was developed by John Stroop in 1935. Although the Stroop Test is 81 years old, it is a quick measure that is used regularly in screening for executive function deficits (Homak & Riccio, 2004). According to Homak and Riccio (2004:729), "research suggests that temporal reliability of the Stroop Test is good ($r>0.80$; O'Connor *et al*., 1988; Sacks *et al*., 1991; Graf *et al*., 1995), with some practise effects evident consistently across all 3 tasks (Feinstein *et al*., 1994)". Malek *et al*. (2013) found that RT and error of almost all cards of the Stroop were reliable and had a good differential validity. Their findings were similar to the reports of good reliability by Sacks *et al*. (1991, cited in Homak & Riccio, 2004), Feinstein *et al*. (1994, cited in Homak & Riccio, 2004), and Graf *et al*. (1995, cited in Homak & Riccio, 2004), who found a reliability higher than 0.80 for scores obtained in the Stroop Colour-Word Test.

Factor analysis is one method to determine construct validity (Homak & Riccio, 2004). According to Graf *et al*. (1995, cited in Homak & Riccio, 2004:729), the "Stroop performance loaded on the same factor as the Block Design, Digit Symbol, Similarities, and Digit Span subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981)". Shum *et al*. (1990, cited in Homak & Riccio, 2004:729), established that the Stroop loaded with sequential deduction tasks. Congruent and incongruent trials of the Stroop Test were used and RT was measured in order to determine whether acute exercise affects cognitive function directly. In the test, individuals were asked to name colours which are randomised with words that are superimposed with the same colour ink but different spelling (McCleod, 1991). For instance, there could be a blue circle with the spelling inside spelling out ‘red’, this is known as an incongruent trail. The goal is to ignore irrelevant cues (spelling), and focus on the task relevant cues. Imaging methods including Positron Emission Tomography and Magnetic Resonance Imaging have demonstrated that the Stroop Test activates the subject’s frontal lobe during the task (Smith & Jonides, 1999).

The two main areas of the frontal lobe that are activated are the Dorsolateral Prefrontal Cortex (DLPFC) and the anterior cingulate cortex (ACC). Both these areas have been shown to be responsible for conflict resolution and monitoring (Adleman *et al*., 2002). When there is an influx of competing information, the ACC activates to allocate attention resources and select appropriate responses. The DLPFC, on the other hand, is more responsible for reducing attention conflict. The DLPFC reduces the influence of irrelevant information affecting task performance (Adleman *et al*., 2002).

Repeated Sprint Test (RST)

The RST was used as the acute anaerobic exercise performed between the administration of the pre- and post-Stroop Test.

