A wait-list controlled evaluation of the Qhubeka bicycle on an adolescent's physiology, executive function, and school performance.

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DECLARATION

I, Reece Brian McDonald, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed by candidate

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(Signature)

20-09-2020

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(Date)

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LIST OF ABBREVIATIONS

CRF – Cardiorespiratory fitness

SRI – Stanford Research Institute

AST – Active school travel

PA – Physical Activity

PAQ-A – Physical Activity Questionnaire for Adolescents

RSEP – Regional Socio-Economic Projects

VPUU – Violence Prevention through Urban Upgrading

OR – Odds Ratios

EF – Executive Function

PE – Physical Exercise

ADHD – Attention Deficit Hyperactive Disorder

WCED – Western Cape Education Department

FFM – Fat-free mass

BMI – body mass index

MUAC – Mid-upper arm circumference

WCST – Wisconsin card sorting test

AHKC - Active Healthy Kids Canada

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ABSTRACT

Learner mobility and active school travel (AST) has been proposed to improve school attendance and academic performance. In South Africa, approximately 86% of learners have been reported as walking to and from school. AST in Africa is becoming less common in urban areas, and this may be a contributing factor to the increased risk and frequency of non-communicable diseases due to decreased physical activity. The aim of this wait-list controlled evaluation was to assess the physiological and cognitive changes of access to a bicycle versus walking on adolescents. Specifically, changes adolescent's physical activity levels and executive function in a South African low-income community. Two schools were recruited, with the evaluation school receiving bicycles and the control a school who were yet to receive bicycles. Significant differences were observed across the physiological and executive function assessments. Most notably in the executive function tests, the evaluation group showed significant time to completion decreases across all three tests (N-Back, Arrow-Flanker, WCST: $p<0.001$). The results from this study are significant, as they are the first to assess anthropometric, physiological and executive function in South African adolescents from low-socioeconomic regions. It is evident that there are potential improvements in working memory, inhibition and shifting due to cycling as a mode of AST or during leisure-time. Further research needs to determine the specific mechanisms associated with these improvements.

Key words: Adolescents, Bicycles, Active School Travel, Executive Function.

1. INTRODUCTION

This literature review aims to explore the current evidence pertaining to adolescent active school travel, executive function, scholastic performance, physical activity and physical fitness.

1.1 Active school travel and physical activity

The most recent World Health Organisation (WHO) guidelines on physical activity for children and adolescents are children and adolescents aged 5-17 years should do at least an average of 60 minutes per day of moderate-to-vigorous intensity, mostly aerobic, physical activity, across the week. They should incorporate vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone, at least 3 days a week. They should limit the amount of time spent being sedentary, particularly the amount of recreational screen time (https://www.who.int/news-room/fact-sheets/detail/physical-activity).

Globally, the body of literature on AST and its benefits is extensive, although in the South African context is scarce. The Active Healthy Kids Canada (AHKC) Report Card on Physical Activity for Children and Youth by (Tremblay et al., 2014) was established assessing countries' overall physical activity, organized sports participation, AST, schooling, the community and built environment and finally government strategies and investments. The combined scorecard used overall ratings of A (>80%), B (60-79%), C (40-59%), D (20-39%) and F (<20%). South Africa scored a D for overall physical activity, C for organized sports participation, C for AST, D for school, D for community and built environment and B for government strategy and investments. More recently, (Uys et al., 2016) performed a review and an update of the Active Healthy Active Kids South Africa (HAKSA) scorecard. This study showed that AST remained at C, whereas overall physical activity levels improved to a C. A need was shown to improve South Africa's AST and physical activity score, although more evidence is needed to allow effective and practical interventions.

The latest HAKSA scorecard was conducted in 2018 and the data showed no evidence in improvement or decline of the scores for PA, nutrition, and body composition. Three main areas of concern were highlighted. The first concern was that of safety for South African low-income children and adolescents. Secondly, there appears to be a lack of accountability for

the current implementation of policies in improving child and adolescent PA and nutrition in both the schools and from the government. Finally, over- and under-nutrition remains present in South African children and adolescents. High rates of obesity are still present - particular in girls, and a lack of quality food sources and easily accessible food with a high caloric content was highlighted as a main area of concern (Draper et al., 2019).

Behrens demonstrated that 6200 South African learners reported walking a mean of 1950 metres to school, with the 95th percentile trip length of up to 4250 metres (Behrens, 2005). These data were from the Gauteng region of South Africa and Bloemfontein. Walking these distances may take up to 45 to 60 minutes and doubling this trip time daily will accumulate a significant amount of AST time. This overwhelming amount of travel time impacts the wake-up time as they need to allow preparation for school in addition to this hour of commuting. Learners may be more sleepy due to poor sleep quality and duration. Particularly in South Africa, school start time is early when compared to globally. These factors may contribute to poor school attendance and reduced time for completion of homework tasks (Hysing, Harvey, Linton, Askeland, & Sivertsen, 2016).

This reduced time may also result in less time for physical activity and reaching the daily requirements as indicated later on in the review (Master et al., 2019). The authors measured sleep duration, efficiency, sleep timing as well as physical activity by means of actigraphy in adolescents. Their results showed that higher MVPA was significantly associated with longer sleep duration and sleep efficiency maintenance, which is a measure of sleep quality. Increased sedentary behaviour was associated with shorter sleep duration. These findings were bidirectional, suggesting that sleep effects physical activity, as well as that increased physical activity promotes healthier sleep patterns.

Data from a household travel was used by the same authors (Behrens, 2002) PhD thesis in 2002, reporting that 67% of low-income 13 to 18 year olds walk to school, 28% use public transport and 5% travel by car (Behrens, 2004). In the 2014 National Household Travel Survey report, the Western Cape completed an 85.1% survey response rate. In the education section of the report, 1.6 million learners reported attending a school. Walking to school was reported by 50.5% of learners, 25.3% by car or truck and 10.7% by taxi (Schmidt, 2014). The

survey was used in high, mid and low-income regions and the proportion of low-income children walking to school was in agreement with previous data.

Although the travel survey data in South Africa appears to be frequent, AST interventions and studies in low socioeconomic communities are under-represented, which is particularly interesting as these regions are generally less active (Baig et al., 2009). A review of active school transport, physical activity levels and body weight of children and youth demonstrated that children who are active commuters to school accumulate significantly greater physical activity (Faulkner, Buliung, Flora, & Fusco, 2009). Schoeppe and colleagues reviewed the associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status. They included 52 studies, where the majority of these focused on AST and demonstrated significant positive associations with physical activity. The authors concluded that independent mobility of children is important as children who have the freedom to be outdoors and travel without parent supervision have been shown to accumulate greater physical activity (Schoeppe, Duncan, Badland, Oliver, & Curtis, 2013)). Furthermore, the same authors found that this freedom to be outdoors and accumulate greater physical activity contributed towards the recommended (US Department of Health and Human Services. Physical Activity Guidelines for Americans, 2nd edition. Washington, DC: US Department of Health and Human Services; 2018.) daily 60 minutes of moderate to vigorous physical activity, and therefore may be a preventative measure against obesity and non-communicable diseases.

Although the benefits of physical activity are known, Ramirez and colleagues summarised that the current literature has shown that cycling as a mode of AST is associated with a greater cardiorespiratory fitness, although the association between AST and indicators of body composition and physical activity levels remains unclear (Ramirez-Velez et al., 2017). This may be due to the tests being self-reported, containing small cohorts, or utilizing cross-sectional data instead of longitudinal datasets. The same authors concluded that the variables which have been reported to affect adherence to AST are socioeconomic status, natural environmental characteristics, parental educational status, social support or a culture for AST, the distance from school to home, and both the parent and children’s perceptions of the

neighbourhood characteristics. There are therefore different barriers to AST which are dependent on the community that a child lives in.

A study conducted by (Baig et al., 2009) in Birmingham, England assessed the frequency of AST in 673 children aged 11 – 14 years. The children were of differing ethnicity, physical activity levels, body mass and transportation mode to school. AST was defined as either walking or cycling, and passive travel was defined as using a car, train, or bus. The questionnaire results demonstrated no association between walking to school and overall physical activity levels. The authors concluded that the AST children may have accumulated their physical activity distribution due to their travel, and therefore resulted in reduced physical activity at other times. Supporting this, the children in the passive group were found to be more active at school than the AST group. The authors further added to the previously reported barriers of AST, such as the distance to school.

Berrigan and colleagues in a Californian based study, investigated the engagement in physical activity via differing active travel modalities in differing socioeconomic groups (Berrigan, Troiano, McNeel, Disogra, & Ballard-Barbash, 2006). Children who either walked or cycled to school showed a reduction in the physical activity difference between the high and low-income groups, which demonstrates that AST may narrow the margin between these income groups. Furthermore, (Arango et al., 2011) conducted a study in low socioeconomic developing regions, and found that in the AST group there was a significantly lower likelihood of being overweight than in the non-AST group.

Silva and colleagues aimed to assess the prevalence, barriers and associated variables with AST, in a group of eleven to seventeen year-old learners (Silva, Vasques, Martins Cde, Williams, & Lopes, 2011). No differences in body composition were shown, although environmental variables such as distance to school, crime in the region, traffic congestion levels and personal barriers were strongly associated with AST.

In 2014, a review by (Larouche et al., 2014) investigated AST in Africa and the psychometric properties of the measurement tools for children and youth. At the time there was no data on African children and AST. In rural areas, AST was found to be longer, although an important

AST barrier that was noted was fear of safety while travelling. As a result, the journeys were found to be more difficult and dangerous for younger children as they were more vulnerable. The walking distances of more than 5km were associated with a higher overall physical activity, particularly in boys. The factors which contributed to the difficulty of AST agreed with most recent findings, adding that children performing household tasks before school could lead to their late arrival, punishment, and school dropout. The authors summarized that in Africa the main method of AST is walking or by means of a bicycle with a frequency of once per week.

In South Africa, approximately 86% of South African learners have been reported as walking to and from school (Hampshire, Porter, Mashiri, Maponya, & Dube, 2011). It was shown that AST in Africa is becoming less common in urban areas, and this may be a contributing factor to the increased risk and frequency of non-communicable diseases due to decreased physical activity. The authors did note that the body of literature mainly used self-reported physical activity measures, and there may be a difference to what the true objective levels are. The authors concluded that further research is needed to develop valid and reliable instruments to assess the AST trips, in addition to active commuting to non-school related activities such as the shops, friends and or family residences, sports facilities and parks. This portion of physical activity may be a large contribution which has not been assessed.

Larouche and colleagues reviewed the effectiveness of the current AST interventions, and whether these were physical or educational (Larouche, Mammen, Rowe, & Faulkner, 2018). Physical interventions being the handing out of bicycles or equipment to facilitate AST. The educational interventions were informing students about the positive benefits of AST. It was shown that most of the interventions were education based, and this may highlight the difficulty of funding the costs of the necessary equipment, training, and maintenance to promote physical AST. The interventions assessed were shown to potentially increase AST among children, although overall evidence was low. Longitudinal follow-ups and studies were suggested, as there was a lack there-of. In addition to this, outcome measures were suggested to be standardized by authors to allow comparability between data sets.

1.2 Physiological variables

Physical activity, and the combination of walking and cycling in active commuting studies have been extensively researched (Abu-Omar & Rutten, 2008; Barengo, Kastarinen, Lakka, Nissinen, & Tuomilehto, 2006; Nakanishi & Suzuki, 2005; Tudor-Locke, Ainsworth, & Popkin, 2001). These authors have shown that AST may decrease the risk of type-2 diabetes, hypertension and improve general physical fitness, which are in agreement with the current literature.

A cross sectional study by (Andersen, Lawlor, Cooper, Froberg, & Anderssen, 2009) assessed 545 and 705 Danish boys and girls aged fifteen to nineteen years old. They focused on determining if physical fitness has a relation to AST in adolescents. The authors used questionnaires to determine the participants sociodemographic characteristics, AST mode and physical activity levels. The learners' aerobic power, muscular endurance, functional strength, flexibility, and functional strength were assessed. Their main findings were that the learners who used cycling as a mode of AST had a greater aerobic power, muscular endurance, and flexibility than the children who walked as a mode of AST or passive travelled.

A cross-sectional study by (Cohen et al., 2014) assessed 6829 AST English children and the association with musculoskeletal fitness. The authors added that musculoskeletal fitness may be a youth health marker which is independent of cardiorespiratory fitness. Physical activity was measured using the PAQ-A, and hand grip strength using a hand grip dynamometer. Their results showed that the learners who used cycling as a mode of AST had a greater total hand grip strength when compared to passive travelers. When the total hand grip strength was adjusted for overall physical activity, similar results were observed. Binary logistic regression analysis was used to calculate odds ratios (OR), and this showed that cyclists were more likely (OR = 1.42, 95%CI; 1.14 to 1.76) to have 'good' total hand grip strength when compared with passive travelers. When these OR were adjusted for physical activity, the same results remained. The authors added that their data was the first to show a greater likelihood of 'good' muscular fitness in English children who commute actively to school. They added that the subjective PAQ-A may be better supported by objective physical activity measures.

In terms of data that are more relevant to South Africa, (Larouche et al., 2014) determined that African studies involving AST have shown inconsistent relationships between AST and overall physical activity levels. Only three studies have shown positive associations between AST and overall physical activity levels. In contrast to the previous studies, no associations between AST and CRF were found.

More recently, (Noonan, Boddy, Knowles, & Fairclough, 2017) discussed how low socioeconomic regions generally show greater levels of childhood obesity. In line with previous studies, they added that physical activity has been shown to improve general health and weight status, as well as CRF. It has been established and mentioned previously that AST is influenced by environmental factors, which the authors noted. This studies results showed that AST was associated with a higher BMI and lower CRF, although body fat percentage was not measured, and the reported higher BMI may be because of increased growth and maturation. One hypothesis for the observed results, was that these children were from poorer backgrounds, and this may encourage the purchase of inexpensive and more unhealthy food, in addition to the already discouraging factors of AST. The distance from home to school was determined as the strongest predictor of AST, where shorter distances favoured AST. Only 4.1% of the cohort reported to cycle to school. This contrasts with studies with differing findings which have a greater proportion of cycling as a mode of AST.

A study of 2877 Colombian boy and girl children and adolescents by (Ramirez-Velez et al., 2017) evaluated the association between cycling as a mode of AST and its effect on body composition, physical fitness and Metabolic Syndrome (MetS). The groups were divided into cycling (n=668) and non-cycling (n=2209), and further into boys (n=1309) and girls (n=1568). The anthropometric variables measured were stature, body mass and body mass index (BMI), although body fat percentage was not measured. Physical fitness was assessed using a single leg jump, hand grip strength test, 4 x 10-m agility test, sit-and-reach test and a 20m shuttle run test.

In the girl's group, those who AST using cycling (n=271) had a lower likelihood of an unhealthy SLJ (p=0.012), 4 x 10-m test (p=0.05) and 20mSRT (p=0.026) than non-cycling group (n=1297). In the boy's group, those who AST using cycling (n=397) showed a lower likelihood of an

unhealthy 4 x 10-m test (p=0.006) and sit-and-reach test (p=0.025) than the non-cycling boys (n=912). No significant differences were observed in handgrip strength and cardiometabolic risk factors across both girls and boys. The authors concluded that cycling as a mode of AST may provide greater muscular and cardiorespiratory fitness when compared to passive school travel.

1.3 Executive Function

Executive function (EF) is a broad term, which is described as the cognitive processes necessary for goal-directed cognition and behaviour, which develops throughout childhood and adolescence (Best, 2010). Three fundamental components of EF have been identified: inhibition, updating of working memory and shifting. Executive function involves an assortment of cognitive processes and behavioural aptitude, which are known as the "cold" components. They involve slight emotional arousal and are more logically based (Grafman & Litvan, 1999). Examples are those such as problem-solving, sustaining attention, the ability to multi-task and verbal reasoning (Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Damasio, 1995; Grafman & Litvan, 1999; Stuss, Shallice, Alexander, & Picton, 1995). The "hot" components of executive function are driven or influenced by desire, emotion and belief. These are then further affected by the notion of being rewarded or punished, social behaviour regulation and the ability to regulate social behaviour (Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, Damasio, & Damasio, 1996; Grafman & Litvan, 1999).

Miyake and colleagues examined the three proposed sub-divisions of EF and aimed to demonstrate that these may be separated into three different processes and be assessed via different EF tests with 137 college students. The three sub-divisions of EF were described as shifting, updating and inhibition. Their results showed that the WCST test was strongly related to shifting, with the Tower of Hanoi (TOH) strongly related to Inhibition and the random number generation (RNG) to updating. The authors concluded that it is important to understand each EF component on its own as well as in conjunction with other EF components (Miyake et al., 2000).

The current literature demonstrates that a deficit in these mentioned divisions of the executive function in a person may result in learning and social disabilities. These may range from the ability to work and concentrate, attend school, maintain social relations and function independently (Goel, Grafman, Tajik, Gana, & Danto, 1997; Green, 1996; Green, Kern, Braff, & Mintz, 2000). There is a wide array of literature investigating the effect of exercise on EF. These differ by design, especially the type of exercise used and the tests used to evaluate the EF, and may prove difficulty in assessing exact EF changes.

The majority of studies have examined the acute effects of exercise on EF, and current chronic interventions are limited. This may be due to the financial cost of a long-term intervention as well as participant commitment to the full intervention.

In an early meta-analysis by (Colcombe et al., 2003) working memory was shown to benefit from physical exercise (PE). Adding to this, PE was shown to improve physical health, but also brain functioning and cognitive processes (Hillman, Erickson, & Kramer, 2008). The tasks of inhibition, shifting and updating of working memory have been commonly used in the literature (Barenberg, Berse, & Dutke, 2011). Quantitative reviews have shown that post-exercise, individuals reported increased energy (Loy, O'Connor, & Dishman, 2013), decreased symptoms of anxiety (Ensari, Greenlee, Motl, & Petruzzello, 2015) and increased performance on memory tasks (Lambourne, Audiffren, & Tomporowski, 2010).

