

**Movement programmes to enhance motor competence and physical fitness
among high school girls in a low-income community of Cape Town, South
Africa.**



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Publication 4: *The efficacy of two activity-based interventions in adolescents with Developmental Coordination Disorder (Published).*

Publication 5: *Benefits of activity-based interventions among female adolescents who are overweight and obese (Under review).*

Publication 6: *Effects of task-oriented functional training on fitness performance in female adolescents with varying weight status (Under review).*

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Abstract

Title: Movement programmes to enhance motor competence and physical fitness among high school girls in a low-income community of Cape Town, South Africa.

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Although motor skills, physical fitness and self-efficacy are considered important agents in promoting health and well-being, there is limited research on how exercise can be used to enhance these factors in children within the South African context, particularly among those living in low socio-economic environments. Accumulating evidence worldwide and in South Africa has shown decreased levels of physical activity (PA) among the youth. It is now known that the greatest decline in PA occurs in adolescent girls as compared to boys. Given that insufficient PA and the lack of opportunities to engage in PA is linked to poor motor skills, obesity and harmful health outcomes, it is important to identify effective methods to address PA among high school girls with motor problems and among those who are overweight and obese.

International and local data suggest that adolescent girls are “a high-risk” population who have greater risks for obesity and chronic diseases compared to children and adolescent boys. Research has found that adolescent girls are more likely to exhibit poor motor skills and become overweight or obese. Within the South African context, it is believed that adolescent girls in low-income settings are even more prone to becoming physically inactive and obese because they have fewer opportunities to participate in regular PA. Compared to boys, girls have a higher prevalence of overweight and obesity, and perform poorly on motor performance tests. However, the healthcare community has been challenged to provide effective health promotion solutions to these physical health problems encountered in this demographic group due to the lack of empirical evidence on the efficacy of motor interventions.

In recognition of this gap, this study was designed to develop and evaluate the efficacy of exercise programmes among high school girls. The study had four aims. The first aim was to examine the relationship between body mass index (BMI), motor competence, physical fitness and self-efficacy in adolescent girls attending high school in a low-income community of Cape Town, South Africa. The second aim was to determine the effects of different motor interventions in a sub-sample of girls with low motor abilities. The third aim was to compare intervention effects of two different exercises in a separate sample of girls who are overweight and obese. The fourth aim was to determine if participation in a task-oriented functional training would elicit different changes in fitness performance between girls with varying weight status.

To achieve these aims, six separate but interrelated studies were conducted in two phases. In phase 1, eligible participants completed various tests aimed to assess their levels of motor competence, physical fitness, self-efficacy and body composition. Phase 2 involved four other intervention studies which examined the effectiveness of two movement programmes in specified populations. In each of these studies, participants were exposed to either a novel Wii Fit protocol (specifically developed for this research) or task-oriented functional training. Both interventions were scheduled 45 minutes per week for 14 weeks. Pre- and post-testing were performed using selected measures of motor coordination, physical fitness and self-efficacy. In this thesis, aim 1 was assessed by Studies 1 and 2, and aim 2 was evaluated by Studies 3 and 4. Similarly, aims 3 and 4 were assessed by Studies 5 and 6. Inclusive, six papers presented in this thesis provided answers to all the aims formulated.

With regards to aim 1, the findings indicated that BMI was negatively and independently associated with cardiorespiratory fitness, musculoskeletal fitness, motor competence and self-efficacy. Adolescent girls with increased BMI had decreased cardiorespiratory levels, low musculoskeletal fitness, poor motor competence and reduced self-efficacy compared to peers with a healthy weight.

The results highlight the need to develop interventions to target these health markers to optimise health and well-being.

To address aim 2, preliminary data were collected to quantify the effects of the newly developed Wii Fit intervention, called the graded Wii Fit protocol among a sample of adolescent girls with low motor ability (probable developmental coordination disorder). Results demonstrated that graded Wii Fit training may be capable of increasing aerobic and anaerobic fitness without decreasing participants' perception of enjoyment. Following this pilot study, the Wii Fit intervention was compared to task-oriented functional training in a relatively large sample of adolescent girls (who were not included in the preliminary study) with developmental coordination disorder. Significant improvements in motor coordination, aspects of physical fitness and overall self-efficacy emerged for both groups. However, no between group differences were observed on any of the outcomes. These findings indicate that activity-based interventions may elicit positive physical and psychological health benefits in girls with movement difficulties. Either of these interventions could be prescribed to treat motor impairments in female adolescents. The choice of interventions may be influenced by available resources (such as equipment, instructors, electricity etc.) or individual preferences.

In relation to aim 3, seeking to compare intervention effects of the two programmes in female adolescents who are overweight and obese, girls who received either the Wii Fit protocol or task-oriented functional training demonstrated improved motor competence and physical fitness without any significant changes in self-efficacy for the two groups. However, no significant differences were observed between the groups on any of the outcomes. This finding indicates that activity-based motor interventions may be useful tools for addressing obesity-related impairments. People working with high school girls who have excess weight could adapt these strategies to promote health, particularly in resource-limited environments.

With regards to aim 4, looking at the changes in fitness performance between female adolescents with low and high BMI following the intervention, the results showed significant gains in fitness performance for all participants regardless of weight status. In contrast to girls with high BMI, participants with low BMI demonstrated greater changes in performance on balance and agility tasks. This finding suggests that individuals with excess weight may need adapted programmes to improve their balance and agility performance.

In conclusion, the findings of this thesis provide first-hand empirical data explaining the relationship between BMI, motor competence and physical fitness among high school girls in low-income settings. More importantly, results have demonstrated that activity-based motor interventions are capable of improving motor performance in girls with motor difficulties as well as those with excess weight. Further, this thesis makes a significant contribution to the paediatric exercise science literature by showing how ecological theories can be used to develop cost-efficient exercise interventions for the adolescent girls in low-income settings. It is envisaged that people working in low-income schools would apply these ideas to promote optimal physical health. Moreover, the findings may serve as an important resource to inform policy frameworks aimed at promoting physical and psychological health among high school girls within the South African low-income contexts or other populations with similar characteristics. It is hoped that future studies will evaluate these interventions in heterogeneous samples (e.g. boys and girls) and diverse contexts. Lastly, the sustainability of the changes associated with these interventions needs to be further investigated.

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Abbreviations

ADHD	Attention-deficit Hyperactivity Disorder
ADL	Activities of Daily Living
ANOVA	Analysis of Variance
AMDS	Acquired Movement Deficiency Syndrome
ASD	Autism Spectrum Disorder
AVG	Active Video Game
BAI	Body Adiposity Index
BMI	Body Mass Index
BOT-2	Bruininks-Oseretsky Motor Performance Test, second edition
CDC	Centre for Disease Control
CI	Confidence Interval
CONSORT	Consolidated Standards of Reporting Trials
COM	Centre of Mass
CO-OP	Cognitive Orientation to daily Occupational Performance
CSAPPA	Children's Self-perceptions of Adequacy and Predilection for Physical Activity
DCD	Developmental Coordination Disorder
DEXA	Dual Energy X-ray Absorptiometry
DSM V	Diagnostic and Statistical Manual of Mental Disorders, fifth edition
ECG	Electrocardiography
EMHR	Estimated Maximum Heart Rate
HR	Heart Rate
ICC	Intraclass Correlation Coefficient
ICF	International Classification of Functioning, Disability and Health
IOTF	International Obesity Task Force
KT	Kinaesthetic Training
KTK	KorperKoordinations Test fur Kinder
LMIC	Low and Middle-Income Country
MABC-2	Movement Assessment Battery for Children, second edition
MD	Manual Dexterity

MI	Motor Imagery
MNS	Mirror Neuron System
MSF	Musculoskeletal Fitness
MPST	Muscle Power Sprint Test
NEAT	Nutrition and Enjoyable Activity for Teens
NTT	Neuromotor Task Training
PA	Physical Activity
PADLA-Q	Participation in Activities of Daily Living Questionnaire
pDCD	Probable Developmental Coordination Disorder
PE	Physical Education
PMT	Perceptual Motor Therapy
ROM	Range of Motion
RPE	Rating of Perceived Exertion
SDD	Smallest Detectable Difference
SE	Standard Error
SIT	Sensory Integration Therapy
SMD	Smallest Meaningful Difference
SPSS	Statistical Package for Social Sciences
6MWD	Six-Minute Walk Distance
6MWT	Six-Minute Walk Test
TAAG	Trial of Activity for Adolescent Girls
TD	Typical Development
TFT	Task-oriented Functional Training
TSS	Total Standard Score
20mSRT	Twenty metre Shuttle Run Test
VO ₂ max	Maximum Oxygen Consumption
WCED	Western Cape Education Directorate
WHO	World Health Organisation
WHR	Waist-to-hip Ratio
WFT	Wii Fit Training

PART I: Introduction and Literature Review

CHAPTER 1: Introduction

1.1 Background

This thesis reports on the outcomes of a research project designed to investigate the efficacy of different exercise interventions on improving motor competence and physical fitness among high school girls in a low-income setting of Cape Town, South Africa. Obesity and physical inactivity are significant health challenges among children and adults worldwide. In South Africa, estimates of adolescent obesity are higher in girls than boys. In addition, girls exhibit poorer motor proficiency compared to boys, making them more susceptible to developing motor problems and decreased physical fitness. Yet, information on the effects of exercise programmes among high school girls with motor impairments, overweight or obesity is exiguous, especially among those in low-resourced communities. Historically, physiotherapists have focused on the management of movement dysfunctions in clinical populations. However, the scope of contemporary physiotherapy practice has evolved to include health promotion and community-based rehabilitation. Therefore, developing and evaluating movement programmes among high school girls is an important priority. Findings of this study may help therapists, researchers and physical education teachers to make evidenced-based recommendations to adolescents seeking to improve motor skills and/or physical fitness. In addition, results may influence policy and inform the development of an effective physical education curriculum for female learners in low-income settings of South Africa or other countries with similar circumstances.

1.2 Defining the Problem

1.2.1 Physical inactivity, poor motor performance and obesity in children and adolescents.

Globally, the levels of physical activity (PA) and fitness are low in children and youth [1-3]. Previous research has indicated that girls experience reductions in PA after 11 years [4]. There is also evidence indicating that girls (aged 13-15 years) with low socio-economic status are the least active sub-group in many low- and

middle-income countries (LMICs) including South Africa [5]. Other studies have shown that lower socio-economic status is associated with reduced PA [6-9]. In South Africa, learners in low socio-economic environments have limited access to PA opportunities compared to peers in high-income communities [10]. Therefore, they have fewer opportunities to develop motor skills and are more likely to have motor coordination problems such as Developmental Coordination Disorder (DCD). Poor motor skills, low physical fitness and decreased psychological well-being may hinder participation in PA [11]. In addition, it is now accepted that learners with motor problems have a greater risk for overweight or obesity and tend to have reduced physical conditioning [12,13]. Therefore, it is critical to identify effective methods for treating motor problems, overweight and obesity among adolescent girls living in low socio-economic communities.

1.2.1.1 International and national trends of physical inactivity and obesity

There are suggestions that the levels of PA of youth worldwide are lower compared to previous generations [14,15]. Reports show that most adolescents (about 80%) aged 13-15 years don't accumulate the current recommendations of at least 60 minutes of moderate-to-vigorous PA per day [15,16]. In developed countries such as the United States of America and the Netherlands, estimates show that more than 70% of adolescents do not meet the recommended amount of PA [17,18]. In South Africa, only 50% of children and youth are purported to have sufficient levels of PA [19]. Though the number of South African children meeting PA norms has improved, declines in PA have been observed among specified populations such as high school girls with a low socio-economic status [20,21]. In a local study conducted among adolescent girls (aged 13-15 years) living in the North West Province of South Africa, it was shown that 73.3% of girls have low PA levels [22].

In terms of obesity epidemiology, data show that the prevalence of childhood obesity is still rising, particularly in lower and middle-income countries [23]. In 2013, the prevalence of overweight and obesity increased from 8.1% to 12.9% for

boys, and from 8.4% to 13.4% among girls in developing countries [24]. Studies in South Africa have suggested that the prevalence of overweight and obesity is higher in girls than boys [23,25-30]; with some arguing that current trends could be attributed to insufficient levels of PA and poor dietary habits [28]. The South African Health and Nutrition Examination Survey that was conducted in 2012 reported a higher prevalence of overweight and obesity among adolescent girls (overweight-19.3%, obese-8%) compared to boys (overweight-7.3%, obese-1.5%) [30]. Reddy *et al.* [23] investigated the prevalence and correlates (e.g. gender, physical inactivity and age) of obesity among South African children between 2002 and 2008. The authors found a greater increase in obesity rates among girls as compared to boys and recommended that strategies should be developed to prevent further increases in obesity among girls.

Furthermore, low levels of motor competence and cardiorespiratory fitness have been documented among girls [19]. Children and adolescents with poor motor proficiency or DCD tend to have lower self-efficacy towards PA than peers with typical development [31,32]. Self-efficacy can be defined as an individual's estimation of his/her abilities to successfully perform a specific task [33]. Self-efficacy is an important psychological variable that influences people's behaviour. It has been suggested that self-efficacy may explain the low levels of PA experienced by children with motor problems [31]. Despite the increased knowledge regarding the connection between physical and psychological health markers [34], little is still known about the impact of exercise interventions on these variables among older children. Specifically, the effects of exercises among high school girls with DCD and those who are overweight or obese remains unknown, especially among those with low socio-economic status [35,36].

1.2.2 Interventions for treating motor coordination problems and obesity in children and adolescents

Many interventions have been developed to treat motor problems and to address obesity-related impairments among children and adolescents [37-45]. The next

section will provide a concise summary of available programmes. Programmes focusing on children with DCD will first be reviewed followed by those targeting children with overweight and obesity.

1.2.2.1 Interventions for treating Developmental Coordination Disorder (DCD)

Several studies have tested various interventions in paediatric populations with DCD [37-39]. However, the majority of existing studies have focused on younger children. Presently, there is no study that has evaluated the efficacy of interventions in adolescents with DCD, though evidence shows that the symptoms of DCD track through adolescence and adulthood [37,38]. In a recent systematic review and meta-analysis, Smits-Engelsman *et al.* [39] analysed 30 studies involving 807 children (aged 4-12 years) with DCD. The majority of the studies in this review evaluated the effects of activity-based interventions (e.g. functional training, general skill training and neuromotor task training), technologically-driven strategies (e.g. active video gaming), and body-function approaches (e.g. strength training, selective muscle activation and aerobic fitness training). The researchers found that the overall effect size of an intervention on motor performance was large (Cohen $d=1.06$). While body-function approaches had an average effect size of 1.81 (0.60-4.37), it was reported that studies that tested activity-based interventions among children produced a mean effect size of 0.96 (0.21-2.77). Based on this data, one would expect body-oriented approaches to be promoted. However, the authors argued that because the effects of body-oriented interventions showed little transfer to real-life situations compared to activity-focused interventions, it would be best to combine both treatment approaches. Consequently, the authors suggested that both activity-based programmes and body function-oriented interventions can produce beneficial effects on motor skills and function. The authors also revealed that though active video games elicited minimal effects on motor performance, children who engaged in active video gaming demonstrated increased enjoyment. Accordingly, it was suggested that active video games could be promoted as adjunct therapy [39].

In another systematic review and meta-analysis, 66 studies involving 2585 children (aged 3-17 years) were reviewed [40]. Of this, 87% of the children were identified as having DCD whereas the remaining was classified as typically developing (TD) children. A greater proportion (44%) of the studies used task-oriented interventions, 15% used process-oriented approach and 21% used a combination of the two approaches [40]. The authors found moderate intervention effects on motor competence (Hedges $g=0.63$; 95%CI 0.31-0.94; $p<0.001$) and psychological factors including cognitive ability (Hedges $g=0.65$; 95%CI 0.25-1.04; $p<0.001$). The dosage and frequency of training were also found to be significant moderators of intervention effects [40]. The authors concluded that motor skill interventions elicited positive short-term effects on motor competence and other components of psychological health including improved cognition. Additionally, they suggested that interventions with larger dosage are more likely to produce significant results compared to those with smaller dosage [40]. Though programmes with large dosage are likely to produce significant results, it is usually difficult to provide such interventions in research and clinical settings due to financial and logistical constraints. Collectively, results of these reviews confirm the usefulness of activity-based programmes in children with DCD. Given the lack of intervention studies among adolescents with DCD, it may be prudent to evaluate the effectiveness of evidence-based programmes in high school girls with DCD.

1.2.2.2 Interventions for treating overweight and obesity

Studies investigating the impact of interventions among adolescent girls who are overweight and obese have focused on Western populations [41-56]. To date, evidence on the efficacy of motor interventions among obese high school girls in low and middle-income countries is sparse. Lubans *et al.* [42] evaluated a 12-month school-based obesity prevention programme among 357 adolescent girls living in low income communities of Australia. Using a cluster randomised controlled trial, the researchers assessed the impact of the intervention on body

mass index (BMI), PA, dietary behaviour and self-esteem. The intervention involved multiple components including enhanced school sports sessions, nutrition workshops, lunch-time PA sessions, handbooks and pedometers, parents' newsletters and text-messaging for social support. Results indicated that the school-based obesity prevention intervention did not produce a significant reduction in BMI and had no effect on PA and self-esteem [42].

Cliff *et al.* [43] assessed the feasibility of a community-based motor programme among overweight and obese children. BMI, motor development, perceived competence, objectively measured PA and performance in activities of daily living were measured at baseline, post-intervention and a nine-month follow-up period. The intervention was administered for 10 weeks. At post-intervention and follow-up, there were significant improvements in motor development and perceived competence, but not for BMI, PA or engagement in activities of daily living. The findings show that community-based PA programmes are feasible to administer and might improve motor skills and perceived competence [43]. However, these results should be treated with caution as the study had a small sample size ($n = 13$) and did not have a control group.

In a similar study, Neumark-Sztainer *et al.* [44] tested the feasibility of a multi-component, girls-only high school physical education (PE) programme; called New Moves among American girls (with an average age of 15 years) using a group randomised controlled trial. This intervention was based on the social cognitive theory and was intended to address personal, behavioural and environmental factors, and the interactions between these factors. Girls who were assigned to the intervention group participated in regular PA (four times per week), nutrition class (once every other week) and social support sessions (once every other week) for 16 weeks. The intervention was implemented by a team of researchers and school staff. The control group received regular PE in their respective schools. Outcome measures that were measured at pre- and post-intervention, and eight months after the intervention included BMI, PA and self-perceptions. There were no

significant differences in outcomes between the intervention and control groups. However, there was a high satisfaction among participants, parents and school staff in the intervention group. Again, this finding indicates that it is feasible to implement girls-only programmes in schools. It is also possible that girls would engage with such programmes and find them enjoyable depending on the strategies used in designing and implementing the interventions.

In a systematic review and meta-analysis seeking to determine the effects of game-based interventions among overweight and obese children [46], 10 papers were reviewed. Results showed that active video gaming may elicit small reductions in BMI (SMD: -0.23, SE: 0.07). It was also observed that studies that combined multiple strategies had greater reductions in BMI than others [46]. Several narrative and systematic reviews have also reported that PA programmes may be effective in improving obesity-related outcomes, but effect sizes have been found to be either small or moderate [47-51], demonstrating the need for more research in this area.

In Africa and South Africa in particular, few studies have looked into the effectiveness of interventions in obese and overweight paediatric populations. Naude *et al.* [57] investigated the effects of a PA programme among adolescents in the North West Province of South Africa. Two hundred and eighty (n=280) participants attending two different schools were included. Participants in one school were enrolled as the intervention group whereas learners in the other school served as a control group. A 60-minute exercise session performed twice weekly for 19 weeks were administered to the intervention group. The programme consisted of aerobic dancing, ball skills training and strength and flexibility exercises. The control group did not receive any form of training. In this study, the researchers divided participants in the intervention group into two; high and low attendees. Waist-to-hip ratio (WHR), BMI, percentage body fat and skinfold measurements were taken before and after the intervention. The researchers found that WHR decreased among the high attendees than low attendees

($p < 0.05$). Boys showed a higher decrease in percentage body fat than girls, although no significant reductions in BMI emerged. The conclusions drawn from this study was that regular participation in PA may reduce body fat. A major limitation of this study is that the number of participants classified as high attendees was small, and group allocation was not done at random. Hence, other factors such as PA levels and dietary habits could have influenced the results.

Another study examined the effects of an aerobic-based PA programme among girls (10-15 years) living in a farming community in the North West Province [58]. There were 38 girls from two schools that participated in the study, with 20 participants (in one school) receiving the intervention and 18 participants (in another school) serving as a control group. The intervention group received two 30-minute exercise sessions per week for 10 weeks. The control group followed no exercise protocol. The intervention involved warm-ups, aerobic dance, endurance and strength training and cool down activities. The FITNESSGRAM protocol was used to assess physical fitness whereas the Actical activity monitor was used to measure PA at pre- and post-intervention. Significant differences in cardiovascular endurance, muscle strength and endurance were found between the intervention and control groups. The authors concluded that an aerobic exercise programme delivered in a playful and enjoyable manner may be capable of improving physical fitness [58].

Racil *et al.* [59] tested the effects of physical exercise among obese girls (average age: 10 years) in Tunisia. There were 36 obese girls assigned to either an experimental or control group. While both groups participated in the 60-minute exercise session held thrice a week for 6 weeks, only the experimental group was trained in a rhythm-based environment. The exercises consisted of motor-based activities (e.g. walking on toes, running, hopping, jumping) and stretching. Before and after the intervention, cardiovascular parameters and motor skills were measured. It was revealed that participants in the experimental group had a significant increase in cardiovascular fitness and motor skills compared to the control group. Subsequently, it was suggested that physical exercises performed

in accordance with regular and irregular rhythms may improve motor skills and cardiovascular fitness. Though these findings are promising, this study focused on pre-adolescent girls (average age: 10 years). Therefore, there is an urgent need for further intervention studies to be conducted among African adolescent girls. Hence, the justification of the current study is warranted.

1.2.3 Summarising the Problem

There is strong evidence to support the value of PA programmes for children with DCD and those with high BMI. However, results from the review provided above indicates that there is still a number of questions that remain to be answered. Firstly, the majority of previous interventions had methodological challenges including poor designs, and small sample sizes. Secondly, available intervention studies have not adequately addressed issues of health disparities. Currently, studies focusing on vulnerable groups such as high school girls in low income settings are limited.

Another challenge is that a greater proportion of participants in past studies have been primary school children or pre-adolescents. Research investigating the impact of motor interventions among adolescents is still lacking, particularly among girls with motor problems and excess weight. Because motor competence, physical fitness and self-efficacy are considered as important mediators of PA [19,28], understanding the relationship between these factors among adolescent girls might extend the current body of knowledge. Lastly, given the link between DCD, obesity and poor physical fitness, and the notion that the symptoms of DCD persist into adolescence, it may be important to develop and evaluate new interventions among female adolescents within the South African low-income context.

1.3 Rationale of the Study

The South African society is diverse, and the majority of the population live in poor neighbourhoods. Compared to peers residing in affluent areas, children in low-income settings have little access to PA facilities and programmes. In addition, functional public health services are not readily available in most socio-economically deprived communities. As such, children and adolescents with motor problems and those with a high BMI have little access to intervention. This study seeks to contribute to efforts targeted at addressing these challenges by making interventions available to high school girls in such settings. Providing accessible programmes to girls might improve their physical performance and prevent further declines in health outcomes. Given the lack of intervention studies among adolescents with DCD, the outcomes of this study may provide evidence to inform the development of effective programmes for treating DCD and related complications such as overweight and obesity among older children.

In terms of practical significance, the knowledge gained from this study might contribute to the development of an evidence-based (adapted) PE curriculum for this age group. In addition, therapists, teachers and public health practitioners would be better informed to recommend appropriate interventions to learners desiring to enhance their health and well-being. Finally, the results of this study may inform policy and public health initiatives within the South African low-income context.

1.4 Aim and Objectives of the Study

The aims of this study were;

1. To determine the relationship between BMI, motor competence, physical fitness, and self-efficacy among adolescent girls.
2. To determine the effects of movement programmes among adolescent girls with motor coordination problems.
3. To determine the efficacy of exercise programmes among adolescent girls who are overweight and obese.

4. To determine whether short-term changes in fitness performance would differ between adolescent girls with varying weight status following exercise training.

To achieve these aims, a two-phased project was designed to address the objectives specified below;

1.4.1 Objective of Phase 1

The objective of this study was to determine the associations between BMI, motor competence, physical fitness and self-efficacy among female adolescents attending school in a low-income community of Cape Town, South Africa. This objective was assessed by Study 1 and 2 that will be described in subsequent chapters.

1.4.2 Objectives of Phase 2

Four studies (Studies 3-6) were conducted in this phase. Each study had its own objective, and these have been outlined below;

1.4.2.1 Objective of Study 3

This pilot study investigated the effects of an active video gaming programme among female adolescents with probable DCD.

1.4.2.2 Objective of Study 4

The objective of this study was to evaluate the efficacy of two movement interventions in female adolescents with DCD.

1.4.2.3 Objective of Study 5

The objective of this study was to compare intervention effects of two exercise programmes in female adolescents who are overweight and obese.

1.4.2.4 Objective of Study 6

This study aimed to determine if changes in fitness performance following exercise training would differ between adolescent girls with varying weight status.

1.5 Research Questions

The following research questions were formulated:

1. Is there a relationship between BMI, motor competence, physical fitness and self-efficacy among female adolescents?
2. Can Wii Fit training increase physical fitness among female adolescents with probable DCD?
3. Will participation in activity-based motor interventions result in positive changes in motor competence, physical fitness and self-efficacy among female adolescents with DCD?
4. Will participation in activity-based programmes result in positive changes in motor competence, physical fitness and self-efficacy among female adolescents who are overweight and obese?
5. Will there be changes in fitness performance between female adolescents with high and low BMI after participating in functional training?

1.6 Overview of Methodological Approach

The studies being reported in this thesis were conducted using quantitative research methods [60] consisting of both cross-sectional and experimental designs. As it was important to understand the unique characteristics of the target population to inform the design of the interventions, cross-sectional data were initially collected from one hundred and fifty-one (n=151) girls. Associations between the various variables measured at this stage were determined. Furthermore, different intervention studies were performed to assess the effectiveness of two exercise programmes in separate sub-samples with specified characteristics. Figure 1.1 provides a flow chart of the research design.

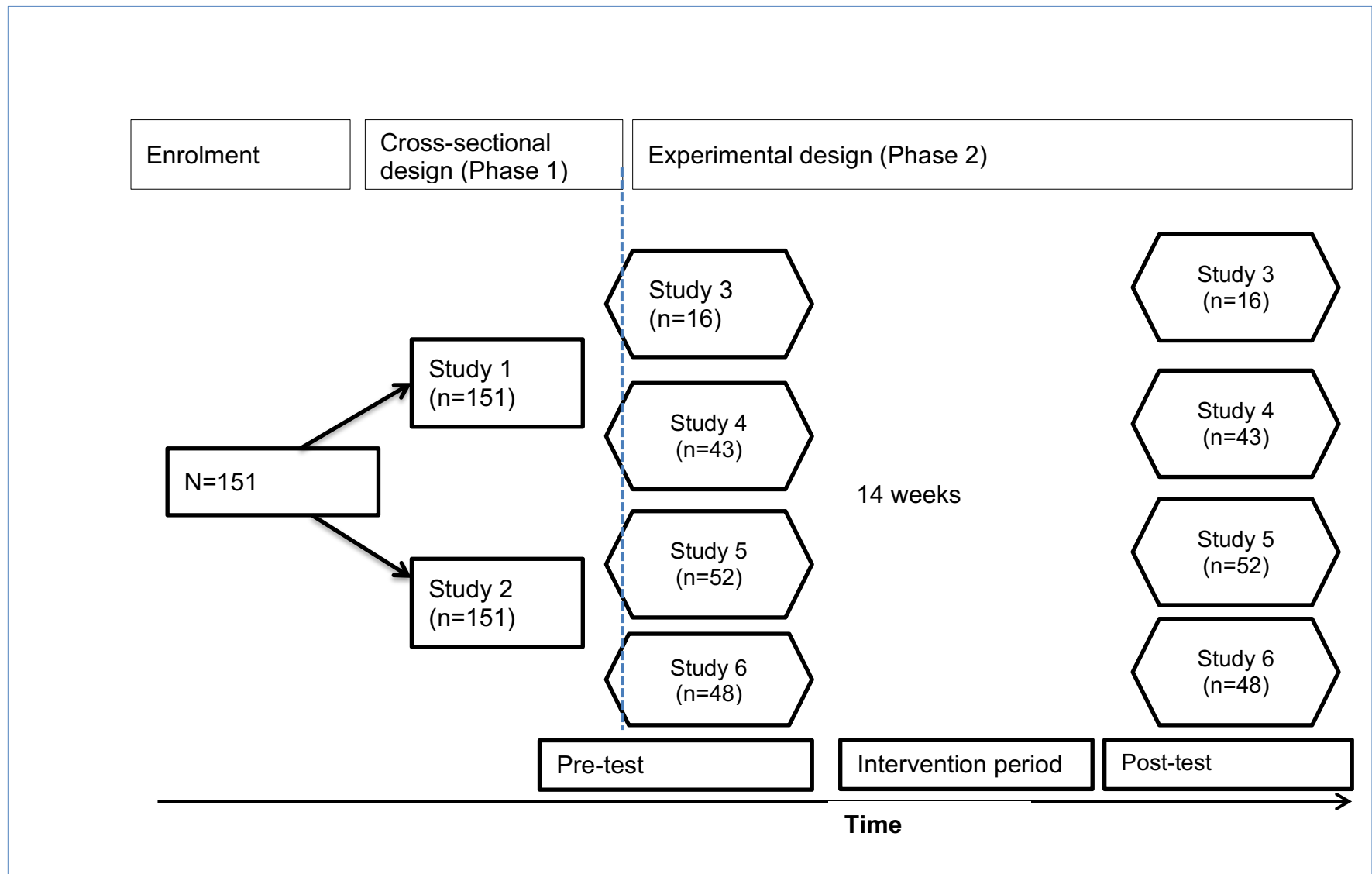


Figure 1.1: A flow chart of the research design

1.6.1 Synopsis of Research Design

Table 1.1 summarises the various studies included in this thesis and their respective methods. Descriptive details will be provided in specified chapters.

Table 1.1: Summary of Research Design

Study Number	Study Title	Study Design	Assessments
1	Relationship between body mass index, cardiorespiratory and musculoskeletal fitness among South African adolescent girls.	A cross-sectional, descriptive design.	Anthropometric data (weight, height, BMI); 20m shuttle run test; Handheld dynamometry; Sit-and-reach test; Musculoskeletal complaints (self-report); Beighton's joint mobility test.
2	Association between body mass index, motor competence and self-efficacy among adolescent girls	A cross-sectional, descriptive design.	Anthropometric data (weight, height, BMI); Movement Assessment Battery for children, second edition (MABC-2); Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity Scale (CSAPPA); Physical activity and sedentary time (self-reports).
3	"Not just another Wii training", a graded Wii	Quasi-experimental/single-group pre-post	Anthropometric data (weight, height, BMI);

	protocol to increase physical fitness in female adolescents with probable developmental coordination disorder: a pilot study	design.	Six-minute walk test; Muscle power sprint test; Heart rate monitoring; Rating of Perceived Exertion (Borg's rating scale); Perception of enjoyment (self-report).
4	The efficacy of two activity-based interventions in adolescents with developmental coordination disorder	A randomised controlled trial.	Anthropometric data (weight, height, BMI); Movement Assessment Battery for children, second edition (MABC-2); Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2); 20m shuttle run test; Handheld dynamometry; 10x5 sprint test (straight); 10x5 sprint test (slalom); Stair-climbing sub-item of the Functional Strength Measurement test; Children's Self-Perceptions of Adequacy in and Predilection for Physical

5	Benefits of activity-based interventions in female adolescents who are overweight and obese.	A randomised controlled trial.	Activity Scale (CSAPPA); Participation in activities of daily living (self-report) Anthropometric data (weight, height, BMI); Movement Assessment Battery for children, second edition (MABC-2); 20m shuttle run test; Handheld dynamometry; 10×5 sprint test (straight); 10×5 sprint test (slalom); Functional Strength Measurement; Children’s Self-Perceptions of Adequacy in and Predilection for Physical Activity Scale (CSAPPA); Perception of Enjoyment (self-report).
6	Effects of a task-oriented functional training on fitness performance in female adolescents with varying weight status.	An experimental study design.	Anthropometric data (weight, height, BMI); Movement Assessment Battery for children, second edition (MABC-2); Yoga balance

test (Nintendo Wii Fit test); strength sub-items of the Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2); Six-minute walk test; Muscle power sprint test;

1.6.2 Research Setting, Ethical considerations and Participant characteristics

South Africa is a country characterised by inequality, segregation and deprivation. As a result, a greater proportion of the population is socio-economically disadvantaged [61,62]. These segments of the population live in urban township communities, which are classified as low socio-economic environments. The studies in this thesis were carried out in a suburb of Cape Town called Khayelitsha (Figure 1.2). Khayelitsha is considered as the third largest township in South Africa and is characterised by informal settlements [61,62]. The size of the population in this area is estimated to be 400,000 [63]. Of this, 75% are less than 35 years old [62] and poverty and unemployment rates are reportedly high [64,65]. Most households earn less than R1600 per month [62] and vices such as violent crime and rape are widespread [62].