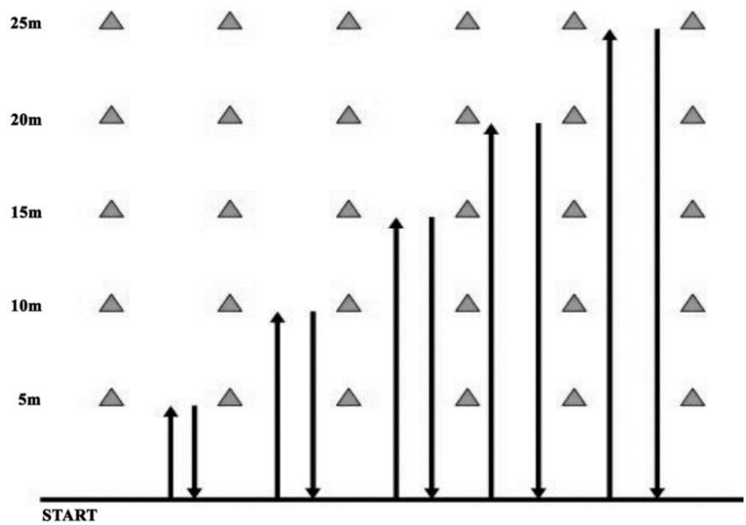

Figure 1. **REPEATED SPRINT TEST**

The repeated sprint test cones are placed 5m apart, up to 25m. The participants: (1) start by running to cone 1, 5m away, and then run back to the start; (2) followed by running to the second cone, 10m away, and then back to the start; (3) then to cone 3, 15m away, and then to the start; (4) then cone 4, 20m away, then back to the start; 5) then to cone 5, 25m away, then back to the start. The participants had 30 seconds to run as far as possible and then had a 35-second rest period. This procedure was repeated six times (Bucheit *et al*., 2010). Regarding the validity of the RST, Bishop *et al*. (2001) postulates that correlation coefficients between dependent variables were calculated using Pearson's Product Moment (r). There was a significant correlation between power decrement during the 5 x 6s cycle test and decrement in 15-m time across the three periods (r=0.76; p<0.05), but not decrement in 10-m time (r=0.54) or 5-m time (r=0.42). These results suggest that the 5 x 6s cycle test is valid for assessing the decrement in 15-m time, but not the decrement in 5m or 10m time. The typical error of measurement (TE) was used to assess the reliability of the test variables. The TE for the total sprint time was 0.7% (95% CL, 0.5-1.2%) indicating that it was very reliable (T1: 26.79±0.76s versus T2: 26.83±0.74s). Yet, the percentage sprint decrement was less reliable (T1: 5.6±0.9% versus T2: 5.8±1.0%), with the TE being 14.9% (95% CL, 10.8-31.3%) (Spencer *et al*., 2006).

Statistical analyses

All values were computed as means and standard deviations. An unpaired *t-test* was used to determine the differences in the distance covered in the repeated sprint test between the moderately active and the sedentary groups. To assess the effects of the acute exercise bout on cognitive performance on the Stroop conditions, a paired *t-test* was used to analyse the seconds it took both the moderately active and sedentary groups to respond to the Stroop conditions. The mean and standard deviations were used for only one congruent condition (pre-colour blocks and post-colour blocks), and one incongruent condition (pre-mixed question and post-mixed). An alpha of 0.05 was used as the target level of statistical significance.

RESULTS

Repeated Sprint Test Performance

The *unpaired t-test* revealed that the active group (691.66m±0.965, p<0.05) covered a statistically significant greater distance compared to the sedentary group (613.33m±11.902, p<0.5) during the repeated sprint test (Figure 2).

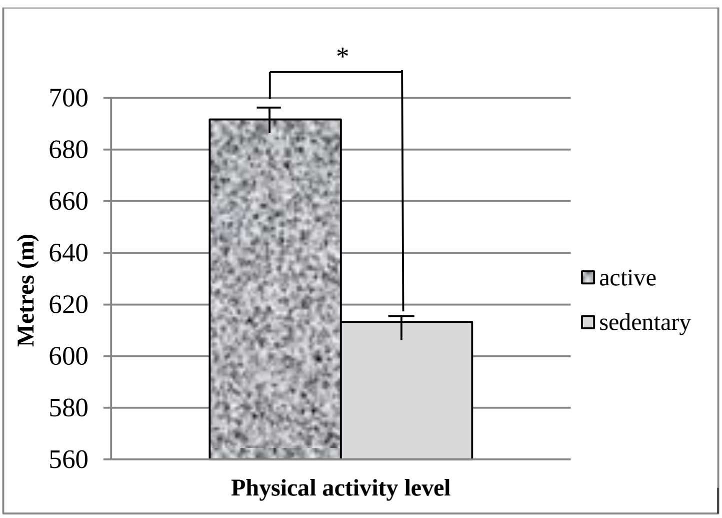

Figure 2. **TOTAL DISTANCE COVERED IN REPEATED SPRINT TEST** (*=p<0.05)

Stroop Test Performance

Reaction time (RT)

Figure 3 presents the performance of the Stroop Test between pre- and post-tests for both the moderately active and sedentary groups. A shorter RT represents better performance. Data is presented as means. Results of the *paired t-test* revealed that each group made a statistically significant improvement in RT between the pre- and post-tests ($p<0.05$). The results reveal that the active group performed better than the sedentary group in both the congruent (colour blocks) and incongruent (mixed questions) conditions ($p<0.05$).

With regards to Stroop performance within groups (Figure 4), there was a statistical significant improvement from pre-test to post-test for both the sedentary and the active group in relation to the congruent and incongruent RT. The main findings of the *paired t-test* indicated that the active group performed significantly better than the sedentary group with regards to RT.

Accuracy

With regards to accuracy during the Stroop Test (Figure 5), the results indicate that the moderately active group performed more accurately in the congruent condition during both the pre- and post-tests. Another main finding indicates a longer RT in the incongruent condition that was statistically significant in comparison to the congruent condition.