Pontifex et al performed assessments on children aged 8 to 10, with Attention Deficit Hyperactive Disorder (ADHD) (Pontifex, Saliba, Raine, Picchietti, & Hillman, 2013). They used the Eriksen Flanker task, which looks at the inhibitory aspects of cognitive control. This test involves the identification of congruent or incongruent shapes and being able to determine a single shape and its direction throughout the test conditions without influence from the surrounding shapes. Their findings suggest that motivating children with or without ADHD to perform an acute bout of physical activity may have a positive effect on aspects of neurocognitive function and inhibitory control.

Tuckman & Hinkle studied the impact of a longer physical activity intervention on perceptual motor skills and visual motor coordination in fourth, fifth and sixth grade children (Tuckman & Hinkle, 1986). The intervention group performed a running program as their 12-week

aerobic exercise intervention (three 30 min sessions per week) in addition to normal school physical education classes (except for the sixth graders who did not have physical education classes). In contrast, the control group participated only in the regular school physical education classes where children performed structured outdoor activities. It is stated that 154 children partook in this study, but it was not described in the methodology how many children were assigned to each test group. Although there were significant improvements seen in cardiovascular fitness post-intervention, the running intervention did not improve the perceptual motor skills or visual motor coordination of the children.

Budde found that frontal-dependent cognitive process improved after an exercise bout, and therefore their Executive Function (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008). Pesce performed an immediate word recall after exercise, where an improvement was found (Pesce, Crova, Cereatti, Casella, & Bellucci, 2009). In the delayed recall, both exercise forms used resulted in better memory performance. The group games activity did although induce a more specific cognitive activation which further improved the immediate recall results.

Lambourne assessed the effects of an acute exercise bout on sensory and executive processing tasks in 21-year-old adults (Lambourne et al., 2010). The intervention group performed 40 minutes of steady state cycling while performing the tests. As a control, each participant performed the same protocol while sitting on the ergometer without pedaling. The executive function of working memory was assessed using random number generation, and the working memory did not differ between either group. The authors discussed how the physiological changes that occur during aerobic exercise are well known, although the mental functioning which accompanies this is less well understood. They added that variables which are important to consider in such studies are the intensity and duration of the exercise, the mental task being performed, and the region assessed, as well as the timing of the tests and exercise. The authors added that exercise may even interfere with high-level executive functioning and found that inhibitory processes were affected by the exercise bouts.

Berse assessed an acute physical exercise bout on the shifting component of executive function in adolescents (Berse et al., 2015). The study protocol used an incremental bicycle

exercise protocol, and the control condition was the same participants watching a cartoon while sitting. Their results showed that the physical exercise bout significantly improved shifting. The authors concluded that there is a moderate positive effect of acute PE on shifting performance. Furthermore, acute physical exercise of even 10-14min may promote executive shifting performance, which is an important component for academic achievement.

More recently, a study by (Lindheimer, O'Connor, McCully, & Dishman, 2017) assessed the effect of light-intensity cycling on mood and working memory in response to a randomized, placebo-controlled design. The study used 18 – 34-year-old adults and assessed working memory using the N-back test. The main outcome variables assessed were percentage accuracy and reaction time for correct responses during the tests. They found that mood and cognitive performance were not improved by active or passive cycling, although shorter reaction times after the exercise bout were observed.

Domazet measured PA, organized sports participation and AST in relation to mathematic performance and inhibitory control in adolescents, with 568 twelve to fourteen-year-olds (Domazet et al., 2016). Inhibition was assessed using the Eriksen-Flanker task, and PA was objectively measured using GTX-3 accelerometers. AST and the learner's sports participation were self-reported. Their results showed that cycling as a mode of AST and partaking in organized sports participation were positively associated with mathematic performance.

As has been shown, habitual PA has beneficial effects on physiology (Janssen et al., 2010). PA has been associated with better cognitive performance and functioning in older and cognitively impaired individuals (Colcombe et al., 2003; Heyn, Abreu, & Ottenbacher, 2004). There is although a growing body of research which suggests similar effects on the developing brain (Chaddock, Pontifex, Hillman, & Kramer, 2011). (Berchicci et al., 2015) Showed that children who are aerobically fit have demonstrated higher prefrontal cortex activity when compared to less aerobically fit counterparts during the Eriksen-Flanker task, and this suggests greater inhibition.

A systematic review with meta-analysis involving children and adolescents assessed the effects of chronic exercise interventions on EF. A total of 19 studies and 5038 participants

were included. Their results demonstrated improved EF, specifically inhibitory control. Adding to this, a meta-regression analysis was performed and demonstrated that higher BMI values were associated with improved EF. In terms of exercise duration PA interventions of less than 90 minutes showed improvements in EF, although sessions greater than 90 minutes showed no EF improvements. The authors concluded that chronic PA interventions may promote EF improvements.

García-Hermoso and colleagues summarized that the current literature demonstrates AST may be positively associated with scholastic performance (García-Hermoso, Esteban-Cornejo, Olloquequi, & Ramírez-Vélez, 2017). Although this is a broad statement, as curriculum differs between countries as well as standard of examinations.

A recent review by (Ruiz-Hermosa et al., 2019) evaluated the effects of AST to and from school on both cognitive and scholastic performance. The studies were classified into two groups, where the first group were focused on assessing cognitive performance, without executive function testing. The second group focused on scholastic performance and different subject grades. The authors concluded that AST showed no significant associations with cognitive performance or scholastic performance. This is further supported by (Phansikar, Ashrafi, Khan, Massey, & Mullen, 2019), who showed that AST was not significantly associated with scholastic performance or broad executive function, although was positively associated with visuospatial skill, working memory, attention and general intelligence.

A narrative review of 125 studies evaluated relationships between PA and academic achievement in adolescents. The authors summarized that many studies use a cross-sectional design and overall study quality has increased. The study conclusions show positive associations of PA and academic achievement, although mixed results are reported. This may be due to the differing protocol or tests utilized as well as socio-economic status of different schools or communities (Howie & Pate, 2012).

There are proposed benefits of AST, PA, or PE on physiological and executive function components. There are reported differences between studies due to study design and the group investigated. The socioeconomic status and environmental factors may also play a large

role in the outcomes reported, and these need to be factored in when assessing these AST, PA or PE on physiological variables and executive function.

1.4 Qhubeka

The Qhubeka bicycle distribution programme is unique, and it is therefore important to highlight how the charity may have a broader impact on society when providing bicycles to less affluent communities. Qhubeka is a global charity whose goal is to move people in Africa forward by the donation of bicycles. It is a Nguni word that means “to progress” or “to move forward”(Https://qhubeka.org/about-us/). One of their programmes is the “Learn to Earn” programme, which is specifically focused on learner mobility by providing an efficient and simple mode of transport for learners to travel to and from school. This has been proposed to improve their school attendance as well as scholastic performance. In terms of sports programmes, the bicycles may serve a similar purpose in enabling attendance at the respective sports practices. Current anecdotal data support this hypothesis, although objective datasets are lacking.

The Stanford Research Institute (SRI) conducted a study of the Qhubeka Bicycle Education Empowerment Programme in South Africa. Four schools in the Limpopo province took part in the study. The study took the form of surveys and interviews of 686 grade 8 to 10 learners over a six-month period. Of these learners 352 were boys and 334 were girls. Academic performance was determined by the learners school reports and academic results. No specific tasks or tests were conducted by the researchers. Their results showed that the Bicycle Education Empowerment Programme is facilitating a reduction in commute times for these learners, increasing on-time arrival at school and improving academic performance (Murphy, Shear, Greif, & Tim, 2016).

There are several steps in the bicycle distribution process, starting with fundraising. The fundraising occurs worldwide via donations as well as through benefactors. The bicycles are then manufactured and assembled in various locations, including within South Africa. The bicycles are robust and are intended to last for at least 50 000km of travel distance or five years of use. The geographic region and specific schools are then selected by Qhubeka, and the learners are trained to use the bicycles by the Qhubeka charity as well as on general bicycle and road safety. The training process occurs prior to a special handover ceremony of

their new bicycles. Furthermore, a mechanic at the school is trained, and a spare part supply chain is established in the region to assist the learners with equipment related maintenance and supply for the mechanic (https://qhubeka.org/how-bicycles-change-lives/).

Measuring the potential physiological and cognitive changes from the distribution programme in South African adolescents over a prolonged period may create a robust assessment of cycling as a mode of AST and its effect on overall PA, physiological adaptations and executive function.

2. AIMS AND OBJECTIVES

2.1 Aim

The aim of this wait-list controlled evaluation was to assess the physiological and cognitive changes of access to a bicycle versus walking on adolescents. Specifically, changes in executive function, physiology, and the adolescent's physical activity levels in a South African low-income community.

2.2 Specific objectives

The specific objectives are:

1. To determine the overall physical activity, musculoskeletal and cardiorespiratory fitness levels of a specific group of adolescent learners in a South African low-income community.
2. To determine if a bicycle as a mode of AST in a South African low-income community results in changes in these stated variables.
3. To determine if the executive function components of working memory, response inhibition and switching and preservation are improved by access to a bicycle as a mode of AST and recreational use.

3. METHODOLOGY

3.1 Research design

This study design took the form of a wait-list controlled evaluation. Two schools were recruited, with the evaluation school participants receiving bicycles from the distribution programme, and the control a school who were yet to receive bicycles from the distribution programme.

3.2 Schools

The two recruited schools were based in different geographical regions, 100 kilometers apart. The evaluation school in Worcester, Breede Valley was selected due to the timing of the bicycle distribution programme. Worcester is a low density, spread out town with a lack of community infrastructure such social and recreational facilities. The control school in Khayelitsha, Cape Town was selected as no bicycle distributions have taken place there and the effect of the bicycle wanted to be eliminated. The evaluation school falls under the Breede Valley Local Municipality, and is currently under phase 1 of the Regional Socio-Economic Projects Programme (RSEP). The control school falls under the City of Cape Town Municipality and is currently in phase 4 of the Violence Prevention through Urban Upgrading (VPUU) Programme. These programmes differ in methodology and implementation, but have a similar aim of improving quality of life and safe communities (*RSEP VPUU Programme Annual Review Final Draft Signed*, 2019)

Data were collected in the Worcester school in the months of March to October. These were at the end of Summer and the beginning of Spring. Therefore this groups time points were separated by Winter. In the Khayelitsha school, data were collected in the months of June to February. These were in the middle of winter and towards the end of Summer. Therefore this groups time points were separated by the end of Winter and Summer.

3.3 The Qhubeka bicycle distribution training programme

The bicycles are distributed to selected learners whose families have applied for the bicycles distribution programme. Learners may be selected based off their travel distance and current

transport methods to the school. Qhubeka provides training in terms of: riding skills and competency, safety and road awareness, as well as maintenance and care of the bicycles.

3.4 Participants

The inclusion criteria for this evaluation were males and females aged 14 to 18 years old.
The Western Cape Education Department (WCED) requirement was such that participants under the age of 18 needed to have both assent and consent. As such, learner and parental consent was obtained for all participants. Exclusion criteria for both schools were if the learners previously received a Qhubeka Bicycle. Had any illness, hospitalization, or surgical procedures in the past year. Had any chronic conditions requiring medication that might alter metabolic responses to exercise and exercise performance i.e., thyroid abnormalities, uncontrolled asthma, cardiovascular conditions, diabetes, impaired glucose tolerance and high blood pressure.

3.5 Ethical Considerations

No participants were enrolled into the study until the Human Research Ethics Committee of the University of Cape Town had approved the protocol and informed assent and consent, in writing, had been obtained from each participant and their parent or legal guardian. Participants and their parents were fully informed of the risks associated with the study. The study was performed in accordance with the principles of the Declaration of Helsinki (World Medical Association, 2013) ICH Good Clinical Practice (GCP) and the laws of South Africa. Participants had the right to withdraw from the trial at any stage without stating a reason, and investigators also had the right to withdraw a participant from the study at any time. Prior to commencement, approval for the study was obtained from the Western Cape Department of Education.

The investigators maintained responsibility for informing the Human Research Ethics Committee in writing of any amendment to the protocol, or of any adverse events resulting from participation in the study, of which there were no protocol amendments or adverse events.

The anonymity of participants is ensured in any publication of data.

3.6 Risks to Participants

The data collection involved a series of physiological and executive function tests, with no invasive measurements. While the physiological tests allowed the participants to reach their maximal effort, only healthy individuals were recruited for this evaluation. It has been well-documented that overall risk of maximal exercise testing in healthy individuals (without known diseases) is very low, with complications rate of 0.8 per 10 000 tests. Therefore, the protocol of these participants did not expose them to any additional risks over and above that to which they are normally exposed to during exercise.

3.7 Benefits to participants

The participants received feedback on their anthropometric results and predicted VO_2max data once the study was completed. These measurements are beneficial, as it would provide them with insight about their current fitness and activity levels. It would further provide motivation to exercise more, or confirm that their daily habits were in fact allowing them to live a healthy lifestyle.

3.8 Participants evaluated

In total, 57 participants between the ages of 14 and 18 completed the evaluation. The evaluation school consisted of 33 participants, and the control school consisted of 24 participants.

3.9 Measurement Instrumentation

3.9.1 Anthropometry measurements

The anthropometric measurements included:

3.9.1.1. Stature

Stature was measured using a stadiometer mounted onto a wall. As the stadiometer was portable, it was assessed for accuracy with a person of known height, prior to testing. Participants were instructed to stand against the wall, with their feet and ankles together,

arms to the side and back and buttocks against the wall. Their head was assessed to be neutral, and participants were instructed to inhale as the stadiometer was pulled down and placed on top of head. The height was recorded, and the test performed again to ensure both readings were in agreement.

3.9.1.2 Tanita bioelectrical impedance scale

The Tanita bioelectrical impedance scale was used to record: body mass, body fat percentage, fat mass, fat free mass (FFM) and muscle mass. The scale was set up as per the manufacturer guidelines. The participants were barefoot when standing on the scale.

BMI was calculated using the previously recorded stature and body mass. This was checked against the Tanita BMI output to ensure accuracy.

$$BMI = \frac{body\ mass\ (kg)}{(stature\ [m])^2} \qquad (1)$$

3.9.1.3 Mid-upper arm circumference

The mid-upper arm circumference from both the right and left arm were measured. This assessed the circumference of the individuals upper arm, and measured midway between the olecranon process and acromion of the scapula. The participants arm was straight and not touching the body, with the measurement tape used to measure the circumference of the upper arm at this point.

3.9.2 Physical Activity Questionnaire for Adolescents

The PAQ-A is a self-reported general physical activity questionnaire which has been well used and validated in the literature (Kowalski, Crocker, & Donen, 2004). The questionnaire was used to determine the participants general physical activity and is self-reported. The questionnaire was is presented English and not the learners home languages. If learners were uncertain of any questions they were allowed to ask the testers for assistance. The questionnaire was completed at the beginning of the testing session, and explained as per the questionnaire guidelines. The answers were converted to a physical activity score using the questionnaire scoring methods.

3.9.3 Bicycle logbook

The evaluation participants were asked to fill in a log book to determine their approximate usage of the bicycle in the last week. This logbook asked them to record the amount of hours they used the bicycle on each day of the past week prior to the testing day.

3.9.4 Physiological assessments

3.9.4.1 Musculoskeletal fitness: assessment of grip strength

Grip strength is an indicator of upper body strength (Healthy Active Living and Obesity Research Group, 2013). The hand grip test was performed using a digital hand grip dynamometer. The participants were shown how to use the dynamometer, and the tester assessed the participants to ensure a valid test. A valid test is defined as the participant standing upright with their arm straight at their side, not pressing against their side and not anterior or posterior. Participants had a chance to become familiarised with the equipment prior to testing. Two tests on each hand were recorded and the average of both used. The sum of each average from both hands were taken to calculate the total hand grip score.

3.9.4.2 Plank Assessment of torso strength

Torso endurance and strength are related to back health, the ability to stabilize the body, and the function of both the upper and lower limb (Healthy Active Living and Obesity Research Group, 2013). The tester used a cell phone stopwatch to time each assessment. The participants were to keep a straight back, maintain their elbows at 90 degrees with their forearms extended and hands open. If the participants hips began to lift or drop a warning was given, and after a second lifting or dropping of the hips the timer was stopped and the test terminated.

3.9.4.3 Cardiorespiratory fitness

The Beep test, which is a 20m shuttle run test, assessed the participants cardiorespiratory fitness level and predicted their maximal oxygen uptake (VO_2max). It is a valid and reliable test (Olds, Tomkinson, Léger, & Cazorla, 2006). The learners predicted VO_2max was calculated using the equation below (2), where x = number of shuttles performed.

$$predicted\ VO_2\ \max = 0.2761\ (x) + 27.504 \qquad (2)$$

A 20 metre course was constructed using a measuring tape with masking tape marking the zero and 20 metre ends. Prior to the test, the participants performed two full laps of the course and basic stretches as a warm up, while the test protocol was explained. A speaker

with the pre-recorded test played while the participants performed the test, as the participants are required to run between the 0 m and 20 m mark in time with the audio beeps. The time between the audio beeps increases on each level. The speed that the participants are required to run at therefore increases at each stage. During the test the participants were encouraged to go as long as they could.

3.9.5 Executive function

The executive functions are neurologically-based skills which are used to regulate actions to conduct a specific task. These involve mental control and the ability to self-regulate. Three tests were used to assess the executive function; WCST, N-back task and the Arrow-Flanker task (Chan, Shum, Toulopoulou, & Chen, 2008). These three tests measure switching and preservation, working memory and response inhibition respectively, and are reliable and valid.