Since the focus of this thesis was to evaluate movement programmes among adolescent girls in low-income settings, it was necessary to identify schools in low-socio-economic communities, whose principals were willing to support the project. In this regard, one high school in Khayelitsha that happens to be a partner institution of the University of Cape Town's (UCT) Schools Improvement Initiative (SII) was selected. After the principal and senior management provided consent,

the researcher sought permission from the Western Cape Education Department (WCED) to perform the assessments and to implement the interventions. Ethical approval was also granted by the University of Cape Town's Human Research Ethics Committee (#232/2016). Once approvals were obtained (See Appendices C and D), information sessions were organized to explain the purpose of the study to all female students at the school premises.

The school comprised of 359 learners [girls (n=205); boys (n=154)] in grades 8 to 12. However, because the learners in the upper classes (grades 11 and 12) were busily preparing for their school completion (matric) examinations, it was collectively agreed that the project should be limited to only girls in grades 8 to 10. Accordingly, information letters detailing the objectives of the research were sent to parents and/or legal guardians to request their consent for the involvement of their children. Learners whose parents returned completed consent forms were invited for voluntary participation. Those who indicated their desire to participate gave written informed assent before commencement of the study. Learners who agreed to participate were made to understand that some of them would be selected to receive different interventions and that assignment to groups would be done at random. Each girl agreed to this arrangement. As previously mentioned, one hundred and fifty-one adolescent girls completed assessments in Phase 1. Following initial testing, different sub-samples were identified and recruited into four independent studies (Phase 2) based on specified entry criteria. The school's principal agreed that the project would be considered as PE for the participating classes. The reason for this was to minimise potential disruptions to the learners' academic work. In line with this arrangement, it was decided that the interventions would be delivered for a maximum of 60 minutes, once weekly throughout the school year for a period of 14 weeks.

In South Africa, elementary and high schools are assigned a quintile rank based on the relative poverty level of the area in which they are located [66]. Typically, schools are classified into five quintiles (Q1 to Q5). Schools in the lowest quintiles

(Q1-Q3) are generally located in low socio-economic environments and tend to have limited resources. Low quintile schools do not charge fees and provide free feeding services to learners. These initiatives receive funding support from the government [67]. The specific school where this study took place is considered as a quintile three (Q3) high school and learners are predominantly black South Africans. Because of the partnership agreement between this school and UCT, the learners receive various forms of support (e.g. additional tutorials, counselling, therapy services etc.) from members of the university community. However, resources for promoting PA are scarce, which make it difficult for the learners to engage in organised PA.

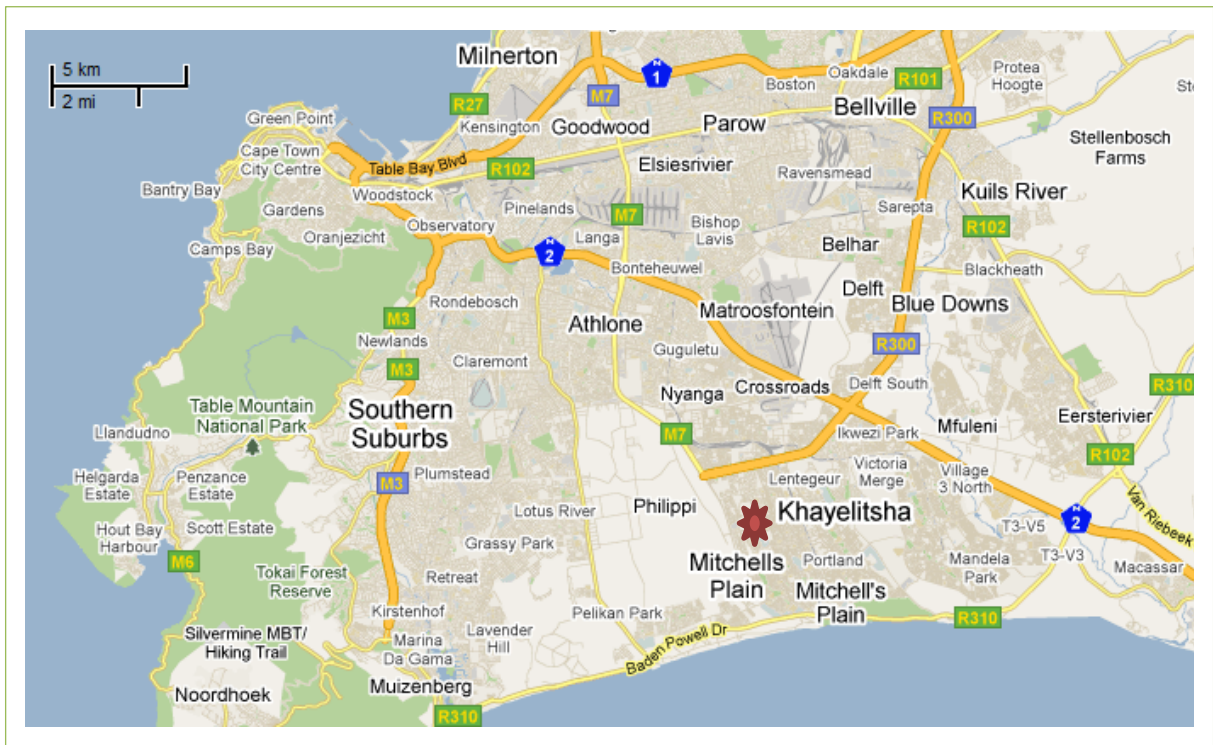


Figure 1.2: A map showing the location of Khayelitsha in Cape Town

1.7 Outline of the thesis

This thesis is organised in three parts: Parts I, II and III. Part I deals primarily with background information and consists of two chapters (Chapters 1 and 2). Part II covers six empirical research papers. In Part III, a consolidated discussion of the main research findings is presented. An outline of the structure of this thesis is provided in eight further chapters.

1.7.1 Chapter 2: Literature Review

In this chapter, information on the epidemiology of DCD, overweight and obesity will be provided. Additionally, relevant literature on exercise interventions for treating DCD, overweight and obesity will be reviewed. Subsequently, key characteristics of effective programmes will be discussed and the theory behind the interventions used in this thesis will be discussed. Lastly, relevant gaps in the extant literature will be summarised.

1.7.2 Chapter 3: Relationship between body mass index, cardiorespiratory and musculoskeletal fitness among South African adolescent girls.

This chapter describes a study that examined the relationship between body mass index, cardiorespiratory and musculoskeletal fitness in a cohort of South African female adolescents.

1.7.3 Chapter 4: Association between body mass index, motor competence and self-efficacy among adolescent girls

The nature of the relationship between BMI, motor competence and self-efficacy has not been well-explored. This study was designed to investigate whether motor competence, self-efficacy, can predict BMI among female adolescents.

1.7.4 Chapter 5: “Not just another Wii training”, a graded Wii protocol to increase physical fitness among female adolescents with probable Developmental Coordination Disorder: A pilot study

Pilot studies provide important information for planning and implementing successful interventions. In this chapter, details of a preliminary study conducted to ascertain the effects of a newly developed active video gaming protocol will be provided.

1.7.5 Chapter 6: The efficacy of two-activity based interventions among adolescents with Developmental Coordination Disorder

Determining the effectiveness of movement programmes among female adolescents with developmental coordination disorder is necessary to inform therapeutic actions. This chapter details the outcomes of a randomised trial that evaluated the impact of two exercise programmes among female adolescents with DCD.

1.7.6 Chapter 7: Benefits of activity-based interventions among female adolescents who are overweight and obese

This chapter summarises the results of a study designed to compare intervention effects among female adolescents who are overweight and obese.

1.7.7 Chapter 8: Effects of task-oriented functional training on fitness performance among female adolescents with varying weight status.

Knowledge of how female adolescents with low or high BMI respond to short-term functional training is critical for exercise prescription. This chapter presents a study seeking to examine if changes in fitness performance would differ among female adolescents with varying weight status following functional training.

1.7.8 Chapter 9: Discussion & Conclusions

The final chapter provides a general discussion of the various studies in this thesis. The chapter will provide an overview and summary of the major findings and discuss them accordingly. In addition, the strengths and limitations of the various studies in this thesis will be discussed. Finally, conclusions drawn from this research will be highlighted and recommendations for future research will be provided.

For presentation clarity, relevant references will be listed at the end of each chapter.

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CHAPTER 2: Literature Review

2.1 Introduction

This chapter will cover current prevalence trends of Developmental Coordination Disorder (DCD), overweight and obesity in children and adolescents. The chapter will also provide a review of available interventions designed to manage children and youth with DCD, overweight and obesity. In addition, the key characteristics of successful interventions will be highlighted. The theoretical considerations underpinning the development and implementation of the interventions used in the current project will also be discussed. Finally, an overview of significant gaps in the literature will be summarised.

2.2 Trends of Developmental Coordination Disorder, overweight and obesity

2.2.1 Defining Developmental Coordination Disorder

Developmental Coordination Disorder (DCD) is a developmental condition that affects motor coordination [1]. This disorder occurs in different racial and ethnic populations and across diverse cultures or socio-economic conditions [2]. Various terminologies have been used to describe the disorder in the past, including the clumsy child syndrome, perceptuo-motor dysfunction, physically awkward child and developmental dyspraxia [3]. However, DCD is now the acceptable diagnostic label for motor coordination difficulties in children [1]. DCD can be defined as a motor coordination problem unrelated to medical conditions (e.g. cerebral palsy), intellectual disability or visual impairment that occurs in early childhood [1,4]. The symptoms of the disorder are well documented in children, adolescents and adults [3,6,7].

Children with DCD experience deficits in gross and fine motor skills and struggle to perform everyday activities including handwriting, getting dressed and participating in sports or games [4]. The specific manifestations of DCD may vary depending on the child's age and task requirements. For instance, young children may display difficulty in gross motor tasks while adolescents tend to exhibit more fine motor

deficits such as poor handwriting. As children transition from childhood to adolescence, they encounter new task demands. Thus, impairments in motor coordination make it even more difficult for adolescents with DCD to cope with the changes that occur at this stage of life [3]. Compared to peers with typical development, children and adolescents with DCD tend to exhibit low self-esteem, poor self-efficacy, greater social isolation and defective peer relationship [7,8]. Given that these issues could have a negative impact on health, it is essential for health care providers, particularly paediatric physiotherapists and kinderkineticists to find effective strategies to address both the primary and secondary symptoms of DCD among adolescent girls, who are often less active than boys [9].

The American Psychiatric Association has specified the criteria to be used for the identification of children with DCD. The current criteria have been published in the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-V) of the American Psychiatric Association [1] (Table 2.1).

Table 2.1 Diagnostic Criteria of DCD [1]

Diagnostic Criteria

- A. The acquisition and execution of coordinated motor skills is substantially below that expected given the individual's chronological age and opportunity for skill learning and use. Difficulties are manifested as clumsiness (e.g. dropping or bumping into objects) as well as slowness and inaccuracy of performance of motor skills (e.g. catching an object, using scissors or cutlery, handwriting, riding a bike or participation in sports).
 - B. The motor skills deficits in Criterion A significantly and persistently interferes with activities of daily living appropriate to chronological age (e.g. self-care and self-maintenance) and impacts academic/school productivity, prevocational and vocational activities, leisure and play.
 - C. The onset of symptoms is in the early developmental period.
 - D. The motor skills deficits are not better explained by intellectual disability (intellectual developmental disorder) or visual impairment and are not attributable to a neurological condition affecting movement (e.g. cerebral palsy, muscular dystrophy, degenerative disorder).
-

Generally, it is expected that children with DCD should demonstrate problems in motor skills that are significant enough to interfere with everyday activities including social interactions and academic performance [1]. In accordance with the recommendations by the American Psychiatric Association [1], all four criteria presented above should be met before a child can be identified as having DCD. However, when researchers are unable to strictly apply each of these selection criteria, they often use the expression 'probable DCD' to describe children who have some sorts of problems with motor skills [10]. Therefore, it is not uncommon to find this terminology being used in the literature [10,11]. There is a strong indication that DCD can co-occur with other developmental conditions such as attention-deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and learning disabilities [2,11].

2.2.1.1 Epidemiology of DCD

It is believed that DCD is one of the most common motor problems in school-aged children [10]. Currently, the prevalence of DCD is estimated to range from 1.4% to 19%, with 5-6% being the most cited prevalence estimates in the literature [12-15]. In a UK study, Lingam *et al.* [15] found a much lower prevalence of 1.8% among children in England. Tsiotra *et al.* [14] reported estimates of 19% among Greece children. In South Africa, there is currently no national study that has investigated the prevalence of DCD among children. However, one of the earliest studies conducted in the North West Province of the country estimated the prevalence of DCD to be as high as 36.4% [16]. This figure is higher than reports from other parts of the world, suggesting that DCD may be more common among South African children than children living in Western societies. This underscores the urgent need to identify effective interventions to treat and manage South African children with DCD.

Evidence shows that DCD is more common in boys than girls, with variable boy-girl ratios of 3:1 to 7:1 [11]. Conversely, in a recent study conducted among 2282 mainstream children in India, the prevalence of DCD was reportedly higher in girls than boys [17]. This is the only study so far to have reported a higher prevalence of DCD among girls as compared to boys. The differences in the epidemiological data on DCD across cultures may be explained by cultural diversity and variations in the application of the diagnostic criteria. While many researchers apply conservative selection criteria, it is not unusual to find less strict criteria in the literature.

2.2.1.2 Aetiology of DCD

Over the last decade, there has been a surge in the number of studies seeking to improve the understanding of the potential causes of DCD. However, the exact cause of the disorder has still not been determined [18]. Three main neurobiological mechanisms have been proposed as plausible explanatory mechanisms for DCD. The first explanation is called the automatisisation deficit

hypothesis [19]. According to this idea, children with DCD lack the ability to execute completely fluent (automatic) motor skills without conscious efforts [18,19]. Proponents of this hypothesis speculate that DCD is a learning deficit which is confined to the autonomous stage of skill acquisition [19]. Based on this assertion, some investigators have claimed that dysfunction of the cerebellum may be partially responsible for the primary symptom (motor incoordination) of DCD [18,20].

The second explanation is called the internal modelling deficit hypothesis [21-23], which also associates cerebellar involvement with DCD [18]. Internal modelling refers to one's ability to generate and/or monitor internal models (motor representations) of skilled actions [23]. The internal modelling hypothesis suggests that children with DCD are unable to utilise internal models to motor control accurately [23]. Abnormalities in the internal modelling processes may account for the varied and pervasive symptoms of DCD. Finally, Werner *et al.* [24] suggested that motor skills problems seen in children with DCD can be explained by what the authors referred to as the mirror neuron system hypothesis. According to mirror neuron system hypothesis, motor coordination impairments reflect abnormalities in the mirror neuron system [24]. In a systematic review that sought to harness evidence to support the notion that children and adults with DCD display abnormal functioning of the mirror neuron system (MNS) [25], it was revealed that children with DCD struggle to imitate and perform motor gestures as compared to healthy controls. Though these ideas have expanded our knowledge about DCD, there is still an ongoing debate regarding these assumptions, and a consensus is yet to be determined. This implies that more research needs to be done to provide a broader view about the causative mechanisms of DCD. A deeper understanding of the neuroanatomical basis of DCD may shape and transform clinical practice.

2.2.1.3 Consequences of DCD

It is generally recognised that DCD is associated with several physical and mental health problems [26]. Impairments in motor coordination limit the child's ability to

participate in activities of daily living and to enjoy sports [27,28]. As a result, children with DCD participate less in physical activity (PA) or sports compared to children with typical development [28]. Insufficient PA experienced by children with DCD may increase their risk for obesity [29] and coronary vascular diseases [30]. It has also been indicated that children with DCD exhibit mental health problems such as low-self-esteem [26] and decreased self-efficacy [31]. Consequently, children with DCD may isolate themselves from activities and exhibit poor social skills [27,28]. Withdrawal from PA can lead to increased sedentary behaviour, overweight and obesity [27,28].

There is evidence showing a strong connection between DCD and obesity. Cairney *et al.* [29] documented an association between DCD and obesity in boys. In addition, reports show that children with DCD have poorer physical fitness compared to peers with TD [32-34]. It has also been observed that school-aged children with DCD demonstrate inferior academic performance compared to peers without DCD [35,36]. These problems create a huge burden on the child with DCD, on his/her family and the society at large. Low levels of motor skills and physical fitness seen in children with DCD might impair functional performance. Consequently, poor functional performance exhibited by children with DCD may have long-term adverse health complications. To better support individuals with DCD, it may be prudent to explore effective ways of addressing these issues alongside the principal symptoms.

2.2.1.4 Current Treatment Paradigms for DCD

Different kinds of treatments for DCD have emerged [18], many of which have been tested primarily in younger children with DCD [2]. These studies have provided evidence on the effectiveness of the variety of different programmes that have been documented [37]. Typically, interventions are broadly categorised into two types; process and product or task-oriented approaches [38]. Process-oriented approaches engage some underlying process deficit, with the expectation that remediation of specific deficits will result in improved functional performance

[18,37,38]. Examples of process-oriented therapies include sensory integration therapy, strength training and kinaesthetic training [18,38]. Most of these interventions are based on the neuromaturational and hierarchical theories of motor control [18,38]. To date, evidence for the effectiveness of these treatments among children with DCD remains inconclusive [18]. The main criticism against these approaches is that their effects have little or no influence on functional skills. In addition, children who receive these interventions are usually unable to apply acquired skills to different contexts (limited skills transfer).

Product or task-oriented approaches focus on the teaching of functional skills or activities of daily living [38]. The premise of this approach is that equipping the child with functional motor skills will increase task performance [38] and facilitate participation in diverse environmental contexts [37]. Depending on the context and the needs of the child, tasks can be taught as specific skills within a problem-solving environment or by linking different activities to enhance the transfer of skills or generalisation [38]. Task-oriented interventions are grounded in modern theories of motor control and motor learning including the dynamic systems theory and the principles of cognitive neuroscience [37,38]. Growing evidence suggests that task-oriented interventions such as neuromotor task training [37] and ecological interventions [38] are more effective for the treatment of DCD. However, the impact of task-oriented interventions on participation and skill transfer has not been thoroughly explored.

In their first meta-analysis, Miyahara *et al.* [39] evaluated the effectiveness of interventions for DCD with a total of four studies. They reported that both task-oriented and process-oriented approaches can improve motor coordination [1]. Nonetheless, no significant differences were found between the two approaches and these results need to be treated with caution because of the small number of studies involved. Pless and Carlsson [40] published a meta-analysis to determine the effects of motor skill interventions among children with DCD. They included 21 studies involving children aged 5-13 years. The authors classified interventions

based on their theoretical underpinnings. Accordingly, three approaches were identified, namely the general abilities method, specific skills techniques and sensory integration therapy [40]. The highest effect size (1.46) was reported for the specific skills (functional) interventions. Again, it was revealed that group-based interventions delivered more significant results than any other strategy [40]. Though these findings contradict what was reported earlier [39], Pless and Carlsson's work [40] provides important ideas to guide therapeutic actions.

Hillier [41] attempted to consolidate the evidence on the effectiveness of DCD interventions in a systematic review involving 47 studies (with more than 1000 participants) published between 1970 and 2004. Studies included used different types of interventions and outcome measures included the Movement Assessment Battery for Children, Test of Gross Motor Development, Visual Motor Integration Assessment, Test of Motor Impairment and other sensori-motor assessments [40]. Some of the interventions identified in this review were the Cognitive Orientation to daily Occupational Performance (CO-OP), kinaesthetic training (KT), motor imagery (MI) training, neuromotor task training (NTT), perceptual motor therapy (PMT), sensory integration therapy (SIT), physical education and psychomotor training. Hillier [41] suggested that PMT and SIT were the most frequently used therapies for managing DCD. The SIT method was found to be more effective, although only six studies reported positive treatment effects [41]. Hillier [41] suggested that interventions delivered better response than no intervention. Based on this evidence, it can be argued that depriving children of DCD treatment opportunities might be unethical.

Smits-Engelsman *et al.* [42] published a combined systematic review and meta-analysis aimed at establishing the efficacy of interventions among children with DCD. A total of 26 studies with different research designs and intervention philosophies were reviewed. Similar to Pless and Carlsson [40], the authors broadly categorized interventions into four groups: (1) process-oriented therapies, (2) task-oriented interventions, (3) conventional physical and occupational therapy

remedies and (4) chemical supplements or treatments (e.g. fatty acids and vitamin E) [42]. The overall effect size reported in this paper was moderate (0.56). However, when different interventions were compared, it was shown that task-oriented approaches were more effective, supporting the results of Pless and Carlsson [40].

Miyahara *et al.* [43] also published a meta-analysis to evaluate the effectiveness of task-oriented interventions in children with DCD. A total of 15 studies [eight randomised controlled trials (RCTs) and seven quasi-RCTs] involving 649 children aged 5-12 years were reviewed. However, the authors included only six studies in their meta-analysis because some studies had missing data. Results showed that task-oriented interventions may lead to improved motor performance. But, the effects of task-oriented treatments on psychological outcomes were inconclusive. This finding gives a strong indication that more work needs to be done to evaluate intervention effectiveness on psychological variables. Given that the manifestations of DCD persist through adolescence and adulthood, investigations for the effectiveness of interventions among adolescents with DCD are warranted.

Preston *et al.* [44] performed another systematic review to assess high quality randomised controlled trials in children with DCD. The authors adopted strict inclusion criteria (a score of seven out of 11 or higher on the PEDro scale). In view of this, only nine studies met their inclusion criteria. The authors demonstrated that task-oriented programmes prescribed by physical and occupational therapists, and motor imagery combined with motor skills instruction are the most effective interventions [44]. A small effect size was found for programmes such as the Wii Fit training, core stability training, aquatic therapy and Tai Kwon Do. Similarly, de Oliveira [45] also reviewed nine studies with 339 participants with DCD and concluded that motor-based interventions produce significant results. However, this report could not specify the particular programmes that delivered the greatest benefits. Obviously, there seems to be some level of consensus regarding the superiority of task-oriented interventions in DCD management. Therefore, it may

be reasonable to implement and evaluate task-oriented interventions among adolescents with DCD, a group that has received little attention.

Recently, two new systematic reviews examining the effects of interventions have been published [37,46]. Smits-Engelsman *et al.* [37] updated the evidence on motor-based interventions among children with DCD. Their review covered studies published from January 2012 to February 2017 and had a total of 30 studies. Participants in this review were children (4-12 years) living in countries such as Australia, Hong Kong, United States of America, South Africa and Tunisia. The authors found that activity-based interventions and body function interventions with activity components yielded positive effects on motor function and skills. In addition, group therapy was found to be more superior compared to other delivery formats such as one-on-one [37]. These findings reinforce results from previous studies [40,44]. Although active video gaming was found to increase engagement, evidence gathered for its effectiveness was weak. Therefore, the authors suggested that active video games should be used adjunct treatments. Similarly, the review by Jane *et al.* [46], confirmed that motor skill interventions may be effective at improving motor performance, physical fitness and psychological well-being. A total of 66 studies was included, with motor performance being the most frequently reported outcome. Jane and colleagues [46] found that the short-term effects of motor skill interventions on motor performance were moderate ($g=0.63$). In addition, moderate effects were observed on psychological outcomes ($g=0.65$). Larger effects were associated with interventions that had high dosage parameters (high intensity and frequency, and, greater duration) as well as group-based therapies [47-49]. Again, while these findings lend support to previous data, the authors pointed out that the impact of interventions on secondary symptoms of DCD such as self-esteem and self-efficacy has been less investigated.

From these reviews, it is evident that activity-focused interventions may deliver optimal benefits than others. Additionally, group-based programmes and those grounded in theory appear to produce significant results. However, several areas

are still in dire need of research. For example, there is the need to assess the effects of interventions in older children and adults with symptoms of DCD. Also, it is essential to compare group-based interventions to individual therapy in both clinical and research populations with DCD. The impact of interventions on skills transfer and participation also require more investigation.

2.2.2 Overweight and obesity in childhood and adolescence

Overweight and obesity are global health threats characterised by excess weight gain [50]. Because of the detrimental effects of these conditions, childhood obesity has attracted enormous scientific interest [51]. Evidence suggests that the prevalence of obesity has doubled in children and tripled in adolescents over the past few years [52]. Adolescents who are obese have a higher prevalence of vascular abnormalities (e.g. atherosclerosis and left ventricular hypertrophy), hypertension and type 2 diabetes than peers who have normal weight [51]. Furthermore, musculoskeletal and cardiovascular health, and the ability to participate in physical activities or sports may be diminished in individuals with overweight and obesity [53-56]. The negative influence of obesity on functional performance should be a source of concern to physiotherapy [50] as it can trigger further deterioration in health. The next sections will discuss classification of weight status, epidemiology of overweight and obesity and review currently available exercise interventions for treating overweight and obesity.

2.2.2.1 Classification of overweight and obesity

Quantifying body composition is an important step in the fight against the obesity epidemic. For the past 30 years, a plethora of techniques and equations have been developed [50]. These include hydrostatic weighing, dual-energy x-ray absorptiometry (DEXA) and isotope dilution, bioelectric impedance analysis, skinfold thickness assessments, BMI, waist circumference and WHR [50,57-59]. Although sophisticated techniques such as hydrostatic weight are more accurate, they are expensive and often require cumbersome equipment and advanced technical expertise [57-59]. Because of these issues, the BMI has been widely

accepted as a proxy measure to assess body fatness in children and adults. It is advantageous to use the BMI because it is simple to compute and allows for easy comparison of data worldwide [57]. As a derived quantity, BMI is computed by dividing body weight (in kilogrammes) by the square of the height (in metres) [57]. Though the BMI is a frequently used anthropometric indicator, it is of limited accuracy. For example, the BMI does not discriminate between weight that is fat (fat mass) and weight that is muscle (fat-free mass) and might lead to the identification of extremely muscular children as overweight or obese [50]. In addition, BMI does not allow for predicting fat distribution in the body [59]. Furthermore, in populations where undernutrition is prevalent, the validity of BMI might be compromised [59].

In adults, a BMI that is greater or equal to 25kg/m^2 is classified as overweight, and obesity is defined by a BMI that is greater or equal to 30kg/m^2 regardless of sex [50,59]. However, these definitions cannot be applied to paediatric populations due to the rapid changes in BMI during childhood. Consequently, several age and gender-specific cut-off points have been developed to categorise weight status in children and adolescents [60]. These include the United States of America's Centres for Disease Control and Prevention (CDC) BMI for age and sex-criteria [61,62], the International Obesity Task Force (IOTF) age- and gender-specific BMI definitions [60,63] and the World Health Organisation (WHO) guidelines [64]. The CDC criteria were based on nationally representative data [61-62] whereas the WHO and the IOTF cut-off points were based on international samples [60,63,64]. For example, the IOTF criteria were developed from pooled data collected in both low and high-income countries (Brazil, Hong Kong, Singapore, the Netherlands, United Kingdom and the United States of America) [60,63] and can be used for boys and girls aged 2-18 years [63]. The IOTF (Table 2.2) BMI definitions use age- and gender specific percentiles, with overweight and obesity corresponding to an adult BMI of 25 and 30kg/m^2 respectively [60,63]. In this thesis, the IOTF cut off-points were chosen as they facilitate comparisons across studies. In addition, the IOTF has been used in previous research involving South African children [65].

Due to the inherent limitations of BMI, Bergman and colleagues [66] proposed an alternative parameter called the body adiposity index (BAI). It has been suggested that the BAI could be used to estimate the percentage of body fat in various ethnic populations without adjusting for age and/or sex [66]. The BAI is determined by using the mathematical equation $[BAI = (\text{hip circumference}) / ((\text{height})^{1.5} - 18)]$. Since its inception, several studies have investigated how well the BAI performs in various populations in relation to the BMI [67-70]. Freedman *et al.* [70] conducted a study to examine if the prediction of body percentage of fat by BAI is more accurate than BMI and hip and waist circumference. A total of 1151 adult participated in this study and anthropometric and DEXA assessments were performed. The authors found that BAI strongly correlates with percentage body fat than BMI when age and sex are not controlled in the analyses. However, when adjustments for age are taken into consideration, the correlation between BAI and percentage body fat is weak compared to BMI, waist and hip circumference. These findings suggest that the BAI may not be an accurate alternative of adiposity as compared to BMI. It also appears that most of the studies examining the BAI have involved only adults. It may be useful to assess the accuracy of the BAI in relation with other anthropometric indices in children.

Apart from the BMI, waist circumference is also considered as another simple way of estimating abdominal fat [50]. Waist circumference is associated with BMI and requires only a tape measure [50]. It can be measured at the midpoint between the tenth rib and the iliac crest with the individual assuming an upright standing posture [65]. The measurement can be done alongside BMI or as a separate measure [50]. The World Health Organisation (WHO) has provided sex-specific guidelines for waist circumference (i.e. $\geq 80\text{cm}$ for women, $\geq 94\text{cm}$ for men) to identify individuals with increased health risks. In addition, people with waist circumference values that are $\geq 88\text{cm}$ for women and $\geq 102\text{cm}$ for men are said to have substantially increased health risks [50].

In terms of assessment, procedures for body composition both sophisticated and simple measures are considered to be useful. However, advanced techniques such as the DEXA are preferable in many instances because they have high degree of accuracy. Unfortunately, these measures are usually not suitable for low-income settings due to resource constraints. In this regard, indicators including the BMI, WHR and waist circumference become the obvious choice.