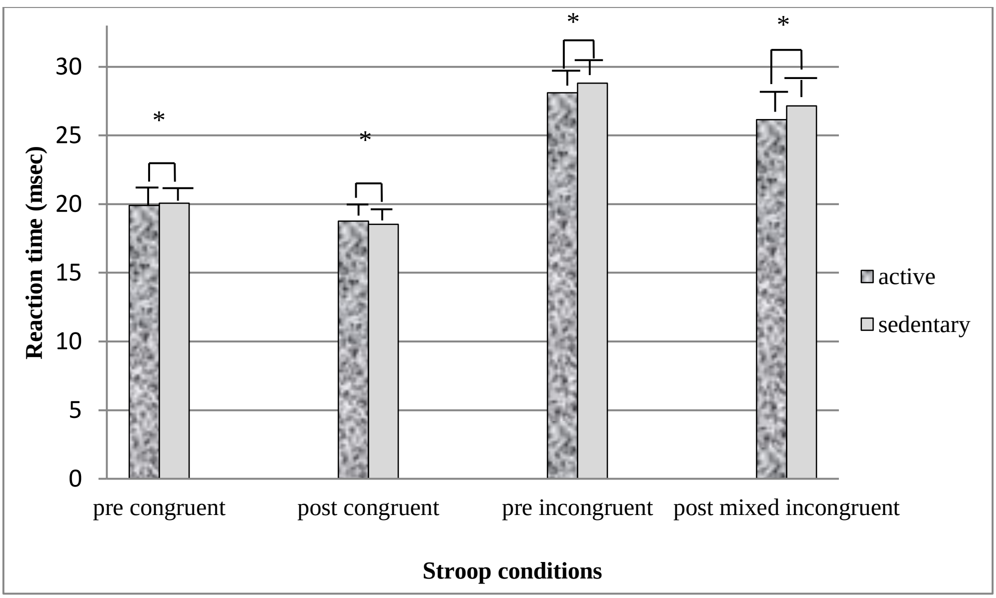

Figure 3. **REACTION TIME IN STROOP PERFORMANCE BETWEEN GROUPS: ACTIVE AND SEDENTARY** (*=p<0.05)

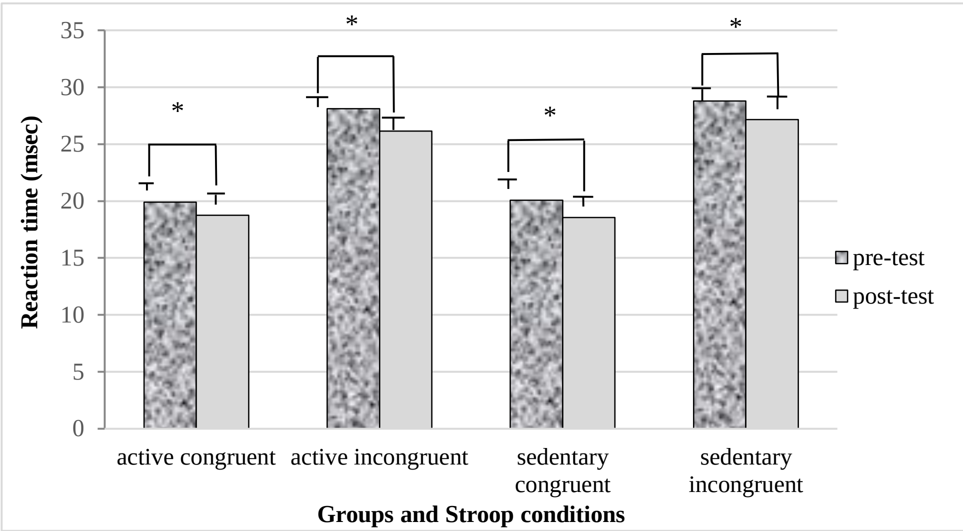

Figure 4. **REACTION TIME IN STROOP PERFORMANCE WITHIN GROUPS: ACTIVE AND SEDENTARY** (*=p<0.05)