The tests were performed on two computers with preloaded (Inquisit 5 [Computer software]. (2016). Retrieved from https://www.millisecond.com., n.d.). The individual tests were downloaded from millisecond test library. The tests were explained before and during the practice rounds, however during the tests learners received no additional assistance. There was no translation of the tests which are presented in English into the learners home languages. The respective outputs from each test are explained below.

3.9.5.1 N-back

This test is performed with single letters on a screen. The participants goal is to identify the letter which was *n* times back, where n represents a trial number of 0, 1, 2 or 3. A letter on the keyboard was pressed to indicate a "hit" or answer. The output variables are described as follows:

	Term	Definition
1	*Elapsed time*	Total time taken for the test to be completed
2	*Total hits*	Total number of hits during the test, where a hit is the pressing of the key on the keyboard to provide an answer.
3	*Total false alarm rate*	Pressing an answer key for a non-target, meaning an incorrect answer.
4	*DV*	Describing the amount of correct answers as a ratio calculated using (3), with a negative score indicating a poorly executed test.

$$DV = \frac{(total\ hits - total\ false\ alarm\ rate)}{number\ of\ experimental\ blocks} \qquad (3)$$

3.9.5.2 Arrow-Flanker

This test is performed with arrows on a screen, where the arrows are all congruent. The centre arrow is the changing variable, and can either be congruent or incongruent to the other arrows. The participants goal is to identify the direction of the centre arrow on each trial. The output variables are described as follows:

	Term	Definition
1	*Elapsed time*	Total time taken for the test to be completed
2	*Proportion correct*	Overall test trials which are correct and expressed as a proportion.
3	*Mean response time*	Mean latency in milliseconds of correct response time.
4	*Proportion correct congruent*	Proportion of correct answers where the participant identified a congruent arrow.
5	*Proportion correct incongruent*	Proportion of correct answers where the participant identified an incongruent arrow.
6	*Mean response time congruent*	Mean latency in milliseconds of a correct congruent answer.
7	*Mean response time incongruent*	Mean latency in milliseconds of a correct incongruent answer.

3.9.5.3 Wisconsin card sorting test

This test is performed with cards on a screen. The participants goal is to identify the rule of the top row containing four card options with the bottom row card which is the indicator card. The rule can be colour, shape or number, and alternates randomly during the test, with a rule change indicated before it occurs. The output variables are described as follows:

	Term	Definition
1	*Elapsed time*	Total time taken for the test to be completed
2	*Total trials*	Total number of trials completed by the participant
3	*Total correct*	Total correct number of trials completed by the participant
4	*Total error*	Total correct number of trials completed by the participant
5	*Preservative error*	Represents the continuing recurrence of an error or misidentification of the current rule.
6	*Percentage preservative error*	Represents the percentage of the preservative errors.
7	*Completed categories*	Number of categories or “rules” completed, and is an equivalent indication of preservative error.
8	*Failure to maintain set*	Counts the number of times an individual fails to figure out new rule after they maintained the set.
9	*Trials completed first category*	Shows how many trials were needed to complete the first category after having maintained a correct streak of greater than or equal to five.

3.10 Testing Procedure

The participants were evaluated over a period of six months. A baseline assessment was conducted at time zero, and six months later a follow up assessment repeating the initial protocol to assess any changes was conducted.

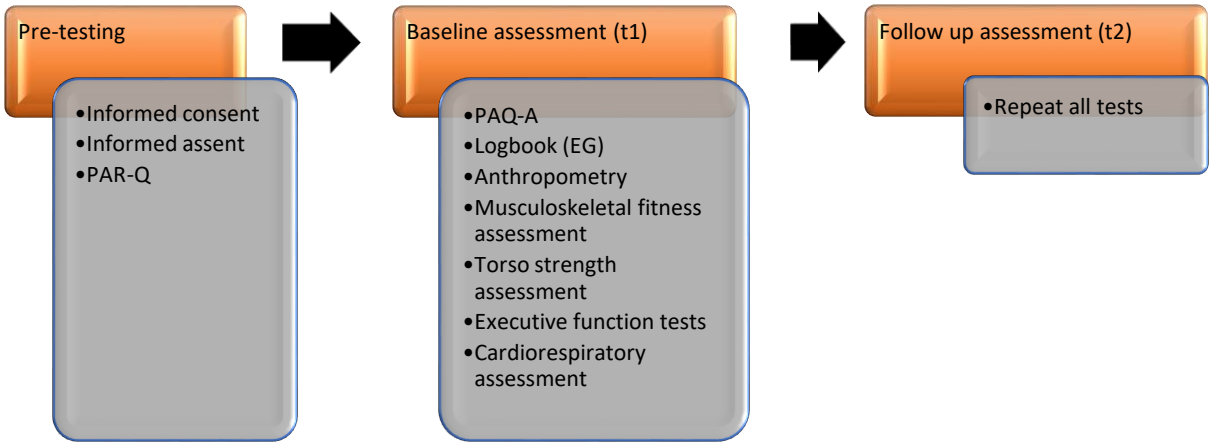

Figure 1. Testing procedure.

3.11 Statistical analysis

All results were expressed as means and standard deviations, and analysed using a statistical software programme (Prism 8, Graphpad Software, Le Jolia, Ca, USA). Shapiro-wilk tests for normality were performed to determine parametric and non-parametric data. The data was assessed for outliers greater than 2SD from the mean and these were removed. All parametric and non-parametric data were assessed by independent t-tests between groups and dependent t-tests within groups. The figures were presented as box and whisker plots, demonstrating the minimum, second quartile, median, third quartile and maximum values.

A two-way ANOVA with repeated measures was then used as a secondary measure to confirm any significant differences between groups. For significant differences, a post hoc Bonferonni's multiple comparisons test was used to determine any significant differences between the evaluation and control groups at time point one and two. This method is

suggested for multiple comparisons correction (Maxwell, 1980). The ANOVA statistical outcomes were presented as the p values between both methods were similar and the presence of F-values made this data useful for future meta-analyses. Where the data distribution and uneven learner numbers were observed, such as in the VO2max test, F-values were unable to be presented and the t-test results were presented.

4. RESULTS

The participants in both the evaluation and control groups were well matched for age, stature and body mass (Table 1.). The evaluation group consisted off 33 learners, 24 of which were boys and 9 were girls. The control group consisted of 24 learners, 21 of which were boys and 3 were girls. To assess for the possibility of the unbalanced gender composition between groups acting as a cofounder we analysed differences by gender alone. These did not alter the findings. The evaluation groups bicycle usage was assessed using a self-reported logbook for a period of seven days prior to the testing session, of which the reported mean use was 12 hrs 47 min ± 7 hrs 17 min per week.

Table 1. General participant characteristics.

	Evaluation	Control
	n = 33	n = 24
Age (yrs)	15.67 ± 1.11	15.17 ± 0.76
Stature (cm)	161.58 ± 8.51	159.50 ± 7.70
Body mass (kg)	54.29 ± 10.97	55.07 ± 12.04

4.1 Anthropometrics

4.1.1 Stature

The evaluation group participants demonstrated a mean stature of 161.58 ± 8.51 cm at entry into study, and the control group a mean stature of 159.50 ± 7.70 cm. Participants in both groups grew over time to 162.20 ± 8.46 cm and 163.83 ± 7.27 cm respectively. There was a significant interaction ($F_{1,55}$=89.6, p<0.001) and time effect ($F_{1,55}$=167, p<0.001), although no significant group effect ($F_{1,55}$=0.013, p=0.911).

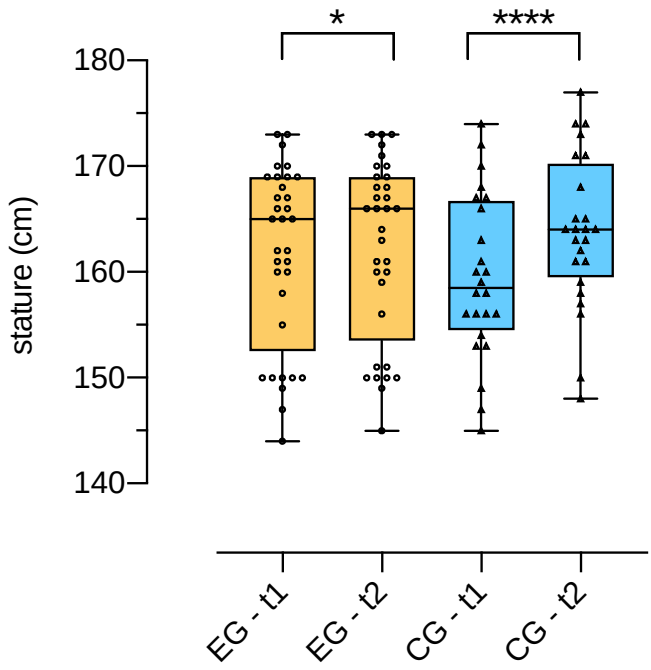

Figure 2. Stature.

4.1.2 Body mass

The evaluation group exhibited a mean body mass of 54.29 ± 10.97 kg at entry into study and the control group 55.10 ± 12.04 kg. Both groups gained mass and at time point two weighed 56.64 ± 11.14 kg and 57.70 ± 12.05 kg respectively. A significant time effect was observed ($F_{1,55}$=76.8, p<0.001), although no interaction ($F_{1,55}$=0.225, p=0.637) or group effect ($F_{1,55}$=0.090, p=0.766) thus both groups gained similar mass.

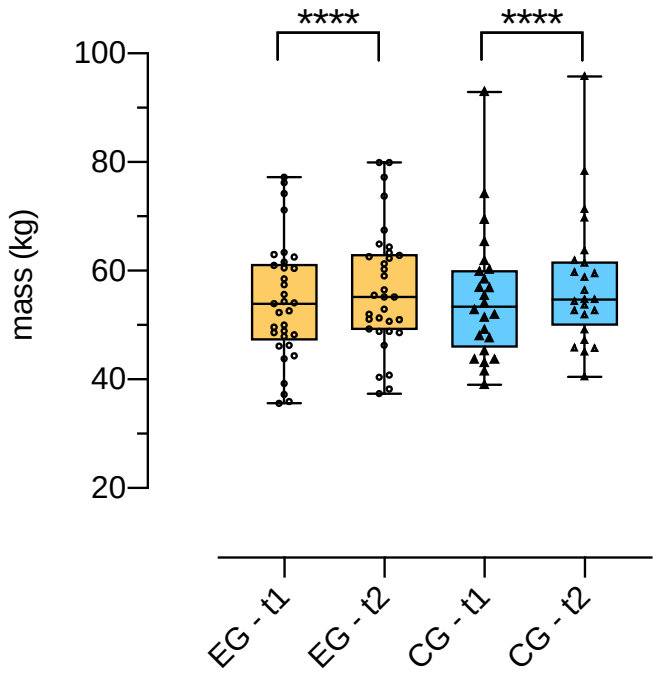

Figure 3. Body mass.

4.1.3 Body mass index

At entry into the study, the evaluation group mean BMI was of 20.82 ± 4.42 kg/m^2 and the control group mean BMI was 21.60 ± 3.77 kg/m^2. BMI for both groups increased and reached 21.68 ± 4.83 kg/m^2 and 21.40 ± 3.70 kg/m^2 respectively. There was a significant interaction ($F_{1,55}$=17.29, p<0.001) and time effect ($F_{1,55}$=8.832, p=0.004), although no group effect ($F_{1,55}$=0.043, p=0.836).

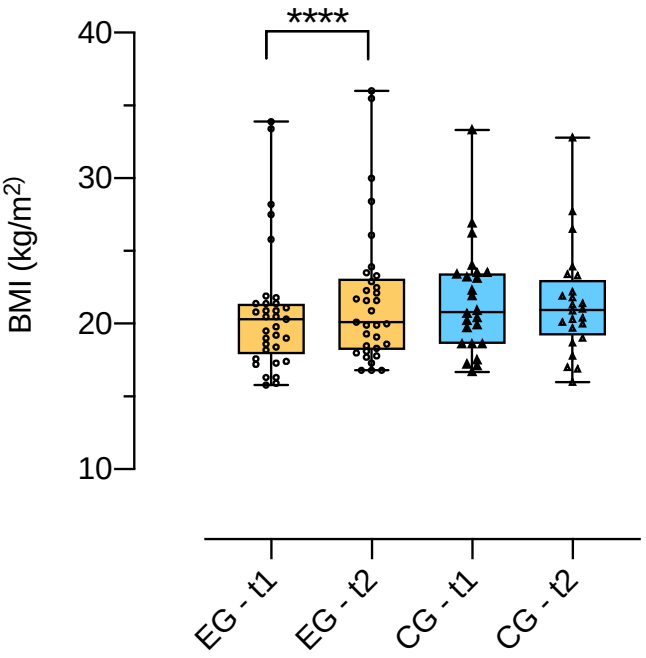

Figure 4. Body mass index.

4.1.4 Body fat percentage

The evaluation group demonstrated a mean body fat percentage of 15.11 ± 10.30 % at entry into study and the control a mean of 17.97 ± 7.78 %. The evaluation group body fat percentage increased to 17.42 ± 10.78 % and the control decreased to 14.01 ± 7.04 %. There was a significant interaction ($F_{1,55}$=100.1, p<0.001) and time effect ($F_{1,55}$=6.937, p=0.011), although no group effect ($F_{1,55}$=0.012, p=0.912).

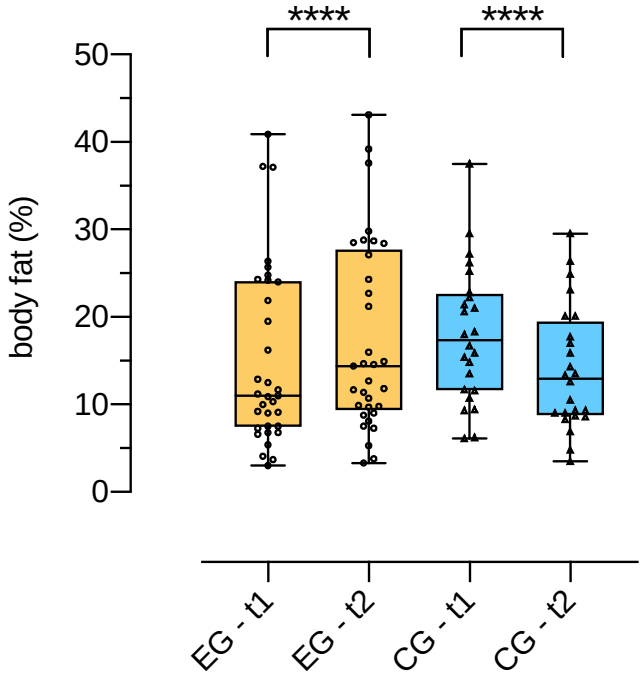

Figure 5. Body fat percentage.

4.1.5 Fat mass

The evaluation group mean fat mass was 8.92 ± 7.51 kg at entry into study, and the control group mean fat mass was 10.58 ± 6.68 kg. The evaluation group increased to 10.70 ± 8.36 kg and control decreased to 8.54 ± 5.96 kg respectively. A significant interaction ($F_{1,55}$=78.95, p=78.95) was observed, although no time ($F_{1,55}$=0.334, p=0.566) or group effect ($F_{1.55}$=0.017, p=0.898).

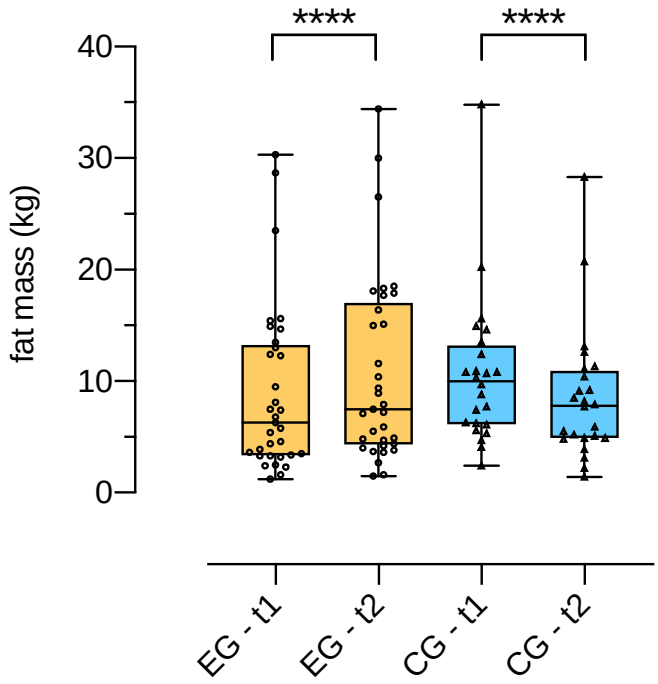

Figure 6. Fat mass.

4.1.6 Fat free mass

The evaluation group demonstrated a mean FFM of 45.43 ± 7.22 kg at entry into study, and the control group a mean FFM of 44.50 ± 7.18 kg. Both groups FFM increased to 45.94 ± 6.43 kg and 49.15 ± 7.87 kg respectively. A significant interaction ($F_{1,55}$=79.76, p<0.001) and time effect ($F_{1,55}$=123.4, p<0.001), although no group effect ($F_{1,55}$=0.360, p=0.551) were observed.