Table 2.2: The International Obesity Task Force age and gender specific BMI cut off points [61]

Age (years)	Body mass index <25kg/m ²		Body mass index 25kg/m ²		Body mass index <30 kg/m ²	
	Males	Females	Males	Females	Males	Females
2.0	15.24	14.96	18.36	18.09	19.99	19.81
2.5	15.02	14.77	18.09	17.84	19.73	19.57
3.0	14.83	14.60	17.85	17.64	19.50	19.38
3.5	14.66	14.44	17.66	17.48	19.33	19.25
4.0	14.51	14.30	17.52	17.36	19.23	19.16
4.5	14.38	14.16	17.43	17.27	19.20	19.14
5.0	14.26	14.04	17.39	17.23	19.27	19.20
5.5	14.15	13.93	17.42	17.25	19.46	19.36
6.0	14.06	13.85	17.52	17.33	19.76	19.62
6.5	14.00	13.81	17.67	17.48	20.15	19.96
7.0	14.00	13.83	17.88	17.69	20.59	20.39
7.5	14.05	13.90	18.12	17.96	21.06	20.89
8.0	14.13	14.00	18.41	18.28	21.56	21.44
8.5	14.24	14.13	18.73	18.63	22.11	22.04
9.0	14.36	14.26	19.07	18.99	22.71	22.66
9.5	14.49	14.40	19.43	19.38	23.34	23.31
10.0	14.63	14.58	19.80	19.78	23.96	23.97
10.5	14.79	14.78	20.15	20.21	24.54	24.62
11.0	14.96	15.03	20.51	20.66	25.07	25.25
11.5	15.15	15.30	20.85	21.12	25.56	25.87
12.0	15.36	15.59	21.20	21.59	26.02	26.47
12.5	15.59	15.91	21.54	22.05	26.45	27.04
13.0	15.84	16.23	21.89	22.49	26.87	27.57
13.5	16.11	16.55	22.25	22.90	27.26	28.03
14.0	16.39	16.86	22.60	23.27	27.64	28.42
14.5	16.69	17.16	22.95	23.60	28.00	28.74
15.0	16.98	17.43	23.28	23.89	28.32	29.01
15.5	17.26	17.68	23.59	24.13	28.61	29.22
16.0	17.53	17.90	23.89	24.34	28.88	29.40
16.5	17.79	18.08	24.18	24.53	29.15	29.55
17.0	18.04	18.24	24.46	24.70	29.43	29.70
17.5	18.28	18.38	24.73	24.85	29.71	29.85
18.0	18.50	18.5	25	25	30	30

Note: Shaded area represents the age band and its corresponding cut-off points (females only) used in the present study.

2.2.2.2 Epidemiology of overweight and obesity

2.2.2.2.1 Global trends in overweight and obesity

Globally, the prevalence of overweight and obesity in children and adolescents has skyrocketed [51]. Data indicates that between 1980 and 2013, the prevalence of overweight and obesity rose by about 47% in both developed and developing nations [51]. Five years ago, it was reported that the prevalence of overweight and obesity combined was 24% for boys and 23% for girls in high-income countries, and 13% among boys and girls in low and middle-income countries [51]. In a recent study on trends in BMI, underweight, overweight and obesity, population-based data from 1975 to 2016 was analysed for 128.9 million children, adolescents and adults [71]. The authors found that the rising trends in overweight and obesity as determined by mean BMI in children and adolescents had plateaued in most high-income nations but continue to increase in several parts of Asia and Africa [71]. Additionally, it was revealed that the proportion of children and adolescents aged 5-19 years who are underweight is higher than those who are obese in developing countries [71]. This means that more efforts need to be directed towards addressing the burden of underweight and overweight simultaneously.

In a systematic review that compared the prevalence of overweight and obesity among youth aged 10-16 years from 34 countries, it was observed that the number of children in high-income countries with a high prevalence of overweight and obesity was more than that of low and middle-income countries [72]. Specifically, the three countries that were reported to have the highest prevalence of overweight in youth were the United States of America, the United Kingdom and Malta. On the other hand, Latvia recorded the lowest prevalence of overweight. In fact, the prevalence of overweight in youth was greater than 15% in North American Countries (e.g. the United States of America and Canada), Britain and the southern part of Western Europe (e.g. Italy, Portugal, Spain, Greece and Malta). Other European countries such as Denmark, Finland, Norway, Sweden, Belgium, Netherlands, Germany and France had relatively low (between 10-15%)

prevalence of overweight in young people [72]. Though this study did not include data from Africa and relied solely on self-reported body weights and heights, findings are still relevant as they highlight important variations in the prevalence of overweight and obesity. In addition, these results call for aggressive efforts to be directed towards the fight against childhood obesity.

Reports from the United States of America had indicated that the prevalence of overweight remained stable from 2003 through 2010 [73-74]. However, when changes in weight status among these children and adolescents (aged 2-19 years) were recently analysed, it was found that the prevalence of overweight and obesity had not stabilised or declined. Rather, the data suggested an increase in the rates of overweight and obesity in children less than 5 years [75]. There are also indications that children from the United States of America under the age of 5 are more likely to become obese at the age of 35 years [76]. These observations call for urgent pragmatic actions focused on early identification, prevention and treatments to help avert future health problems.

Over the past few years, there seems to be an increase in the prevalence of overweight and obesity in many low and middle-income countries. According to a Chinese study, the prevalence of overweight in boys and girls doubled between 1995 and 2014 [77]. Another study highlighted the co-existence of underweight and obesity in Chinese minority groups [78]. This double burden of the disease appears to be widespread since some studies in South Africa have made similar observations [65]. Within the African continent, available information suggests that the prevalence of overweight and obesity is gradually rising in Northern and Southern Africa [79]. Recently, it was found that the prevalence of overweight and obesity among Algerian adolescents is high, with girls reportedly having a greater prevalence of overweight (18%) than boys (13%) [80]. This trend appears to be similar to trends seen in children in South Africa. The following section will discuss the prevalence of overweight and obesity in South African children.

2.2.2.2.2 Prevalence of overweight and obesity in South Africa

There has not been any national study on the prevalence of overweight and obesity among children and adolescents in South Africa in recent times. However, many cross-sectional studies performed in different parts of the country have estimated an increase in overweight and obesity in children and adolescents, with girls purported to have a higher prevalence of overweight and obesity than boys [81-90]. It has been suggested that the prevalence of overweight and obesity in South African children and adolescents may be the highest in the African region [81,89]. In addition, current estimates of overweight and obesity prevalence in South Africa show comparable trends with that of many high-income countries [81,83,89]. Indeed, local studies have reported that the average prevalence of overweight and obesity combined is more than 15% [82,89]. In South Africa, the prevalence of childhood obesity may vary by factors such as gender, ethnicity, geographical location, socio-economic status, and age group [89]. Ample evidence suggests that the prevalence of overweight in children less than 19 years is about 19% in boys and 26% among girls [81].

The National Youth Risk Behaviour survey conducted among adolescents aged 13-19 years in South Africa over a decade ago found the prevalence of overweight to be 6.9% for boys and 24.5% for girls. In that same study, the prevalence of obesity for boys and girls was reported to be 2.2% and 5.3% respectively [83]. Other studies have also documented a higher prevalence in overweight and obesity in girls compared to boys [82,84-90]. Possible explanations for the gender disparity in the prevalence of overweight and obesity may relate to variations in PA, the timing of sexual maturation, and cultural beliefs or perceptions about body weight [89]. Compared to boys, adolescent girls have lower levels of PA [91] and are more likely to develop an unhealthy weight. In addition, in certain communities and ethnic populations in South Africa, overweight and obesity are viewed as a sign of beauty, wealth, health and happiness making healthy weight an undesirable goal especially among young women [89, 92-94]. These cultural beliefs may partly account for the increased prevalence of overweight and obesity

among children and adolescents. Nonetheless, given the association between childhood obesity and adult obesity and the relationship between obesity and health complications, it is necessary to develop tailored interventions to address obesity-related concerns particularly among girls who have greater risks for overweight or obesity.

Apart from the high prevalence of overweight and obesity among children and adolescents, South Africa also faces a double burden of disease where underweight and overweight co-exist across the country [89,95]. The primary cause of underweight in children and adolescents is malnutrition, a problem that is more prevalent in disadvantaged communities [95]. The combination of stunting and obesity in the same population may create a variety of health complications across their life-course [89]. The high prevalence of overweight and obesity in adolescent girls have negative implications for the affected persons, families and the entire economy. Therefore, effective remedies are immediately needed to address these menaces.

2.2.2.3 Aetiology of overweight and obesity

Overweight and obesity are multifactorial conditions that are caused by genetic and non-genetic (environmental) factors or a combination of both [59] (Figure 2.1). While genetics account for about 50-70% of the variability in BMI [96], behavioural and environmental factors may be the significant causative agents for the high prevalence of obesity in children and adolescents worldwide [50]. In paediatric populations, overweight and obesity are caused by a combination of poor dietary habits and lack of PA resulting in energy imbalance [59]. Environmental and cultural factors such as socio-economic status and ethnicity may also contribute to energy consumption and expenditure [59]. In South Africa, evidence indicates that poor dietary patterns and low levels of PA may be responsible for the high prevalence of overweight and obesity in children and adolescents [89].

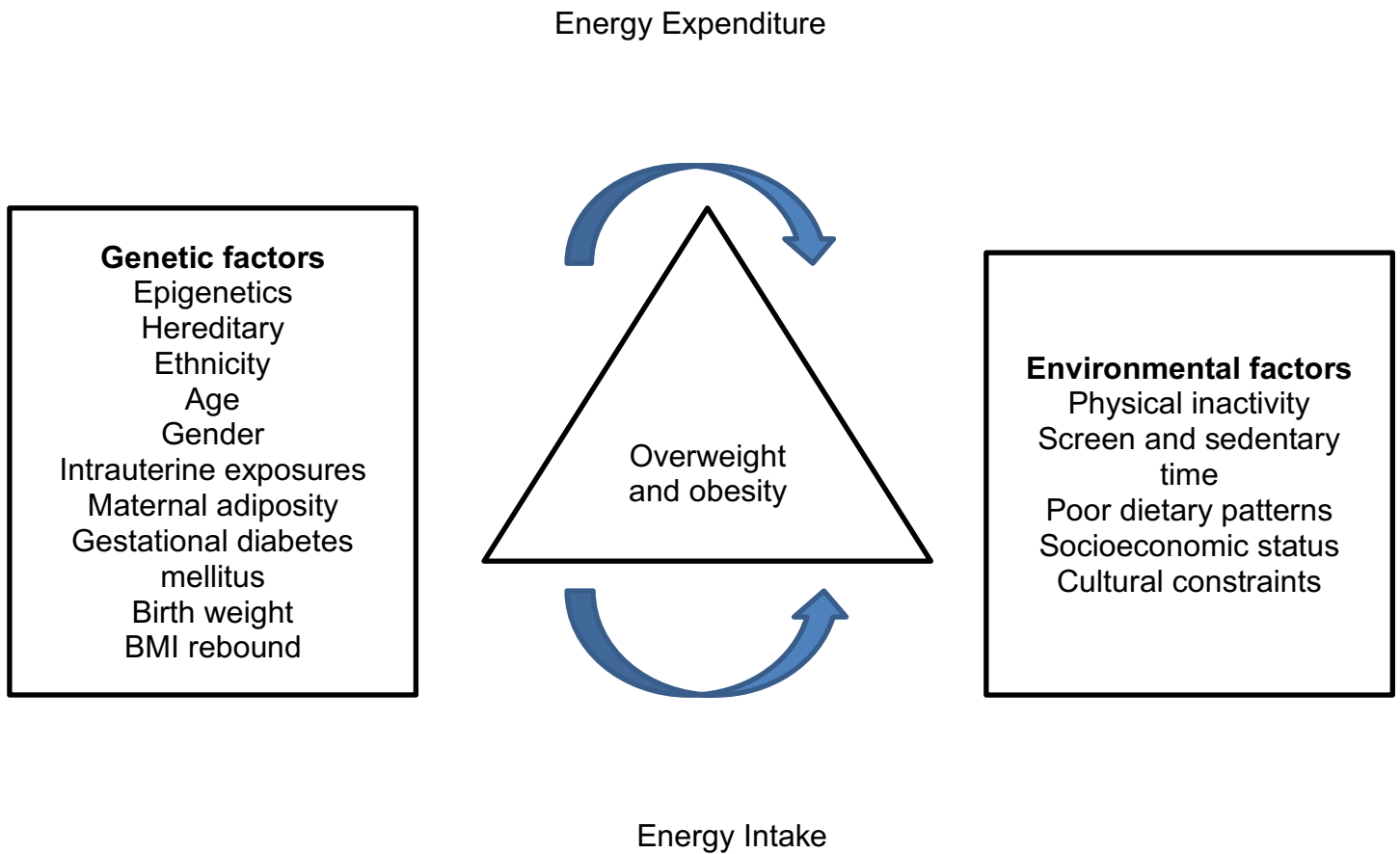


Figure 2.1: Determinants of paediatric obesity adapted from Gungor [59]

2.2.2.4 Consequences and comorbidities associated with overweight and obesity

Substantial short and long-term health consequences associated with overweight and obesity have been identified. Overweight and obesity in children and adolescents have been linked with a number of medical conditions [73], physical and psychosocial abnormalities [59] (Table 2.3). Medical conditions such as metabolic syndrome, type 2 diabetes, Blount's disease, slipped capital epiphyses and hypertension are thought to be associated with childhood obesity in the immediate (short) term [97]. In terms of long-term consequences, childhood obesity tends to show persistence into adulthood and increases the risks for adult morbidity and mortality [97]. In a recent study that examined the presence of medical and non-medical complications of obesity in children and adolescents, it was suggested that a greater proportion of children with obesity suffer from at least one medical condition [98]. Indeed, orthopaedic problems were more prevalent in the study cohort (54%), followed by metabolic and cardiovascular disturbances. Psychological complaints were also reported by the participants. Children with obesity are more likely to die from chronic diseases such as coronary heart disease in their adult life as compared to healthy weight peers [73]. For example, idiopathic increased hypertension (Pseudotumour cerebri), a condition that presents with headaches, vomiting and diplopia mostly occurs in obese people in their third decade of life [97].

From a physical health perspective, childhood obesity is associated with negative changes in motor skills, PA and physical fitness, and musculoskeletal constraints [99-104]. These findings have implications for people who develop exercise interventions to treat overweight and obesity. Surprisingly, studies investigating the effects of exercises on these variables in obese individuals are limited. In a study that investigated the relationships between obesity, physical activity and conditioning among Australian children aged 10-13 years, it was demonstrated that obese children had a poorer strength and lower physical conditioning than non-obese peers [100]. This may be explained by the biomechanical constraints

imposed by the additional load and the high energy cost associated with physical performance [100]. A systematic review of the association between PA and obesity suggested that PA is inversely associated with obesity in both childhood and adulthood [102]. Shultz *et al.* [103] performed a review to examine the link between paediatric obesity, PA and orthopaedic problems. The researchers suggested that children with overweight and obesity tended to experience pain and discomfort during regular PA, which in turn reduces participation in sports and recreation. Despite the increased research on childhood obesity, motor skills and PA, the causal direction between these variables remain uncertain.

In terms of psychosocial problems, children with overweight and obesity are known to have low-self-esteem [73] and reduced self-efficacy [103] as compared to normal-weight peers. In addition, children who are overweight and obese are more likely to have lower academic achievement than normal weight peers [97]. Low self-esteem decreased self-efficacy, low-confidence and discrimination against overweight and obese children have been hypothesised as significant contributors to poor academic performance in this population [97].

Table 2.3: Summary of comorbidities and complications of overweight and obesity in children and adolescents

Physiological system	Health complications
Orthopaedic	Slipped capital femoral epiphysis [99-104]
	Blount's disease [59,73,97-104]
	Fractures [59,73,97-104]
	Legg-Calve-Perthes disease [59,73,97-104]
	Hyperlordosis [59,73,97-104]
	Musculoskeletal pain [59,73,97-104]
Neurological	Idiopathic intracranial hypertension (Pseudotumour cerebri) [59,73,97-104]
	Motor incoordination [29]
Pulmonary	Asthma [59,73,97-104]
	Obstructive sleep apnea [59,73,97-104]
	Obesity hypoventilation syndrome [59,73,97-104]
Gastrointestinal	Non-alcoholic fatty liver disease [59,73,97-104]
	Steatohepatitis [59,73,97-104]
	Cholestasis [59,73,97-104]
Cardiovascular	Hypertension [59,73,97-104]
	Dyslipidaemia [59,73,97-104]
	Adult coronary heart disease [59,73,97-104]
Endocrine	Insulin resistance [59,73,97-104]
	Type 2 diabetes [59,73,97-104]
	Thyroid function abnormalities [59,73,97-104]
	Metabolic syndrome [59,73,97-104]
	Menstrual abnormalities [59,73,97-104]
	Polycystic ovary syndrome [59,73,97-104]
Psychosocial	Depression [59,73,103]
	Discrimination [59,73,103]
	Stigmatization or victimization [59,73,103]
	Low self-esteem [59,73,103]

	Decreased self-efficacy [59,103]
	Body image abnormalities [59,73,103]

2.2.2.5 Intervention approaches for treating overweight and obesity

For decades, exercises have been widely acknowledged as essential methods for weight control [105]. However, the efficacy of exercise interventions in improving motor control and physical fitness is under-researched. It has been suggested that interventions targeting individuals with overweight and obesity should focus more on physical fitness, PA and relevant health markers than weight loss as it is difficult to reduce weight in obese populations [105,106]. In a study that was conducted to evaluate the effectiveness of exercises on reducing weight and improving health markers, it was found that participants experienced less than expected weight loss but had vast improvements in several health markers including blood pressure and cardiovascular fitness [107]. This finding suggests that it may be important to explore the types of interventions that may be capable of providing optimal benefits in overweight or obese populations. In the sections below, PA interventions for children and adolescents will be discussed. Thereafter, the programmes used to treat overweight and obesity will be reviewed.

2.2.2.5.1 Interventions to promote physical activity

Several systematic reviews have been conducted to assess the efficacy of PA interventions in children aged 6-18 years [108-122]. Voskuil *et al.* [108] conducted a systematic review of randomised controlled trials of PA interventions to evaluate their effects on objectively measured PA, BMI, and percentage of body fat amongst girls with ages ranging between 6-18 years. Owen *et al.* [109] also performed systematic review and meta-analysis on school-based PA interventions in girls. Other investigators including Pearson *et al.* [110], Biddle *et al.* [111] and Camacho-Minano *et al.* [112] have also published meta-analyses to quantify the effectiveness of interventions in adolescent girls. Camacho-Minano *et al.* [112] reviewed 29 published studies to determine the most effective interventions and to

characterise the key elements of such interventions. A systematic review focusing on implementation issues has also been published [113]. Between 2007 and 2013, at least eight other systematic reviews and updates on PA interventions were published including that of Lonsdale *et al.* [114], Dobbins *et al.* [115], Kriemler *et al.* [116], Metcalfe *et al.* [117], Van Sluijs *et al.* [118], Demetriou and Honer [119], Lai *et al.* [120], and Biddiss and Irwin [121]. Overall, evidence from the majority of studies and reviews suggests that participation in structured PA interventions provide significant health benefits. Importantly, most of these papers have provided detailed descriptions of core attributes of effective interventions. Many researchers agree that elements such as the types of interventions, dosage parameters, mode of delivery and the setting in which interventions are delivered are important features of successful programmes [118].

Voskuil *et al.* [108] reviewed 15 randomised controlled trials among girls aged 6-18 years. Studies were included if they measured PA objectively (using accelerometers) and reported on the effects of interventions on BMI and/or percentage of body fat. Results showed that interventions elicited marginal effects on accelerometer-measured PA, BMI and percentage of body fat. Only a few studies in this review demonstrated between-group differences in accelerometer-measured PA, BMI and percentage of body fat. Therefore, the authors suggested that current interventions may not be suitable for improving health outcomes in school-aged girls [108]. Though Voskuil *et al.* [108] reviewed the literature on interventions published between 1985 and 2014, none involved girls living in Africa. Several reasons including the absence of studies or the lack of well-designed trials among girls in Africa might explain this observation. This demonstrates the need for the development and testing of new programmes among African girls.

Owen *et al.* [109] systematically reviewed a total of 20 studies involving adolescents. Of these, 70% were randomised controlled trials and the remaining were either pilot or quasi-experimental studies. Studies in their review were

implemented with both boys and girls residing in developed nations such as the United States of America, the United Kingdom, and Australia. In addition, PA (measured either objectively or subjectively) was the primary outcome in most of these studies. Again, results revealed that effect sizes of the interventions were small ($g=0.37$). Although subgroup analysis yielded negligible effects ($g=0.09$) for multi-component interventions, the authors recommended the promotion of theory-based multi-component interventions among children to prevent sedentary behaviour and obesity. This might be attributed to the fact that most of the studies that tested theory-driven multi-dimensional interventions had significant results.

Pearson *et al.* [110] reviewed 45 studies involving adolescents aged 12-18 years. The interventions implemented with girls showed small but significant effects on PA. Results demonstrated that interventions that employed multi-component strategies yielded larger effects than others. Biddle *et al.* [111] conducted a meta-analysis involving 22 intervention studies on pre-adolescent girls aged 5-11 years. Results from their meta-analysis revealed significant but small ($g=0.31$) effects on PA. Furthermore, Camacho-Minano and colleagues [112] suggested that evidence for the effectiveness of exercise programmes on PA and related outcomes were inconclusive. However, they observed that interventions with multiple components may be more effective for adolescent girls. Though the mechanisms behind multi-component interventions have not been studied, it is possible that these programmes are effective because they target multiple factors (e.g. personal, environmental, family and community related factors) that are known to influence behaviour.

Kriemler *et al.* [116] provided an update of systematic reviews published prior to 2011. In their updated review, 20 studies were identified including relevant systematic reviews from Van Sluijs *et al.* [118], De Meester *et al.* [121] and Dobbins *et al.* [122]. Van Sluijs *et al.* [118] reviewed 57 studies involving children and adolescents younger than 18 years. The majority of these studies focused on children ($n=33$, aged 6-12 years) whereas 24 involved adolescents (aged 13-18

years). Of these, only five studies focused on girls. Most of the studies reviewed by Van Sluijs *et al.* [118] were from the United States of America and the United Kingdom. They found that multi-modal interventions with family or community involvement resulted in an increased PA, but no strong evidence for the effectiveness of interventions in children with low socio-economic status was found. In addition, studies that evaluated environmental interventions showed no effects on PA. Again, none of the studies included in this review was performed among African children or adolescents.

De Meester *et al.* [121] reported a systematic review consisting of 20 studies with the goal to identify the most effective interventions in European teenagers. They found that school-based interventions produced short-term improvements in PA, but it was unclear if these changes could be transferred to contexts outside the school environment. Likewise, Dobbins *et al.* [122] reviewed 26 studies involving children and adolescents (6-18 years) living in Australia, Europe, South America and North America. Their findings indicated that school-based interventions are effective in increasing the duration of PA, lowering blood cholesterol, reducing time spent watching television and increasing physical fitness. The authors suggested that interventions that use a combination of strategies may be more effective than others. Nonetheless, Dobbins *et al.* [122] emphasised that school-based interventions may not change leisure time PA. This particular finding reinforces previous observations [109,118]. In 2013, Dobbins *et al.* [115] updated their previous systematic review with a total of 44 studies conducted between July 2007 and October 2011. Overall, the results of this updated review were similar to the one reported earlier [122], indicating that school-based interventions produce minimal short-term effects on PA. However, it was indicated that children and adolescents who participate in regular PA tend to increase the time spent on moderate-to-vigorous PA and are more likely to be fitter than those who do not engage in exercises.

Although there appears to be some level of consistency in these reviews, effect sizes have been small. In addition, most studies have focused on PA only. Few studies focused on other markers such as motor competence and physical fitness. More importantly, there appears to be a paucity of data regarding the effectiveness of interventions in low and middle-income countries. Without evidence on the impact of interventions on specified population groups in these countries, PA promotion and obesity prevention efforts may not yield desirable results. Determining what types of interventions that are feasible to implement in low socio-economic environments may be an important initial step in the fight against physical inactivity and obesity.

Kriemler *et al.* [116] pointed out that amongst the number of studies they reviewed, a limited number focused on motor competence. Out of the 20 studies they reviewed, only six focused on motor competence. However, not all of these involved adolescents. A plausible explanation for the limited number of intervention studies targeting motor competence and physical fitness as outcomes might be due to the assumption that most adolescents have proficient motor skills. While this assumption may be true for settings where PA opportunities abound, it may not reflect the conditions in socio-economically deprived communities or even affluent areas where children fail to use the available PA resources. Hence, regardless of the age of the child, it may be prudent to ensure that adequate levels of motor proficiency are attained to facilitate the adoption of active lifestyles. Since motor competence is a strong predictor of PA, implementing interventions to target motor competence and other mediators such as fitness is an important research endeavour [123]. Studies testing the effects of interventions on motor skills among high school girls in sub-Saharan Africa are scarce. To date, only one study has evaluated the effects of exercise programmes in pre-adolescent girls from Tunisia [124]. Within the African low-income settings, information on the efficacy of exercise programmes among high school girls is still limited. Previous research focused on younger age groups (6-12-year olds) with little information available for adolescent girls [124].

The use of technology in PA promotion has become pervasive in recent times. Many technologies including internet-based strategies [125,126], smartphone applications [127-130] and active video games [131-139] have been widely studied. There has been an increased interest in active video games (AVG) as a tool for promoting PA in children with and without obesity [140-141]. AVGs are gaming systems that promote PA through interactive play [140]. They allow users to apply whole body movements to participate in everyday sports, and physical activities in a virtual environment [140]. A wide array of gaming systems has been used in PE classes [140,141] and clinical settings [142-144]. Examples of active video gaming consoles include the Microsoft Xbox 360, the Sony PlayStation, the Sony EyeToy, the Dance Dance Revolution, the Cybex Trazer, the Cateye Gamebike, the Sportwall and the Nintendo Wii Fit [134,140,141].

Compared to other gaming systems, the Nintendo Wii Fit has received considerable attention in rehabilitation and PE settings [140-145]. This is because it is less expensive, easy to set-up and does not take up much space. The Nintendo Wii Fit (Kyoto, Japan) system consists of multiple components such as the balance board, Wii console, TV screen, and connecting cables [144]. The balance board is a rectangular plastic board that contains inbuilt pressure sensors. With these sensors, the board is able to measure weight distribution and provides feedback via the TV screen. The console operates with a software that provides several game options categorised into aerobics, muscle workout, balance, yoga and training plus [144]. Users assume an upright standing position and shift their weights continuously to control an avatar (an onscreen representation of the user) [144]. Depending on the game being played, both gross and fine motor abilities could be employed. For example, the boxing rhythm game encourages the use of the upper extremity, lower extremity as well as trunk movements in a well-coordinated manner [144]. Similarly, the dance games encourage multiple segmental movements.

Research suggests that the Wii Fit is capable of improving balance control and many other health outcomes in both children and adults [142,145, 146-155]. It has also been suggested that adaptation of the Wii games may help to improve health outcomes [146]. Though the Wii Fit is marketed as a health and fitness tool, evidence of its impact on physical fitness is still unknown. To date, very little is known about how the gaming environment can be manipulated to increase fitness. Biddiss and Irwin [134] performed a systematic review of the effectiveness of AVGs in promoting PA among children and youth. Eighteen studies published between 1998 and 2010 in children (less than 21 years) were reviewed. The studies included measures of energy expenditure, patterns of PA, physiological markers, enjoyment of activity and motivation. While several studies showed that active video game play leads to changes in energy expenditure [134], the sustainability of these effects remains elusive. According to Biddiss and Irwin [134], AVGs can enhance light to moderate PA and may be useful for promoting PA in circumstances where there are numerous barriers to participation (e.g. unsafe neighbourhoods, lack of transportation, lack of exercise facilities and unfavourable climatic conditions).

Peng *et al.* [136] reviewed 41 studies (13 intervention studies and 28 laboratory studies). Of the 13 intervention studies, none focused on children and only one was conducted among females. The laboratory-based studies quantified exercise intensity of active video games. While the laboratory-based studies revealed that AVGs can have greater impact on light to moderate PA, only three intervention studies demonstrated a significant increase in PA. This means that AVGs may be less beneficial in promoting activity when compared to traditional exercise programmes. However, the authors reported that children tended to like the active video games better than traditional PA programmes. Another systematic review by LeBlanc *et al.* [137] reinforced previous findings suggesting that AVGs can increase light to moderate intensity PA, but also emphasised that AVGs may elicit other health benefits in special populations. However, evidence supporting this assertion was very weak. Before AVGs can be recommended as an effective

exercise programme, there is the need for more data to be generated regarding its effectiveness in paediatric populations from different backgrounds.

2.2.2.5.2 Interventions to treat overweight and obesity

For the past two decades, several attempts have been made to find the most effective obesity prevention or treatment interventions for children and adolescents. These efforts have culminated in numerous programmes and systematic reviews [156-164]. Some of the programmes that have delivered promising results include Girlfriends for KEEPS [156], GEMS programme [157,158], GO GIRLS [159], Trial of Activity for Adolescent Girls (TAAG) [160], New Moves programme [161] and the Nutrition and Enjoyable Activity for Teen Girls (NEAT) [162]. Story *et al.* [156] tested the feasibility of an after-school obesity prevention programme for African-American girls. Participants (n=25) with a BMI $\geq 25^{\text{th}}$ percentile enrolled and were randomly allocated to intervention or control groups.

The intervention group participated in a 60-minute multi-component treatment held three times weekly for 12 weeks. The programme was based on the Social Cognitive theory and focused on improving personal, environmental and behavioural factors that limited participation in PA. Participants in the intervention group were exposed to PA and healthy dietary habits as well as family support activities. In contrast, members of the control group attended three meetings that focused on promoting self-esteem and cultural enrichment. Results showed a high level of satisfaction and acceptability among participants, which was confirmed by the high retention rate (98%). Whereas no significant differences were observed for BMI between the groups, PA levels (both objective and self-reported) were higher in the intervention group than the control group. Compared to the control group, the intervention group had a lower caloric intake. Though this pilot study was not powered to detect group differences, the findings provide an indication that theory-driven multi-factorial interventions delivered over longer durations might be more effective.

In the NEAT Girls trial [162] in which 357 adolescent girls participated, it was suggested that school-based multi-component intervention may not produce significant reductions in BMI but might be associated with positive health outcomes. Another study [163] evaluated the effectiveness of positive youth development-based sports programme on physical and psychological health outcomes in Chinese adolescent girls using a randomised controlled trial. While the control group had no treatment, participants belonging to the intervention group received a 90-minute weekly programme that focused on building skills and enhancing confidence in an empowering environment. Results indicated a tremendous improvement in physical fitness, self-efficacy, dynamic balance and muscle strength in favour of the intervention group. However, there was no significant improvement in body fat composition and social connectedness. These findings provide empirical evidence supporting the effectiveness of a programme formulated around skills building and psychological empowerment in adolescent girls. The improvements observed may be attributed to the features of the intervention, suggesting that multi-component interventions may be more beneficial in this age group. It has also been demonstrated that aspects of physical fitness can be improved with community-based (multi-component) interventions [164].

Kelly and Kelly [165] performed a systematic review of meta-analyses investigating the effects of exercises in overweight and obese children and adolescents. After reviewing a total of 308 studies, two meta-analyses with high methodological quality were included in their review. It was concluded that exercise interventions are capable of reducing the percentage of body fat. However, evidence for the effectiveness of interventions on BMI and waist circumference was weak. Atlantis *et al.* [166] reviewed 13 randomised controlled trials investigating the effects of exercises on the percentage of body fat, BMI and related measures such as waist circumference in overweight and obese children and adolescents. Unlike the study of Kelly and Kelly [165], most of the studies

included in this review had inappropriate designs with intervention doses reported to be lower than the recommended doses of between 210-360 minutes per week [73,167]. The authors found that exercise interventions of lower dosage elicited significant effects on percentage of body fat. Conversely, effect sizes of interventions on weight and central obesity was small and non-significant.

In an attempt to analyze exercise interventions for treating children and adolescents with obesity, Cauderay and Cachat [168] reviewed 19 studies that were published between 2010 and 2015. There were many variations in the duration of interventions, dosage parameters, settings and types of exercises making it difficult for comparisons to be made across studies. The authors revealed that interventions with short durations delivered the greatest benefits on PA. In addition, they found that obesity treatments are capable of improving motor competence and advised that future studies should address the specific needs of overweight or obese populations such as poor motor control. According to Nooigen *et al.* [169], there is no evidence to support the effectiveness of currently available programmes in improving PA in overweight and obese children. This calls for more research to identify new strategies that can be used to enhance PA in this population.

Other reviews examining the effects of AVGs in overweight and obese populations showed that AVGs can increase PA to promote health [170,171]. In addition, it has been suggested that engaging in AVGs may provide psychosocial benefits which might result in increased participation. Because of these benefits, it may be important to promote AVGs as options for physical activity and fitness promotion. However, given the differences in games, it may be necessary to identify appropriate games or programmes that can be implemented with overweight or obese populations to improve fitness.