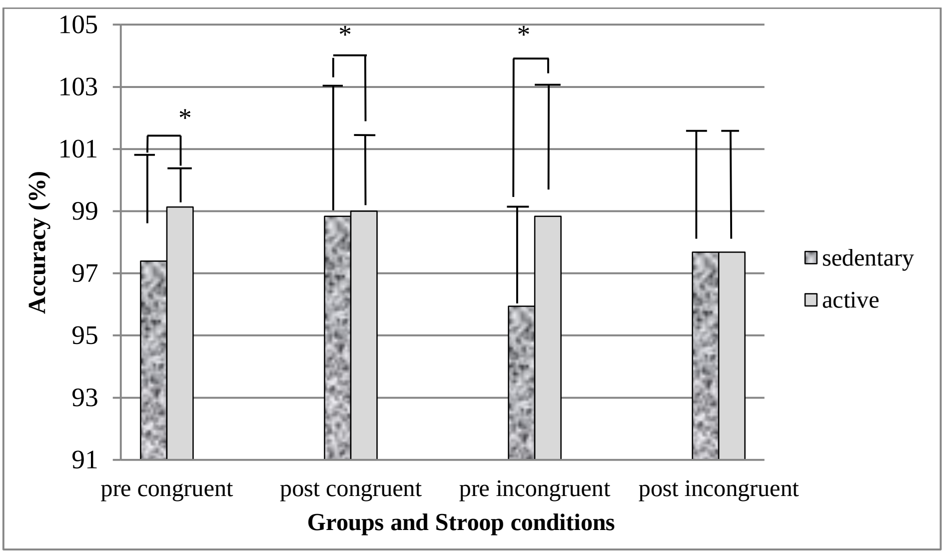

Figure 5. **ACCURACY FOR PRE- AND POST-STROOP CONDITION: ACTIVE AND SEDENTARY GROUPS** (*=p<0.05)

DISCUSSION

Previous research by Chang *et al*. (2014) found that cognitive performance is affected by fitness levels and that acute bouts of exercise benefit several types of cognitive performance differently. There are only a few studies that researched the potential for a combined interactive effect of PA and cognitive task types on the effects of acute exercise on cognitive performance (Brisswalter *et al*., 2002; Chaddock *et al*., 2011; Chang *et al*., 2012; Hogan *et al*., 2013; Chang *et al*., 2014). The purpose of this study was to assess if the level of physical activity and cognitive task type have an influence on the relationship between cognition and acute exercise.

The study classified individuals as either sedentary or moderately active based on their participation in physical activity over the past three months. The results of the repeated sprint test indicate that there was a statistical significant difference ($p<0.05$) regarding the total distance covered between the two groups, with the moderately active individuals scoring a higher average score than the sedentary group. This indicates that the moderately active individuals were indeed significantly fitter than the sedentary group.

Regarding cognitive function, the results of the current study indicate an improvement in executive functioning for both the sedentary and moderately active group. This is in agreement with Tomporowski *et al*. (2008), Chang *et al*. (2014) and Tomporowski *et al*. (2015), who also found statistically significant improvements in cognition following an acute bout of exercise.

Noteworthy improvements in the Stroop Test serve as an indicator that general improvements in cognition are partly as a result of the acute bout of exercise. The experimental design of the current study did not have a control group and, therefore, it is not possible to separate the effect of acute exercise from effects of learning or familiarity (Chang *et al*., 2014). However, participants were all provided with a trial-run of the Stroop Test, all subjects attained more than 90% accuracy prior to performing the actual pre-test. Therefore, this minimised the potential effects of learning or familiarity.

Interestingly, the current study found that the moderately active individuals were superior to the sedentary individuals in all aspects of the Stroop Test besides accuracy in the post-test congruent scores (Figure 5). This could be as a result of numerous factors, which are beyond the scope of this article to explain. One, in particular, could be due to the high level of physiological stress placed on the moderately active individuals following a repeated sprint test. Moderately active individuals have been accustomed to exercise and consequently can do physical work at a higher physiological level. They have the ability to work physically at a maximal or near maximal level and this could lead to higher levels of fatigue post-test and consequently their congruent scores may suffer (Hung *et al*., 2013).

The acute exercise test used in this study, namely the repeated sprint test, mimics that of those used in other studies. These other studies (Brisswalter *et al*., 2002; Tomporowski, 2003; Córdova *et al*., 2009; Kashihara *et al*., 2009; Pesce *et al*., 2011; Chang *et al*., 2012; Hogan *et al*., 2013; Hung *et al*., 2013; Chang *et al*., 2014), according to Chang *et al*. (2014), repeatedly show an improvement in cognitive performance following acute exercise in comparison to control conditions. Therefore, it seems that the subjects in the current study had cognitive performance benefits associated with performance from a single bout of moderate intensity aerobic exercise.