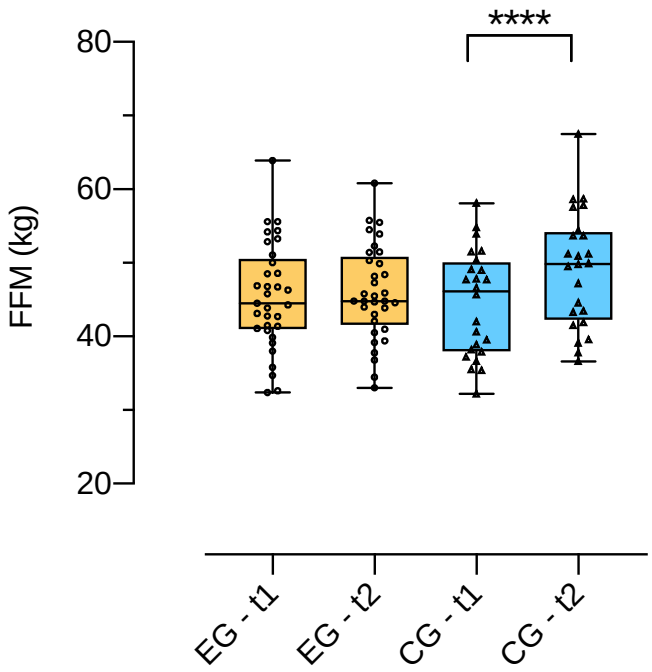

Figure 7. Fat free mass.

4.1.7 Muscle mass

The evaluation group showed a mean muscle mass of 43.05 ± 6.85 kg at entry into study, and the control a mean muscle mass of 42.22 ± 6.84 kg. Both groups increased muscle mass over time to 43.60 ± 6.14 kg and 46.67 ± 7.51 kg respectively. A significant interaction ($F_{1,55}$=77.45, p<0.001) and time effect ($F_{1,55}$=126.6, p<0.001), although no group effect ($F_{1,55}$=0.382, p=0.539) were observed.

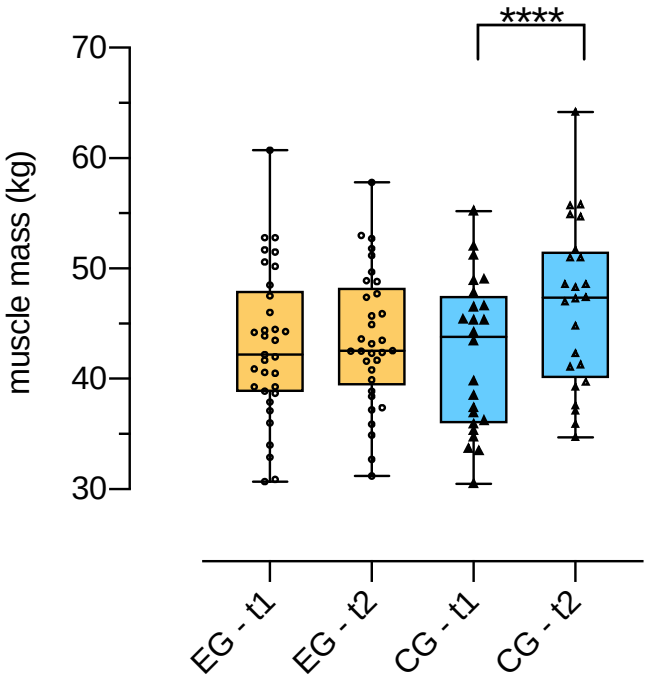

Figure 8. Muscle mass.

4.1.8 Mid-upper arm circumference

The evaluation group showed mean left and right upper arm circumference of 24.77 ± 3.60 cm and 24.80 ± 3.57 cm at entry into the study, and the control a mean left and right upper arm circumference of 24.12 ± 2.94 cm and 24.4 ± 2.90 cm. The evaluation groups upper arm circumference increased to 25.06 ± 3.30 cm (left) and 25.17 ± 3.44 cm (right), and the control groups upper arm circumference increased to 24.93 ± 3.03 cm (left) and 24.9 ± 3.09 cm (right).

An interaction was observed for the left arm ($F_{1,55}$=4.857, p=0.032) and not the right arm ($F_{1,55}$=0.277, p=0.601). A time effect was observed for both left ($F_{1,55}$=21.83, p<0.001) and right ($F_{1,55}$=17.91, p<0.001) arms, although no group effect observed for the left ($F_{1,55}$=0.210, p=0.648) or right ($F_{1,55}$=0.130, p=0.720) circumference.

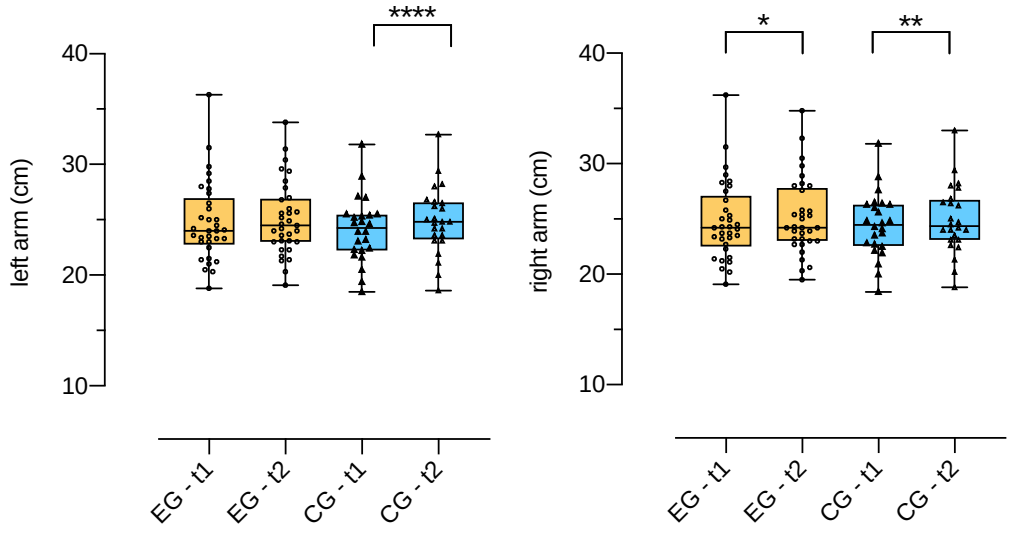

Figure 9. Mid Upper Arm Circumference.

4.2 Self-reported overall physical activity

The evaluation group demonstrated a mean self-reported overall physical activity score of 1.94 ± 0.33 at entry into study and the control a mean physical activity score of 2.27 ± 0.36. Both groups showed an increase in subjective physical activity scores over time. The evaluation group increased to 2.19 ± 0.33 and the control group to 2.45 ± 0.44. No significant interaction was observed ($F_{1,55}$=0.456, p=0.503), although both a significant time ($F_{1,55}$=18.4, p<0.001) and group ($F_{1,55}$=12.92, p<0.001) effect were observed.

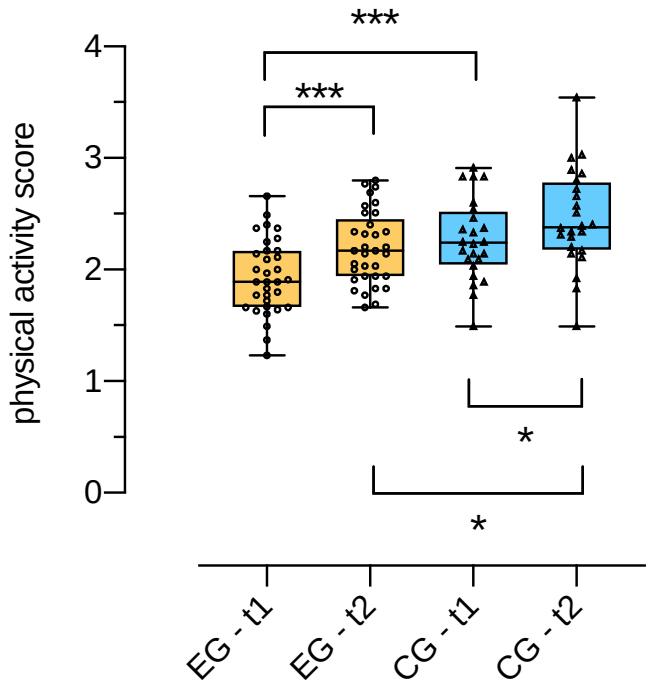

Figure 10. Self-reported Physical Activity Questionnaire for Adolescents.

4.3 Physiological assessment

4.3.1 Musculoskeletal fitness

The evaluation group showed a mean total hand grip score of 58.42 ± 16.19 kg at entry into study, and the control a mean total hand grip score of 62.34 ± 13.46 kg. Both groups increased their total hand grip strength over time to 62.82 ± 16.93 kg and 67.01 ± 14.32 kg respectively. No significant interaction ($F_{1,55}$=0.023, p=0.880) or group effect ($F_{1,55}$=0.993, p=0.324) were observed, although a significant time effect was observed ($F_{1,55}$=28.08, p<0.001).

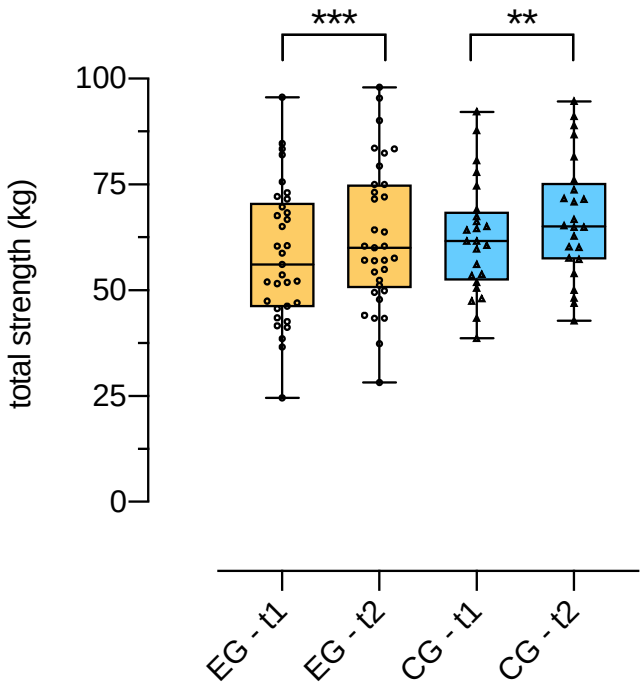

Figure 11. Total hand grip strength.

4.3.2 Torso strength

The evaluation group demonstrated a mean plank time of 56 ± 44 s at entry into study, and the control a mean time of 1 min 39 seconds ± 47 s. Both groups increased their plank times to 1 min 16 s ± 47 s and 1 min 56 s ± 47 s respectively. No significant interaction was observed ($F_{1,55}$=0.101, p=0.752), although both time ($F_{1,55}$=11.38, p=0.001) and group ($F_{1,55}$=13.93, p<0.001) effect were observed.

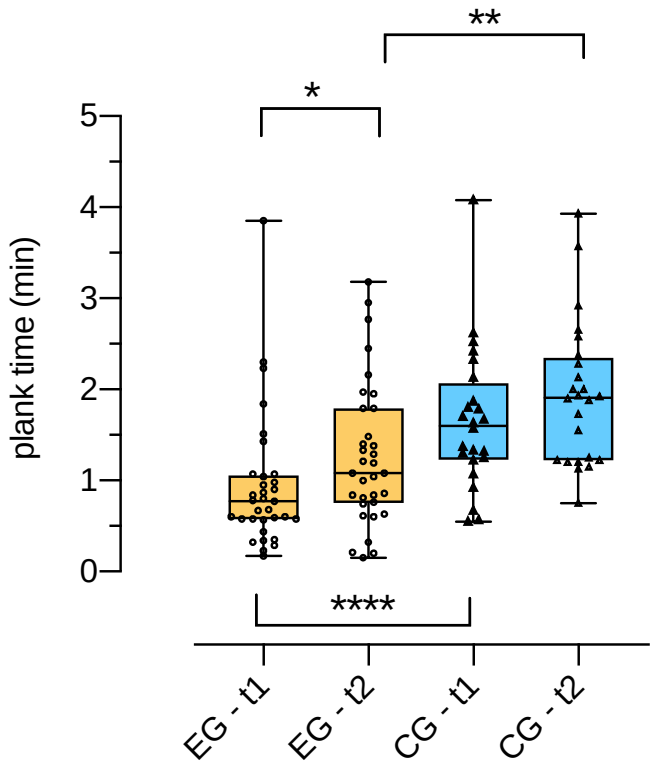

Figure 12. Plank.

4.3.3 Cardiorespiratory fitness

The evaluation group demonstrated a predicted VO_2max of 35.50 ± 4.20 ml/kg/min at entry into study, and the control a predicted VO_2max of 36.10 ± 2.56 ml/kg/min. The evaluation group decreased their predicted VO_2max to 34.40 ± 3.81 ml/kg/min and the control increased their predicted VO_2max to 39.00 ± 4.00 ml/kg/min respectively. The groups showed significantly different cardiorespiratory fitness at time point two ($p<0.001$). The evaluation group showed no difference from time point one to time point two.. Within the control group a significant increase in cardiorespiratory fitness were found from time point one to two ($p=0.003$).

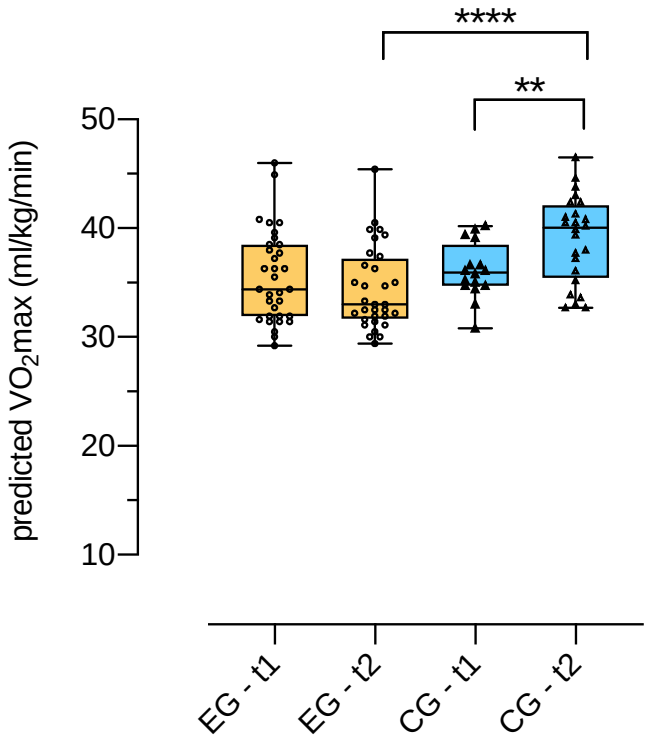

Figure 13. 20m shuttle run test.

4.4 Executive function assessments

4.4.1 Working memory (N-Back)

4.4.1.1 Elapsed time

The evaluation group exhibited a mean elapsed time of 18 min 1 s ± 2 min 38 s at entry into study, and the control group a mean elapsed time of 14 min 58 s ± 2 min 5 s. Both groups elapsed time decreased to 13 min 42 s ± 1 min 2 s and 14 min 40 s ± 1 min 3 s respectively.
A significant interaction ($F_{1,52}$=30.39, p<0.001), time ($F_{1,52}$=40.35, p<0.001) and group ($F_{1,52}$=10.54, p=0.002) effect were observed.

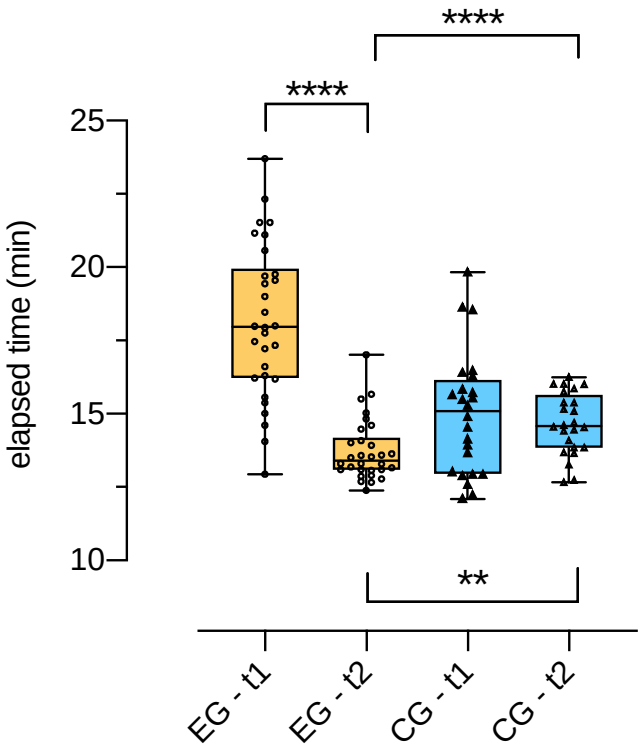

Figure 14. Elapsed test time.

4.4.1.2 Total hits

The evaluation group demonstrated a mean total hits of 42.60 ± 9.54 at entry into study, and the control group a mean total hits of 44.20 ± 7.54. Both groups total hits increased to 43.30 ± 8.09 and 45.67 ± 8.34 respectively. The groups were not significantly different at time point. Within each group, no differences were observed.

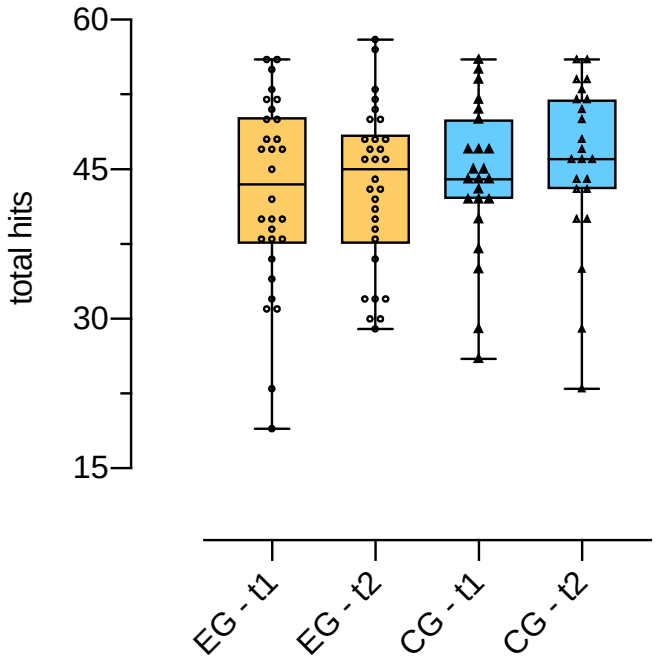

Figure 15. Total test hits.