Results of the above reviews show that exercise interventions are capable of improving health outcomes in both healthy individuals and those who are

overweight and obese. However, not every study found significant results indicating the need for further research. It is crucial for investigators to identify critical factors that need to be incorporated into intervention planning and implementation. While most studies recommended the use of multi-component programmes, there are multiple views on what constitute multi-component interventions. In addition, the active ingredients in such interventions have not been specified. It is therefore important to further discuss the common characteristics shared by successful interventions.

2.2.3 Common elements of effective interventions

Previous studies have characterised key features of effective programmes. It is anticipated that this knowledge would be applied to the development of future interventions to improve outcomes. In the current study, there was commitment to use these ideas in planning and implementing the interventions. However, because of logistical constraints, it was impossible to adhere to each of the recommendations discussed below.

2.2.3.1 Content and type of interventions

Several studies have shown that multi-component interventions that target personal, environmental and behavioural factors are more effective than others [108,118,156-158]. Multi-component interventions have several aspects that provide opportunities to activate positive changes in an individual [110]. Various components of multi-modal programmes have been identified including modified physical education, environmental adaptations, educational sessions, counselling sessions, technology and family or community involvement [109,118]. Kriemler *et al.* [116] reported in their review that multi-component interventions involving a combination of elements appear to be more effective than those with individual components. Preston *et al.* [44] also demonstrated that multi-factorial interventions such as the NTT are more effective in children with DCD. In line with these findings and the lack of PA opportunities among the target population, the researcher chose to develop interventions that would address multiple factors known to limit movement performance. Accordingly, two different interventions

were designed with the goal of manipulating multiple factors (individual, task and environmental conditions) to enhance motor performance.

2.2.3.2 Duration and intensity of interventions

There seems to be no agreement regarding the ideal duration for effective interventions. While some studies had longer durations, others were administered over a short time frame. Interestingly, both time frames recorded impressive outcomes [37,44,116,118]. This indicates that perhaps the choice of intervention duration may be influenced by multiple factors. This may include published data, programme goals, availability of resources and/or logistical challenges [108,116,118]. Several studies suggested that interventions with shorter durations and lower doses may achieve significant results and sustain participants' interests [37,108,111,166]. Since engagement and sustained motivation are critical for voluntary participation in interventions, it might be helpful to provide relatively shorter interventions in adolescents with DCD, overweight and obesity.

2.2.3.3 Mode of Delivery

Interventions for treating DCD and overweight or obesity can be delivered in one-on-one basis or group-based formats. Reports have shown that group-based programmes involving limited participants are more effective [37,46]. *Cacola et al.* [48] demonstrated that group-based interventions offer better motor skill benefits. Physical education teachers, research team members, school health officers, and dance instructors have supervised interventions in children and adolescents [109]. Another channel for delivering interventions that have been found to be beneficial is the use of technology [136,137]. Though evidence for AVGs is weak, the researcher used AVG as one of the interventions in the current study as it was thought to sustain engagement. Also, because adolescents derive a lot of motivation from peers, the interventions were administered in groups.

2.2.3.4 Settings of Interventions

Interventions for managing DCD and overweight and obesity have been delivered in diverse settings. These include clinics, hospitals, churches, homes, communities and schools [37,46,116,118,163,164]. Schools are ideal settings for reaching out to the majority of children who may be in need of treatment for physical and psychological health conditions. Given that participants had limited access to programmes in their school, motor-based interventions were developed and made available in the school premises to help promote motor development and physical fitness.

2.2.3.5 Theoretical Framework of Interventions

It has consistently been demonstrated that interventions that are grounded in theory are more effective than those with no theoretical basis. There is strong evidence in both the DCD and obesity literature to support this assertion [37,44,46,118,156-162]. It is therefore imperative that new interventions seeking to address impairments in motor coordination and obesity-related problems be based on sound theory. With this knowledge in mind, the development and implementation of the interventions in the current study were based on a well-known theory and relevant exercise principles. In the next section, a description of the interventions and their components will be presented. Thereafter a review of the theory and principles underpinning them will be provided.

2.2.4 Principles underpinning the development and implementation of interventions

As previously stated, experts have suggested that successful interventions should be based on theory [172]. In line with evidence-based recommendations, two multi-layered interventions were developed to improve motor competence and physical fitness in adolescent girls with DCD and those who are overweight and obese. The two programmes, an AVG intervention and task-oriented functional training were developed and implemented based on the principles of the constraints-led hybrid model of motor performance proposed by Wilson *et al.* [173]. The rationale for choosing Wilson *et al.*'s model [173] was to develop

programmes that would address the multiple factors (e.g. personal and environmental factors) known to contribute to poor motor control and reduced physical fitness exhibited by children DCD, overweight and obesity.

As mentioned earlier, DCD and obesity are important global health concerns in children. The manifestations of both conditions are varied. However, DCD and childhood obesity share some common similarities in terms of symptomatology. Importantly, DCD and obesity results in impaired motor coordination decreased physical fitness and low self-efficacy. These shared symptoms can limit participation in PA, facilitate a further decline in motor skills resulting in unhealthy weight [123]. Wilson *et al.*'s [173] conceptual model, therefore, serves as a useful guide to aid the selection and organization of activities to improve motor competence and/or physical fitness in individuals with deficits in motor control and physical fitness. The hybrid model has been described below.

2.2.4.1 Hybrid (multi-component) model of motor performance

Wilson *et al.*'s [173] hybrid model (Figure 2.2), was formulated based on the idea of constraints originally proposed by Karl Newell [174]. Along the concepts of constraints, Wilson *et al.* [173] explained that motor actions emerge from the independent interactions that occur among people who move in a given environment and execute a particular task [173]. In such situations, three types of constraints can be identified; individual, task and environmental conditions. These constraints interact reciprocally with one another to encourage certain motor actions and discourage others [175, 176]. For example, in an activity such as writing with a pen, individual factors such as hand size, vision and skills level can interact with task properties (i.e. size and weight of the pen) and with environmental conditions such nature of the writing surface (e.g. hard or soft pad) to influence how a person execute this motor action [176]. Similarly, in children with DCD or obesity, a combination of individual, task and environmental constraints can influence their experiences in relation to why and how they adopt certain motor behaviours [176].

Traditionally, individual constraints are defined as the individual's emotional and physiologic state that influence how the person moves or executes motor actions [174,177]. In Wilson *et al.*'s model [173], two kinds of individual constraints are described, structural and functional. Structural constraints relate to the anatomical structure of the person and include height, weight, BMI, and size of body segments [173]. Functional constraints refer to specific functions such as coordination, balance, and psychological factors (e.g. motivation, self-esteem, self-efficacy and attention) [173]. Individual constraints interact with one another to encourage or limit motor output [173]. For example, a person who is overweight or obese with adequate strength may perform abysmally on an agility task because of the functional constraints of poor coordination and balance [176].

Task constraints refer to specific, intentional activities and tasks, which often have pre-defined structure, goals, rules or equipment [176]. For example, when a girl is asked to jump between two points, she will do so by elevating her body from the starting point and ending at the finish line without dragging her feet along the space between the said points [176]. This means that every task has inherent rules that determine what one can or cannot do in a given situation [174,176,177]. Task constraints have strong impacts on psychological factors and can interact with such factors to limit or encourage performance. The hybrid model of motor performance [173] was first introduced to help explain the movement patterns of children with DCD and to provide a guide for developing interventions to optimize motor performance. Because of the linkage between motor competence and obesity, Wilson *et al.*'s model [173] can be extended to provide solutions to address movement problems in children with excess weight.

The environment in which the individual lives, moves and plays can also serve as a constraint [176]. Environmental constraints relate to both physical and socio-cultural features outside of the individual's body that contribute to the encouragement or discouragement of certain movements [176]. Examples of

physical environmental constraints are air temperature, wind, ambient light, ground or floor architecture, and exercise space [173,176]. Variability in the physical (environmental) constraints can influence an individual decision and make him or her adopt different movement behaviours [176]. For example, a child living in a community with tarred road network might move quite differently when asked to run on a muddy road [176]. The socio-cultural environment includes societal or cultural norms, values, beliefs, attitudes, and expectations that promote certain kinds of behaviour in a particular group or setting [175,177]. For example, when an obese adolescent girl is asked to dance to a popular music alone or with colleagues who are also obese, she can successfully exhibit the motor actions [176]. However, when the same girl is requested to dance at a social gathering with her mates, parents and teachers present, the girl might feel reluctant to perform because of fear of ridicule [176]. In the section below, an explanation of how these concepts were applied to the target population is presented.

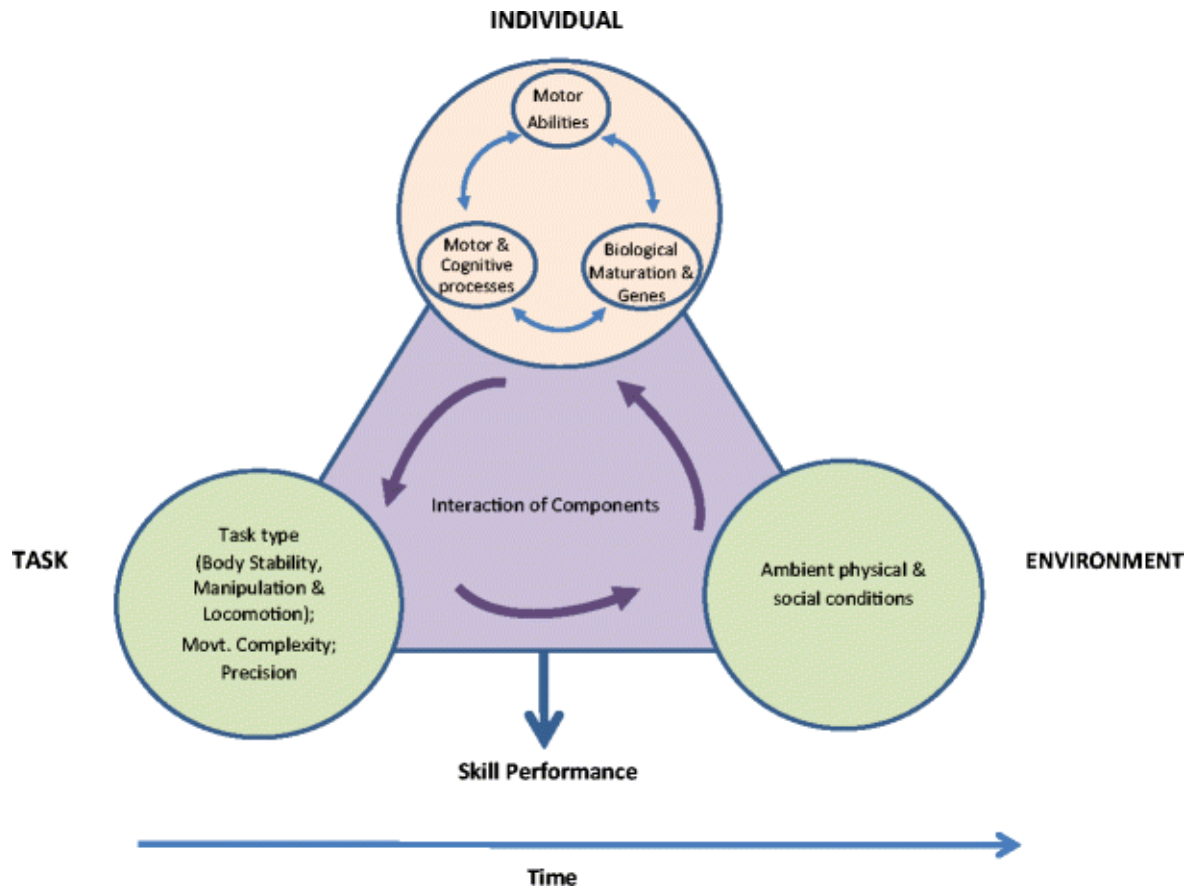


Figure 2.2: The hybrid model of motor performance adopted from Wilson *et al.* [173]

2.2.4.2 Application of the hybrid model to designing Interventions for high school adolescents with DCD and those with overweight and obesity

To improve motor competence and physical fitness, three principal ideas derived from Wilson *et al.*'s [173] model were followed;

1. Identification of commonly observed constraints in the target population.
2. Selection of strategies that would create opportunities for motor actions.
3. Modification and scaling of appropriate constraints to increase motor skills and relevant aspects of physical fitness.

2.2.4.2.1 Adolescent girls with DCD in low socio-economic environments

For adolescent girls with DCD, several individual constraints that vary from one person to another can affect the movement choices they make and how they actually perform those movements. In this particular group, functional constraints that were thought to limit motor performance included poor motor coordination, low physical fitness, poor balance, reduced strength, less experience, low motivation and decreased self-efficacy [173,176]. It was also acknowledged that these constraints would make it difficult for them to successfully engage in complex tasks with high coordination and fitness load such as sports, running over long distances and jumping over obstacles. Finally, climatic conditions, unsafe nature of their surroundings, the lack of PA resources, and absence of support systems from peers, role models and family members which were peculiar in this setting constituted important environmental constraints. Because of the independent relationship between these constraints, all the girls identified as having DCD had difficulty performing gross motor skills such as throwing and catching, hopping and jumping, running, which were evident during the motor performance assessments conducted in Phase 1.

To create opportunities for movement within the participants' boundaries of limitations, the girls were exposed to two different sets of activities; task-oriented functional training and AVGs. The two interventions were presented in the form of games to make them fun and enjoyable, and to enhance participants' confidence in their abilities to play these games (increase their self-efficacy). The objective of these protocols was to improve motor skills and fitness by enhancing enjoyment and self-efficacy. Because of this, the interventions were planned and delivered in three phases with the task and environmental constraints increasingly modified over time. The purpose of manipulating task and environmental constraints was to create experiences to meet individual constraints and to introduce an appropriate challenge to develop coordination, strength and conditioning [176]. This was achieved using a combination of relevant motor learning (e.g. practice scheduling, feedback and reinforcement) [178,179] and exercise training principles (i.e.:

specificity, progressive overload, reversibility and transfer of skills to diverse contexts) [180].

Since the aim of the training was to improve skills and fitness, each training session involved gross motor activities believed to produce significant gains in motor skill competence, strength and conditioning. During the early stage of learning, practice environments were structured to allow the girls to practice at the lowest level of difficulty [176]. This was intended to promote the acquisition of skills needed for successful motor performance. In the intermediate stage of learning, the frequency of feedback was reduced for the task-oriented functional training group whereas the AVGs continued to receive the same kind of feedback. As participants advanced through the stages of learning, the level of difficulty of the activities was progressively modified based on the idea of progressive overload [180,181]. For instance, among the AVG group, the gaming environment was gradually adjusted using wooden platforms and weighted backpacks. Modification of constraints was executed by training instructors and occurred at specific time points as depicted in the change drum in Figure 2.3. Each wave of modifications was executed to match changes in participants' performance.

2.2.4.2.2 Adolescent girls with overweight and obesity in low socio-economic environments

In extending the interventions to adolescent girls with overweight and obesity, the same guiding principles stipulated above were taken into account. Consequently, individual tasks and environmental constraints were identified. In the case of this group, both structural (overweight or obesity) and functional constraints (poor motor coordination, low physical fitness, poor balance, and reduced strength, less experience, low motivation and decreased self-efficacy) were identified. Again, because of the reciprocal nature of the relationship between the individual, task and environmental constraints and the influence of this interaction on motor performance, the same ideas discussed above were employed. More importantly, because it was practically impossible to get the girls to lose weight before participating in the interventions, low-impact activities such as walking, catching

and throwing were used as channels to improve motor performance and physical fitness.

As indicated earlier, during the initial phase of learning, girls were required to practise selected games and activities capable of increasing motor skills, strength and conditioning. As training progressed and improvements were realized in the participants' performance, the principle of progressive overload was used to gradually increase the difficulty of the exercise sessions [180,181]. Furthermore, the instructors of the task-oriented functional training and virtual reality technology provided motivational feedback (environmental adaptation) throughout the training period. Modification of task and environmental constraints was affected in a planned and structured manner to match observed changes in motor performance over time. Figure 2.3 displays the process of constraints modification used during the implementation of the interventions.

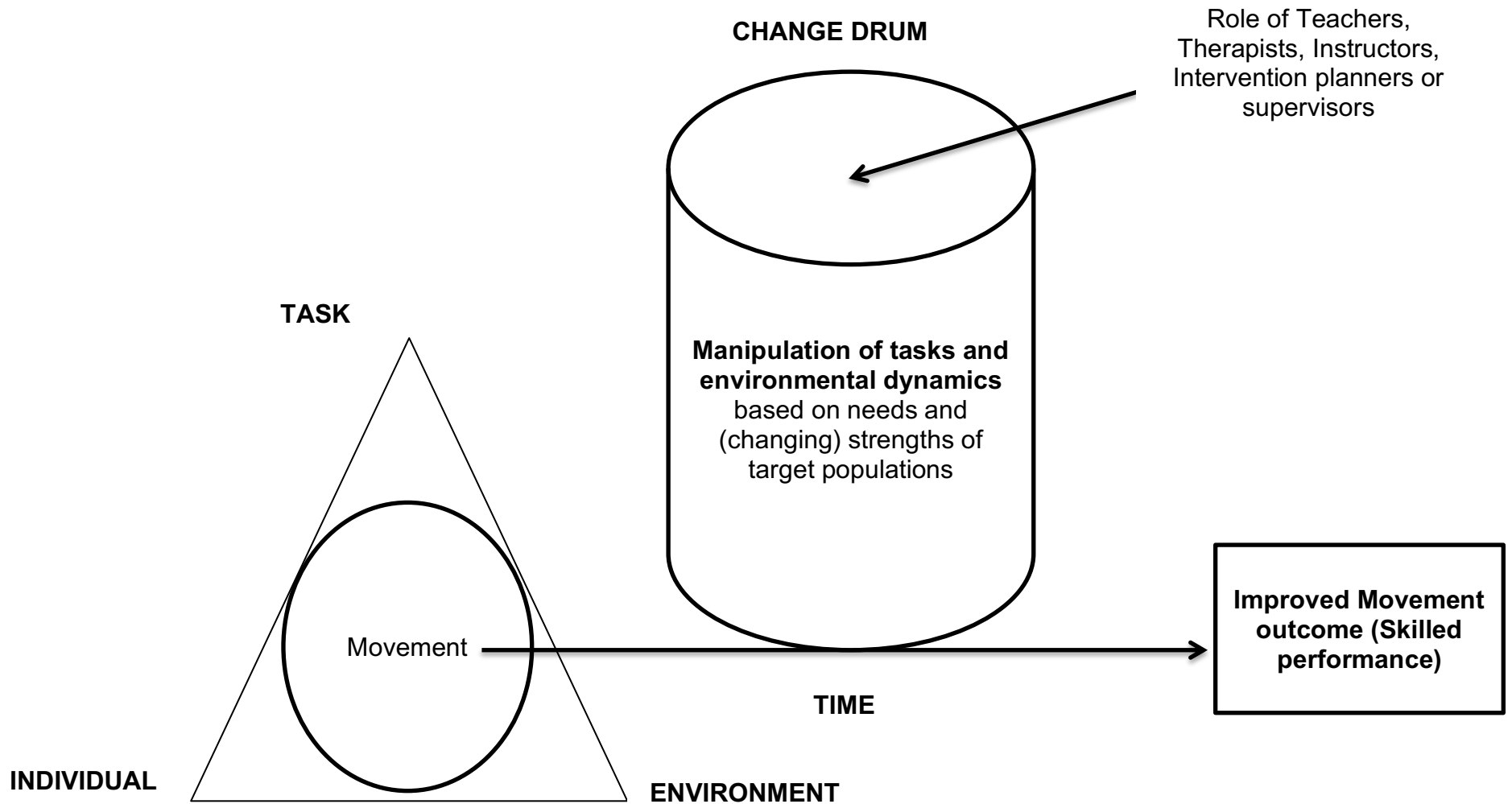


Figure 2.3: Modified hybrid model of motor performance showing the process of constraints manipulation

2.2.4.3 Description of Interventions: Components and Structure

Two different interventions were developed to increase motor competence and physical fitness. A detailed description of each programme is provided in the following section.

2.2.4.3.1 Wii Fit Training

The Nintendo Wii Fit gaming system was used to develop the AVG protocol. This gaming system was selected because of its capability to improve motor performance in young children with DCD [47]. The Nintendo Wii Fit allows users to interact with a virtual environment through its motion capturing technology. The system consists of the Wii consoles, balance board, TV screen, motion sensor devices and connecting cables. Users stand on the balance board and use their movements to control a virtual character on the screen. During gameplay, participants' performance is tracked, and feedback is provided in the course of play and at the end of each game.

For this study, a new AVG intervention called the graded Wii protocol was developed. The graded Wii protocol is an adaptable Wii Fit intervention in which the gaming environment is modified using the principle of progressive overload to promote motor skills, strength and conditioning. A three-step process was used to design the graded Wii Fit protocol namely identification of tasks, task segmentation, task-environment modification. Identification of tasks as used in this context relates to the act of selecting games to target specific components of fitness. The researcher selected games intended to challenge balance, improve endurance and increase strength and flexibility. Task segmentation relates to the grouping of games into training sessions so that users could have varied experiences at each episode of training. Finally, task-environment modification refers to the process of manipulating the gaming environment to increase the level of challenge to induce adaptations in strength and conditioning. As the goal of the interventions was to increase skills and fitness, games requiring whole body movements and were chosen. Next, the selected games were mixed up in various

combinations such that each session would involve tasks directed at different aspects of fitness. Lastly, weighted backpacks and rectangular wooden platforms were used to adjust the gaming environment over time.

The graded Wii protocol involved a 45-minute exercise session held once weekly for 14 weeks. The protocol was administered in three blocks [Block 1 (Weeks 1-5), Block 2 (Weeks 6-10), Block 3 (Weeks 11-14)]. Block 1 was meant for familiarisation and so participants played the games in their raw form with environmental adaptation. However, Blocks 2 and 3 represented periods where the gaming environment was adapted to increase the training load and to enhance motivation. During these phases, participants carried weighted backpacks and stood on elevated balance boards. All the training sessions were supervised by physiotherapists and human movement science graduates. Details of the graded Wii protocol can be found in Appendix A.

2.2.4.3.2 Task Oriented Functional Training.

Task-oriented functional training focuses on teaching functional skills and requires participants to practise real-world tasks (e.g. walking, catching and throwing). The task-oriented functional training was based on the idea that learning occurs when people engage in the repetitive practice of a particular task in a given context [178]. A fundamental tenet of this approach to training is that the tasks should be challenging and fun to ensure that participants succeed in eliciting the motor skills required for performing those tasks [178]. As stated earlier, the hybrid model of motor performance predicts that motor behaviours are built around functional tasks or goals and that specific movement solutions are influenced by the spontaneous interaction among individual characteristics, task demands, and environmental conditions [173]. Individual characteristics encompass both physical impairments (e.g. a limited range of motion or balance) and non-physical characteristics such as motivation, attention, and cognition [173,182]. Task characteristics include the rules and goals governing an activity or the equipment used to execute the said activity [173]. Environmental considerations are the physical, social, and attitudinal

influences that limit or encourage movements. Examples include accessibility of facilities or programmes, availability of instructors or assistants, and the attitudes of persons within the child's environment [173,182].

Based on participants' interests, three specific culturally appropriate activities were chosen; dance with music, the teaching of everyday motor skills, and team-based games. The task-oriented functional training involved 45 minutes of exercise sessions held once weekly for 14 weeks. Essentially, each exercise session involved group dance with music (which served as warm-up workout of 10 minutes), motor skills instructions (25 minutes) and culturally appropriate games (10 minutes). Over time, all the tasks were adapted to participants' progress in a systematic manner. A progressive adaptation was achieved through the use of available materials such as sandbags with specified weight, filled water bottles, exercise balls, hula hoops, and portable wooden stairs. All training sessions were supervised by qualified physiotherapists and occurred on the school's soccer field.

2.3 Mediators and moderators of physical activity

Most researchers agree that a better understanding of the factors associated with movement and PA (correlates) and elements that demonstrate a strong causal relationship with activity (determinants) is needed to inform the selection of outcomes for interventions [183,184]. Bauman *et al.* [184] argued that programmes that target modifiable correlates of PA may elicit significant changes in motor behaviour. Past research examined the correlates of PA in children and adolescents [183-185]. Sallis *et al.* [183] identified demographic, biological and psychological correlates of PA. Among adolescents, demographic and biological correlates that were found to have a strong influence on PA included age (inverse relationship), gender (males had higher levels of activity than females), ethnicity, previous PA, sensation seeking and participation in community sports [183].

Caucasians were consistently found to be more active than other ethnic populations [183]. Psychological variables reported as potential correlates of PA were depression, perceived competence, achievement orientation and intention to be active [179]. In addition to the above correlates, self-efficacy was identified both as a correlate and as a determinant of PA in adolescents [184]. Motivation and enjoyment have also been shown to positively associate with PA, especially in girls [186]. Other factors including genetics [187], low socio-economic status, the incidence of crime [188], access to facilities, proximity to recreational centres and family and social support have all been documented [184]. In a recent systematic review [188], the authors observed that gender, age, ethnicity, family income, parental education, perceived competence, self-efficacy, access to recreational/sports facilities and time spent outdoors were associated with PA in children and youth, confirming previous reports [189].

In South Africa, a low socio-economic status and poor environmental conditions including overcrowding and increased crime rate have been linked to physical inactivity and obesity [190,191]. In a recent qualitative study [192] investigating the barriers and facilitators of PA in rural South African adolescent girls, focus group discussions were held with girls and sports teachers and community leaders were interviewed. Adolescent girls aged 13-19 (n=51) and seven youth leaders participated in this study. The researchers identified seven major themes that interacted to influence PA participation among female adolescents in low-income settings of South Africa. These were poverty, body image ideals, demographic factors, perceived health effects of physical activity, human and infrastructural resources, parents and home life as well as gender [192]. Based on these findings, the researchers developed a model detailing practical steps that can be taken to improve physical activity in adolescent girls. Also, they recommended among other things the development of girls only interventions that are fun and attractive to encourage girls to be PA [192]. There appears to be a consensus among researchers about the need for interventions to target important correlates

of PA. However, most intervention studies have paid little attention to these correlates. Few studies have targeted these factors as outcomes of interventions.

Stodden and colleagues [123] developed a developmental model to explain the reciprocal relationship between motor competence and PA. In their model, four correlates (motor competence, perceived motor competence, health-related physical fitness and physical activity) were identified. It was hypothesised that these components interact to influence the risk of obesity [123]. Stodden *et al*'s [123] model predicts that the overall effect of the dynamic relationship between these factors would promote either healthy or unhealthy weight status over time. This implies that while a synergistic negative trajectory would produce overweight or obesity, a positive interaction might lead to a healthy weight status [123]. Clearly, the idea expressed in this model highlights the importance of motor competence, physical fitness and psychological well-being in the fight against physical inactivity and obesity. Physical fitness and psychological variables play an important moderating role in the relationship between motor competence and PA [193]. Hence, considerable attention needs to be given to these factors when planning and designing programmes. Welk [194] classified various determinants of PA into three categories including predisposing, reinforcing and enabling factors [194]. Predisposing factors increase the likelihood that a person will participate in regular PA. Examples of predisposing factors are self-efficacy, perceived competence, attitudes and beliefs [194]. Reinforcing factors include such variables as family and peer influences that reinforce a person's physical activity behaviour. Enabling factors are those variables that allow the youth to be physically active. Enabling factors include biological and environmental factors such as physical skills, fitness, body fat, and weather, access to programmes and facilities and safety [194]. Since several studies affirmed that motor skill competence, physical fitness and self-efficacy are influential correlates of PA, they were selected as outcomes for the current study. These factors have been further discussed below.

2.3.1 Motor competence

Motor competence has a positive impact on growth and development [195]. Various terminologies have been used to describe motor competence including motor coordination, motor proficiency, motor development, motor performance, motor skills, fundamental movement skills and motor ability [196]. In an attempt to understand how these terms are conceptualised by researchers, Logan *et al.* [196] conducted a systematic review of 124 studies published between 2000 and 2015. They observed that the expression 'fundamental movement skill' was frequently used to describe motor competence. They advocated for the need to promote the use of an operational definition for fundamental movement skills that satisfies the following three criteria: (1) the inclusion of a "building blocks" statement (2) the identification of sub-categories and (3) the inclusion of specific examples. According to the authors, motor competence can be viewed as a holistic terminology that encompasses multiple terms in the motor domain [196].

Valkova [197] defined motor competence as the minimum level of fitness, skills or motor abilities required to achieve a given movement goal such as walking, running or hitting a tennis ball. Haga *et al.* [195] explained that motor competence is an individual's ability to execute different acts, including the coordination of both fine (manual dexterity) and gross motor tasks (locomotion, static and dynamic balance). According to Stodden *et al.* [198], motor competence is the ability to control movement and to demonstrate proficiency in fundamental movement skills. Fundamental movement skills can be conceptualised as the building blocks of more advanced complex movements required for successful participation in physical activity, sports or broader life situations, and include locomotor skills, object control and balance or stability skills [196,199]. Locomotor skills involve the skills required to successfully move the body from one point to another [200]. Examples of such skills include walking, running, jumping and hopping. Object control skills are those actions used to manipulate or project objects through space and include throwing and catching [200]. Lastly, stability skills help an individual to maintain equilibrium during stationary or moving contexts [200]. Common

examples are one-leg stands, standing on a beam and walking on a horizontal rod. In the current study, motor competence was used to describe various forms of goal-directed actions involving the control and coordination of human movement.

Movement skill assessment can be done in various settings and for several purposes. Assessments can be performed in research environments using different instruments, depending upon the purpose of the test [177]. In research settings, testing is usually done to establish baseline performance, and to monitor progress. In addition, motor skill assessments help researchers to describe, understand and explain how the process and product of movement change over time [177,201]. Assessments done in the clinic may have somewhat a different rationale and are almost exclusively performed for diagnostic purposes, seeking to explain the cause of a clinical problem or alternatively for monitoring the effectiveness of therapeutic interventions [177]. Assessment tools may differ in several ways including the type of outcome, skills measured, target population, ease of administration and scoring procedures [201].

Typically, motor competence measurements are divided into process or product-oriented assessments [201]. Process-oriented assessments tend to evaluate how the movement is performed (the techniques of the movement) and describe the qualitative features of the movement patterns [201]. Examples of process-oriented protocols are the Test of Gross Motor Development, 2nd edition [202], and developmental sequences [201,203]. Process-oriented assessments measure movement patterns or components of a skill in accordance with defined performance criteria. Conversely, product-oriented assessments quantify the outcome of movements and are normally recorded as a quantitative score [201] such as speed, distance, number of successful hits, and time taken to complete a task. Examples of commonly used product-oriented assessments include the Movement Assessment Battery for Children, 2nd edition [204], Bruininks-Oseretsky Test of Motor Performance, 2nd edition (BOT-2) [205], KörperKoordinationsTest für Kinder (KTK) [206] and McCarron Assessment of Neuromuscular Development

[207]. These tests have been widely used by various professionals to assess motor development in children and adolescents.

2.3.2 Physical fitness

Physical fitness is a multi-dimensional construct that relates to the capacity for movement [208,209]. Physical fitness is often defined as a set of attributes that people have or achieve that relates to the ability to perform PA [208,210]. As observed by Corbin *et al.* [211], physical fitness can be classified into health-related and skill-related components. A third component that is widely described in the literature is physiological fitness [212-214]. Health-related fitness refers to those components of fitness that are associated with good health and represent capacities that lower an individual's risk of developing lifestyle diseases [208-211]. Examples of health-related physical fitness are body composition, cardiorespiratory fitness, flexibility, muscular strength and endurance [208].