General consensus accepts that increased physiological arousal, following acute exercise, is one of the causes for change in cognitive performance (Kashihara *et al*., 2009). The inverted-U hypothesis links moderate arousal to optimal cognitive performance, while arousal levels too high or too low from optimal, would decrease these beneficial effects. Fontana (2007) and Chang *et al*. (2014) support this hypothesis. According to Chang *et al*. (2014), research found that neuro-electrical activation from a moderate intensity perspective to be more beneficial in comparison to low and high intensity conditions. Moderate intensity exercise may be the most optimal intensity, allowing for the most beneficial level of arousal and having the best effect on attentional resources, which are important for cognitive performance (Tomporowski, 2003; Ferris *et al*., 2007; Chang *et al*., 2012; Chang *et al*., 2014). Findings from the studies of Kamijo *et al*. (2004) and Larson *et al*. (2009) are consistent with the findings of the present study, which shows that PA levels did not influence the positive relationship between acute moderate exercise and cognition.

The results of the current study show a longer response in the Stroop incongruent condition when compared to the Stroop congruent condition for both the moderately active and the sedentary individuals. This is expected as the test trial uses different colours and words and subjects are, therefore, required to use more cognitive resources to prevent the automatic response, which is to read the word and, thus, interference, inhibition and selective attention are required to complete the task (Ploughman, 2008; Tomporowski *et al*., 2008; Hung *et al*., 2013; Chang *et al*., 2014; Tomporowski *et al*., 2015). This collectively results in a prolonged amount of time to complete the task.

Even though both groups show longer RT in the incongruent condition, the present results indicate that the moderately active individuals had better RT than the sedentary group for both the congruent and incongruent scores. This was statistically significant ($p<0.05$) and suggests that moderate physical activity may play a role in executive functioning. This is in agreement with Córdova *et al*. (2009), Pesce *et al*. (2011) and Luque-Casado *et al*. (2013), who all found that acute exercise resulted in enhancements of executive functioning and alertness. Pesce *et al*. (2011) found that these enhancements were greatest in trained or fitter individuals in comparison to the sedentary individuals.

The main finding of the current study was that subjects at both levels of physical activity, namely sedentary and moderately active, showed an improvement in cognitive performance following the cessation of the acute bout of exercise, the moderately fit individuals saw the greatest cognitive improvements. These cognitive improvements following acute bouts of exercise were also seen in the study of Hung *et al*. (2013).

LIMITATIONS AND RECOMMENDATIONS

One major limitation of this study is that moderately physically active individuals from various sporting codes were used. Future studies could make use of a specific population in relation to sport. The current study only focused on two groups, with regard to PA levels namely, sedentary and moderately active individuals. Future studies could investigate the effects of acute exercise on the cognitive performance of highly active individuals in comparison to moderately active individuals. Contrary to previous research, Chang *et al*. (2014) found that people with high fitness levels attained longer RT in the Stroop incongruent condition. This implies that high fitness is associated with poor performance for this measure of executive functioning. Tomporowski (2003), Ferris *et al*. (2007), Chang *et al*. (2012) and Chang *et al*. (2014) found that moderate PA levels resulted in better cognitive performance than lower or higher PA levels. Future research should explore how and why lower and higher levels of fitness are related to poorer performance. Additionally, it is suggested that future studies test the effect of a maximal aerobic and/or anaerobic exercise bouts on cognitive performance. Researchers might want to make use of popular maximal testing protocols, such as the VO_2-max or the Wingate test.

A second limitation of the current study was that no control group was used. This decision was based on the fact that there was substantial evidence in support of acute exercise having a benefit on the Stroop Test performance and the aim was to determine if the benefits, as determined by Stroop Test performance, would differ between sedentary and moderately active individuals (Chang & Etnier, 2009). However, it is recommended that a control group should be used in future studies of this nature. Another limitation was the omission of gender comparisons. It is also recommended that future research examine the extent to which acute exercise and PA levels affect the conflict adaptation effect (this refers to the observation that RT on a given trial is influenced by a previous trial).

CONCLUSION

The results of the current study are in agreement with previous studies in showing the beneficial relationship between acute exercise and cognitive performance for basic information processing, as well as executive control. It should also be noted that this trend can be seen regardless of PA levels. From a practical perspective, individuals should be aware of the significance of performing single bouts of exercise regularly and maintaining a moderate level of PA.

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