4.4.1.3 Total false alarm rate

The evaluation group showed a mean total false alarm rate of 12.30 ± 8.31 at entry into study, and the control a mean total false alarm rate of 13.10 ± 7.34. The evaluation group increased to 15.30 ± 11.10 and control decreased to 11.60 ± 4.68. The groups were not significantly different at time point. Within each group, no differences were observed.

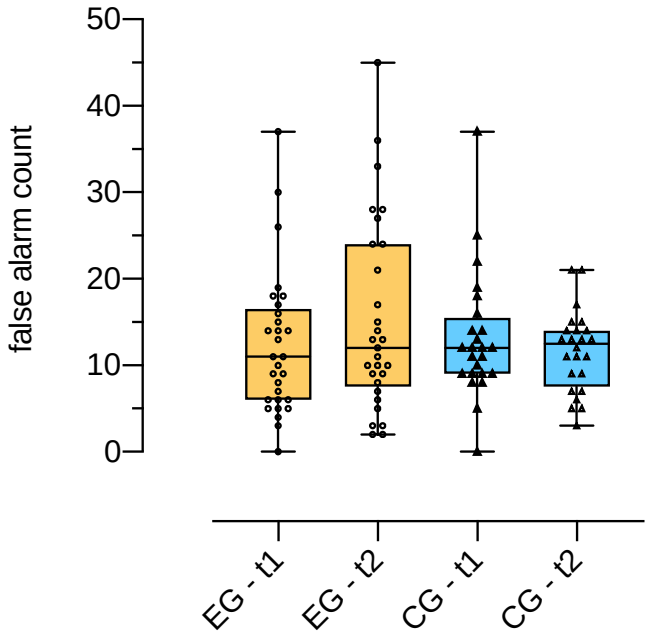

Figure 16. Total false alarm rate.

4.4.1.4 Deviation

The evaluation group demonstrated a mean deviation score of 2.34 ± 0.90 at entry into study, and the control group a mean deviation score of 2.54 ± 0.84. The evaluation group increased to 2.35 ± 0.78 and the control group increased to 2.93 ± 0.53. No significant interaction ($F_{1,49}$=2.239, p=0.141) or time effect ($F_{1,49}$=2.303, p=0.136) were observed. A significant group effect was observed ($F_{1,49}$=4.737, p=0.034).

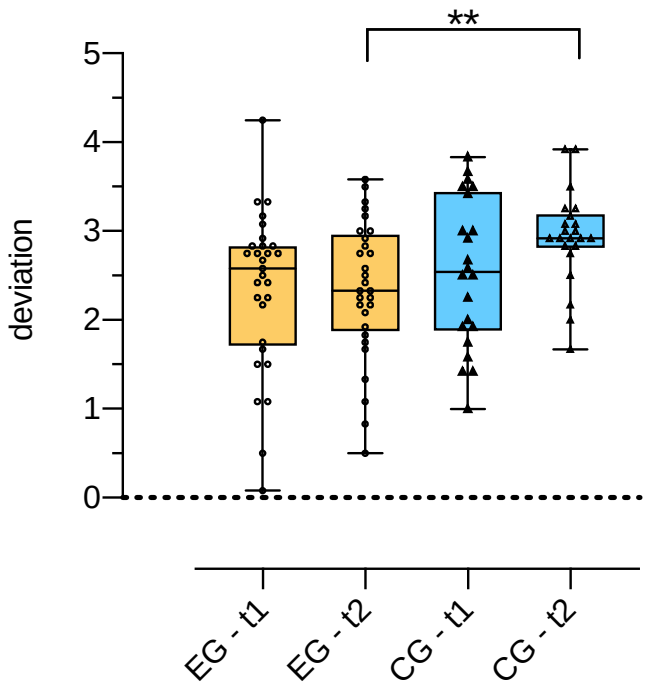

Figure 17. Total deviation.

4.4.2 Response Inhibition (Arrow-Flanker)

4.4.2.1 Elapsed time

The evaluation groups mean time of 2 min 51 s ± 31 s at entry into the study decreased to 2 min 11 s ± 11 s. The control groups initial mean time of 2 min 14 ± 25 s increased to 2 min 22 s ± 14 s. A significant interaction ($F_{1,54}$=37.18, p<0.001), time ($F_{1,54}$=16.74, p<0.001) and group ($F_{1,54}$=8.068, p=0.006) effect were observed.

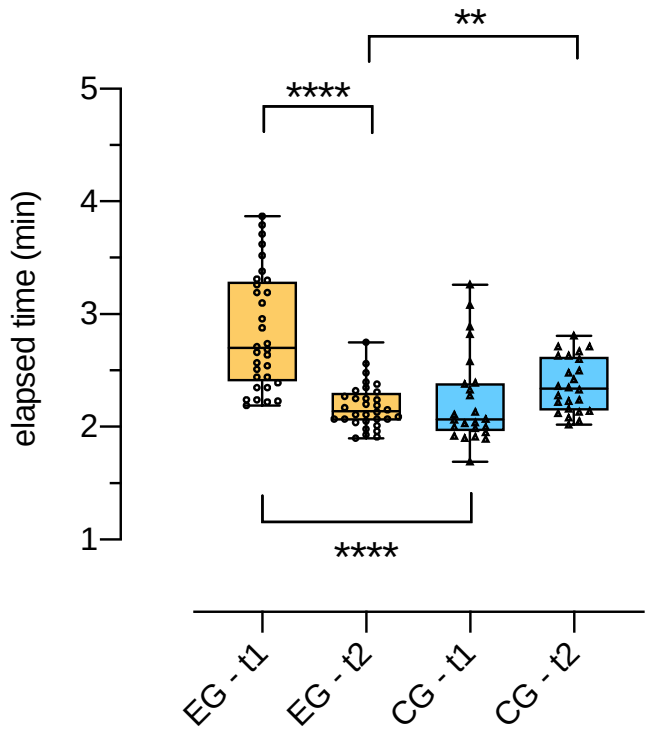

Figure 18. Elapsed test time.

4.4.2.2 Proportion correct

The evaluation group showed a mean correct proportion of 0.92 ± 0.14 at entry into study, and the control a mean correct proportion of 0.97 ± 0.09. The evaluation groups correct proportion increased to 0.98 ± 0.05 and control group decreased to 0.96 ± 0.09. A significant interaction was observed ($F_{1,52}$=4.400, p=0.041), although no significant time ($F_{1,52}$=3.726, p=0.076) or group ($F_{1,52}$=0.485, p=0.484) effect. As this test is using a proportion, floor and ceiling effects were present in the data.

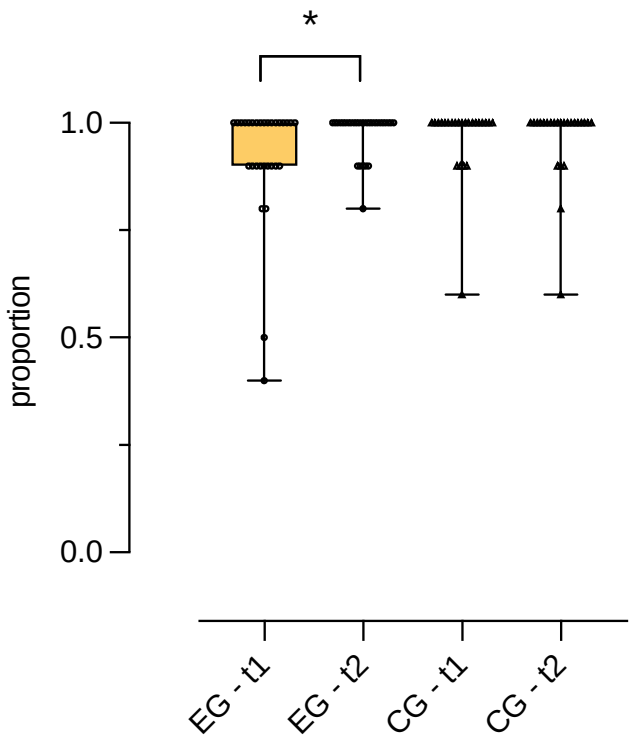

Figure 19. Proportion correct.

4.4.2.3 Mean response time

The evaluation groups initial mean response time of 548.00 ± 169.00 ms decreased to 504.00 ± 77.40 ms. As seen in the evaluation group, the control groups initial mean response time of 547.00 ± 145.00 ms decreased to 512.00 ± 139.00 ms. The groups were not significantly different at time point. Within each group, no differences were observed.

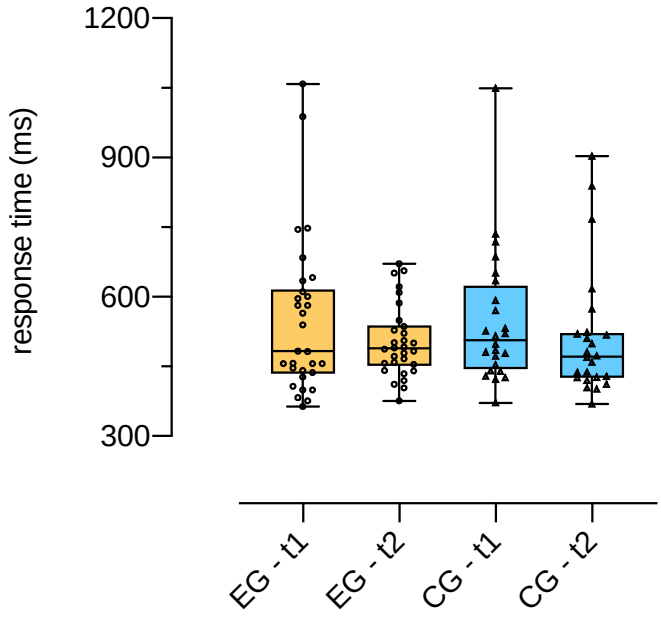

Figure 20. Mean response time.

4.4.2.4 Proportion correct congruent

The evaluation groups initial mean correct congruent proportion of 0.95 ± 0.15 increased to 0.99 ± 0.04, and the controls initial mean correct congruent proportion of 0.99 ± 0.02 showed no change. There was no significant interaction ($F_{1,52}$=2.693, p=0.107), time ($F_{1,52}$=2.963, p=0.107) or group ($F_{1,52}$=0.1505, p=0.226) effect. As this test is using a proportion, floor and ceiling effects were present in the data.

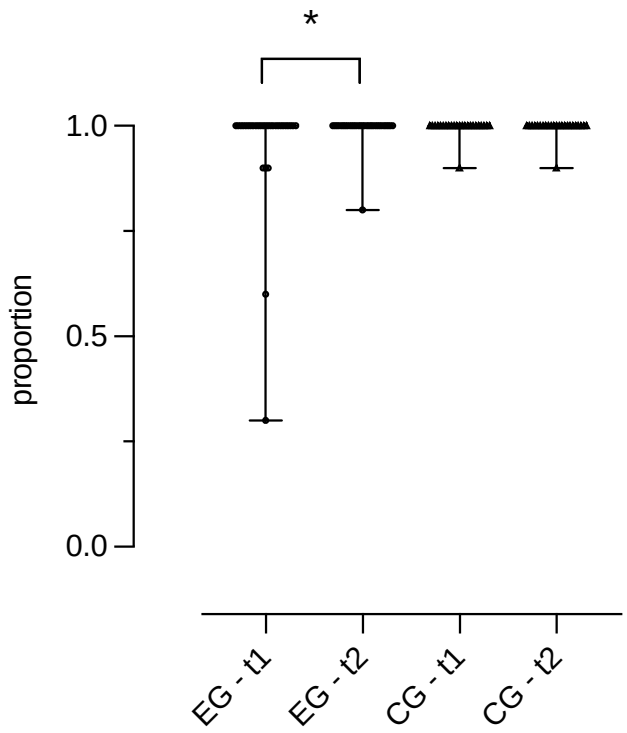

Figure 21. Proportion correct congruent.

4.4.2.5 Proportion correct incongruent

The evaluation groups initial mean correct incongruent proportion of 0.93 ± 0.18 increased to 0.97 ± 0.07 and the controls initial mean correct incongruent proportion of 0.94 ± 0.16 decreased to 0.93 ± 0.18 The groups were not significantly different at time point. Within each group, no differences were observed. As this test is using a proportion, floor and ceiling effects were present in the data.

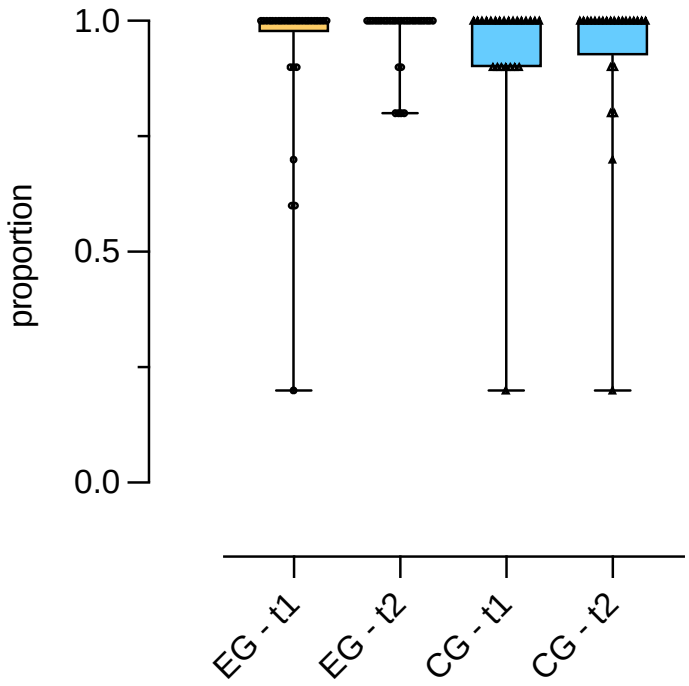

Figure 22. Proportion correct incongruent.

4.4.2.6 Congruent mean response time

The evaluation groups initial congruent response time of 524.00 ± 175.00 ms decreased to 490 ± 84.20 ms. As seen in the evaluation group, the control groups initial mean response time of 526.00 ± 151.00 ms decreased to 484.00 ± 135.00 ms. The groups were not significantly different at time point. Within each group, no differences were observed.

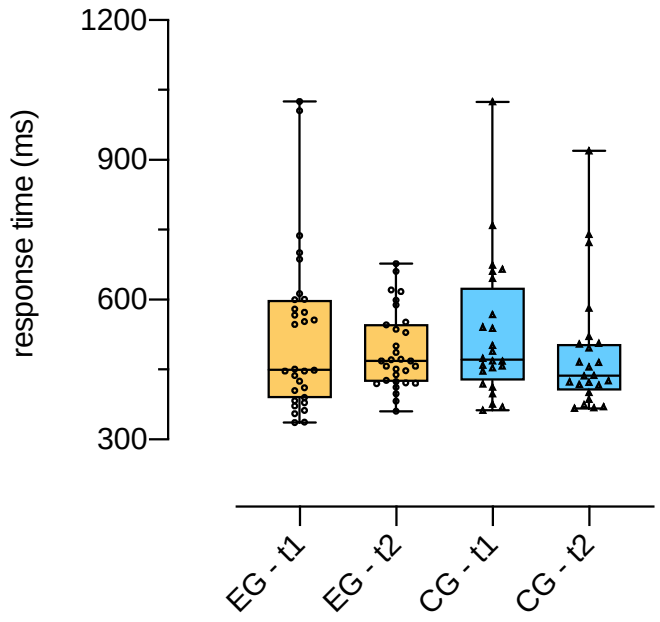

Figure 23. Mean response time congruent.

4.4.2.7 Incongruent mean response time

The evaluation groups initial congruent response time of 576.00 ± 174.00 ms decreased to 517.00 ± 76.00 ms. As seen in the evaluation group, the control groups initial mean response time of 573.00 ± 158.00 ms decreased to 560.00 ± 216.00 ms. Within each group, no differences were observed. Although the control groups response time was also faster, the change from time point one to time point two was not significant.

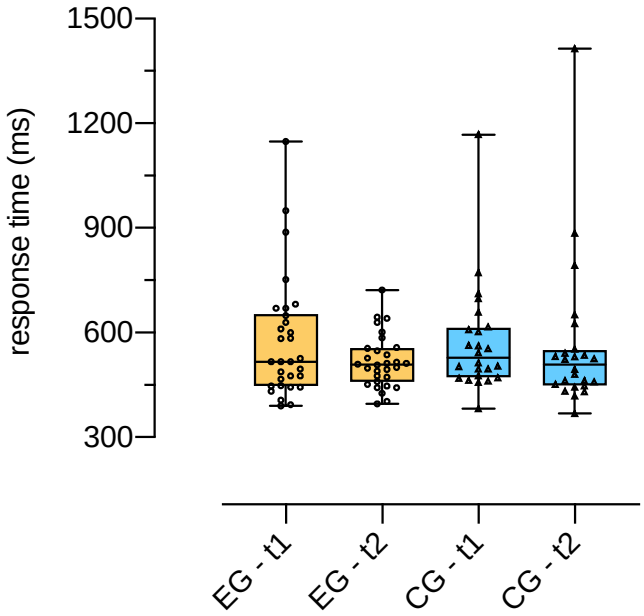

Figure 24. Mean response time incongruent.