Skill-related physical fitness encompasses those facets of physical fitness that are necessary for optimal work and sports performance [208]. Skill-related components of physical fitness consist of agility, balance, coordination, power, speed and reaction time [208]. Physiological fitness is defined as relating to biological systems that are influenced by regular PA [211]. Sub-components of physiological fitness are metabolic fitness, morphological fitness and bone integrity [211]. The various components for physical fitness can be measured by a variety of laboratory-based and field-based tests. While laboratory-based measures are considered to provide accurate assessments, field-based tests have been found to be more suitable for epidemiological studies. Table 2.4 summarises frequently used measures of physical fitness.

Table 2.4: Summary of commonly used Physical Fitness Tests

Physical Fitness Components	Laboratory-based measurements	Field-based measurements
Health-related components		
Cardiovascular fitness	Graded Exercise Tests, Submaximal cycle ergometer tests [208-211]	Distance runs (1 mile, 1.5 miles), Walk tests e.g. six-minute walk tests, 20m shuttle run, Step tests [208-211]
Body composition	Bioelectric Impedance, under water weighing, Deuterium oxide dilution, potassium counting [208-211]	Skinfold thickness, Height/weight and BMI, circumference and waist-to-hip ratio [59,211].
Flexibility	Leighton flexometer, Goniometry, Angular kinematic analysis [208-211]	Sit-and-reach test, modified sit-and-reach tests, Back-saver sit and reach test, V sit and reach, Shoulder stretch [208-211].
Muscular strength	Cable tensiometer, Isometric dynamometer, Isokinetic dynamometer, Isotonic one repetition maximum [208-211].	Hand dynamometre Functional strength measurement Pull-ups, modified pull-ups, Sit-ups, Curl-ups, Standing broad jump, Squat jump, Countermovement jump [211].
Muscular endurance	Repetitions or time to fatigue at set percentage of maximum force [208-211]	Pull-ups, Modified pull-ups, Sit-ups, Curl-ups, Parallel bar dips [208-211].
Skill-related components		
Agility	Running Kinematics [208-211]	Shuttle run (10×5m), Shuttle run with sponges (10×4m), 10×5 slalom sprint tests, 10×5 straight tests, Illinois agility test, T-test, 505 test, modified 505 test, L-run test [208-211].

Balance	Force platforms [208-211]	Flamingo balance, Y-balance test, One-leg balance, balances on a beam or tilt board.
Coordination	Force platforms [208-211]	Movement Assessment Battery for Children, second edition (MABC-2). Bruininks-Oseretsky Test of Motor Performance, second edition (BOT-2). Körperkoordinationstest für Kinder (KTK) [204-206]
Power	Want [208-211]	Vertical jumping test, Muscle Power Sprint test (MPST) [208-211].
Speed	Movement tracking systems [208-211]	100m dash, 50m dash [208-211].
Reaction Time	Motion tracking systems [208-211]	Reaction time tests [208-211].

2.3.3 Self-efficacy

Interest in the relationship between psychological factors and PA has increased over the last few years. Psychological variables such as perceived competence and self-efficacy are believed to play important roles in the development of active lifestyles [123,194,215]. While perceived competence refers to an individual's perception of mastery of skills [216], self-efficacy is conceptually defined as people's self-assessment of their capabilities to successfully perform specific tasks (behaviours) and overcome challenges that might hinder participation in those behaviours [216,217]. Self-efficacy is believed to be a situationally specific attribute that influences people's choices in relation to the activities that they perform and the amount of energy they expend on those activities [218]. The concept of self-efficacy is viewed as consisting of two components, namely task efficacy and barrier efficacy [218-221].

From a psychological perspective, learning of new skills and the motivation for learning are directly and indirectly influenced by self-efficacy [221]. In addition, self-efficacy contributes to the adoption of both healthy and unhealthy behaviours [222]. For example, people who believe in their abilities to perform physical exercises are more likely to engage in regular physical activity than those with a low sense of self-efficacy [217]. Four sources of information that influence self-efficacy have been identified namely enactive mastery experience, vicarious modelling, verbal persuasion and physiologic and affective cues experienced during activity such as pain and anxiety [217,219]. Enactive mastery experience is the idea that individuals can increase their self-efficacy through regular practice of tasks. When people practice specific tasks repeatedly, they gain more experience, which tends to increase their confidence in the performance of the given task [217,219]. Vicarious modelling is the notion that people can become self-efficacious by observing others accomplish tasks they would like to perform. Verbal persuasion simply implies one's self-efficacy can be affected by the information that he/she receives from other people. This means that feedback from other people such as teachers, parents, and peers can have a positive impact on one's self-efficacy in a given situation [217,219]. Finally, physiological states such as anxiety, depression and fear could impact one's feelings of confidence and affect his/her self-efficacy [217,219,221]. Enactive mastery is the most important means to increase self-efficacy [222]. This means that providing practice opportunities might help individuals with low self-efficacy to improve their self-efficacy.

Studies have consistently shown that self-efficacy is a strong predictor of PA in adolescents [194,223]. McAuley and Blissmer [224] expanded on this idea and proposed that self-efficacy should be considered both as a determinant and a consequence of regular PA. The researchers explained that there is a reciprocal relationship between self-efficacy and PA. Individuals with high levels of self-efficacy tend to engage in regular PA [224]. On the other hand, people with reduced confidence in their abilities may withdraw from PA and sports, which in

turn will diminish their self-efficacy [224]. In addition, self-efficacy has been reported to be negatively correlated with depression and affective disorders in adolescents [225,226]. Since affective disorders tend to have their onset during adolescence [227], designing programmes to influence self-efficacy may be necessary to prevent or reduce depressive symptoms.

2.4 Relationship between motor competence, physical fitness, self-efficacy and physical activity

As previously indicated, Stodden and colleagues [123] proposed that there is a synergistic and reciprocal relationship between motor competence and PA and that these relationships will become stronger over time. The authors also noted that the relationship between motor competence and PA are mediated by perceived competence and health-related physical fitness. Since the publication of this model, several studies have been conducted to explore the relationships of motor competence, physical fitness, perceived competence and PA. The next section will clarify the relationship between motor competence and these health outcomes in young people.

2.4.1 Motor competence and physical fitness

From a physiological viewpoint, motor competence and physical fitness are inherently related as the neuromuscular system seems to regulate various aspects of both constructs [123,228]. Stodden *et al.* [123] investigated the associations between motor competence and health-related fitness in youth using hierarchical regression modelling. A convenience sample of 456 boys and girls aged 4-13 years participated in this study. Product-oriented assessments (i.e. throwing and kicking speed and standing long jump distance) were used to measure motor competence and the FITNESSGRAM protocol was implemented to assess health-related fitness. Throwing and jumping performance was found to be significantly associated with the composite score of health-related fitness in both boys and girls. While associations between throwing and kicking speed and health-related physical fitness increased from early to late childhood, relationships between jumping and health-related fitness varied across age groups. The authors

concluded that the relationship between motor competence and health-related physical fitness are not fixed and may change over developmental time. It was also suggested that proficiency in object control skills (ball skills) may be important for increasing and maintaining physical fitness from childhood through adolescence.

Cattuzzo *et al.* [229] performed a systematic review that included 44 studies to examine the associations between motor competence and health-related physical fitness in children and adolescents. The researchers noted a positive relationship between motor competence and cardiorespiratory fitness ($r=0.32-0.57$), and muscular strength/endurance ($r=0.27-0.68$) in children and adolescents. However, evidence on the association between motor competence and flexibility was unclear. In addition, a narrative review by Robinson *et al.* [228] provided strong evidence to support the associations of motor competence, cardiorespiratory and musculoskeletal fitness during childhood and adolescence. There are indications that these relationships may show stability into adulthood. Haga *et al.* [230] examined the relationship between motor competence and physical fitness in school-aged Finnish children and reported a positive association between motor competence and physical fitness in children. In another study, Stodden *et al.* [231] demonstrated that product scores for jumping, kicking, and throwing predicted and explained 79% of the variance in overall physical fitness. This data provides support to the reported relationship between motor competence and physical fitness.

Furthermore, few longitudinal studies have also found a strong relationship between motor competence and physical fitness in both children and adolescents [232-235]. Barnett *et al.* [232] showed that object control in childhood was associated with adolescent cardiorespiratory fitness and explained about 26% of the variance in physical fitness. Similarly, Hands [234] followed 19 children with low motor competence and 19 age-matched peers with high motor competence for five years and monitored changes in their motor skills and fitness. Results showed

between-group differences in performance on all measures over time, except body composition. Though evidence exists on the relationship between motor competence and physical fitness, there is still the need for more investigations as current data are mostly cross-sectional in nature. It may also be necessary to examine the relationship between these variables in specified populations.

2.4.2 Motor competence and self-efficacy

Moritz *et al.* [236] conducted a meta-analysis involving 45 studies to clarify the relationship between self-efficacy and sports performance. They reported an average correlation between self-efficacy and sports performance of 0.38 (95% CI: 0.35-0.41). This suggests that an individual's perceptions of efficacy have a positive moderate relationship with sport performance in adolescents. Therefore, self-efficacy may play an important role in facilitating engagement in sports. Cairney *et al.* [237] tested a theoretical model linking DCD and reduced PA through the mediating influence of generalised self-efficacy among elementary school children in Ontario, Canada. Motor competence, self-efficacy and PA were measured using self-reports (Bruininks-Oseretsky Test of Motor Performance-2 Short Form was used for motor competence, the CSAPPA for self-efficacy and the Participation questionnaire for physical activity). The authors found that 28% of the variance in participants' PA was explained by self-efficacy and proposed that interventions should be designed to increase self-efficacy in children with low motor ability. In a similar study, Batey *et al.* [216] assessed the effect of barrier and task-efficacy on PA in children with DCD and typically developing children (n=105). Motor competence was assessed with the MABC-2 test and PA was measured using accelerometers. Task and barrier efficacy was measured using the self-efficacy toward physical activity scale. Results indicated that children with DCD have a lower task and barrier efficacy than their TD peers. In addition, the authors found a direct impact of DCD on physical activity among boys but not girls. Therefore, boys with DCD had a lower physical activity than their TD peers, yet the relationship between DCD and PA was not mediated by any of the two aspects of self-efficacy investigated in this study. Results indicate that children with DCD who

have lower physical activity levels are more likely to have a low sense of self-efficacy than typically developing children. Findings underscore the need to further investigate the mechanism behind motor competence, self-efficacy and PA to inform the development of effective treatments.

Numerous studies have examined the association between motor competence and various aspects of physical self-concept. The relationship between perceived competence and motor competence has been well-documented [238-247]. It is known that a positive association exists between motor competence with perceived competence in children [238,239]. While several studies reported moderate associations between perceived and actual motor competence [238,247], one study found no significant relationship between motor competence and perceived motor competence [244]. The reason for the moderate associations could be due to the subjective nature of the instruments used to assess these constructs. In addition, due to measurement differences, it may be impossible to make comparisons across various studies.

Research studies have compared the levels of perceived and actual competence in normal weight and overweight children. Jones *et al.* [242] demonstrated that overweight children have a lower perceived and actual competence than non-overweight children. These findings were confirmed in another study conducted among Italian children. In this study, it was found that girls had decreased perceived and actual competence compared to boys. There are suggestions that perceived competence can be considered as a mediator between competence and PA. Barnett *et al.* [243], found that perceived competence mediates the relationship between motor competence in childhood and adolescent PA and fitness. Specifically, Barnett and colleagues [243] showed that perceived competence mediated object control proficiency and subjectively measured PA. This suggests that improving perceived competence may contribute to reducing physical inactivity in children and adolescents.

2.4.3 Motor competence and physical activity

Motor competence has been reported to be positively associated with PA but inversely related with sedentary habits [123,248]. Children with greater motor competence demonstrate higher levels of PA and lower levels of sedentariness compared with those with poor motor proficiency [248]. In a recent systematic review on the relationship of fundamental movement skills and PA, Holfelder and Schott [249] reviewed 23 studies involving children aged 3-18 years. The researchers concluded that fundamental movement skills have a significant positive relationship with PA. This suggests that focusing on fundamental movement skills could be a viable means of reducing physical inactivity in young people.

Another study examined the associations of BMI, motor performance, perceived athletic competence and PA among Canadian children [56]. The researchers found that among boys PA was significantly associated with motor performance, perceived athletic performance and socio-economic status but not with BMI. Furthermore, it was found that PA correlated significantly with motor performance, perceived athletic competence, socio-economic status and BMI among girls. Additionally, findings of a linear regression analysis showed that perceived athletic competence was the most significant predictor of PA participation in both boys and girls. Specifically, perceived athletic competence independently explained 17% of the variance in PA in boys whereas motor performance, BMI and socio-economic status accounted for 0.6%, 0.7% and 0.5% respectively. Among girls, 17.5% of the variance in PA was explained by perceived athletic competence while motor performance contributed only 0.8%. BMI and socio-economic status were non-significant correlates of PA in this population. The authors emphasized that perceived competence should be given considerable attention when designing PA interventions [56].

Lubans *et al.* [250] reported a strong relationship between fundamental movement skills and PA in children and adolescents when they conducted a systematic

review to examine the relationship between motor competence and potential health benefits. These studies have shown that motor competence development may contribute immensely to health and general wellbeing. Therefore, promoting motor development across critical periods of development is an important priority [251].

2.5 Overview of knowledge gaps in the current literature

This review has summarised evidence on interventions for children with DCD, overweight and obesity. However, several issues warrant further investigations. This section attempts to highlight some of the major gaps in the current literature. Below is a summary of what the researcher considers to be the most significant knowledge gaps.

2.5.1 Limited intervention studies in low and middle-income countries

An important gap is that existing studies have not adequately addressed issues of health disparities regarding intervention development. Intervention studies targeting specified populations (e.g. female adolescent girls) living in socioeconomically disadvantaged communities are sparse. To maximize public health impact in addressing motor problems and obesity, research efforts need to be directed towards populations in deprived areas of the world, particularly those in low and middle-income nations. More importantly, interventions should be tested among adolescent girls who have been repeatedly identified as being vulnerable.

2.5.2 Limited number of well-designed studies

The review showed that previous intervention studies had numerous methodological challenges. These included underpowered studies, small sample sizes, lack of randomisation and the use of observational designs. Poor methodological quality might explain the small effect sizes associated with most

studies. It is therefore necessary to design studies with strong designs such as randomised controlled trials for future research.

2.5.3 Lack of intervention studies among adolescents with DCD

Although it is widely acknowledged that the symptoms of DCD persist throughout adolescence and adulthood, currently no published studies could be found that has focused on adolescents with DCD. In addition, studies assessing the impact of interventions on activity and participation outcomes are rare. Available studies have largely targeted impairment-related outcomes. Determining the effectiveness of interventions on impairments, activity and participation outcomes among adolescent populations with DCD would make a significant contribution to the extant literature.

2.5.4 Limited focus on motor skills and physical fitness as intervention targets in adolescents

Previous studies that have evaluated motor programmes in adolescents have focused less on important health markers such as motor competence, physical fitness and self-efficacy. Given that physical and psychological changes that occur during adolescence, it may be important to equip adolescents with the physical skills and psychological resources required to deal with the challenges that they encounter at this critical stage of life. Therefore, it may be useful to target these key mediators of PA when planning and testing interventions.

2.5.5 Lack of comparative effectiveness research

Technology has now become pervasive in every society. Today, children and adolescents spend much time interacting with different forms of technology including television, computer games, mobile phones and video games. There is evidence supporting the use of AVGs to increase energy expenditure and light to moderate PA. However, no study has compared intervention effects of AVGs and traditional motor interventions in adolescents.

2.6.6 Limited evidence on the pattern of change in fitness performance after training

The current body of knowledge supports the use of multi-component interventions. However, it is unclear whether training-induced changes would differ among children with varying weight status. Therefore, investigating the pattern of change following training might produce data to shape current exercise prescription guidelines or physical education practices.

2.6 Conclusion

This chapter has discussed the epidemiology of DCD, overweight and obesity in children and adolescents. Information on current intervention options and key characteristics of effective interventions have been highlighted. In addition, important mediators of PA such as motor competence, physical fitness and self-efficacy and the relationship between these factors have been provided. The review has demonstrated that estimates of DCD, overweight and obesity are still high in children and adolescents. Also, because effects of interventions have not been determined among adolescents with DCD, there is an unmet demand for physiotherapists to contribute their expertise to this area. Furthermore, the review provided comprehensive information on available programmes for promoting PA and treating overweight and obesity. However, it was evidently clear that effect sizes have largely been small. Therefore, there is the need for more research to be conducted among adolescents with motor coordination and weight problems, particularly those living in resource-limited communities.

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PART II: Empirical Research Papers

CHAPTER 3: Relationship between body mass index, cardiorespiratory and musculoskeletal fitness among South African adolescent girls

Abstract

Background: Cardiorespiratory and musculoskeletal fitness are important health indicators that support optimal physical functioning. Understanding the relationship between body mass index and these health markers may contribute to the development of evidence-based interventions to address obesity-related complications. The relationship between body mass index, cardiorespiratory and musculoskeletal fitness has not been well explored, particularly in female adolescents. The aim of this study was to investigate the association between body mass index, cardiorespiratory and musculoskeletal fitness among South African adolescent girls in low-income communities.

Methods: This cross-sectional study included 151 adolescent girls, aged 13–16 years. Cardiorespiratory fitness was measured using the 20m shuttle run test and musculoskeletal fitness was assessed with a variety of field-based tests. Height and weight were measured with standardised procedures and body mass index (BMI) was derived by the formula $[BMI = \text{weight (kg)}/\text{height (m)}^2]$. Participants were categorised into three BMI groups using the International Obesity Task Force age-and-gender-specific cut-off points. Pearson correlations were used to determine associations between BMI, cardiorespiratory fitness and measures of musculoskeletal fitness at $p \leq 0.05$.

Results: Overweight and obese girls were found to have lower cardiorespiratory fitness, decreased lower extremity muscular strength, greater grip strength, and more hypermobile joints compared to normal-weight peers. BMI was negatively associated with cardiorespiratory fitness and lower extremity muscular strength.

Conclusions: The findings indicate that increased body mass correlates with decreased cardiorespiratory and musculoskeletal fitness. Interventions should be developed to target these important components of physical fitness in this demographic group.

3.1 Introduction

Childhood obesity is a global health priority [1,2]. Growing evidence indicates that childhood obesity rates seem to be reaching a plateau in high-income societies. However, estimates in low- and middle-income countries (LMIC) have increased rapidly over the past few years [3,4]. Research shows that about 8%–13% of boys and girls in low-income communities are overweight or obese [3]. The prevalence of overweight and obesity combined among South African children is slightly above 15% [5]. Within the South African context, girls have a higher prevalence of overweight and obesity than boys [5–9]. These statistics are worrying as they pose serious threats to the country's health care system [4]. Obesity is associated with health complications including hypertension, type 2 diabetes and orthopaedic problems [10–12]. Further, obesity is known to impair physical fitness and academic performance [13–15].

Several factors have been postulated to explain how obesity promotes decreased physical fitness. First, obese children have low levels of physical activity compared to non-obese peers [16]. Consequently, they have less opportunity to develop motor skills which causes further participation restrictions and muscle deconditioning [17–19]. Compared to non-obese peers, obese children tend to avoid weight-bearing tasks (e.g. walking and running) due to the high energy cost associated with such activities. This leads to poor musculoskeletal and cardiorespiratory fitness [20]. Secondly, it has been suggested that obesity-related fitness impairments are caused by neuromuscular dysfunction resulting from metabolic imbalance [21].

The association between obesity and academic performance is purported to be influenced by factors such as poor peer-relationships, low-self-esteem, and reduced cognitive abilities [13]. Though, obesity is known to negatively impact physical performance, the nature of the relationship between body mass index (BMI) and aspects of physical fitness is less clear, particularly among female adolescents from low socio-economic backgrounds. Given the current interest in

adolescent health [22] and the increased prevalence of adolescent obesity in LMIC [3], examining the association between BMI, cardiorespiratory and musculoskeletal fitness (MSF) may provide opportunities to identify effective interventions to reduce obesity-related complications.

Several studies have documented an inverse relationship between BMI and cardiorespiratory fitness [10,14,23–26]. Higher BMI has also been reported to have a negative influence on MSF [27]. Improved cardiorespiratory and MSF are each associated with better health outcomes [13–15]. Musculoskeletal fitness encompasses those components of physical fitness responsible for successful execution of motor tasks such as walking and running [28], and includes measures such as muscular strength and endurance, flexibility and joint mobility [29]. As previously stated, low levels of MSF are associated with higher BMI in school-aged children [6].

Though these trends are thought to be gender-dependent [30], the majority of existing data are based on pre-adolescent children of both sexes. Evidence of the association between BMI, cardiorespiratory and MSF in female adolescents are limited. Previous studies were conducted among children from high-income countries. It is unclear if findings from such studies can be extrapolated to populations in low-income contexts. As environmental conditions exert much influence on physical performance, it is possible that the association between these factors might differ for populations in different settings. Without better understanding of how BMI relates to cardiorespiratory and MSF, health professionals may be less effective at promoting physical health in adolescent populations.

Examining the relationship between BMI, cardiorespiratory and MSF in female adolescents would extend the current body of knowledge. Therefore, the purpose of this study was to determine the association between BMI, cardiorespiratory and MSF among female adolescents attending school in a low-income community of

Cape Town, South Africa. It was hypothesised that participants with higher BMI would have decreased cardiorespiratory and MSF than normal-weight peers.

3.2 Methods

3.2.1. Study design and setting

This cross-sectional study analysed baseline data of a larger school-based intervention study designed to improve motor competence and physical fitness among South African adolescent girls. The sample comprised of female adolescents attending a quintile three high school in a low-income area of Cape Town. In South Africa, schools are classified into five categories called quintiles (Q1–Q5), based on their poverty score or quintile rank [9]. The quintile rank of a school is determined on the basis of the poverty level of the community in which it is located [9]. Schools in lower quintiles (Q1–Q3) are the poorest compared to higher quintile schools (Q4 and Q5). Because of this, children in lower quintile schools do not pay school fees as they receive financial support from the government. The school in which the present study was conducted was purposively selected as it is located in the largest township community in Cape Town and has a relatively large number of students. Secondly, it is a beneficiary of the University of Cape Town's (UCT) Schools Improvement Initiative (SII). The SII is one of the numerous social responsive programmes that draw on the university community's resources to improve learning experiences of children living in low-income settings. Parents and children provided written informed consent before participation. Ethical approval for this study was granted by the Human Research and Ethics Committee of the University of Cape Town (ref# 232/2016). Permission was sought from the Western Cape Education Directorate and senior management of the school.

3.2.2. Participants

One hundred and fifty-one (n=151) female students (aged 13–16 years) participated in this study. Participants were recruited using convenience sampling techniques. Participation was entirely voluntary, and participants were free to withdraw at any time. All the female students in grades 8–10 were invited to

participate. Participants with any physical disability (e.g. fractures) that hindered their participation in the testing procedures were not included. In addition, girls whose parents reported cardiovascular and neuromuscular complications were excluded. Participants were isiXhosa speaking (isiXhosa is one of the native languages of South Africa) South African adolescent girls and could communicate effectively in English. The fact that participants attended a quintile three school confirmed they had lower socio-economic backgrounds. Assessments were carried out within the school environment and occurred during regular physical education hours. All assessments were performed by trained research assistants (physiotherapists and physiotherapy students) with experience working with children and adolescents.

3.2.3. Measures

3.2.3.1. Anthropometric measures

Height and weight were measured, and BMI was calculated using the formula [BMI = weight (kg)/height (m)²]. Height was measured to the nearest 0.1cm with a wall mounted tape measure while weight was measured to the nearest 0.1 kg using an electronic scale. BMI scores were categorised into normal-weight, overweight and obese groups using the BMI definitions proposed by the International Obesity Task Force [31]. Demographic data including age and grade were collected by a self-administered questionnaire.

3.2.3.2. Cardiorespiratory fitness

The 20-metre shuttle run test [32] was used to measure cardiorespiratory fitness. The 20-metre shuttle run test was performed in accordance with standardised procedures [32]. Participants ran from one cone to another, which was 20 metres apart, while keeping pace with a pre-recorded beep [33]. The beep increased after every minute and participants were told to keep up with the beep for as long as possible [33]. When a participant failed to reach the appropriate cone within the stipulated time on two consecutive occasions or could no longer maintain the pace, the test was stopped. The number of shuttles (level) was recorded and used in the analysis.

3.2.3.3. Muscular strength

3.2.3.3.1 Upper and lower extremity isometric strength

This was assessed with a handheld dynamometer (the MicroFET2, Hogan Health Industries Inc., USA) using the break test [34]. The elbow flexors and extensors, knee extensors, ankle plantarflexors and dorsiflexors were assessed. Participants were tested in supine (for the muscles of the elbow and ankle) and in seated position (for the knee extensors). Testing was conducted in accordance with published protocol [34]. The handheld dynamometer is viewed as a valid and reliable measure of isometric muscle strength [35,36]. The test-retest reliability [Intraclass Correlation Coefficient (ICC)] for the MicroFet2 dynamometer reliability ranges from 0.73 to 0.91 [37].

3.2.3.3.2 Handgrip strength

Grip strength was measured using the Jamar hydraulic hand dynamometer [38]. The test was performed in accordance with standard procedures [39]. Three trials were conducted for each muscle group and the best score was used in the analysis.

3.2.3.4. Flexibility

The sit-and-reach (SR) test was used to assess flexibility [40]. Participants were tested individually under supervision. Each participant was required to sit with their feet approximately hip-wide apart against a wooden test box, with their knees in extension. In addition, they were asked to place the right hand over their left hand, and slowly reach forward as far as possible by sliding their hands along the measuring ruler. The farthest distance reached was recorded to represent the participant's flexibility. Three trials were conducted, and the best score was reported. The SR is reported to have moderate criterion validity ($r = 0.32-0.67$) in young people [41]. Therefore, it was considered to be a good measure of flexibility in this population.

3.2.3.5. Joint mobility

The Beighton test was used to assess joint hypermobility [42]. The test consists of four passive range of motion (ROM) items (assessed bilaterally) and one active forward flexion task. Briefly, the test involved dorsiflexion of the little finger beyond 90°, hyperextension of the elbow beyond 90°, hyperextension of the knee, apposition of the thumb to the flexor side of the forearm and forward flexion of the trunk with the knees straight, so that the palms of the hand can easily touch the floor [42]. Participants were given a numerical score of 0 to 9, one point being awarded for a positive test [42]. For this test, higher scores represent hypermobile joints. Although the Beighton test has not been formally evaluated for its psychometric properties in this population, it is considered as a valid test of joint mobility in children [42]. Additionally, joint ROM was assessed to the nearest 1-degree with a standard 2-legged 360-degree type Collehon extendable goniometer (01135; Lafayette Instrument Company, Lafayette, IN, USA).

3.2.3.6. Musculoskeletal complaints

Musculoskeletal complaints were assessed using a self-administered questionnaire designed for this study. The questionnaire included two closed ended questions that sought to determine the presence of pain in specific anatomical structures (Question 1. “Do you have pains in your joints?”, Question 2. “Do you have pains in your muscles?”). Participants responded to each of the above questions with either a yes or no. A third question sought to establish the severity of pain (Question 3. How severe is your pain today?). For this question, participants were required to rate their pain intensity (severity) on a 10-point (0 = no pain, 10 = most severe pain) smiley faces sheet adapted from the Faces Pain Scale (FPS-R) [43].

3.2.4. Statistical Analysis

Data analyses were performed using SPSS (version 24.0, SPSS Inc., Chicago, IL, USA). Descriptive statistics including means, standard deviations and percentages were used to summarise descriptive data. Differences in age and anthropometric characteristics were determined using a one-way Analysis of variance (ANOVA).

For comparison, participants were initially categorised into one of three groups (normal-weight, overweight and obese) as defined by the International Obesity Task Force guidelines [31]. Further, an ANOVA was performed to compare the differences in cardiorespiratory fitness, muscular strength, flexibility and joint mobility among the three groups. Bonferroni *post-hoc* pairwise comparisons were used to extrapolate statistically significant differences. In addition, Chi-square (χ^2) analysis was completed to compare if there were any differences in musculoskeletal complaints and three sub-items of the Beighton test among the groups. Lastly, Pearson product-moment correlation coefficients were computed to examine the relationships between cardiorespiratory fitness, muscular strength, joint mobility, flexibility and BMI variables. The level of significance was established at $p \leq 0.05$.

3.3 Results

3.3.1 Participants' characteristics

Table 3.1 displays means \pm standard deviations (SD) of participants' characteristics. Female adolescents ($n = 151$) were classified as normal-weight ($n = 78$), overweight ($n = 51$) and obese ($n = 22$). The average age and BMI were (14.3 ± 0.9) years and (24.3 ± 5.5) kg/m^2 , respectively.

Table 3.1: Demographic and anthropometric characteristics of participants.

Variables	Groups			ANOVA (<i>F</i>)	<i>p</i> -value
	Normal-weight ($n = 78$)	Overweight ($n = 51$)	Obese ($n = 22$)		
Age (years)	14.3 ± 0.9	14.4 ± 0.9	14.2 ± 0.9	0.455	0.636
Height (cm)	158.2 ± 6.8	157.9 ± 6.3	157.8 ± 6.1	0.050	0.951
Weight (kg)	51.1 ± 6.6	$64.9 \pm 5.7^*$	$85.8 \pm 14.1^{* \#}$	177.203	0.001
BMI (kg/m^2)	20.4 ± 2.0	$26.0 \pm 1.5^*$	$34.4 \pm 5.1^{* \#}$	277.057	0.001

Note: Data are presented as (Means \pm SD); BMI-Body Mass Index. $*p < 0.05$, Normal vs overweight, $+p < 0.05$, Obese vs. normal, $\#p < 0.05$, Overweight vs. obese (One-way ANOVA; Bonferroni *Post-hoc* test).

3.3.2 The differences between cardiorespiratory fitness and measures of musculoskeletal fitness among the BMI Groups

Normal-weight girls demonstrated greater cardiorespiratory fitness compared to overweight and obese girls. There was no significant difference between normal-weight and overweight girls in terms of cardiorespiratory fitness. However, normal-weight girls performed significantly better than obese girls on the 20-metre shuttle run test. The same trend was evident between overweight and obese girls (Table 3.2).

For all the measures of MSF except elbow flexion strength, a significant difference was found among the three groups (Table 3.2). A *post-hoc* analysis conducted using the Bonferroni test revealed statistically significant differences among the groups in all cases, with the exception of strength of the knee extensors, where significant differences were only seen between normal-weight and overweight girls. In general, normal-weight girls had stronger knee extensors than overweight girls. Again, normal-weight girls showed greater ankle plantarflexion and dorsiflexion strength in comparison with overweight and obese girls. Both obese and overweight girls had stronger elbow extensors compared to their normal-weight peers. With regards to grip strength, overweight and obese girls outperformed normal-weight girls, and obese girls demonstrated stronger grip strength than overweight girls. With regards to flexibility, we observed significant differences between normal-weight and overweight girls, and also between obese and normal-weight girls (Table 3.2). With regards to joint mobility, overweight girls demonstrated an increased ROM than their normal-weight counterparts (Table 3.3). The Chi-square analysis of self-reported musculoskeletal complaints and pain did not yield any significant differences among the groups (Table 3.4).

3.3.3 The relationship between body mass index, cardiorespiratory and musculoskeletal fitness among participants

A positive relationship was observed between BMI and mean grip strength ($r=0.410$, $p < 0.01$). Further, a positive relationship was observed between BMI and Beighton total score ($r=0.215$, $p < 0.001$), and mean elbow extensor strength ($r = 0.323$, $p < 0.01$).

A significant negative relationship was found between BMI and mean knee extensor strength ($r=-0.224$, $p < 0.01$), mean ankle plantarflexor strength ($r=-0.362$, $p < 0.01$) and mean ankle dorsiflexor strength ($r=-0.312$, $p < 0.01$). Finally, there was a negative correlation between BMI and cardiorespiratory fitness ($r=-0.336$, $p < 0.01$) (Table 3.5).