4.4.3 Switching and perseveration (WCST)

4.4.3.1 Elapsed time

The evaluation group showed an initial mean elapsed time of 5 min 16 s ± 1 min 57 s, and the control with a lower 3 min 55 s ± 1 min 11 s. Both groups decreased their overall elapsed times to 3 min 46 s ± 1 min 8 s and 3 min 45 s ± 32 s respectively. A significant interaction ($F_{1,54}$=8.395, p=0.005), time ($F_{1,54}$=13.00, p<0.001) and group ($F_{1,54}$=5.684, p=0.021) effect were observed.

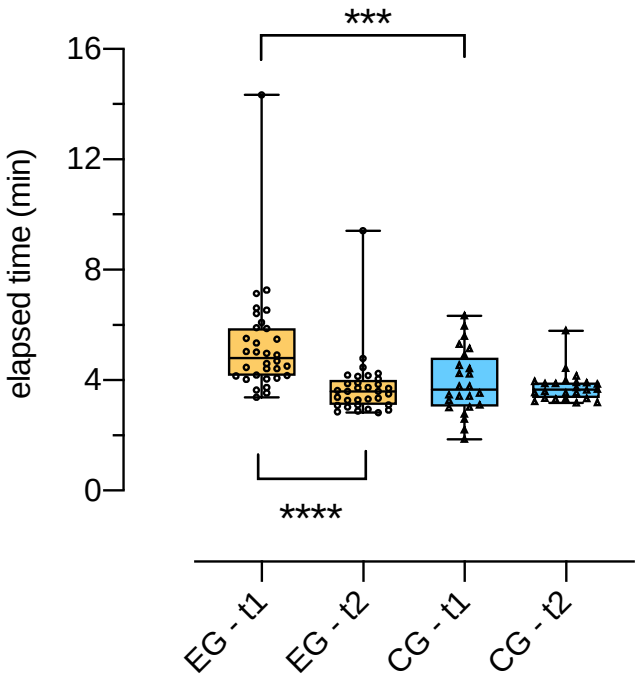

Figure 25. Elapsed test time.

4.4.3.2 Total trials

The evaluation group showed a mean total trial count of 46.97 ± 2.35 at entry into study, and the control a mean total trial count of 45.38 ± 3.39. Both groups decreased their total trial count to 46.03 ± 3.93 and 44.38 ± 3.51 respectively. No interaction ($F_{1,54}$=0.000, p>0.999) or time effect ($F_{1,54}$=3.291, p=0.075) was observed, although a significant group effect ($F_{1,54}$=6.977, p=0.011) was observed. As the participants were completing a set total number of trials, ceiling effects were present.

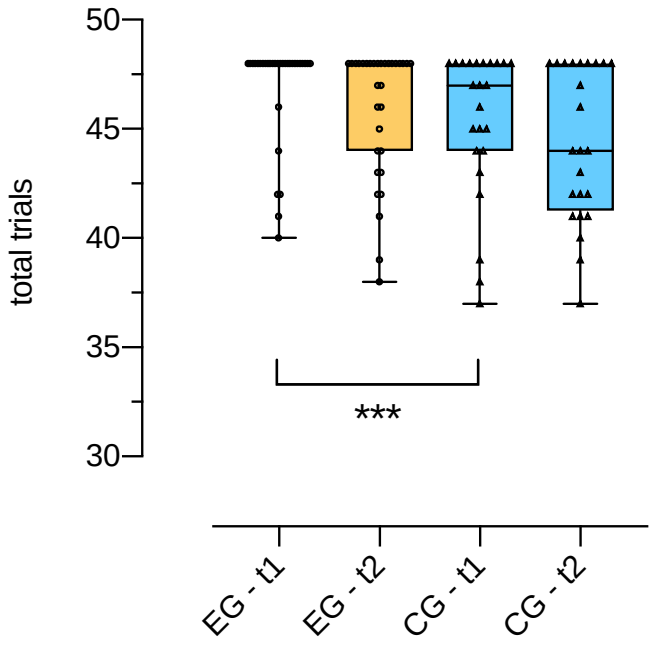

Figure 26. Total test trials.

4.4.3.3 Total correct

The evaluation group showed a mean total correct of 31.16 ± 6.34 at entry into study, with the control a mean total correct of 36.13 ± 3.85. The evaluation group increased their total correct to 36.55 ± 2.45 and control decreased their total correct to 35.38 ± 3.56. A significant interaction ($F_{1,54}$=20.14, p<0.001) and time effect ($F_{1,54}$=11.67, p=0.001) were observed, although no group effect ($F_{1,54}$=3.734, p=0.058).

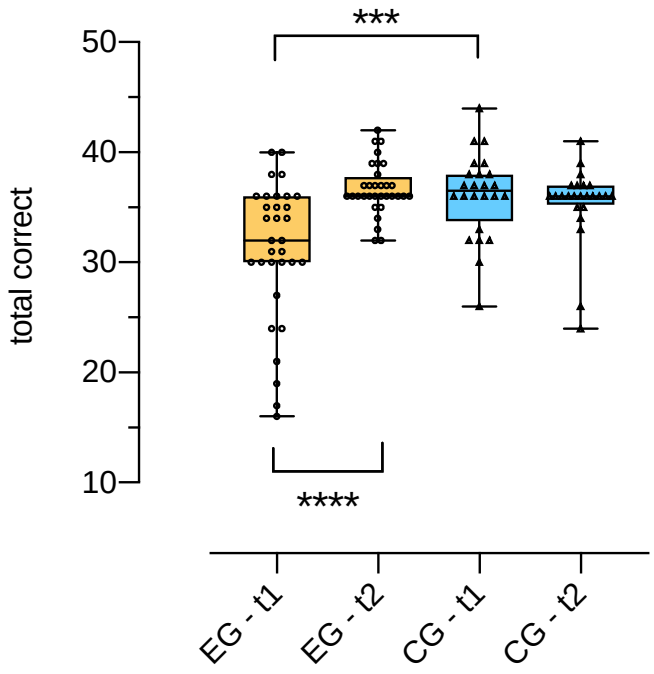

Figure 27. Total correct.

4.4.3.4 Total error

The evaluation group mean total error showed an initial value of 15.81 ± 7.66, with the control group mean total error of 9.25 ± 5.80. Both groups mean total error decreased to 9.28 ± 3.95 and 9.00 ± 5.83 respectively. An interaction ($F_{1,54}$=11.17, p=0.002), time ($F_{1,54}$=13.02, p<0.001) and group ($F_{1,54}$=6.802, p=0.012) effect were observed.

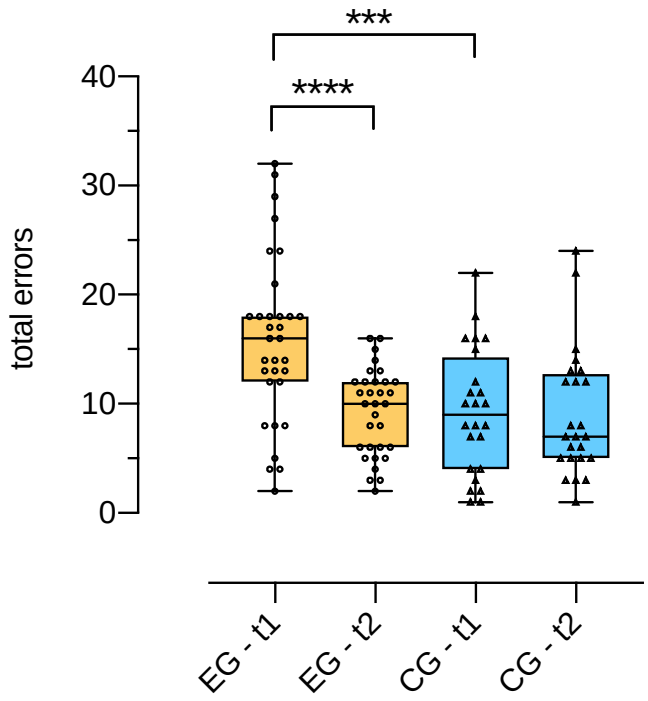

Figure 28. Total error.

4.4.3.5 Preservative error

The evaluation group demonstrated a mean preservative error of 2.25 ± 1.87 at entry into study, and the control group a mean preservative error of 1.54 ± 1.50 . Both group mean preservative errors increased to 2.34 ± 1.98 and 2.00 ± 1.35 respectively. The groups were not significantly different at time point. Within each group, no differences were observed. Floor effects were present in the data due to a low number of preservative errors.

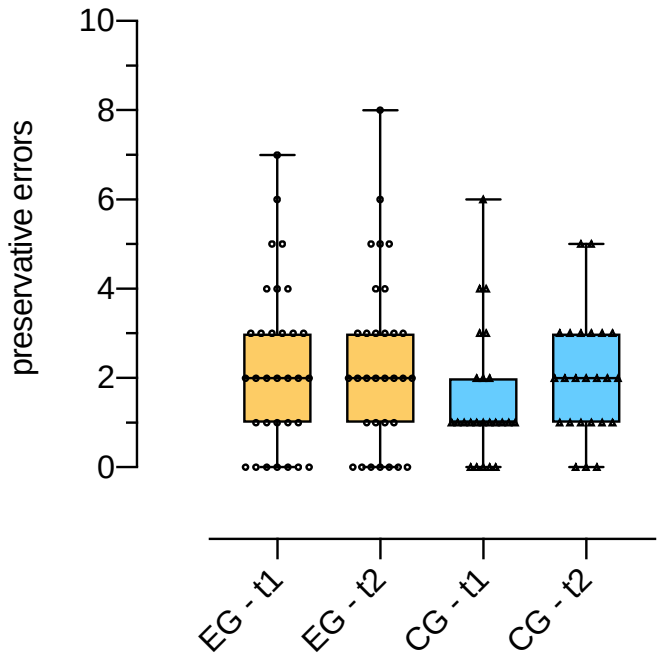

Figure 29. Preservative error.

4.4.3.6 Percentage preservative error

The mean percentage of preservative error in the evaluation group started at 17.28 ± 14.62 %, and the control group 19.60 ± 21.68 %. Both groups percentage of preservative error increased to 26.60 ± 23.06 and 29.77 ± 25.23 % respectively. The groups were not significantly different at time point. Within each group, no differences were observed.

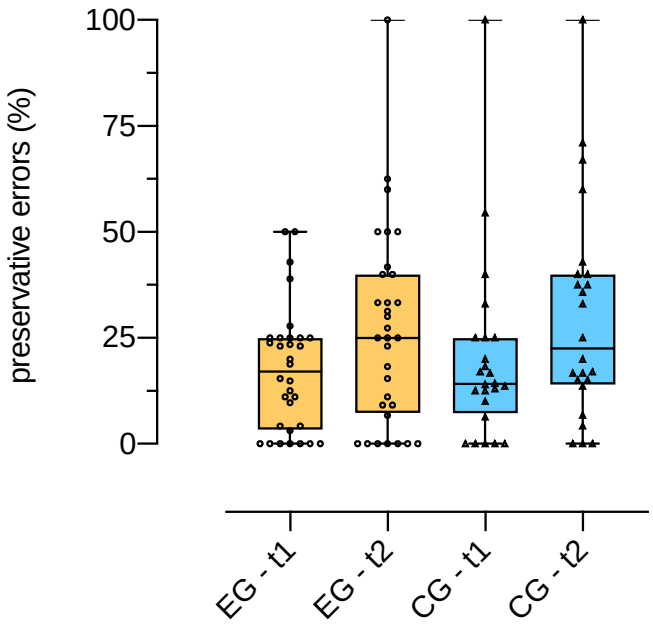

Figure 30. Percentage preservative error.

4.4.3.7 Completed categories

The evaluation group showed a mean completed categories of 4.13 ± 1.48 at initial time point, and the control a mean completed categories of 5.46 ± 0.83. Both groups increased to 5.22 ± 0.91 and 5.50 ± 0.78 respectively. An interaction ($F_{1,54}$=9.349, p=0.004), time ($F_{1,54}$=10.89, p=0.002) and group ($F_{1,54}$=12.21, p=0.001) effect were observed.

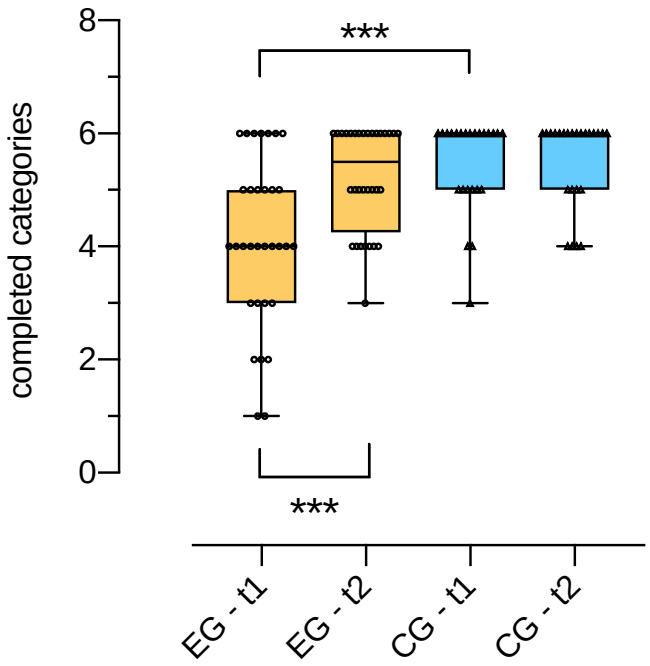

Figure 31. Completed categories.

4.4.3.8 Failure to maintain set

The evaluation groups failure to maintain the set mean was initially 0.78 ± 1.18, with the control at a lower mean of 0.38 ± 0.65. The evaluation group mean increased to 0.91 ± 0.93 and the control decreased to 0.17 ± 0.38. As most learners would have performed a similar number of sets, floor and ceiling effects were present in the data.

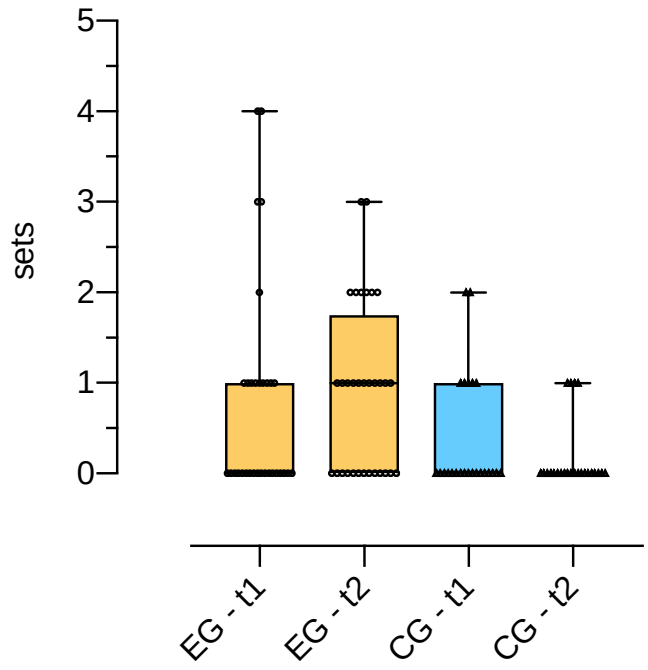

Figure 32. Failure to maintain set.

9.4.3.9 Trials completed first category

The evaluation group showed an initial mean completed category count of 7.84 ± 2.03 at entry, and the control an initial mean completed category count of 7.54 ± 2.23. The evaluation group mean count increased over time to 7.94 ± 2.51 and the control group mean count decreased to 6.96 ± 1.37. The groups were not significantly different at time point. Within each group, no differences were observed. The groups were not significantly different at time point. Within each group, no differences were observed. As the minimum number of trials in each category were similar, floor effects were present in the data.

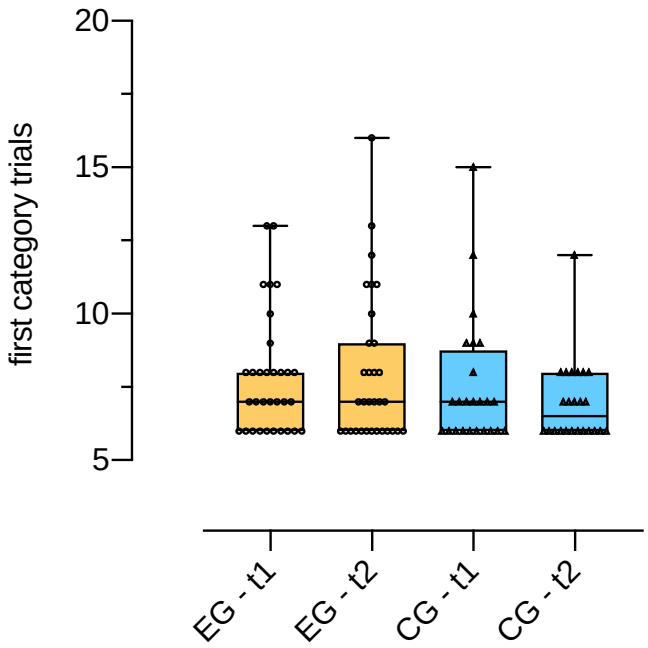

Figure 33. Trials completed first category.

5. DISCUSSION

This evaluation provides the first prolonged data in South African adolescents, assessing the effect of a bicycle intervention promoting AST in low-socioeconomic areas. More so, the use of a control group with these measured outcome variables is significant in creating a robust assessment of cycling as a mode of AST and its effect on overall PA, physiological adaptations and executive function.

Both groups were matched for age, stature and body mass at entry into the study, although surprising anthropometric differences occurred across both time points. These may be described by seasonal variation of summer and winter, as the two groups were tested at differing times during the year, due to the wait-list control protocol. The evaluation groups data were collected at the end of Summer and the beginning of Spring and separated by Winter. The control groups data were collected in the middle of winter and towards the end of Summer. Therefore this groups time points were separated by the end of Winter and Summer. This may explain the observed increased body fat percentage in the evaluation group and decreased body fat percentage in the control group. Adding to this, the seasonal variation may also explain the PAQ-A differences at the outset. The difference in both groups activity levels may represent differences in access to school facilities, additional socioeconomic or community factors which may alter activity levels. The bicycle use may therefore not be affecting the overall physical activity levels of the evaluation group, as both groups improved and no differences were found between the groups. The evaluation group PAQ-A scores of 1.94 ± 0.33 and 2.19 ± 0.33, and the control groups scores of 2.27 ± 0.36 and 2.45 ± 0.44, are both lower in comparison to the (Cohen et al., 2014) group where 6829 English school children showed a higher mean PAQ-A score of 2.8 ± 0.7 in comparison. It may therefore imply that physical activity is lower in these South African regions.

The questionnaire, although reliable and valid, is self-reported, and the use of an objective physical activity measure in subsequent research may confirm these overall physical activity levels. In addition to this, being able to quantify the daily distribution of physical activity may prove more useful. We also cannot exclude physical activity levels increasing due to natural development and age increase, although due to the six-month follow up this is unlikely to be

a factor. As explained in the South African report card, there are barriers which adolescents face which may explain why it is challenging to achieve the recommended physical activity levels. As shown by Romero, greater self-reported physical activity levels were associated with more hours spent in school extra-mural programs and higher-quality community facilities (Romero, 2005). This highlights the importance of physical activity at school, and this may provide a safer space for adolescents to engage in exercise and activity. These barriers may result in the learners with bicycles opting not to cycle for active school travel or around their communities and therefore less overall physical activity. Schools in South African communities allowing safer spaces for learners to participate in physical activity may be integral in instigating this change moving forward. This may act as an appropriate intervention in South African schools to ensure that the current PA guidelines are met and in turn benefit EF, sleep and academic performance (Hysing et al., 2016; Zhang et al., 2017).

In both groups the musculoskeletal assessment total hand grip strength score increased, and this follows a similar trend to the PAQ-A. The evaluation groups second time point showed a mean total hand grip score of 62.8 ± 16.9 and the control groups second time point a mean total hand grip score of 67.0 ± 14.3. These scores are not comparable to other data, as different methodologies of calculating the score may have been used. In this study, the mean of two scores on each hand was totalled to create a total hand grip score. Other studies have not reported on the method, which was used, although it appears as if a mean of one hand was taken and not a total of both hands. The increased total hand grip score observed in this study may be a result of both groups increased physical activity, or an increase in general strength or muscle mass, as both increased. Both stature and muscle mass increased similarly in the control and not in the evaluation. An additional explanatory factor may be that the groups may differ with regards to their onset of puberty and peak growth rates.

The evaluation groups torso strength increases from time point one to time point two (p=0,013), whereas the control group showed no significant difference (p=0.099). This increase in torso strength may be because of increased bicycle usage and stability required to balance while using the bicycle. The data from (Andersen et al., 2009) and their demonstrated that cycling as a mode of AST resulted greater aerobic power, muscular endurance and flexibility than the children who walked as a mode of AST or passive travelled.

The control group observed a reduction in body fat, whereas the evaluation groups body fat percentage increased, and once again may be explained by seasonal variation. One additional hypothesis may be that the bicycle reduces overall energy expenditure due to the more economical active school travel. The differences observed are not skewed by more girls in the evaluation group, which was considered, as the data was analysed with boys only and the observed differences remained. The plank assessment followed the same trend as the PAQ-A, although not seen in the hand grip. It is therefore not clear as to why these differences occurred.

The predicted VO2max of the evaluation group declined, and this was despite a more active phase which was indicated by the PAQ-A. The predicted VO2max in the control group increased. The mean of both groups mean predicted VO2max of 36.7 ml/kg/min is lower than (Ramirez-Velez et al., 2017) group of Colombian children, who a reported a mean predicted VO2max of 41.4 ml/kg/min. The bicycle may therefore be reducing the intensity of exercise or weight-bearing exercise, and the children were less-conditioned in the beep test. The BMI and body fat percentage increases in the evaluation group may support these findings. This may complement the observed executive function test results, due to potential greater energy availability.

This study is the first to examine all three executive functions in South African adolescents over a prolonged period. The data is difficult to compare to other studies, as methods and tests used differ. Specific to this study and across all three tests, there were improvements in the evaluation group with respect to overall time to complete the tests, which was not observed in the control group. The learning effect could not be a factor, as the children performed the test at two points with a six-month interval. If a learning effect was present, this would have shown in both groups. An additional factor to consider is that the control school had a computer room, and students are frequently exposed to the use of computers, whereas to our knowledge the evaluation school did not have a computer room with information technology (IT) facilities for learners to regularly use. Although once again the single use of the computer during the tests may not provide sufficient familiarisation to improve IT proficiency.

In the assessment of working memory using the N-back, the evaluation group showed a significant decrease ($p<0.001$) in elapsed time from time point one (18 m 6 s) to time point two (13 m 42 s), whereas no differences were observed in the control group (from time point one (15 m 0 s to 14 m 42 s). The faster working time is supported by (Lindheimer et al., 2017), who assessed the effect of light-intensity cycling on mood and working memory in response to a randomized, placebo-controlled design. The same working memory test was used, and shorter reaction times after the exercise bout were observed. Both groups total hits improved, although no significant differences were shown. The total false alarm rate, which is hitting an answer key for a non-target and indicates an incorrect answer, increased in the evaluation group (12.3 to 15.3) and decreased in the control group (13.1 to 11). These data were not significant, but there is a possibility that this non-significant change may have influenced the elapsed time result. The DV, which describes the amount of correct answers as a ratio calculated using formula (3), remained similar in both groups. It is evident that the evaluation group were working faster, although they made more mistakes in time point two compared to time point one. The potential improvement in working memory may be supported by the study by (Phansikar et al., 2019), as they demonstrated that AST showed positive associations with working memory. This still may represent better cognitive efficiency as opposed to their initial test results. A useful metric in the executive function tests may be an efficiency calculation, where more variables than pure scores are considered to determine if the test was performed more efficiently or not.

The Arrow Flanker, which assessed response inhibition, showed a significantly shorter elapsed time ($p<0.001$) in the evaluation group from time point one (2 m 51 s) to time point two (2 m 11 s), where the control group remained similar from time point one (2 m 14 s) to time point two (2 m 22 s). The evaluation group proportion correct increased from 0.92 ± 0.142 to 0.98 ± 0.05 whereas the control remained the similar. The mean response time was similar in both groups, and both groups time decreased from time point one to time point two, meaning that they were responding faster, although no significant differences were shown. The apparent improvement in inhibition is in agreement with (Berchicci et al., 2015), who demonstrated that aerobically fit children showed higher pre-frontal cortex activity during the Flanker task, and postulated greater inhibition.

In the WCST the evaluation group as seen with the previous executive function tests, significantly improved ($p<0.001$) their elapsed time from time point one (5 m 16 s) to time point two (3 m 45 s). The same trend was observed with the evaluation groups total correct and total error, with an increase and decrease respectively. An increase in the amount of completed categories in the evaluation group was also observed. It is evident that the evaluation group may have showed an improvement in their switching and preservation. This may be supported by (Berse et al., 2015), who showed that after a cycling exercise bout, shifting improved significantly. Understanding this data when compared to adolescents in other countries may provide a contextual understanding of our baseline values and secondly the impact of the bicycle usage. In terms of percentage of preservative error, the mean of both groups increased from time point one to time point two. Both groups percentage of preservative error were higher than those reported by (Lung & Bertone, 2021), who assessed the cognitive flexibility of Canadian autistic adolescents using the WCST. Their mean reported percentage preservative error were 17.15 % and 14.02 % in the autistic and non-autistic groups. The additional WCST variables which we assessed were unfortunately not reported by the authors. Furthermore, a study in Taiwan adolescents assessed the WCST performance between 45 Schizotypal and 157 control participants (Lin et al., 2010). The authors reported on the same test variables which we assessed and found no significant differences between either group across all WCST outcome variables. Their adolescents showed a higher number of total errors, preservative errors, and trials to complete first category when compared to our WCST data.

The significant improvement in the executive function tests for the evaluation group when compared to the control may be due to several factors:

If the learners were able to travel to school faster than the control, as well as faster travel for other activities such as journeys to the supermarket or other stores, family, and friends, they would free up more time for non-travel related activities. This could allow a greater time availability for homework, chores and or mental and physical relaxation. These have been reported in the literature as factors affecting learners in low-socioeconomic areas (Ramirez-Velez et al., 2017).

The reduced energy expenditure, which may be supported by the body fat percentage and BMI values allowed the authors to hypothesise that there may be greater energy available for cognitive functioning and brain development. A cross-sectional examination of four-year-olds suggested that over-activity may be related to poorer executive function in early childhood. This may be due to the energy expenditure trade-off. This study was in younger children, although in the context South African adolescents, it is potentially a combination of early energy expenditure and decreased sleep time that may result in poorer EF in classrooms. (Willoughby, Wylie, & Catellier, 2018).

A reduction in travel time may also result in improved sleep, as well as an increase in leisure time and time to complete school related activities. A large population based study in Norwegian adolescents found that reduced sleep duration was associated with poorer academic performance (Hysing et al., 2016). An additional study assessed sleep duration, sleep timing and mental health markers in the United States of America. Results showed that decreased sleep duration was significantly associated with poorer mental health outcomes (Zhang et al., 2017). These factors may also contribute to a reduction in overall stress levels, although neither of the above-mentioned variables were measured during this study and more specifically measured in the South African context.

6. FUTURE CONSIDERATIONS

Quantifying the learners commute time and movement patterns via the use of GPS devices may provide a comparable variable in which to determine the exact effect of cycling as a mode of AST. Although the learners completed a logbook of their bicycle usage a week prior to testing, the GPS data may further quantify their overall bicycle usage time cross-sectionally and also longitudinally. The learners absolute commute distance may also be determined and compared to previous data, and further establishing trends between distance from home and AST in these South African settings.

In addition to this, objectively quantifying the learners physical activity during the day alongside self-reported measures would validate the self-reported measures in the South

African community. As this study used only the self-reported overall activity measure, as with previous research, there may be a gap in the understanding of the exact physical activity distribution throughout the day.

The PAQ-A questionnaire and executive function assessments were presented in English, although a valid and reliable translation of these into the learners home languages will allow better self-reported physical activity and executive function research within South African communities to be conducted.

An area not tested during this study, although highly relevant to our current society and research, was dietary intake and sleep. These two variables have been shown to influence NCD's, mortality rate and health status. Quantifying these variables alongside the collected data may provide greater insights into the dietary and sleep trends of these learners, as well as if the bicycle is in fact improving sleep by reducing early wake-up times and AST duration.

An additional six-month follow up may provide confirmation of the observed differences, as well as any additional longitudinal changes which may result due to the use of a bicycle.

7. STUDY LIMITATIONS

The study had a number of limitations. Firstly, the sample size was relatively small, and a larger cohort may have provided additional differences in the outcome measures. Although significant differences were seen in many of the outcome variables. This paper as previously included indicates that reaching a general consensus on this topic is difficult as most research papers have inconsistent findings. This is often due to the weakness in methodology, which often comes with complex testing methods, especially those that recruit minors. Consistent research with poor reliability may ultimately lead to meta-analyses being flawed (Howie & Pate, 2012).

Secondly, the timing of the testing between both groups could have been better co-ordinated, to reduce any potential seasonal variation in anthropometrics and physiological variables.

There were challenges with identifying the control school to be assessed, as this needed to be a school identified by Qhubeka as a learner mobility school.

Thirdly, there were challenges working around the school academic calendar, activities and holidays. The testing dates and timing between the tests may have been more precise without these challenges. At the time of completion of the study, due to the worldwide health crisis of covid-19, obtaining the learners academic results was not possible due to closing of schools. These data would have been useful to compare to the executive function testing.

Fourthly, the questionnaires and executive function software were in English and not in the participants home language of isiXhosa. This may have affected the learners ability to fully understand the specific questionnaires and tasks. Unfortunately, the questionnaires and executive function software have not been translated into the participants home language and validated at the time of this evaluation. Future research may explore this avenue and therefore allow a better understanding of these metrics in the South African context.

Finally, there are many differing factors between schools with regards to facilities, teaching and location. Additional schools may need to be included in follow-up studies, aiming to reduce the effect of these factors on the outcome variables. Adding to this, a complex analysis of these variables and similarities or differences between these schools and their broader communities is needed to provide a deeper analysis and interpretation of the outcome variables in South Africa.

8. CONCLUSION

The results from this study are significant, as they are the first to assess the prolonged subjective overall physical activity, musculoskeletal and CRF levels of two male and female adolescent groups in two South African low-income communities. It is evident that there are potential improvements in subjective physical activity, torso strength and executive functioning due to cycling as a mode of AST or during leisure-time. Significant working memory, inhibition and shifting improvements were observed, although the exact

mechanism of these improvements is yet to be determined. Furthermore, the frequency and volume of bicycle usage needed to elicit these changes is yet to be determined.

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10. APPENDICES

10.1 Informed consent form

INFORMED CONSENT FORM
1.1 PARTICIPANT MINOR ASSENT FORM
Good day,

We are conducting a research study about the influence of Qhubeka Bicycles in schools in the Paarl region.

The evaluation is a way for us to learn more about how the Qhubeka bicycle influences your fitness, strength and school performance. If you decide that you want to be involved in the study, you will be required to perform a basic set of tasks on three occasions over a period of six months. These tasks will be a Beep test, Plank test and a Grip Strength test. We will then perform some short Tablet-based activities.
We will have access to your name and some personal information, but please know that this is all strictly confidential and it will not be used in the study.

There are no rewards for taking part in this research, but you will provide valuable information for us to learn more about the impact of these bicycles in communities. You will receive an information sheet, with the complete results of your tests. You will receive a report about the information gathered, and the potential benefits which the bicycles have on your physical well-being and also academics. The report will contain no personal information of yours.

We would greatly appreciate you taking part in this study, but you are under no obligation to do so. If you choose to stop after we begin, that is also perfectly fine. Your parents have been informed about the study and what it is about.
If you decide that you would like to take part in this study, please sign your name below.

_____ _____ _____

Signature Name (Please Print) Date

1.2 PARTICIPANT INFORMATION SHEET & INFORMED CONSENT FORM (parent / legal guardian)

Dear Parent/legal guardian,

I am Masters student in Exercise Science and Sports Medicine at the University of Cape Town. I will be conducting a study to determine the effects of a Qhubeka Bicycle on your child, in terms of physiology and executive function.

Information such as your childs current physical activity levels, anthropometrics, predicted VO_2 max, general strength and executive function will be collected and assessed. The information obtained within the study will be used to complete my dissertation in fulfilment

of the MSc Exercise Science and Sports Medicine course. This study has been given ethical approval by the Human Research Ethics Committee, Faculty of Health Sciences, University of Cape Town (). This study will be supervised by Dr Jeroen Swart from the University of Cape Town. Please take time to read this form thoroughly before signing consent for your child to take part in the study.

Why is this study being done?

Bicycles are an effective mode of transport, as well as promote health benefits and physical activity. There is limited data regarding the effects of a bicycle on an adolescent's lifestyle and schooling. The relationship between the use of a bicycle in day to day functioning on physiology and academic performance needs to be assessed. If there is a positive influence of the bicycle in terms of physiology and academic performance, then this will aid in support of bicycle distribution to communities in need. This will also further enhance physical development and health, beyond that of daily functioning.

What will happen if my child decides to take part in the study?

Your child will be asked to perform a series of three assessments, at your childs local school in Paarl. These assessments will be spread out at an initial assessment, three months and then six months after the initial assessment.

On the first visit:

On the first visit to the school, you and your child will sign an assent and informed consent form. Your child or yourself will complete the Physical Activity Readiness Questionnaire (PAR-Q), and your child the Physical Activity Questionnaire for Adolescents (PAQ-A), and anthropometry measurements such as height, weight and body fat percentage will be taken. Your child will then complete the musculoskeletal fitness grip strength assessment, as well as the plank assessment of torso strength. Thereafter, the Bleep test (20m shuttle run test). The Rate of Perceived Exertion for the physiological assessments will be taken using the 15 point Borg Scale.

On the following day, your child will perform three basic tasks which asses their level of thinking and memory. These are called Executive Function assessments, which are the Wisconsin Card Sorting Test (WCST), N-Back and Flanker tasks. This will be performed digitally on a tablet provided.

On the second visit:

Three month after receiving the bicycles, your child will complete the same tests as performed in the baseline values. Thereafter, a final assessments will be conducted at six months after the initial data was collected.

How long will the study last?

The study will last approximately six months. Your child will be asked to attend a total of three sessions, each three months apart, at your school.

What are the risks and discomforts of this study?

The assessments and methods used in this evaluation pose no inherent risk other than the risk associated with any regular exercise.

I will also ask your child to tell me if they feel any discomfort during the exercises, and if this is the case we can stop testing immediately. Your child may also experience some soreness after the testing, which is similar to the soreness after any unaccustomed or difficult exercise. This soreness should go away within two to five days after the testing. Although every effort will be taken to minimise injury, should your child sustain an injury during testing, they will be referred for the appropriate medical care.

Will your child's test results be shared with you?

Your child will be given feedback on all the exercises and tasks performed.

Will your child receive any reward for taking part in this study?

There is no financial compensation for participation in this study.

What if Something Goes Wrong?