Table 3.2: Comparison of cardiorespiratory and musculoskeletal fitness among groups.

Variables	Groups			ANOVA (F)	p-value
	Normal-Weight (n = 78)	Overweight (n = 51)	Obese (n = 22)		
Cardiorespiratory fitness					
20m shuttle run test (level)	2.6 ± 1.3	2.2 ± 1.1	1.4 ± 0.6 ^{+#}	9.878	0.001
Muscular strength					
Knee extension (Right leg) (N)	187.2 ± 68.9	159.3 ± 24.9 [*]	159.3 ± 27.9	5.275	0.006
Knee extension (Left leg) (N)	176.6 ± 63.4	154.5 ± 26.2 [*]	158.2 ± 29.5	3.437	0.035
Ankle plantarflexion (Right leg) (N)	160.5 ± 79.7	108.4 ± 28.0 [*]	108.7 ± 22.5 [#]	14.019	0.001
Ankle plantarflexion (Left leg) (N)	162.0 ± 81.5	109.1 ± 22.4 [*]	113.8 ± 23.2 [#]	13.549	0.001
Ankle dorsiflexion (Right leg) (N)	167.5 ± 70.9	127.5 ± 20.9 [*]	127.4 ± 20.5 [#]	10.677	0.001
Ankle dorsiflexion (Left leg) (N)	162.3 ± 69.6	125.5 ± 21.4 [*]	124.9 ± 23.1 [#]	9.365	0.001
Elbow flexion (Right arm) (N)	138.4 ± 27.2	128.8 ± 16.0	128.6 ± 20.5	3.307	0.039
Elbow flexion (Left arm) (N)	138.4 ± 26.7	138.9 ± 21.1	138.6 ± 21.3	0.007	0.993
Elbow extension (Right arm) (N)	91.1 ± 17.5	97.8 ± 23.9	109.4 ± 29.8 [#]	6.273	0.002
Elbow extension (Left arm) (N)	90.0 ± 19.4	99.4 ± 16.7 [*]	111.7 ± 30.7 [#]	10.341	0.001
Grip strength (Right arm) (N)	20.7 ± 3.7	24.5 ± 4.3 [*]	24.8 ± 5.0 [#]	17.317	0.001
Grip strength (Left arm) (N)	20.7 ± 4.1	23.8 ± 4.6 [*]	25.0 ± 4.9 [#]	12.143	0.001
Flexibility					
Sit-and-reach test (cm)	6.3 ± 5.9	10.5 ± 6.2 [*]	12.1 ± 6.5 ⁺	11.849	0.001

Note: Data are presented as (Means ± SD); N-Newton. ^{*}p<0.05, Normal vs overweight, ⁺p<0.05, Obese vs. normal, [#]p<0.05, Overweight vs. obese (One-way ANOVA; Bonferroni *post-hoc* test).

Table 3.3: Comparison of joint mobility among normal-weight, overweight and obese girls.

Variables	Groups		
	Normal-Weight (<i>n</i> = 78)	Overweight (<i>n</i> = 51)	Obese (<i>n</i> = 22)
Dorsiflexion of the fifth metacarpophalangeal joint (Right arm) (degrees)	77.7 ± 15.9	81.8 ± 16.9	77.5 ± 17.2
Dorsiflexion of the fifth metacarpophalangeal joint (Left arm) (degrees)	80.9 ± 15.8	86.6 ± 15.2	83.6 ± 15.7
Hyperextension of the elbow (Right arm) (degrees)	8.1 ± 6.8	11.2 ± 6.3 *	8.8 ± 5.7
Hyperextension of the elbow (Left arm) (degrees)	8.3 ± 6.8	11.7 ± 6.6 *	9.8 ± 7.8
Hyperextension of the knee (Right leg) (degrees)	7.5 ± 7.4	6.0 ± 4.9	9.2 ± 6.6
Hyperextension of the knee (Left leg) (degrees)	6.9 ± 5.3	8.1 ± 6.1	11.4 ± 12.9 #
Apposition of the thumb to the flexor side of the forearm (Right arm)			
Yes	28 (35.9)	27 (40.3)	12 (54.5)
No	50 (64.1)	24 (47.1)	10 (45.5)
Apposition of the thumb to the flexor side of the forearm (Left arm)			
Yes	24 (30.8)	28 (54.9)	13 (59.1)
No	54 (69.2)	22 (43.1)	9 (40.9)
Forward flexion of the trunk with the knee straight and hands on the floor			
Yes	14 (17.9)	13 (25.5)	9 (40.9)
No	64 (82.1)	38 (74.5) *	13 (59.1)
Beighton total score	3.0 ± 2.2	4.2 ± 2.2 *	4.3 ± 2.5

Note: Data are presented as (Means ± SD) or n (%). **p*<0.05, Normal vs overweight, #*p*<0.05, Overweight vs. obese (one-way ANOVA; Bonferroni *post-hoc* test).

Table 3.4: Comparison of musculoskeletal complaints among normal-weight, overweight and obese girls.

Variables	Groups			χ^2 (df = 2)	p-value
	Normal Weight (n = 78)	Overweight (n = 51)	Obese (n = 22)		
Joint pain					
Yes	12 (15.4)	5 (9.8)	5 (18.2)	1.195	0.550
No	66 (84.6)	46 (90.2)	18 (81.8)		
Muscle pain					
Yes	17 (21.8)	7 (13.7)	7 (31.8)	3.242	0.198
No	61 (78.2)	44 (86.3)	15 (68.2)		
Pain severity					
0	55 (70.5)	41 (80.4)	14 (63.6)	9.193	0.514
2	12 (15.4)	2 (3.9)	5 (22.7)		
4	8 (10.3)	6 (11.8)	2 (9.1)		
6	1 (1.3)	2 (3.9)	1 (4.5)		
8	2 (2.6)	0	0		
10	0	0	0		

Note: Data are presented as n (%). Note. n-number of participants, %-percentage.

Table 3.5: Pearson Correlation matrix for body mass index, cardiorespiratory fitness, and measures of musculoskeletal fitness.

Correlations	1	2	3	4	5	6	7	8	9	10
1.BMI (kg/m ²)	-									
2.Beighton total score	0.215 **	-								
3.Sit-and-reach score (cm)	0.310 **	0.241 **	-							
4.Mean elbow flexors strength (N)	-0.090	-0.119	-0.057	-						
5.Mean elbow extensors strength (N)	0.323 **	0.055	0.124	0.374 **	-					
6.Mean knee extensors strength (N)	-0.224 **	-0.278 **	-0.248 **	0.723 **	0.251 **	-				
7.Mean ankle plantarflexors strength (N)	-0.362 **	-0.365 **	-0.274 **	0.613 *	0.219 **	0.825 **	-			
8.Mean ankle dorsiflexors strength (N)	-0.312 **	-0.303 **	-0.258 **	0.697 **	0.232 **	0.856 **	0.872 **	-		
9.Mean Grip strength (N)	0.410 **	0.117	0.236 **	0.030	0.225 **	-0.130	-0.217 **	-0.210 **	-	
10.20 m shuttle run test (level)	-0.336 **	0.062	0.004	0.102	-0.107	0.036	0.059	0.113	-0.051	-

Abbreviations: BMI-Body Mass Index, N-Newton. **Correlation is significant at 0.01 level (2-tailed), *Correlations are significant at 0.05 level (2-tailed).

3.4 Discussion

The objective of this study was to investigate the relationship between BMI, cardiorespiratory and MSF in a cohort of South African female adolescents. In general, we observed that about half of the participants had higher BMI scores (were either overweight or obese). This finding confirms previous reports that identified a high prevalence of overweight and obesity among adolescent girls in South Africa [4–9]. Though the overweight and obesity trends in the present study were comparable to those found in previous studies, our estimates for overweight (33%) and obesity (14%) were slightly higher than those found in adolescent girls in similar circumstances [4–9]. Nonetheless, our figures are still lower than what has been documented in high-income environments [44,45]. Variations in ethnicity, culture and measurement techniques could explain these differences. The relatively high prevalence of overweight and obesity in our sample can be attributed to a rapid accumulation of fat-mass, which accompanies growth and development among adolescent girls [4]. Also, the cultural interpretations ascribed to excess weight (e.g. excess weight is believed to be a sign of affluence, health and beauty) in this setting could be a plausible explanation [46,47].

With regards to cardiorespiratory fitness, we observed that normal-weight girls demonstrated greater performance on the shuttle run test than overweight and obese peers. Lower cardiorespiratory fitness has been shown to be associated with a higher BMI in earlier research [23–26]. Decreased lower extremity muscle strength among overweight and obese girls could contribute to low cardiorespiratory fitness due to the lack of adequate muscle power to sustain prolonged running. Moreover, decreased cardiorespiratory fitness may limit participation in physical activity, and further cause reductions in muscular strength. The low cardiorespiratory fitness demonstrated by overweight and obese girls in the present study could be attributed to physical fatigue and poor perceived physical competence. As the 20-metre shuttle run test requires individuals to carry their body mass through space, we expected this task to be somewhat difficult for both overweight and obese girls.

Concerning MSF, overweight and obese girls showed reduced lower extremity muscle strength and stronger upper limbs as compared to normal-weight peers. Similar results have previously been reported. It is thought that the lack of regular voluntary activation of the lower extremity muscles among children with higher BMI may explain the decreased lower extremity muscle strength [45]. It should be noted that one important factor that might lead to poor performance with running-based aerobic capacity tests is reduced lower extremity strength. This underscores the need to develop an integrated approach towards addressing the multifaceted problems of obesity in this vulnerable group. It may be prudent to promote physical activity by improving lower extremity muscular strength and dynamic control. This could potentially be useful for weight control and might increase lean body mass [48,49].

Furthermore, we observed that the elbow extensors of overweight and obese girls were stronger than those of that of normal-weight girls. This finding agrees with previous data [29]. It is possible that girls with increased BMI might find alternative or compensatory mechanisms to move their bodies without having to exert their lower extremity musculature. For example, they are more likely to use elbow extensors to push themselves out of a chair or to hold onto a rail when climbing a flight of stairs. Therefore, with these alternative movement adaptations, they could achieve movement goals without necessarily engaging the weaker lower extremity muscles. Frequent use of upper extremity muscles in goal-directed tasks and associated gains in strength might be a plausible explanation for the observed trends in upper extremity strength. Also, we found that overweight and obese girls exhibited increased ROM than normal-weight girls. Related to the frequency of musculoskeletal complaints, we observed no differences in the frequency and/or severity of joint and muscle pain among the groups.

Our findings indicate that overweight and obese girls have about 33% and 15% reduction in mean ankle and knee forces respectively, compared to normal-weight

girls. This suggests that overweight and obese girls, who would naturally require more power to transport their body mass from one place to another, might have to do so with less force. As such, their excess load needs to be supported and transported by relatively weaker muscles. Ankle dorsiflexors and knee extensors are the most important force generating muscles required for daily tasks such as walking, stair-climbing and running. But since overweight and obese girls demonstrated decreased strength in these muscles, participating in weight bearing tasks might be problematic. Though excess body mass may stimulate bone growth, greater loads might damage musculoskeletal tissues over time, and increase risks for degenerative joint diseases such as osteoarthritis [50]. Our findings on the low levels of lower extremity muscle strength confirms the results that are reported in previous studies [51,52]. This finding emphasises the need for regular assessments of functional muscle strength. In addition, exercise strategies involving activities that would ensure gradual functional loading may be a useful approach to promoting physical activity in this population.

Though we were unable to confirm the harmful effects of overloading on musculoskeletal structures, we presumed that reduced lower extremity muscle strength and hypermobility may be detrimental to musculoskeletal health among overweight and obese girls. Hypermobile joints, increased flexibility and reduced strength might be correlates of localized motor control dysfunction (around the hip, knee and ankle joints), and could synergistically limit one's capacity to engage in tasks with high dynamic balance control demands. Additionally, it is likely that these factors might interact together to cause recurring sprains, joint damage and fractures [53,54]. Without effective intervention, overweight and obese girls might continually experience a vicious cycle of reduced lower extremity muscle strength, low cardiorespiratory fitness, and physical inactivity.

The cross-sectional nature of the present study does not allow causal inferences to be made about the relationship between the measured variables. Further longitudinal data and randomised controlled studies are urgently needed to

determine causality, as many available studies are observational in nature. Another limitation is that due to logistical constraints, we were unable to measure maturation indexes. It might be useful to investigate the association between these variables and measures of sexual maturation. Again, as the study involved adolescent girls only, the findings cannot be generalised to boys. Participants of the present study were black South African girls. As such, extrapolation of the results to other ethnic populations with dissimilar characteristics should be done with utmost caution. Further, the use of BMI to define overweight and obesity has inherent limitations. Although BMI is a widely used index, it is not considered as a direct indicator of body composition. Future research should employ more accurate field-based measures such as skinfold or waist circumference assessments.

3.5 Conclusions

Overweight and obese girls have decreased cardiorespiratory and MSF as compared to normal-weight peers. More research efforts should be directed towards developing interventions with the goal of improving these important components of physical fitness, particularly among this group. This might prevent or delay the progression of long-term health complications. Given that overweight and obese female adolescents demonstrate decreased lower extremity strength and cardiorespiratory fitness, we propose that light-intensity, meaningful and fun exercises involving the use of everyday tasks with optimal joint loading should be explored. Due to the functional problems identified in this group, vigorous intensity activities (e.g. running) and complex sports might be too challenging and could decrease enthusiasm. Hence, using familiar activities like walking over obstacles, controlled lunges, and motor skills instruction, might be deemed enjoyable and could increase compliance. Therefore, an exercise approach that focuses on motor development, strength and cardiorespiratory fitness may prove to be useful in preparing these girls for traditional sports-specific physical education programmes.

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CHAPTER 4: Association between body mass index, motor competence and self-efficacy among adolescent girls

Abstract

Background: Motor competence and self-efficacy influence participation in physical activity in young people. Both motor competence and physical activity declines while body mass index increases over developmental time, particularly among girls. Yet, it is unknown whether motor competence and self-efficacy can predict body mass index in this demographic group. The aim of the study was to examine whether motor competence, self-efficacy, physical activity and sedentary behaviour can predict body mass index in adolescent girls aged 13-16 years.

Methods: Motor competence was measured by the Movement Assessment Battery for Children (second edition) among adolescent girls (n = 151). Generalised self-efficacy was assessed using the Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity scale. Body mass index was calculated following standard protocol, and physical activity and sedentary behaviour were determined by self-report. Multiple regression determined the relationship between motor competence, self-efficacy, physical activity, sedentary behaviour and body mass index.

Results: Increased motor competence was associated with greater self-efficacy and lower body mass index. Balance performance, adequacy in physical activity and enjoyment of physical education were found to be significant predictors of body mass index.

Conclusions: Girls with higher levels of motor competence and self-efficacy are more likely to have a healthy body weight. Developing interventions to improve motor competence and self-efficacy may be important for preventing or reducing excess weight in this population.

4.1 Introduction

Adolescent obesity is a symptom of contemporary lifestyle and represents a major health challenge in modern history [1,2]. There is some evidence that the prevalence of obesity increases with age and differs across gender and ethnic groups [3]. Adolescent obesity is an important predictor of cardiovascular, metabolic and orthopaedic complications in adulthood [4], but factors influencing the development of obesity in adolescence have been less documented particularly among girls in low and middle-income settings. Research suggests that adolescent girls have an increased risk for obesity than boys [5]. Hormonal changes and reduced physical activity post-puberty might explain this trend [6]. In low-and-middle income countries such as South Africa, the prevalence of obesity is almost comparable to high income countries [5,7]. Studies conducted in South Africa have documented a higher prevalence of overweight and obesity in school-aged girls compared to boys [3,5,7,8,9,10]. Identifying factors that determine adolescent obesity in girls may be useful for preventing and reducing obesity rates in this population.

Several factors may influence obesity in young people. These include age, gender, decreased self-efficacy [11], low motor competence [12,13], reduced physical activity and higher sedentary behaviour [14]. Physical self-efficacy is negatively associated with body mass index (BMI) [11], and low motor competence is related to increased BMI and low levels of physical activity [13]. Children with high motor competence are usually more physically active and fit and tend to spend less time in sedentary pursuits than those lower in motor competence [12,13]. Furthermore, high levels of motor competence have repeatedly been associated with healthy weight [13,15-20], and superior motor competence has been linked to greater self-efficacy [13,21]. It has been suggested that motor competence and child characteristics such as perceived competence may interact with physical activity to produce healthy weight in children [22,23], and that the association between these factors may become strengthened over time [23].

However, much of the research in this area has been limited to young children [13,19,23]. It is possible that the relationship among these factors may be different in adolescent girls due to biological maturation. Therefore, the primary purpose of the study was to investigate whether motor competence, self-efficacy, sedentary time and physical activity can predict BMI among South African adolescent girls. Secondly, motor competence, self-efficacy, physical activity and sedentary behaviour were compared across different BMI groups. It was postulated that greater motor competence and generalised self-efficacy would be associated with lower body mass. A second hypothesis was that low levels of physical activity and higher sedentary behaviour would be associated with higher BMI.

4.2 Methods

4.2.1 Participants

The participants of this cross-sectional study included a convenience sample of 151 female adolescents (aged 13-16 years) recruited from a high school in a low-income area of Cape Town, South Africa. Participants were South Africans who shared similar socio-economic circumstances. All female students of grades 8-10 were invited to participate (n=157). However, only those who desired to participate were included in the final sample (n=151). Those with physical disabilities that hindered completion of testing procedures were excluded. Parents and/or legal guardians and children provided written informed consent prior to commencement. Ethical approval was obtained from the Human Research Ethics Committee of the University of Cape Town (#232/2016). Permission was granted by the principal of the school and designated education authorities.

4.2.2 Data collection

Data were collected by a team of five researchers (physiotherapists and human movement science students). Data collectors received extensive training on how to accurately administer the tests and measures used in the present study. Data were collected during life orientation and regular physical education hours and all assessments took place at the school premises.

4.2.2.1 Anthropometric assessment

Height was measured to the nearest 0.1 cm using a wall-mounted tape measure. Weight was also measured to the nearest 0.1kg using an electronic scale without shoes. BMI was obtained by the equation; weight (kg)/height (m²). The International Obesity Task Force age-and gender-specific BMI definitions were applied to categorise participants into normal-weight, overweight and obese groups [24].

4.2.2.2 Motor competence assessment

Motor competence was measured using the Movement Assessment Battery for children test (second edition) (MABC-2 test) [25]. The MABC-2 test is a norm-referenced test for children aged 3-16 years and involves eight tasks in each of the three age bands (3-6 years, 7-10 years and 11-16 years) [25]. Tasks assess three domains of motor competence; manual dexterity, ball skills (aiming and catching) and balance (static and dynamic) [25]. Total standard scores (TSS) are estimated and converted into percentiles to determine how a child's motor competence compares to other children of the same age [25]. The TSS at or below the 5th percentile represents poor motor competence, values between the 5th and 15th percentile suggest the individual is "at risk" of developing motor impairments, and TSS above the 16th percentile indicates normal motor competence [25]. The MABC-2 test has established validity and reliability [25] and has demonstrated utility in the South African paediatric population [26]. Due to the lack of South African norms, the Dutch norms were adopted [27,28].

4.2.2.3 Generalised self-efficacy assessment

Generalised self-efficacy was assessed by the Children's Self Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) [29]. The CSAPPA is a 19-item questionnaire that assesses self-efficacy across three domains [i.e.: Self-perceptions of adequacy in physical activity (7 items), Enjoyment of physical education (3 items) and Predilection for physical activity (9 items)]. The participants were required to choose from a pair of statements and to indicate how true the statements were of themselves on a 4-point Likert scale (1=least active

and 4=most active). Examples of items include “Some kids think they are best at sports” but “Other kids think they aren’t good at sports” It takes approximately 20 minutes to complete the questionnaire. The questionnaire has excellent test-retest reliability ($r = 0.84-0.90$) and good construct validity [29].

4.2.2.4 Physical activity and sedentary behaviour assessment

A self-administered questionnaire was developed to assess physical activity and sedentary behaviour. Participants were requested to indicate the number of days per week that they engaged in at least 60 minutes of moderate-to-vigorous intensity of physical activity. To determine sedentary behaviour, participants were asked to indicate the amount of time (hours per day) spent in sedentary activities such as watching television, using computers, playing video games and texting on the phone. Though the questionnaire is yet to be evaluated for reliability, face and content validity were undertaken prior to the commencement of the study. Also, an earlier version of the questionnaire was tested for language comprehension and was found to be acceptable in a small group of girls ($n=10$).

4.2.3 Statistical Analysis

Data were analysed using the Statistical Package for Social Sciences (Version 24.0). Descriptive statistics were calculated to describe demographic and anthropometric data including age, height, weight and BMI. Differences between the three BMI groups were determined using a one-way Analysis of Variance (ANOVA) for all variables including motor competence, self-efficacy, physical activity and sedentary behaviour. In doing this, BMI groups (normal-weight, overweight and obese) served as an independent variable. Post-hoc analysis (Hochberg’s GT2) was performed to examine differences between the group means for each variable. A multiple linear regression was calculated to predict BMI based on participants’ motor competence (MABC-2 subtests), physical activity, sedentary behaviour, and self-efficacy (CSAPPA subtests). Statistical significance was established A priori at $p<0.05$.

4.3 Results

4.3.1 Anthropometric characteristics of participants

Table 4.1 presents the descriptive statistics for the sample. Of the 151 girls who participated, 78 were identified as normal-weight, 51 were overweight and 22 were obese.

Table 4.1: Descriptive characteristics of normal-weight, overweight and obese girls

Variables	NW (n=78) (Mean±SD)	OV(n=51) (Mean±SD)	OB (n=22) (Mean±SD)	Whole Group (N=151) (Mean±SD)
Age (years)	14.3±0.9	14.4±0.9	14.2±0.9	14.3±0.9
Height (cm)	158.2±6.8	157.9±6.3	157.8±14.1	158.1±6.5
Weight (kg)	51.1±6.6	64.9±6.7	85.8±14.1	60.8±14.4
BMI (kg/m ²)	20.3±2.0	25.9±1.5	34.4±5.1	24.3±5.5

Abbreviations: BMI: Body Mass Index, NW: Normal-weight group, OV: Overweight group, OB: Obese group.

4.3.2 Comparison of motor competence, self-efficacy, physical activity and sedentary behaviour among the groups

Regarding motor competence, the three groups significantly differed from one another [$F(2, 148) = 4.596, p = 0.012$]. It should be noted that girls who were classified as normal-weight had normal motor competence (above the 16th percentile on the MABC-2 test) (100%). Only one overweight girl and two obese girls had lower motor competence (at or below the 5th percentile on the MABC-2 test), the rest were either at risk or had normal scores. When we compared the normal-weight and overweight groups, they did not show any differences in motor competence. Also, overweight girls did not differ from their obese peers ($p = 0.286$). However, the normal-weight girls were significantly different from the obese group ($p = 0.011$). The same trend was evident for ball skills. There were no differences among the groups on manual dexterity tasks. However, regarding balance performance, we observed a significant difference between the normal-weight and overweight groups ($p = 0.010$), as well as between the normal-weight and the obese girls ($p = 0.001$) [Table 4.2].

Concerning physical activity and sedentary behaviour, we observed no significant differences among the groups. Interestingly, all the girls reported relatively high sedentary time [Table 4.2].

Furthermore, self-efficacy was found to be different among the BMI-groups [$F(2,148) = 7.605, p=0.001$]. The normal-weight girls had greater self-efficacy than the obese girls ($p=0.001$), and the overweight girls were also better than the obese group ($p=0.011$). However, there were no differences in self-efficacy between the normal-weight and overweight girls ($p=0.918$). With regards to adequacy in physical activity, there were significant differences between the normal-weight and obese groups ($p=0.001$). In addition, the overweight and obese girls were different from each other ($p=0.001$). There were no differences between the normal-weight and overweight girls in this regard ($p=1.000$). The normal-weight group significantly differed from the obese girls on the predilection for physical activity score ($p=0.003$). However, the differences between the normal-weight and overweight groups were not significant ($p=0.063$) and the overweight girls were not different from their obese peers ($p=0.771$). Finally, with regards to enjoyment of physical education, we observed no differences among the groups [Table 4.2].

Table 4.2: Comparison between motor competence, self-efficacy physical activity and sedentary behaviour variables among normal weight, overweight and obese girls

Variables	NW (n=78) (Mean±SD)	OV (n=51) (Mean±SD)	OB (n=22) (Mean±SD)	F	p-value
Motor competence (MABC-2)					
Manual Dexterity (SS)	7.5±2.3	7.9±2.7	7.6±2.4	0.458	0.633
Aiming & Catching (SS)	10.7±2.5	10.3±2.6	9.0±1.9 [#]	4.090	0.019
Balance (SS)	10.2±2.1	8.8±2.7 [*]	7.8±2.9 ^{#%}	9.812	0.001
MABC-2 Total Standard Score (SS)	76.7±9.0	73.8±11.8	69.5±9.8 [#]	4.596	0.012
Physical activity and sedentary behaviour					
Physical activity score	3.3±1.6	3.3±1.3	3.4±1.9	0.120	0.887
Sedentary time (hours)	9.2±3.8	7.8±3.7	7.7±4.1	2.625	0.076
Generalised self-efficacy					
Adequacy score	20.9±4.5	20.2±4.8	15.6±4.5 ^{#%}	10.983	0.001
Enjoyment score	10.1±2.3	9.9±2.3	9.6±2.4	0.355	0.702
Predilection score	25.9±6.2	24.6±6.7	20.9±6.1 [#]	5.514	0.005
CSAPPA Total Score	56.9±11.7	54.8±11.9	46.1±9.9 ^{#%}	7.605	0.001

Abbreviations: CSAPPA: Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity, MABC-2: Movement Assessment Battery for Children second edition, SS: Standard Score,

NW: Normal weight, OV: Overweight, OB: Obese group, *p<0.05, Normal weight vs Overweight; #p<0.05, Normal weight vs Obese; %p<0.05, Overweight vs Obese.

4.3.3 Predictors of body mass index

A multiple regression analysis was performed to predict BMI based on motor competence as measured with the sub-tests of the MABC-2 and self-efficacy (as measured with the sub-tests of the CSSAPPA), physical activity and sedentary behaviour. A significant regression equation emerged [F (8,150) = 8,334, p <.001] with an R² of 0.320. Balance performance, a component of motor competence and adequacy in physical activity and enjoyment of physical education significantly predicted BMI [Table 4.3].

Table 4.3: Results of the regression analysis with motor competence (MABC-2 subtests), self-efficacy (CSAPPA subtests), sedentary time and physical activity as predictor variables and BMI as outcome variable.

	B (SE)	β (95% CI)	p-value	t-value
Constant	34.440 (2.65)	- (29.21-39.67)	< .001	13.016
MABC-2 MD (SS)	0.24 (0.16)	0.10 (-0.08 - 0.56)	0.140	1.480
MABC-2 AC (SS)	-0.28(0.17)	-0.13 (- 0.61 - 0.05)	0.090	-1.694
MABC-2 Balance (SS)	-0.87 (0.16)	-0.41 (-1.18 - -0.55)	< .001	-5.447
Physical Activity score	0.39 (0.29)	0.09 (-0.17 – 0.96)	0.172	1.371
Sedentary time (hours)	-0.12 (0.10)	-0.09 (-0.32 - 0.07)	0.218	-1.237
Adequacy	-0.46 (0.12)	-0.42 (-0.69 - -0.23)	< .001	-3.958
Enjoyment score	0.51 (0.19)	0.21 (0.12 – 0.89)	0.009	2.634
Predilection score	0.12 (0.09)	0.14 (-0.06 - 0.29)	0.182	1.340

Abbreviations: CSAPPA: Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity, MABC-2: Movement Assessment Battery for Children second edition, MD: Manual dexterity, AC: Aiming and Catching, SS: Standard Score

4.4 Discussion

The purpose of this study was to investigate whether motor competence, self-efficacy, physical activity and sedentary behaviour are predictors of BMI in a cohort of South African adolescent girls. The primary finding of this study was that low levels of motor competence (balance in particular) and decreased self-efficacy were associated with higher BMI. Before moving on to discuss the major findings, it is important to point out that almost half of the participants in this study were either overweight or obese. Our findings demonstrate that obese girls have lower

motor competence than normal-weight girls, although the number of girls in the clinical range of the MABC-2 test is quite small. In particular, their competence in the gross motor subtests of the MABC-2 test (ball skills and balance) was lower. In addition, it was noted that the obese girls had lower self-efficacy (perceived competence) than their normal-weight and overweight peers. Further, the normal-weight girls reported significantly higher predilection for physical activity than the obese girls, but the overweight and obese groups did not differ from each another. We observed no significant differences in relation to enjoyment of physical education among the groups. This could be due to the lack of exposure to physical education in the school.

The finding that almost half of the girls had higher BMI confirms previous findings indicating a high prevalence of overweight and obesity among South African school-aged girls [3,5,7,10]. This may be explained by the lower socio-economic status of participants and the cultural beliefs that they hold about excess body mass in this setting. Within the low-income context of South Africa, people share a common belief (and culture) that excess weight signifies beauty, good health and happiness [30,31]. Because of this, girls living in these settings often desire to have an increased body weight to satisfy societal expectations.

With regards to motor competence, the findings of the present study corroborate previous reports, indicating that children with higher BMI have lower motor competence than those with low BMI [21,32,33,34]. Similarly, both actual motor competence and perceived competence were shown to be associated with BMI. This is very important as it would suggest that enhancing perceived motor competence and actual motor competence might be a useful strategy for reducing BMI in this age group. Therefore, we recommend that people working with adolescent girls should consider targeting both perceived motor competence and actual motor competence as important outcomes for interventions.

Considering self-efficacy, we observed an inverse relationship between generalised self-efficacy and BMI. The implication of this observation is that girls with higher perceived motor competence would tend to have a lower BMI. This finding is consistent with previous research showing that overweight children report lower perceived competence [32]. Interestingly, though there were significant differences in perceived motor competence among the groups, their physical activity levels and sedentary behaviour were similar. It is possible that the similarity in physical activity and sedentary behaviour is due to the lack of sufficient practice opportunities. Due to the lack of resources (equipment and personnel), our sample had little access to organised physical activity. Likewise, the unsafe nature of their neighbourhoods could also be a deterrent for participation in outdoor physical activity and games. It should however be noted that inherent weaknesses of the questionnaire used to assess physical activity and sedentary behaviour might have influenced the results. Assessment of physical activity and sedentary behaviour by questionnaires are thought to have serious limitations. It has been revealed that participants struggle to recall activities and are unable to accurately quantify activity and/or sedentary time [35]. These reasons might account for the absence of significant differences in physical activity and sedentary behaviour among the groups.

Importantly, balance, an important component of motor competence, and two aspects of self-efficacy (adequacy in physical activity and enjoyment of physical education) were significant predictors of body mass index. This is likely because balance deficiencies and low adequacy and/or enjoyment in physical activity might lead to physical inactivity and increased sedentary time, factors which are known to influence obesity [14].

This study is not without limitations. First, because the study focused on female adolescents in one school within the Cape Town area, the results may not apply to populations in other geographical locations. In addition, we cannot infer a cause and effect relationship from the current data given the cross-sectional nature of the

design. Longitudinal data is still needed to confirm these findings in a heterogeneous sample of boys and girls, and to describe the direction of these relationships. Secondly, the questionnaire used to assess physical activity and sedentary behaviour has not been formally validated. The use of validated and objective instruments such as accelerometers is recommended for future studies. Despite these limitations, our study appears to be the first to provide preliminary evidence on predictors of BMI among adolescent girls in low-income settings. Another strength of the study is the inclusion of a relatively large sample size and the use of an objective measure of motor competence.

4.5 Conclusions

Girls with increased levels of motor competence and self-efficacy are more likely to have a lower BMI. Balance, adequacy in physical activity and enjoyment of physical education are potential predictors of BMI among adolescent girls. Intervention strategies aiming at improving motor competence and self-efficacy may be useful tools for preventing and/or reducing excess body weight in this population.

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CHAPTER 5: “Not just another Wii training”: a graded Wii protocol to increase physical fitness among adolescent girls with probable Developmental Coordination Disorder – A pilot study

Abstract

Background: Adolescents with low motor competence participate less in physical activity and tend to exhibit decreased physical fitness compared to their peers with high motor competence. It is therefore essential to identify new methods of enhancing physical fitness in this population. Active video games (AVG) have been shown to improve motor performance, yet investigations of its impact on physical fitness are limited. The objective of this study was to examine the impact of the graded Wii protocol among adolescent girls with probable Developmental Coordination Disorder (p-DCD).

Methods: A single-group pre-post design was conducted to assess the impact of a newly developed Wii protocol in adolescent girls attending school in a low-income community of Cape Town, South Africa. Sixteen participants (aged 13-16 years) with p-DCD ($\leq 16^{\text{th}}$ percentile on the MABC-2 test) were recruited. Participants received 45-minutes of Wii training for 14 weeks. Outcome measures included the six-minute walk distance and repeated sprint ability. Information on heart rate, enjoyment and perceived exertion ratings were also collected.

Results: Significant improvements in aerobic and anaerobic fitness were observed. The participants reported high enjoyment scores and low perceived exertion ratings. The graded Wii protocol was easily adaptable and required little resources (space, equipment and expertise) to administer.

Conclusions: The findings provide preliminary evidence to support the use of the graded Wii protocol for promoting physical fitness among adolescent girls with p-DCD. Further studies are needed to confirm these results and to validate the clinical efficacy of the protocol in a larger sample with a more robust design.

5.1 Introduction

Developmental Coordination Disorder (DCD) is a neuro-developmental condition that impairs the development of motor skills and coordination [1]. Children with DCD experience difficulty with motor tasks and participate less in physical activity. The symptoms of DCD track from childhood into adolescence [2,3]. Compared to their typically developing peers, children and adolescents with DCD exhibit low motor competence and decreased physical fitness and tend to have greater risk for overweight and obesity [4]. Given that children with DCD experience an increased risk of developing cardiovascular diseases [4], fitness promotion may be a vital preventative strategy for mitigating adverse health complications. Although the linkage between physical fitness and motor competence is reported to be stronger in adolescence [5], physical fitness declines from childhood to adolescence [6,7]. Therefore, it is critical to identify new ways of boosting physical fitness among adolescent populations with motor coordination problems.

Lately, the use of active video games in neuromotor rehabilitation is increasingly becoming pervasive. Active video games (AVGs) are motion-controlled computer games used to promote physical activity [8]. The Nintendo Wii, used in the present study, consists of a video-based console, handheld remote and balance board that allow the player to interact with the virtual environment via a wireless controller. Players use whole body movements (mostly weight shifting in different directions) and arm gestures to control the game. To enhance the players' performance, the Wii provides several augmented feedbacks (visual and auditory forms) before, during and at the end of each episode of play [9,10]. Earlier studies have shown that the Wii elicits improvements in motor coordination and aspects of physical fitness in young children. Smits-Engelsman *et al.* [11] evaluated the effectiveness of the Wii in children with DCD and their typically developing peers (TD). After 5 weeks, both groups improved on functional strength and anaerobic fitness. This suggests that the Wii might be a useful tool to enhance physical fitness in individuals with low motor competence. In another study, the authors investigated the effects of the Wii on motor and psychological outcomes in children [12]. The

children demonstrated improvements in motor proficiency and emotional well-being. In contrast, a recent study revealed that the Wii offers lesser benefits in motor proficiency, cardiorespiratory fitness and functional strength [13]. In addition, it has been established that the Wii can be implemented as an adjunct for treating children with developmental delay [14] and those with motor coordination deficits [15]. There is growing evidence to support the use of the Wii for balance control training in children and adults with motor problems [16,17]. Though active video games have been found to increase total body movement in adolescents [18], the impact of these games on physical fitness in adolescents with DCD has not been determined.

Providing opportunities for physical activity in adolescent girls with insufficient opportunity (low income community dwellers) [13] is increasingly becoming difficult. Two main reasons have been provided for this challenge. First, traditional physical activities are viewed as physically demanding and are therefore undesirable for this population [13]. Additionally, engaging in outdoor activities and sports do not seem appealing due to safety concerns and lack of resources in most low-income settings [13]. Secondly, girls with motor problems tend to exhibit motor impairments that hinder their participation in everyday tasks. In South Africa, girls are reported to have a high prevalence of overweight and obesity compared to boys [19]. This problem has been partly attributed to low motor competence [19].

Also, it is well established that during adolescence, several unhealthy habits become entrenched [20], with negative implications for adult life. Given the significant influence of physical fitness on health outcomes, developing new interventions that can be implemented to increase physical fitness in adolescent populations with DCD is reasonable. Components of physical fitness such as cardiovascular endurance, muscular strength, and anaerobic performance are compromised among individuals with motor problems [21,22] leading to reduced perceived motor competence and withdrawal from physical activity [23]. As motor

problems trail from childhood into adolescence, adolescents with low motor competence may struggle with daily activities, academic work and social roles. Consequently, their overall health status may deteriorate if tailor-made interventions are not provided.

Based on earlier findings, which sought to suggest that the Wii might improve physical fitness in children with DCD [11,13], this study was set up as an initial step to inform a larger randomized controlled trial aimed at evaluating the effectiveness of a newly developed Wii intervention (the graded Wii protocol). Therefore, the primary purpose of the study was to examine the impact of the graded Wii protocol in adolescent girls with probable DCD. Specifically, we investigated the effects of the graded Wii protocol on aerobic and anaerobic fitness. To accomplish this, the following were assessed: (i) changes in performance on field-based aerobic and anaerobic fitness tests; (ii) experiences of adolescent girls during the training sessions; (iii) exercise intensity during the training sessions; (iv) the ease of implementation of the protocol as reported by the supervising therapists; and (v) injury occurrence during the training sessions.

5.2 Methods

5.2.1 Study design

The study was a single group pre-post design. In South Africa, the prevalence of overweight and obesity is higher among females than males, especially those living in low income communities [24]. Compared to boys, girls exhibit low motor competence more frequently [19]. For this reason, sixteen girls aged 13-16 years, attending a local school in a low-income community of Cape Town, South Africa, were recruited. The school serves underprivileged black communities and is primarily attended by black South African (100%) children who share similar socio-economic status. Parents and participants provided written informed consent before involvement in the study. The informed consent process varied according to age. Essentially, the content of the consent forms used was somewhat similar for

both the parents and children. However, the written expression and structure were aligned to the children's cognitive abilities to facilitate comprehension. Inclusion criteria included a score \leq 16th percentile on the Movement Assessment Battery for Children 2nd edition (MABC-2) test [25] (Criterion A). Participants did not report any medical condition (including cerebral palsy and epilepsy) known to affect motor performance and were at a mainstream high school confirming the absence of intellectual or cognitive impairment (Criterion D). Also, the participants had normal IQ and adequate or corrected vision. It has been suggested that the term DCD should be used to refer to individuals with motor coordination problems that satisfy all the diagnostic criteria stipulated in the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-V) [26,27,28]. In this study, our sampled participants exhibited motor coordination deficits, but we could not confirm all the DSM-V diagnostic criteria. As such, we decided to refer to them as having probable DCD (p-DCD) [29,30].

Ethical approval for the study was granted by the Human Research Ethics Committee of the University of Cape Town (HREC REF: 232/2016) and permission was obtained from the school's principal. The estimated sample size was determined using previous data [31]. Based on this information, it was established that 16 participants were needed to detect a difference between pre and post training measures with a power of 0.8 and an effect size of 0.7. Outcome measures were assessed at baseline and at the end of the training period. None of the participants had prior Wii experience and no participant played any of the Wii games outside the training hours.

5.2.2 Intervention

The graded Wii protocol was developed from commercially available Wii games selected from the Nintendo Wii system. The protocol was created by qualified physiotherapists with experience in exergames rehabilitation. The protocol incorporated the Newell's constraints theory [32,33] and exercise progression principles [34,35]. Specifically, the Wii games that had the tendency to stimulate

the cardiovascular system for positive benefits in strength and conditioning were selected by two experienced independent assessors. A third person also re-evaluated all the selected games and developed the protocol (the graded Wii) to consist of various combinations of games and their adaptations. Two main criteria were adopted for game selection and evaluation: (1) games should require whole bodily movement to control the avatar; and (2) games should be amenable to progressive external modifications without limiting playability. Backpacks with sandbags (which weighed 1kg and 3kg) and wooden platforms (25 centimeters high) were used to externally change the physical demands of the games. These items were used to progressively increase the level of challenge and physiological load over the training period. Each participant was required to play eight games for 45 minutes per session, once weekly, for 14 weeks. For each training session, the participants were required to play different variation of games chosen from the four available game categories (aerobics, balance, muscle workouts and yoga). A detailed scheme of the protocol is provided in Appendix 1. During Week 1 to 5, the participants were instructed to familiarise themselves with the selected games; hence no alterations were introduced throughout this period. From Week 6 to 14, gameplay was gradually adjusted to increase the physiological load. This was conducted through the use of backpacks filled with weights (1kg at the midpoint and 3kg towards the end of the training period) and a 25-centimetre high wooden platform. The training was delivered to a maximum of six participants simultaneously in an enclosed room. Six Wii consoles and televisions were arranged and partitioned so that participants were not distracted by other players. Each session was supervised by physical therapy and human movement science students.

Prior to each session, participants received brief orientation of the Wii games. The supervisors used the orientation period to introduce the games for the session and to encourage the participants to fully engage with the protocol to gain positive benefits in physical fitness. In addition, the orientation segment afforded the

participants a unique opportunity to ask questions regarding aspects of the protocol that were unclear and to report any technical difficulties with the set up.

5.2.3 Measurements

Demographic data including age, grade and hand preference were collected from each participant. In addition, BMI and physical activity data (number of days in which participants were physically active for 30 minutes or more) were collected. Assessments were conducted in the school's playground by two groups of independent assessors at pre and post intervention. The second group of assessors were blinded to the pre-test scores. Participants' perceived exertion, heart rate and enjoyment ratings were monitored during the training and at the end of each session. Injuries that occurred during the training were also recorded. Each supervisor was interviewed to share his or her experiences regarding the organization of the protocol.

5.2.3.1 Physical fitness, heart rate, perceived exertion, enjoyment and experiences of supervisors

5.2.3.1.1 Physical fitness

The six-minute walk test (6MWT) was used to evaluate the aerobic fitness of the participants. The test was chosen because it uses everyday functional activity (walking) and has been extensively used in studies involving children and adolescents. Furthermore, it is known to be safe, easy to perform and highly acceptable to children [36]. It provides a valid and inexpensive means to measure functional capacity in children [37,38,39]. The 6MWT measures aerobic fitness across all ages. The test was executed according to recommended protocol [36] over a 20-meter distance walkway. During the test, each participant was instructed to cover much distance in six-minutes. However, they were allowed to rest if they wanted to and proceeded again when they were ready [37,38,39]. Two trials were performed on the same day with a 30-minute rest between trials and the mean score is reported in this paper. Test-retest reliability of the 6MWT is high [ICC 0.94

(95% CI=0.89–0.96)] among healthy children indicating high reliability, and the Smallest Detectable Difference (SDD) is estimated to be 50 meters [36].

In addition, the Muscle Power Sprint Test (MPST) was used to assess anaerobic fitness. The MPST involved the completion of six 15-meter sprints at maximum speed with 10-second rest intervals. The test took place on a 15-meter level ground at the school's soccer field. Each participant's sprint time was recorded using stopwatches in milliseconds [11]. Based on the time and weight of the participant, the mean power (Watts) over six repetitions was calculated. Greater mean power indicates the ability to maintain power output over time and translates into better maintenance of anaerobic performance. The mean power of the MPST demonstrated an ICC of 0.90 (95% CI = 0.85-0.99) for test-retest reliability in this age group [40]. Steenman and colleagues [40] showed with a Bland-Altman plot that there was no significant learning effect between the first and second trials. In the same paper, the measurement error was found to be 16.8W with an estimated SDD of 33W.

5.2.3.1.2 Heart rate

The American College of Sports Medicine recommends that individuals with chronic diseases and disabilities should perform moderate intensity physical activity (40-70% of maximal HR) for improved cardiorespiratory fitness [41]. To monitor exercise intensity during the training sessions, participants wore Polar heart rate monitors (Polar S810) across their chest accompanied by wristwatches. The Polar S810 has good accuracy compared to ambulatory [42] and supine ECG [43]. Participants' resting heart rate (HR) and peak heart rate were recorded. Resting heart rate was recorded in sitting (3-5 minutes) whereas peak heart rate was recorded in the course of play. Estimated maximum heart rate based on resting HR and participants' age was also calculated using the formula derived by Gulati [44]: Estimated maximum Heart rate (HR_{max}) = $206 - (0.88 \times \text{age})$. Lastly, we calculated the percentage of the estimated HR reached during the training to check if individual peak HR was above the recommended level.

5.2.3.1.3 Perceived Exertion

Table 5.1 shows the Borg's Rating of Perceived Exertion (RPE) scale that was used to measure the participants' perceived exertion. The scale consists of numerical values (6-20, where 6 means "no exertion at all" and 20 means "maximal exertion") and expresses a participant's subjective feeling regarding the intensity of an exercise programme. The tool has valid and reliable reporting [45].

Table 5.1: Borg's Rate of Perceived Exertion (RPE) Scale

Rate of Perceived Exertion (RPE) Scale	
6	
7	Very very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very very hard
20	Maximum exertion

5.2.3.1.4 Enjoyment Rating Scale

Since enjoyment is an important motivator, the Enjoyment rating scale, was used to measure the participants' enjoyment experienced during the training sessions. The scale uses 5 smiley faces with numeric scores (0-4, 0 means boring; 4 is

awesome) to assess how much the participants enjoy playing the Wii games at any given time. The Enjoyment rating scale used in this study has been adequately described elsewhere [46]. It was hypothesized that the harder the level of challenge, the less enjoyable participants would find the games.

5.2.3.1.5 The Supervisors' experiences

At the end of the training period, each supervisor was requested to share their experiences regarding the organization and delivery of the protocol. Also, they were asked to report on technical difficulties associated with the administration of the protocol. Additionally, injuries that occurred during the training sessions were monitored and recorded.

5.2.4 Statistical Analysis

Data were checked for normality using the Kolmogorov-Smirnov test and appropriate analyses are reported. Means and standard deviations (SD) are reported for age, height, weight, and BMI, and pre-test values on the MABC-2 test. To estimate the intensity of the training, averages of the RPE, and peak HR over 14 sessions are reported. In addition, enjoyment over the 14 sessions was assessed. The individual Peak HR was compared to the percentage of the estimated maximum HR. Subsequently, correlation between Peak HR and RPE and between Peak HR and enjoyment scores was determined to ascertain if greater exertion provided less fun when playing the games. Furthermore, we tested if the aerobic fitness (six-minute walk distance) changed between pre and post-tests using a paired *t*-test. To test if anaerobic fitness and susceptibility to fatigue changed, the six runs of the 15-meter sprint test were analysed using a repeated measures ANOVA with runs (six repetitions) and time of measurement (pre and post) as within subject factors at $p \leq 0.05$. Since fatigue index or the percentage decrement score is believed to be a valid indicator of anaerobic capacity, we also calculated the percentage decrement score using the recommended formula [50]. The percentage decrement score quantifies fatigue by comparing actual performance to an imagined 'ideal performance'.

We then calculated a single-group, pretest–post-test raw score effect size [47]. A standardized mean difference was calculated by subtracting the mean of the scores at post-test from the mean at pretest and dividing this raw mean difference by the SD of the scores at the first-time point. The magnitude of the effect size was interpreted using the conventions of Cohen: small = 0.2, medium = 0.5 and large = 0.8 [48]. To compensate for test-retest bias, we looked at the individual change and reported the number of children that improved more than the SDD on the 6MWT and MPST. All statistical analyses were performed with SPSS (SPSS Inc., version 23).

5.3 Results

5.3.1 Baseline characteristics of participants

The mean age of the participants was (14.5±1.0 years, ranging between 13-16 years). The mean weight and BMI was (68.1 ± 18.5 kg) and (27.5 ± 7.3 kg/m²) respectively. Eleven were classified as “at risk of DCD” and five had “definite motor impairments” on the MABC-2 test (Mean TSS±SD: 62.8± 5.6; Range: 48-69) [25]. The median reported days that the participants were physically active for 30 minutes or more was three. Only three out of the 16 reported to be active for 30 minutes every day. All the participants scored below the 5th percentile on the 6MWT (mean walking speed 1.13 m/s ±0.19) [49]. Nine participants perceived themselves as being low motor skilled and all participants had reported their willingness to be more active (see Table 5.2).

5.3.2 Participants' characteristics during training sessions

As shown in Figure 5.1, the average peak HR was (148.1±23.4) beats per minute (bpm) and the mean increase in HR per training computed from the difference in resting HR and peak HR values was 48.3±24.6 bpm. The estimated max HR was 193.3±0.78 bpm. The measured mean peak HR over all sessions reached 74.9% (SD: 13.1) of the estimated max HR (Figure 5.2). Of all the HR readings, 88.1%

were above the 60% level and 61.9% above the 70% level. This confirms that in most cases an adequate maximum level of intensity was reached.

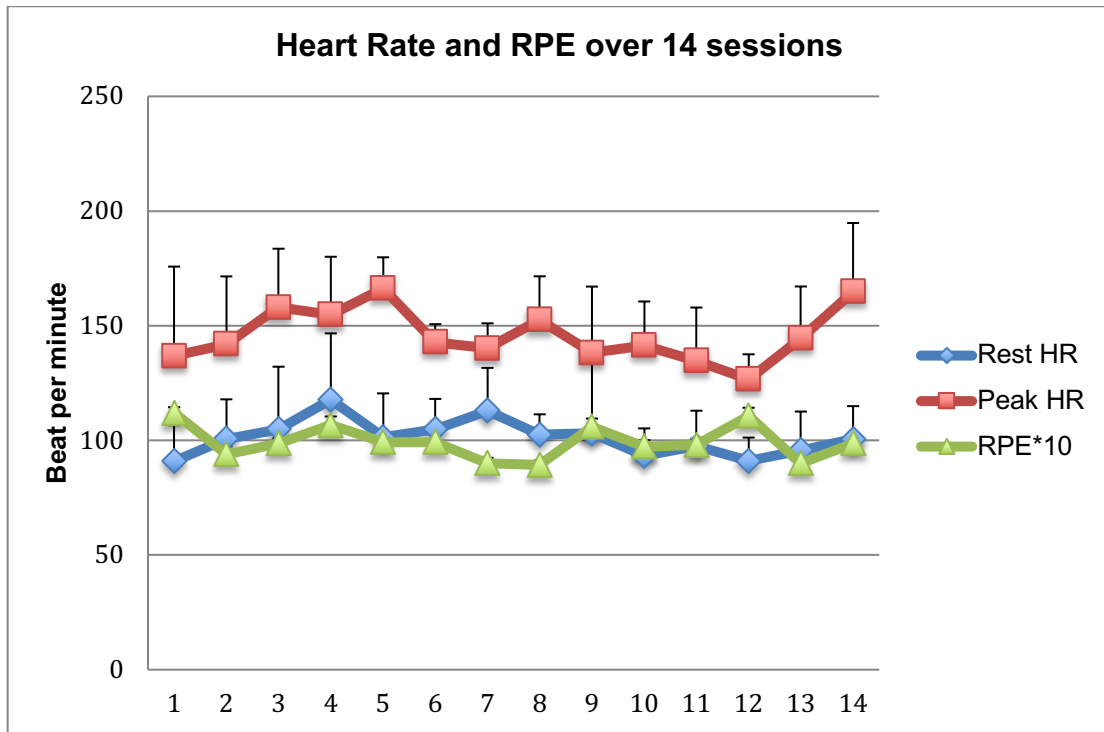


Figure 5.1: Participants' resting HR, Peak HR and perceived exertion (RPE x 10) during the 14 sessions. Note: Error bars indicate Standard Error.

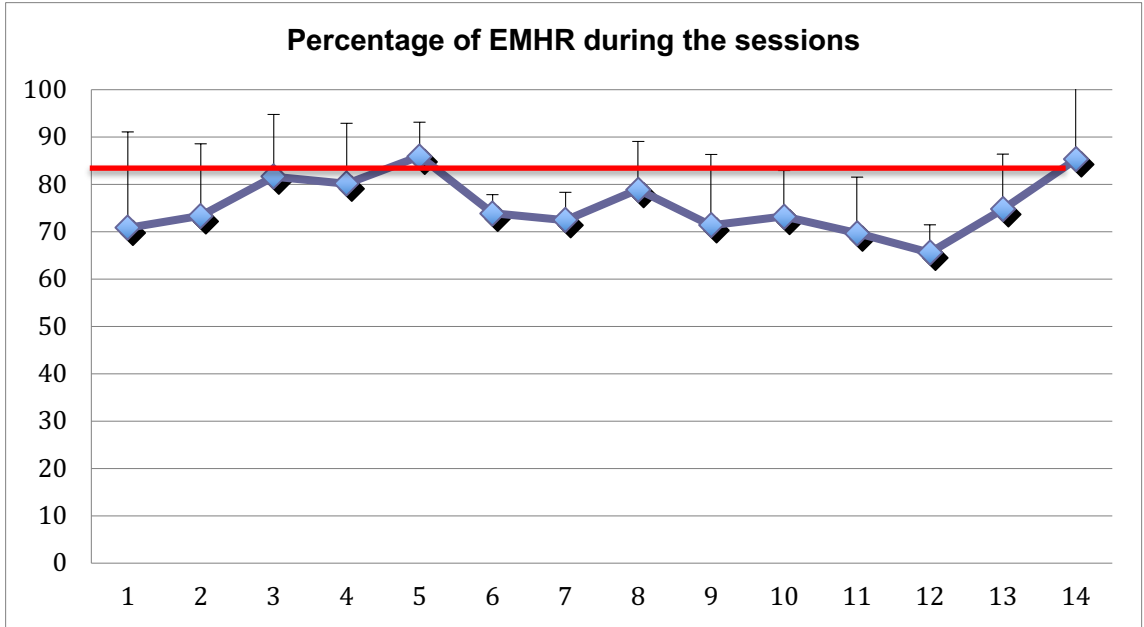


Figure 5.2: Percentage of the estimated maximum heart rate (EMHR) reached across 14 sessions. Note: Error bars indicate Standard Error and the red line represents target EMHR of 60%.

Overall, the participants enjoyed the training (Figure 5.3). The mean enjoyment score was 3.5 ± 0.75 (Median: 4). Over half of the participants (58.6%) rated the training as awesome, 30.5% as fun, 8.6 % as a bit of fun and 2.4 % as boring. Interestingly, there was no correlation between the peak HR and enjoyment scores.

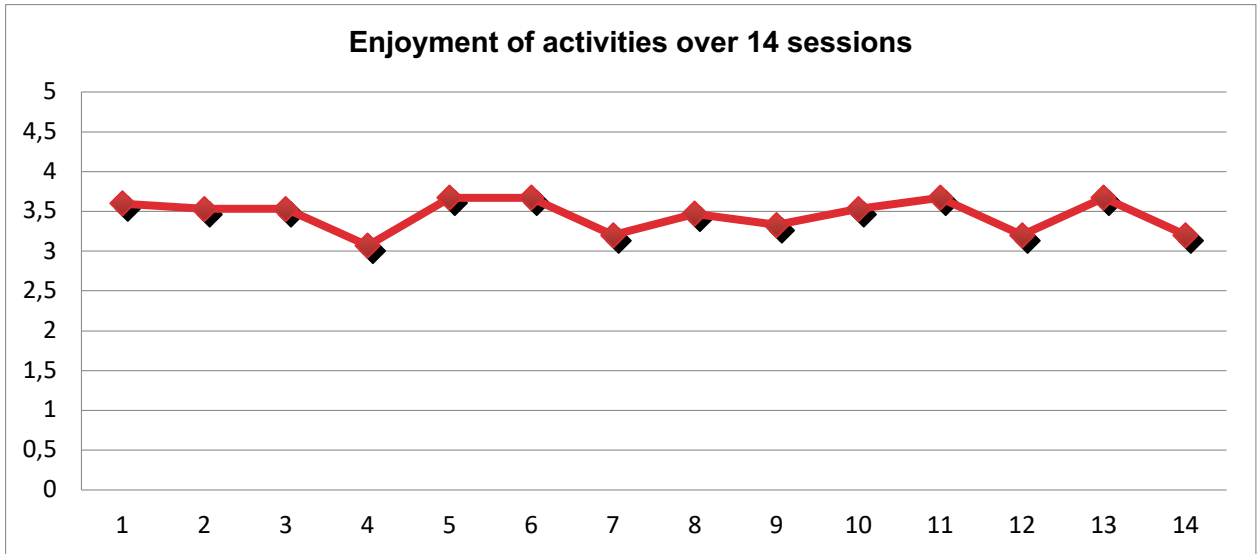


Figure 5.3: Participants' enjoyment of activities over 14 sessions

The mean RPE was 9.93 ± 2.85 (Median: 9). Approximately 46.2% of all the ratings were at least 11 or more whereas 8.6% reported 13 or more. Because of the skewed distribution of the enjoyment scores, we tabulated the percentage of choices of the enjoyment scale against the RPE ratings. It can be noticed that low and high intensity ratings could either be felt as awesome or boring (Table 5.2).

Table 5.2: Values for ratings of perceived exertion (RPE) and enjoyment scale

RPE	6	7	8	9	10	11	12	13	15	16	17	
Enjoyment- boring	0	0	0	0	0	1	0	3	0	0	1	5
Enjoyment- a bit of fun	0	1	1	3	0	3	0	6	2	0	2	18
Enjoyment- Fun	11	9	2	9	3	15	2	8	4	0	1	64
Enjoyment- Awesome	14	24	3	31	2	29	0	12	5	1	2	123
Total	25	34	6	43	5	48	2	29	11	1	6	210

Abbreviation: RPE- Ratings of perceived exertion.

No correlation was found between Peak HR and the RPE. Low non-parametric correlations ($r_s=0.12$, $p=0.008$) were seen between the increase in HR during the training and RPE.

5.3.3 Comparison of physical fitness outcomes (pre and post)

After the training, the recorded six-minute walk distance (6MWD) was longer ($\geq 20\%$) in both trials (6MWD1; pre 409 ± 66.9 m, post 481 ± 63.0 m, $t = -3.26$, $p = 0.005$, $d = 1.11$; 6MWD2; pre 401 ± 65.0 , post 509 ± 34.0 , $t = -5.18$, $p < 0.001$, $d = 2.08$). Respiratory rate (RR) in the post-test increased ($t = -5.88$, $p < 0.001$) compared to the pre-test during the first trial of the 6MWT. No differences in HR ($p = 0.167$ and $p = 0.736$) or RPE ($p = 0.089$ and $p = 0.743$) between pre and post-test was found for both test occasions (for means see Table 5.3). The test was not terminated prematurely for any participant.

Table 5.3: Pre and post mean scores of outcomes

Variables	Pre (Mean \pm SD)	Post (Mean \pm SD)	t , or F value* (df=15)	P-value
Six-minute walk distance trial 1(m)	409 \pm 66.9	481 \pm 63.0	-3.26	0.005
Respiratory rate (breaths per minute)	92 \pm 12.9	126.1 \pm 21.2	-5.88	0.001
Heart rate (bpm)	123.7 \pm 17.6	133.5 \pm 22.1	-1.45	0.167
Rate of Perceived Exertion (#)	9 \pm 2.6	10.2 \pm 2.2	-1.82	0.089
Six-minute walk distance trial 2 (m)	401 \pm 65.0	509 \pm 34.0	-5.18	0.001
Respiratory rate (breaths per minute)	94.8 \pm 13.4	99.8 \pm 31.9	-0.58	0.569
Heart rate (bpm)	126.8 \pm 21.6	129.3 \pm 18.7	-0.34	0.736
Rate of Perceived Exertion (#)	8.4 \pm 2.3	8.7 \pm 2.2	-0.33	0.743
Mean 15-meter sprint time (s)*	4.32 \pm 0.68	3.89 \pm 0.47	4.56	0.005
Mean power (Watts)*	221.2 \pm 101.9	341.3 \pm 166.7	-2.69	0.017

Abbreviations: m-metre, #=number, s=seconds, bpm=beats per minute.

The 15-meter sprint time decreased by 10 %; from 4.32 ± 0.68 s to 3.89 ± 0.47 s ($F(1, 15) 4.56$, $p = 0.05$, $\eta^2 = 0.23$) (Figure 5.4). No main effect of repetition was found, indicating that repeated sprints did not lead to poorer (or better) performance. The interaction effect with the number of sprints and time of testing was also not significant. Moreover, no significant difference was found in the percentage decrement score between pre and post-test (Mean 15.67 ± 9.58 and 18.67 ± 17.2 for pre and post, respectively; $t(1, 15) -0.60$; $p = 0.56$). Generally, the participants did not slow down much upon repeated trials and this was similar in pre and post-tests (Figure 5.4).

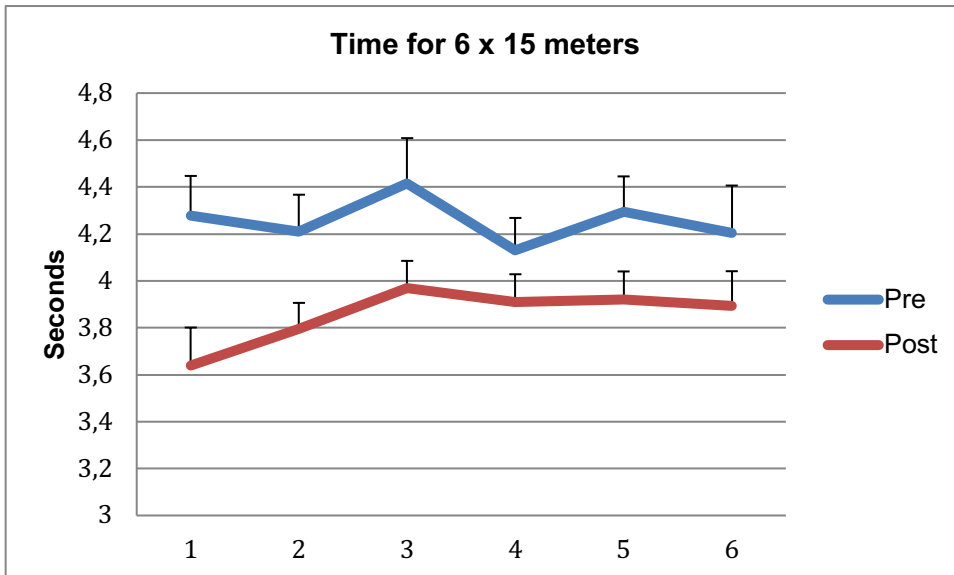


Figure 5.4: Running time before (pre) and after (post) training for the six repetitions of the 15-meter sprint. Note: Error bars indicate Standard Error.

5.3.4 Individual change

Of the 16 children, 11 improved more than the SDD of the 6MWT whereas 12 improved more than SDD of the Mean Power produced from the MPST data.

5.3.5 Experiences of supervisors

Regarding the training supervisors' experience, all reported that when equipment is available, it is simple to administer the graded Wii protocol. They also revealed that it required little space and minimal technical expertise. The supervisors suggested that for the training to be effective, it is important to explain the aim of a gaming session, and to establish adequate rapport with the participants. Provision of positive verbal feedback (Knowledge of Performance) was also highlighted as critical for successful performance. Lastly, no injury was recorded during the training.

5.4 Discussion

This pilot study was designed to examine the impact of the graded Wii protocol on aspects of physical fitness among adolescent girls with p-DCD. While the usefulness of AVGs has been demonstrated in children with DCD, its impact on physical fitness remains unknown. The study involved a sample of physically unfit girls with low motor competence. Besides, the girls had limited opportunities to participate in physical activity. This could be due to cultural and environmental challenges such as lack of facilities, poor weather conditions and unsafe neighbourhoods.