The University of Cape Town (UCT) undertakes that in the event of your child suffering any significant deterioration in health or well-being as a result of the exercises in this evaluation, it will provide immediate medical care. UCT has appropriate insurance cover to provide prompt payment of compensation for any trial-related injury according to the guidelines outlined by the Association of the British Pharmaceutical Industry, ABPI 1991. Broadly-speaking, the ABPI guidelines recommend that the insured company (UCT), without legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study doctor immediately of any side effects and/or injuries during the trial, whether they are research-related or other related complications.

UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while you were taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected. Copies of these guidelines are available on request.

The UCT FHS Human Research Ethics Committee can be contacted on 021 406 6338 in case participants have any questions regarding their rights and welfare as research subjects on the study.

Who does myself or my child speak to if there are any questions about the study?

If at any time you or your child have any questions about the study, please feel free to contact any of the individuals listed below. You are both assured that all inquiries will remain confidential.

Reece McDonald

Physical Address: Sports Science Institute South Africa

Tel number: 079 089 1694

Email: mcdree002@myuct.ac.za

Dr. Jeroen Swart

Physical Address: Sports Science Institute South Africa

Tel number: 021 659 5644

Email: Jeroen.swart@uct.ac.za

Professor Marc Blockman

Human Research Ethics Committee

Email: marc.blockman@uct.ac.za

By placing your signature below, it serves as confirmation that you have had adequate time to read through the study information, that you have understood the consent form and that you are willing to participate in this study. You have the right to withdraw at any time and you may ask questions at any time during the study. All information recorded during this study will remain confidential, and no participants will be identified in the event of future publication. Your signature is further confirmation that you are aware of the possible risks involved in this study.

_____

Name of your child

_____	_____	_____
Signature of Parent/legal guardian	Name (Please Print)	Date
_____	_____	_____
Signature of Investigator	Name (Please Print)	Date

10.2 Qhubeka bicycle distribution training programme

Safe Cycling Competency Course

Contents

- **Introduction to Bicycles and Beyond (BAB)**

- Bicycles and Beyond was established in Feb 2015. It came about when the two founding members Janine Van Beulen Johnson and Beverley Roode saw the need in the community for the empowerment of women and youth in cycling. The name Bicycles and Beyond came about our giving back to the people and about sharing our knowledge, to show and teach people how the bicycle can become part of their everyday lives and how it can be used as a mode of transport in all communities. To train women and youth on how to fix and repair bicycles and how this skill could lead to employment and empowerment of themselves. Also to take the youth and community beyond their everyday lives.
- A women's organisation where we employed 6 women on a assembly plant building bicycles for learners in different schools
- With a vision: of developing, learning and the growing of women and youth in cycling in all diversities

- **Helmet fitting/ How to fit your helmet?**

- Demonstrating to a group/ class of students on how to fit and wear their helmet correctly.

- **Your Visibility / What to wear?**

- Explaining to the class on what type of clothing to wear and how to wear it.
- Explaining to the class to be visible at all times.
- Demonstrating to the class on how to wear a safety reflective bib.
- Explaining on different types of clothing to wear in different weather conditions
- Day and Night clothing
- How to make your bicycle more reflective and visible

- **Cycling Hand signs**

- Demonstrating and explaining to the class what hand signs to use when cycling

- **Cycling Road signs**

- Introducing rules of the road
- Showing actual road signs made in smaller versions to the ones on the road
- What road signs to look out for while riding your bicycle relevant to cycling

- **Pre cycling bicycle check**

  - Demonstrating to the class on what to check for on their bicycle before they go cycling

- **Road Assistance**

  - Puncture repair

- **Do's and Don'ts**

  - Bicycle maintenance demo
  - Explaining to the class on what to do and what not to do while out cycling
  - Explaining to the class what to do and what not to do with their bicycle
  - Explaining to the class on where to cycle and where not too

- **What to pack**

  - Showing the class the most important tools to carry while cycling
  - Showing the class a checklist on what to check before they go cycling

10.3 Physical Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire

MSc Exercise Science and Sports Medicine

The information collected in this questionnaire will only be used for research purposes within the scope of this study. All information will be kept strictly confidential and anonymous.

Instructions

The questionnaire must be completed during the first session of the testing procedure. Please answer each question by filling in the details in the allocated space or checking one or more of the option boxes.

Informed consent must be signed prior to completing the questionnaire online, and handed in to the investigator.

Investigator: Reece McDonald
Tel number: 079 089 1694
E-mail: mcdree002@myuct.ac.za

Supervisor: Dr Jeroen Swart
Tel number: 021 6595644
E-mail: Jeroen.swart@uct.ac.za

Please complete the following sections:

Section A Personal Details
Section B Consolidated Risk Screening

Section A: Personal details
Name:
Email address:
Date of birth:
Cell number:
Home number:
Height:
Weight:
Age:

Section B: Consolidated Risk Screening

1. **Are you sedentary? YES / NO**

Exercise status	**Yes**	**No**
Sedentary life style (not participating in at least 30min of structured, moderate intensity (30-60% of HRR (see equation below)) exercise 3 or more times each week for > 3months)		

2. **Currently, or in the past, have you ever experienced any of these medical conditions?**

Pre-existing Condition screen	**Yes**	**No**
Heart attack		
Undiagnosed chest pain		
Heart failure		
Abnormal heart beat/arrhythmia		
Rheumatic fever		
Heart murmur		
Cardiomyopathy		
Myocarditis		
Inherited cardiac defect		
Coronary artery bypass surgery		
Coronary stent/Balloon angioplasty		
Heart transplant		
Cardiac pacemaker insertion		
Diabetes mellitus/pre-diabetic state (fasting glucose > 5.5mmol/l)		
Chronic lung disease (emphysema / Chronic bronchitis)		
Chronic kidney disease		

3. **Do you CURRENTLY experience any symptoms of heart or blood vessel disease?**

Symptom screen	**Yes**	**No**

Pain when exercising (in the chest/neck/jaw/upper limbs/upper back)		
Swollen ankles (significant swelling)		
Abnormal shortness of breath at rest/on mild exertion/when lying flat		
Dizziness/fainting during or after exercise		
Abnormal heart beats (palpitations)		
Long standing leg/calf pain when exercising that is relieved by rest (other than due to injury)		

10.4 Physical activity questionnaire for Adolescents

Physical Activity Questionnaire (High School)

Name:_____ Age:_____

Sex: M_____ F_____ Grade:_____

Teacher:_____

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

3. There are no right and wrong answers — this is not a test.
4. Please answer all the questions as honestly and accurately as you can — this is very important.

---

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping					
Rowing/canoeing					
In-line skating					
Tag					
Walking for exercise					
Bicycling					
Jogging or running					
Aerobics					
Swimming					
Baseball, softball					
Dance					
Football					
Badminton					
Skateboarding					
Soccer					
Street hockey					
Volleyball					
Floor hockey					
Basketball					
Ice skating					
Cross-country skiing					
Ice hockey/ringette					
Other:					
_____					
_____					

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE .....
Hardly ever .....
Sometimes .....
Quite often
.....
Always
.....

3. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork).....
Stood around or walked around
..... Ran or played a little bit
..... Ran around and
played quite a bit ..... Ran and
played hard most of the time .....

4. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None .....
1 time last week
..... 2 or 3 times
last week 4
times last week .....
5 times last week .....

5. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None .....
1 time last week
..... 2 or 3 times
last week ..... 4 or 5
last week .....
6 or 7 times last week .....

6. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None .....
1 time
.....
2 — 3 times .....

4 — 5 times
.....☐ 6 or more
times .....

7. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

F. All or most of my free time was spent doing things that involve little physical effort .....

G. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) .....

H. I often (3 — 4 times last week) did physical things in my free time .....

I. I quite often (5 — 6 times last week) did physical things in my free time .....

J. I very often (7 or more times last week) did physical things in my free time .....

8. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.☐

	None	Little bit	Medium	Often	Very often
Monday	☐	☐	☐	☐☐	
Tuesday	☐	☐	☐	☐☐	
Wednesday	☐	☐	☐	☐☐	
Thursday	☐	☐	☐	☐☐	
Friday	☐	☐	☐	☐☐	
Saturday	☐	☐	☐	☐☐	
Sunday	☐	☐	☐	☐☐	

9. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ………………………………………………..…
No …………………………………………………….

If Yes, what prevented you? ___________________________________

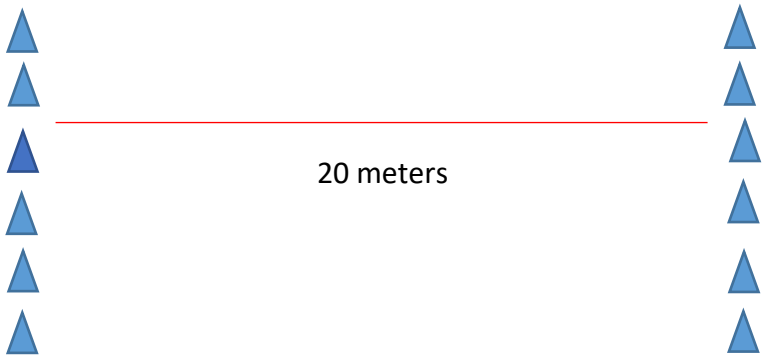
10.5 Borg Scale for Rate of Perceived Exertion

Borg scale: Rate of Perceived Exertion(Borg, 1982)
Choose the number from below that best describes your level of exertion. It should reflect how heavy and strenuous the exercise feels to you, combining all factors of physical stress, effort, and fatigue.

6
7 Very, very light (rest)
8
9 Very light (gentle walking)
10
11 Fairly light
12
13 Somewhat hard (steady pace)
14
15 Hard
16
17 Very hard
18
19 Very, very hard
20 Exhaustion

10.6 Beep Test

The Beep test is a 20 meter multistage fitness test, and is widely used in assessing maximal running aerobic fitness.
The required items for the beep test are: marking cones, 20m measuring tape, the beep test audio, a speaker.
The test involves continuous running between two lines, which are 20 meters apart. The beeps correspond with the time allocated per shuttle between the two lines. The timing of the beeps gets progressively shorter and shorter, requiring the participant to run faster and faster. Each minute, the speed will increase. The participants will begin behind one line, facing the other. The participant must only run once the beep is sounded. If the line is not reached before the beep sounds, the participant will be given a warning, then turn and try to catch up with the pace within two more 'beeps'. The test will be stopped if the participant fails to reach the line (within 2 meters) for two consecutive ends after the initial warning.
The participants score will be calculated as the last level which they completed.
A schematic of the set up:



10.7 Grip Test

The participants will be instructed to hold the dynamometer in their hand, and to present the scale facing outwards. The handle must be gripped between the base of the thumb and fingers. The participants arm must be held so that it is straight and hanging at their side, while not touching their body. The participants must gradually squeeze the handle as hard as they can, whole slowly saying the word ‘squeeze’.
The score will be recorded to the nearest 0.5kg, with two trials being performed per hand. The maximum score of each hand will be combined to calculate the total score.

10.8 Plank Assessment

The participant will begin on their hands and knees, going onto their elbows with their shoulders above. The participant will then lift their knees and straighten their legs, with only their toes on the floor. Once the participants body is straight and off the floor the time will start. The participant must not allow their hips or shoulders to sag down or to raise their hips upwards. If the body position changes, the participant will receive one warning. If a second warning is needed after ten seconds of no posture correction, the test will end. The test will also end when the participant chooses to end the test.

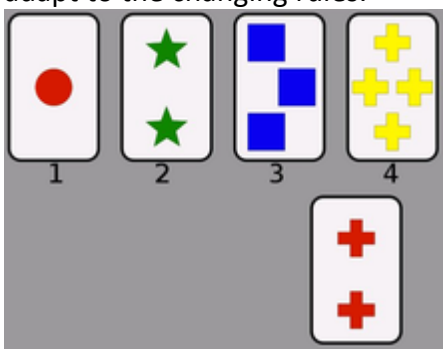
Hips too high:

Hips too low:

10.9 Executive Function tests

10.9.1 Wisconsin Card Sorting Test

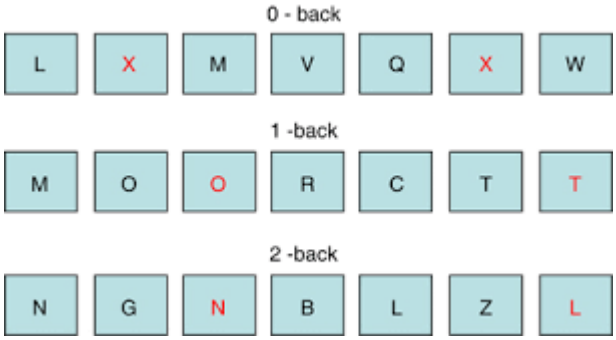
The test involves classifying cards according to differing criteria. Each card has four ways to be classified, and feedback is provided on whether the classification is correct or not. The cards are classified according to symbol colour, symbol shape or the number of shapes on each card. Every ten cards, the rule will change without notification and the participant needs to figure out the change. The purpose is to measure how well the participant can adapt to the changing rules.



Participants will need to match the above image as per the rule which is currently in play.

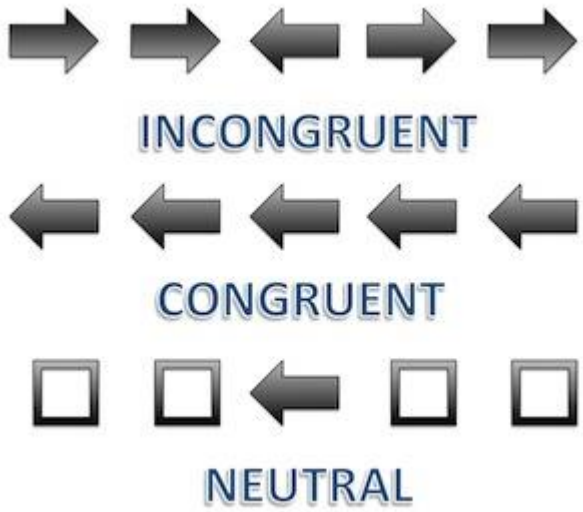
10.9.2 N-Back Test

The N-Back task involves the participants identifying if the stimulus they are seeing is the same as the one which was presented N trials ago, where N can be one, two, three trials back. The higher the N, the more difficult the task is.



10.9.3 Flanker Test

The Flanker task involves incongruent, congruent, and neutral stimuli represented by arrows.



In a congruent stimulus, the response is the same as the target. In the incongruent stimulus, the response is opposite to the target. In the neutral stimulus, the response is neither.

10.10 Data collection sheets

Date		
Visit #		
	Name	Surname
Participant		
Body fat %		
Tanita value		
Weight		
Height		
Beep Test score		
Beep Test RPE		
Plank time (0.1s)		
Plank RPE		
Hand Grip		

Trial 1 (0.5kg)		Trial 2 (0.5kg)	
Left	Right	Left	Right

Bicycle usage logbook:

Name and surname		
Week date:		
Week no:		
	How many times did you use the bicyle this week?	How many hours did you ride on the bicycle this week?

10.11 WCED Approval application

Directorate: Research

Audrey.wyngaard2@pgwc.gov.za
Audrey.Wyngaard@westerncape.gov.za
tel: +27 021 467 9272
Fax: 0865902282
Private Bag x9114, Cape Town, 8000
wced.wcape.gov.za

APPLICATION TO CONDUCT RESEARCH IN PUBLIC SCHOOLS WITHIN THE WESTERN CAPE

Note

- This application has been designed with students in mind.
- If a question does not apply to you indicate with a N/A
- The information is stored in our database to keep track of all studies that have been conducted on the WCED. It is therefore important to provide as much information as is possible

1 APPLICANT INFORMATION

1.1 Personal Details		
1.1.1	Title (Prof / Dr / Mr/ Mrs/Ms)	Mr
1.1.2	Surname	McDonald
1.1.3	Name (s)	Reece
1.1.4	Student Number (If applicable)	MCDREE002

1.2 Contact Details		
1.2.1	Postal Address	Division of Exercise Science and Sports Medicine Department of Human Biology University of Cape Town PO Box 115 Newlands 7725 Cape Town, South Africa
1.2.2	Telephone number	021 650 4561
1.2.3	Cell number	079 089 1694
1.2.4	Fax number	021 650 1796
1.2.5	E-mail Address	Mcdree002@myuct.ac.za
1.2.6	Year of registration	2018

1.2.7	Year of completion	2019

2 DETAILS OF THE STUDY

2.1 Details of the degree or project		
2.1.1	Name of the institution	University of Cape Town
2.1.2	Degree / Qualification registered for	Masters by Dissertation
2.1.3	Faculty and Discipline / Area of study	Health Sciences: Exercise Science
2.1.4	Name of Supervisor / Promoter / Project leader	Dr Jeroen Swart
2.1.5	Telephone number of Supervisor / Promoter	021 659 5644
2.1.6	E-mail address of Supervisor / Promoter	jeroen.swart@uct.ac.za

2.1.7	**Title of the study**
A pragmatic evaluation of the Qhubeka bicycle on an adolescent's physiology, executive function and school performance.	

2.1.8	**What is the research question, aim and objectives of the study**
The aim of this pragmatic evaluation is to assess the physiological changes of access to a bicycle vs walking on adolescent, specifically changes in executive function, formal academic performance and the adolescent's activity levels in an underprivileged South African community. The specific objectives are to determine the general physical activity levels of South African Adolescents from low-income communities. Furthermore, the general fitness levels of South African Adolescents from low-income communities, and if a bicycle as a mode of transport results in physiological adaptations. To determine if executive function and formal school academic assessments are improved by access to a bicycle, and finally provide a comprehensive analysis of the effect of a bicycle on an adolescent in a low-income community.	

2.1.9	**Name (s) of education institutions (schools)**

2.1.10	**Research period in education institutions (Schools)**	
2.1.11	Start date	1 August 2018
2.1.12	End date	28 February 2019