Generally, we have demonstrated that the collective experience of the girls during the training sessions was positive (fun to awesome) and that they reached the required 60-70% estimated peak HR. More importantly, there were significant improvements in walking distance and sprint time, an indication of increased physical fitness. Additionally, the graded Wii protocol was easy to administer even with little resources. This suggests that the Wii protocol might probably be useful for promoting fitness in situations where it is impossible or unsafe for people to engage in outdoor activities or sports. Given the fact that no control group was used in our design, other explanations for the observed changes cannot be ruled out, one being test-retest effects. However, the tests that were utilised have high test-retest reliability; and the reported effect sizes are moderate to large.

To our knowledge, there is only one intervention study that has used the 6MWT and has reported effect sizes of a non-treatment control group [29]. The reported effect size of 0.12 in that study is much smaller than the 1.11 and 2.08 in the present study. Moreover, most children improved beyond the smallest detectable change. Nevertheless, we cannot exclude other explanations for the observed changes. Therefore, further investigations with control groups are required to confirm the outcomes of the present study. Indeed, if a protocol of this nature could elicit individual changes in aerobic and anaerobic fitness, then it could be considered as a viable alternative for physical education programmes in schools

where physical educators are in short supply. The protocol can also be implemented in less-endowed communities to promote physical activity and fitness, as fitness programmes are often not available in such settings.

Although the graded Wii protocol was considered to be entertaining and enjoyable, it created sufficient challenges for improved outcomes among the participants. This suggests that the Wii games could be manipulated to provide adequate intensity for health benefits, without reducing the players' motivation and enjoyment. The introduction of add-ons (such as backpacks with weights) produced a competitive stimulus and increased the participants desire to succeed and might explain the observed changes in HR. While the RPE was low for the participants, their peak HR was higher than the required estimated peak HR. Importantly, exercise intensity was considered adequate enough to improve the physical fitness indicators assessed in the present study.

The perception of exertion was low for a greater proportion of the girls. Robert *et al.* [41] reported much higher perceived exertion ratings among children with Cerebral Palsy. This disparity could be attributed to the differences in the nature of games, level of motor impairments and level of maturity (differences in age). In that study, younger children (7-12 years) played only jogging and cycling games. These two games exert the cardiorespiratory systems and given that children with cerebral palsy have reduced cardiorespiratory fitness, we expect their perception of exertion to be much higher than our sample that played a mix of aerobics, balance, strength and yoga games.

The exercise intensity was relatively high and elicited significant improvements in both aerobic and anaerobic fitness. This finding does not conform to previous reports by Nitz *et al.* [9]. In their study, cardiovascular endurance did not yield any improvements in women (aged 30-58 years) who had two 30 minutes training per week for 10 weeks. Several reasons could explain this discrepancy. Firstly, our participants are much younger and had lower levels of motor coordination,

physical activity and fitness. In addition, the intensity of the protocol (a product of time, frequency and game difficulty) was higher than what was reported. In the present study, extra loads were progressively added to increase the physiological load of the games. These loads (backpacks) provided some kind of resistance and increased the strength of the muscles of the legs. The wooden blocks elevated the balance board and eventually raised the participants' base of support. Therefore, increasing the task constraints regarding their step-up pattern and balance control. Although this study provides preliminary evidence to support the adaptation that Wii games provides to increase measures of physical fitness, there are several limitations that should be recognized. The major limitation of this study is the lack of a control group. The lack of a control group makes the present study vulnerable to threats of internal validity. It was practically impossible to include a control group due to the insufficient number of participants and other ethical concerns. We recommend that future studies should consider the inclusion of a control group when assessing the effects of the graded Wii protocol in a much larger sample. Another limitation was the use of peak HR as indicative of training intensity. Mean HR and time above 60-70% max HR would be more appropriate indicators of training intensity. In the present study, we could not record HR continuously over an entire training session. It would be useful to employ a more appropriate measure to estimate the training intensity in future research. Given that it has been shown that the intervention works in children with DCD [51], it could be unethical to have a non-treatment control group, and therefore a cross-over design might be valuable. Research on the effects of the graded Wii protocol on age and gender should be considered in future research. Furthermore, investigations of the impact of the graded Wii protocol among individuals with and without co-occurring disorders and among populations with neuro-developmental disorders such as cerebral palsy, intellectual disabilities and autism spectrum disorder is recommended. Studies that would increase the training frequency to two or three times per week may yield greater outcomes. Lastly, the impact of the graded Wii protocol on activity levels, motor skills and perceived competence might be worth considering.

5.5 Conclusions

Based on the findings of this study, it can be concluded that the graded Wii protocol could be implemented to increase important components of physical fitness among adolescent girls with probable DCD. Since the participants found the games enjoyable even in the midst of all the adaptations, the protocol could be easily used to stimulate physical activity and to promote fitness in sedentary individuals who have little or reduced motivation to exercise.

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CHAPTER 6: The efficacy of two activity-based interventions among adolescents with Developmental Coordination Disorder

Abstract

Background: Adolescents with Developmental Coordination Disorder (DCD) usually experience psychomotor difficulties that affect their participation in everyday tasks and sports. Without effective intervention, adolescents show persistent motor deficits through adulthood. It is therefore critical to develop interventions to address the specific needs of this population. Studies evaluating the impact of motor interventions among adolescents with DCD are limited. This study evaluated the efficacy of two activity-based motor interventions amongst female adolescents with DCD.

Methods: Forty-three female participants (Mean±SD: 14.3±1.1 years) were identified as having DCD using the DSM-V criteria. They were randomly assigned to either Task-oriented Functional Training (TFT) or Wii training. Both groups received 45-minutes training per week for 14 weeks. Outcome measures included isometric muscular strength, motor proficiency, functional performance and participation in activities of daily living (ADL).

Results: At the conclusion of the intervention, the two groups had significant improvement in muscular strength, motor proficiency, running and agility, a predilection for physical activity and generalised self-efficacy. However, there was no difference in outcomes for the two interventions.

Conclusions: The findings highlight the potential benefits of activity-based motor interventions in reducing impairments, improving functional performance, and enhancing participation. These results support previous findings on the efficacy of task-oriented interventions and demonstrate the value of these approaches at all levels of functioning.

6.1 Introduction

Research acknowledges the impact of Developmental Coordination Disorder (DCD) on adolescents' daily life [1]. The disorder is characterised by impairment in motor coordination that interferes with academic performance and activities of daily living [2]. Children with DCD have difficulty learning skilled movements [3] and participate less in physical activity [4]. They struggle with functional tasks such as dressing, riding a bike and engaging in leisure pursuits [5]. These difficulties are attributable to impairments in posture control, motor learning and sensorimotor coordination [5], which are part of the key motor characteristics of DCD [6]. The lack of physical activity is the root of many clinical conditions [7]. Reduced physical activity in children with DCD leads to increased risk for obesity and coronary heart diseases [8,9]. Besides the detriments of inactivity such as low cardiorespiratory fitness and strength, individuals with DCD exhibit greater risk for social, emotional and psychiatric difficulties [2,10]. Their reduced physical activity is linked to reduced self-efficacy towards physical activity [4], lower self-worth [11] and poorly perceived competence [12]. Without effective intervention, these problems may persist into adulthood [13,14]. Clearly the symptoms of DCD track from childhood through adulthood, yet existing intervention studies have focused on primary school children. There are gaps in the current knowledge regarding the efficacy of interventions in adolescents with DCD, although this is a critical stage of life where several physiological changes occur, and many behavioural habits become established.

Studies in young children reported improvements in motor skills, emotional well-being and aspects of physical fitness after functional training or playing active computer games [15,16,17,18]. In a study conducted among Australian children, it was revealed that a task-oriented motor programme (the Animal Fun) improved motor ability. Compared to girls, the boys showed superior improvements over time [18]. Likewise, when two different group-based task-oriented programmes were compared in children with DCD, both approaches were found to improve motor skills [19]. Similarly, it has been shown that eight weeks of functional skill

training elicited improvements in aerobic endurance, anaerobic performance and exercise tolerance in children with DCD [15]. Collectively, these results confirm the efficacy of task-oriented interventions in the DCD population [20,21].

Much of the current research on active video games (AVGs) has focused on outcomes such as motor function [22], balance [23,24,25,26] and motor proficiency [16,17]. Notably, these works have shown that AVG leads to moderate-to-large improvements in motor proficiency. To date, only one published study has compared functional training (Neuromotor Task Training) and AVG (Wii training) [16]. In children with DCD, the authors demonstrated that functional training yielded greater improvements in motor performance, cardiorespiratory fitness and functional strength compared to AVG. However, the children who played self-selected Wii games performed better on an anaerobic test [16] although that training was not designed to elicit specific adaptations in fitness. This finding underscores the potential benefits of the Wii in improving physical fitness if training principles can be integrated into the protocol.

To the best of our knowledge, research involving a direct comparison of different motor interventions in adolescents with DCD is lacking. In addition, no AVG studies in children with DCD have explored how different parameters of game play can be manipulated to improve physical fitness. Given the complexity of the symptoms of DCD and their impact on daily life, it is necessary to describe the effects of motor-based interventions at the three levels of functioning as stipulated in the International Classification of Functioning, Disability and Health framework (also known as ICF) [27].

Typically, the ICF framework categorises health at three levels, namely body function and structure (impairment), activity (activity limitations), and participation (participation restrictions) [2,27]. This framework provides a broader view of health and functioning and defines the interrelationship between health conditions and contextual factors (environmental and personal factors) [2,28]. According to the

ICF, function emerges from the interactions between body function and structure, activity and participation, and is influenced by health conditions and/or contextual factors [28]. It is therefore not surprising that motor impairments (e.g. motor coordination deficits, muscle weakness), experienced by children with DCD often lead to activity limitations (reduced ability to run, jump or dance) [29,30,31] and participation restrictions (reduced ability to engage in household chores and sports) [32]. It has been suggested that personal and environmental factors constrain physical activity participation in adolescents with DCD [33]. In this paper, the ICF was adopted to enable the description of outcomes in a more functional manner. This would stimulate researchers and clinicians to identify participation as an important outcome in the management of persons with DCD. Participation is integral to children's health and is also recognized as an important intervention goal [34]. However, it has received little attention in DCD research [28,32,35]. This might be due to a lack of validated tools to assess changes in participation in both research and clinical populations with DCD.

To examine how female adolescents, respond to exercise, a virtual reality gaming technology (Wii training) was compared to Task-oriented Functional Training (TFT). The TFT involves the execution of everyday activities and games whereas the Wii training consists of a variety of computer games administered in an organised format to increase functional performance. In this paper, changes occurring at the level of body function, activity and participation are reported. As task-oriented training closely relates to everyday tasks, it was hypothesised that participants who received the TFT would have greater improvements in outcomes than the Wii group. The use of the Wii games in this population was motivated by findings of earlier studies [16,17,22,25] and was adapted to improve motor performance and fitness outcomes. Therefore, the aim of this study was to evaluate changes in muscular strength, motor proficiency, functional performance, self-efficacy and participation in female adolescents with DCD after receiving 14 weeks of training. A secondary aim was to determine whether these changes differ between the two interventions (TFT and Wii training).

6.2 Methods

6.2.1 Study design

An assessor-blinded, stratified, randomised trial was conducted between May and October 2016. Female adolescents identified as having DCD were assigned to receive either TFT or Wii training. Participants were stratified by grade and randomly allocated to the two intervention groups through balloting by an independent person. Following balloting, the participants' codes were concealed in opaque envelopes and distributed to them at their school. Participants who received even number codes were allocated to TFT while those with odd numbers were assigned to the Wii group (See Figure 6.1). Outcome measures were assessed at baseline and immediately after the intervention period (14 weeks).

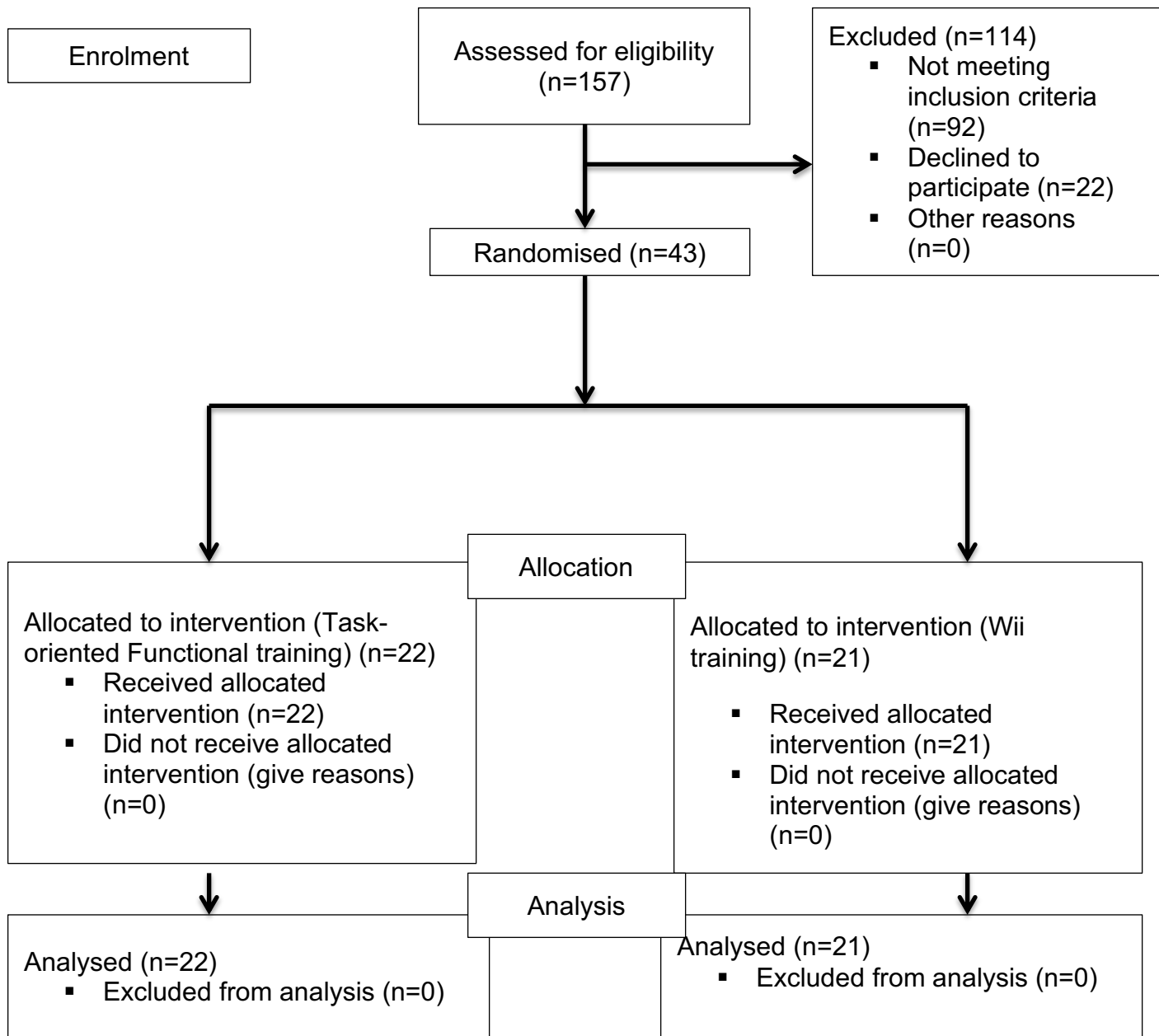


Figure 6.1: CONSORT flow diagram displaying participants' recruitment and analysis process [36]

6.2.2 Participants

6.2.2.1 Identification of DCD

Female students aged 13-16 years attending a local high school in the Cape Town area of South Africa participated in this study. Participants were identified as having DCD using the DSM-V criteria [21]. They were initially screened on the basis of responses to a self-report questionnaire on perceived motor proficiency and readiness to engage in exercise and then they were tested on the Movement Assessment Battery for Children 2nd edition (MABC-2) test. The self-report questionnaire was adapted from a teacher questionnaire previously developed and used by the authors [16]. In the current study participants were asked to indicate their level of motor proficiency by choosing one of three options (0=good, 1=somewhat good 2=poor). In addition, they were required to choose either Yes or No to indicate their readiness to engage in exercise. Though the questionnaire was found to be a valuable screening tool, it has not been formally validated in this population.

All female students of grades 8, 9 and 10 (n=157) filled out this questionnaire. Participants who perceived themselves to be less coordinated (as indicated by their responses on the questionnaire) than their peers completed the MABC-2 assessment, age band 3. Participants were included if they scored at or below the 16th percentile on the MABC-2 (Criterion A). Eligible candidates were asked if they wanted to improve their motor skills. Those included perceived themselves as having motor difficulties (Criterion B) and indicated their desire to improve their motor skills. No diagnosis of a significant medical condition known to affect motor performance was noticed nor reported. All the participants were at a mainstream high school, which affirmed the absence of intellectual or cognitive impairment (Criterion D). Until the start of this study, the school had no physical education lessons and so the participants had never been involved in any organised physical activity programme. In South Africa, females are known to exhibit low motor competence more frequently than males [37]. Based on this, we elected to focus the current study on female adolescents although the study was conducted in a

mixed school. Parents and participants gave written consent prior to commencement. Ethical approval for the study was granted by the University of Cape Town, Faculty of Health Sciences Human Research Ethics committee (HREC REF: 232/2016) and permission was also granted by the principal of the school and designated education authorities within the Western Cape Province of South Africa.

6.2.3 Intervention

6.2.3.1 The Wii training

The Nintendo Wii is a virtual reality gaming technology that can be interacted with by a player using wireless controllers [38]. Six televisions were connected to six Nintendo Wii Fit consoles (Nintendo, Tokyo, Japan) and balance boards and arranged in a designated classroom at the school. The set up was partitioned so that participants could not see other screens while playing. Six girls simultaneously played the games under the supervision of two trained (student) therapists. The supervisors explained the goals of the training and provided verbal encouragement when necessary. They also recorded the participants' enjoyment and perceived physical exertion at the end of each session. The training involved a 45-minute gaming session held once weekly for 14 weeks. Each participant played a maximum of eight games per session.

We incorporated the concept of periodisation [39,40] and the principle of progressive loading [41] into the design of the Wii protocol. Periodisation is defined as a systematic variation (loading) of training variables to achieve an intended goal [40] and has been shown to elicit improvements in strength and other performance goals in healthy individuals and those with physical impairments [40]. Usually, when participants improve their skills and become too familiar with particular games/sports, they tend to exhibit low motivation affecting expectations for optimal performance [42]. For this reason, the physical demands (level of difficulty) of game play was progressively adjusted to avoid boredom and to stimulate gains in strength and conditioning. This was done with the use of objects such as

backpacks containing weights (between 1-3kg) and wooden platforms (25cm high) to elevate the balance board. Likewise, the participants were required to play several variations of the Wii games to sustain engagement, manage fatigue and to improve performance. The purpose of the adaptations was to provide adequate external loading for the intended training effects to be achieved. These adaptations were made in a systematic order over the course of the intervention period (See Figure 6.2 for a scheme of the Wii adjustments). The backpacks augmented the participants' body mass and the wooden platform raised the participants' centre of mass, thereby increasing demands for balance control, coordination and strength.

The training took place during physical education lessons and after school hours. All the participants were novice players and had no prior Wii experience. None of them played any of the games outside the usual training sessions. In order to allow for missed appointments, two extra weeks were added for catch-up training. All the participants completed 14 sessions with 100% adherence (see Appendix A for the list of the selected Wii games).

6.2.3.2 The Task-oriented Functional Training (TFT)

The Task-oriented Functional Training was administered in small groups (6-8 participants). The TFT involved a 45-minute exercise session held once weekly for 14 weeks. Each session consisted of three parts: an initial warm-up phase involving 10-minutes of group dance requiring coordination between several body parts. This was followed by 25-minutes of motor skills instruction designed to improve skills. In the final 10-minutes, the participants engaged in popular games such as capture the flag, traffic cop and netball. These games afforded them the opportunity to apply acquired skills in game situations and to utilize those skills to accomplish short bouts of moderate to high intensity exercises.

In order to increase strength and conditioning, the functional task difficulty [42] of the TFT was gradually adjusted over time. These modifications are supported by the principle of progressive loading [41,43] and were achieved through the use of extra loads. The participants carried extra loads (backpacks with sandbags of weight 1-3kg) while performing functional tasks such as climbing hills and walking up and down on a portion of the school's playground near the soccer field. This was meant to elicit physiological adaptations and to provide an acceptable stimulus to challenge the participants for improved performance. The task difficulty was raised in a structured manner over the intervention period (See Figure 6.3 for a flow diagram of the TFT). Physiotherapists led and monitored all the sessions. The physiotherapists explained the goals of the session, requirements for the tasks and gave verbal encouragement before, during and at the end of each session. The majority of the training took place at the school's soccer field during physical education lessons and after school hours. However, on rainy days, the training occurred in the school's auditorium.

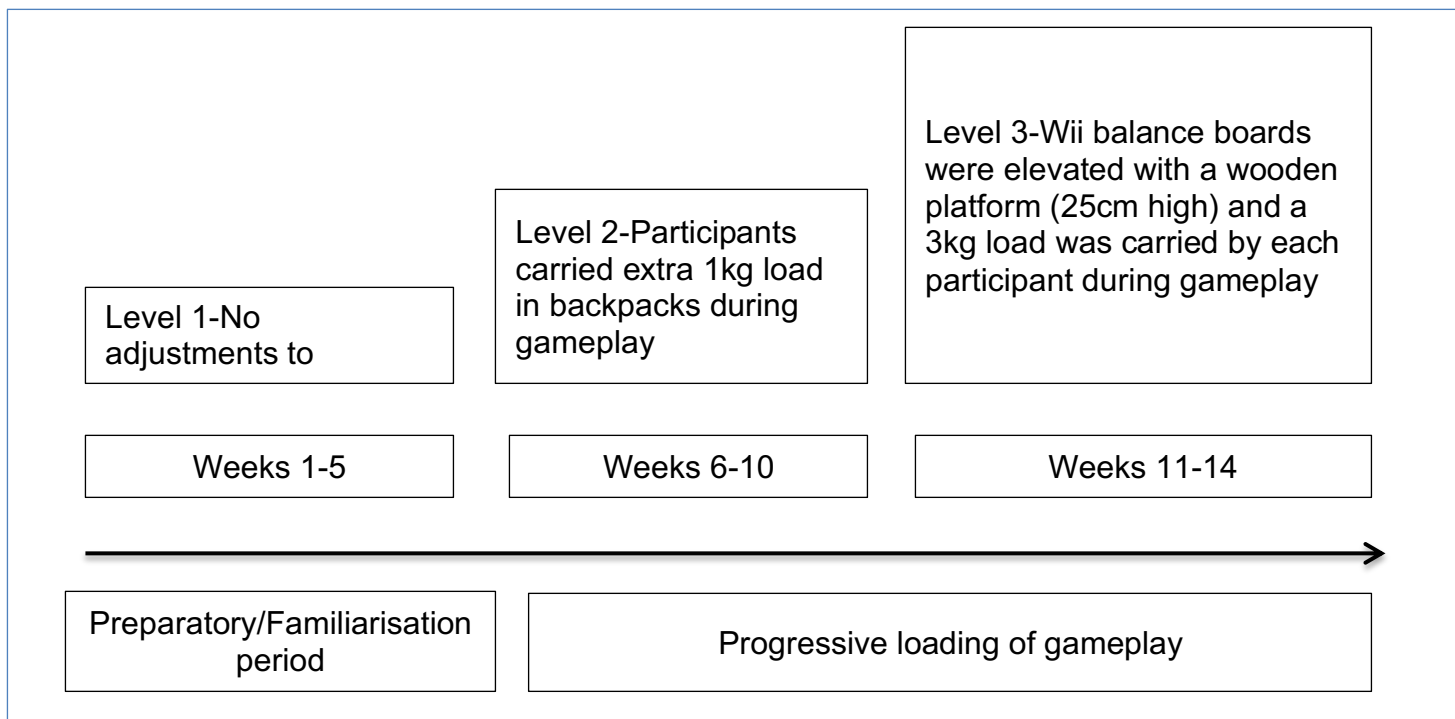


Figure 6.2: A scheme of the Wii adjustments

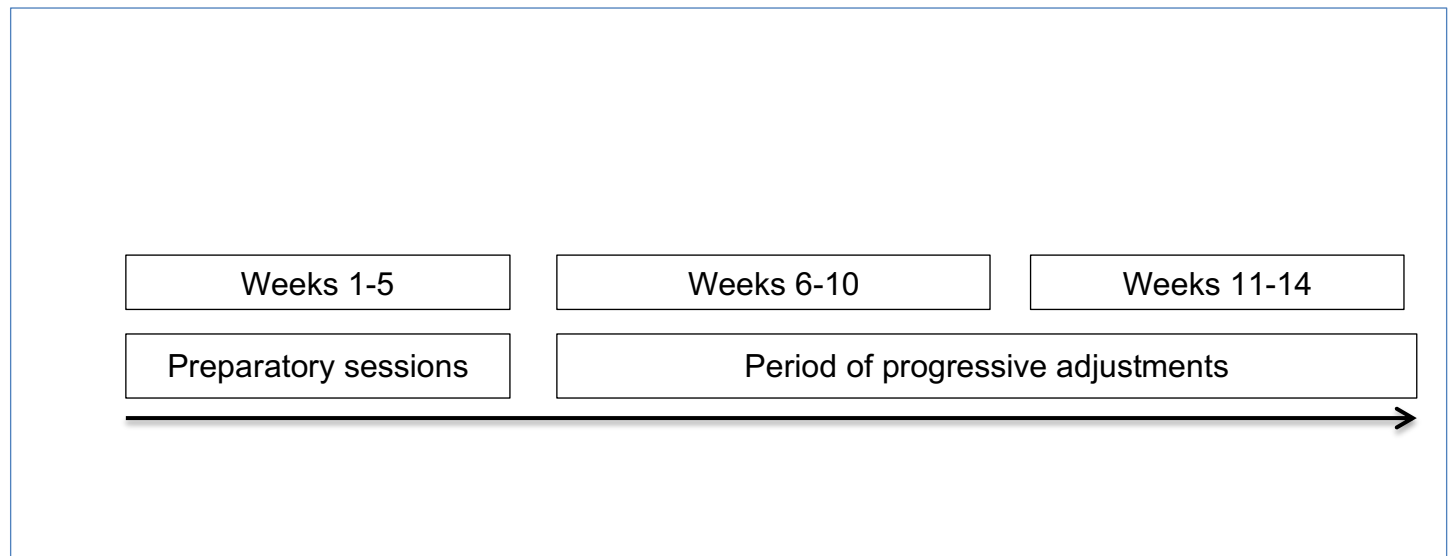


Figure 6.3: A flow diagram of the Task-oriented Functional training

6.2.4 Outcomes

The outcomes for the study were measured at baseline and at the end of the intervention period. Demographic information was collected at baseline and anthropometric measures such as weight and height were also assessed in accordance with a recommended protocol [16]. Trained physiotherapists and human movement science students performed all assessments. Different groups of assessors administered the pre and post-tests. The assessors were blinded to the group allocation and the participants were instructed not to disclose their group allocation to the assessors. In order to avoid testing fatigue, assessments were performed on separate days over a period of two weeks. The MABC-2 and BOT-2 tests took place on the first three days of week 1. The handheld dynamometry, stair climbing, and the ADL questionnaire were completed separately over the remaining days of that same week. Similarly, the aerobic and anaerobic tests were done in the second week of testing. Participants were given a two-day rest between the aerobic and anaerobic tests. In this paper, outcomes are presented according to the ICF framework.

6.2.4.1 Impairments-based outcomes

6.2.4.1.1 The Handheld Dynamometer

A handheld dynamometer (the MicroFET2-Hogan Health Industries Inc., USA) was used to measure isometric strength. The break test method as described elsewhere [44] was performed to evaluate the strength of the knee extensors, ankle plantarflexors and dorsiflexors. To test the strength of the knee extensors, the participants assumed an upright sitting posture at the edge of a padded table with their hips and knees inclined at 90° [45]. The participants were instructed to put their hands on their laps to minimize compensatory movements. Each participant was asked to fully extend the knee while the tester placed the dynamometer perpendicularly at the anterior aspect of the tibia. The tester then exerted pressure to overcome the muscle force produced by the participant (this lasted for about 5 seconds). Similarly, testing of the ankle plantarflexors and

dorsiflexors involved the participant bending the toes upward (dorsiflexion) or downward (plantarflexion) while lying in supine. With the dynamometer, the tester applied pressure to overcome the muscle force (within 5 seconds) after a steady maximal force had been generated by the participant. The testers provided verbal encouragement throughout the testing period [46]. Three trials were conducted, and the best score was used in the analysis.

6.2.4.1.2 The 20-metre shuttle run test

The 20-metre shuttle run test (20mSRT) was used to measure aerobic endurance [47,48]. The test involves running to and fro between two lines 20-meters apart. The participant undergoes repetitive shuttles (runs) in harmony with a pre-recorded beep signal. The signals increase in frequency (each minute) as the test progresses. Each incremental signal corresponds to scaled levels ranging from 0 to 19. The test-retest reliability (ICC = 0.93) and validity ($r = 0.72$) of the 20mSRT has been established against maximum oxygen consumption (VO_2 max) scores with good results [49, 50,51,52] and has been used in earlier research involving children with DCD [16].

6.2.4.2 Activity-based outcomes

6.2.4.2.1 The Movement Assessment Battery for Children-2 (MABC-2)

The MABC-2 test [53] is used to assess motor proficiency in children aged 3-16 years. It consists of eight physical items divided into three components (manual dexterity, aiming and catching, and balance). Three age bands (3-6; 7-10; 11-16 years) offer age-appropriate items. Raw scores for each item are converted into standard scores. The Total Standard Score (TSS) is a sum of the individual standard scores and gives an impression of overall motor proficiency. The MABC-2 test is considered a reliable and valid measure for the assessment of motor performance [54]. In children with DCD, internal consistency is considered to be high ($\alpha=0.90$) and test-retest reliability for the total scores is reported as excellent (ICC= 0.97). The age-appropriate MABC-2 test items were used to confirm motor performance for both groups at pre and post-test and to determine

changes in overall motor proficiency. In this study, the Dutch norms of the MABC-2 test were used, as its utility has been demonstrated in the South African population [16,23,24,55,56].

6.2.4.2.2 The Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2)

Since the intervention targeted skills required for optimal performance in functional activities, we selected the running and agility subtest of the Bruininks-Oseretsky Test of Motor Proficiency, second edition [57] to measure the participants' running and agility performance. The running and agility sub-test consists of one sprint activity and four dynamic balance tasks. To determine overall performance, each raw score is converted into a point score. Then, all the point scores are added into a total point score for each subtest. Based on sub-test values, the total point scores are converted into sub-test scale scores according to sex and age-specific norm tables. All analyses were made using sub-test scale scores for females. Inter-rater reliability for the scale scores is reported to be high for running speed & agility (0.99) [57]. Because there are currently no norms for the South African population, we used the United States of American (USA) norms, which have also been used in previous studies involving South African children [23,25].

6.2.4.2.3 Functional Performance Tests

To test improvements in functional performance, the following tests were selected; sprint tasks (10 x 5m straight and slalom tests) and stair climbing (a subtest of the Functional Strength Measure) [25]. With the sprint tasks, we assessed the participants' speed by asking them to run and turn over short distances.

6.2.4.2.4 The 10 x5 m Sprint Test-Straight

For this test, each participant was required to perform ten quick runs over a distance of 5 metres [25]. Cones and floor tapes were used to demarcate a 5-metre running course in a designated hall at the school's premises. The participant begins at the starting point and runs towards the opposite end as quickly as possible. After every 5-metres, the participant turns around and continues to run

until 10 laps are completed. The time taken to complete the 10 laps was recorded in seconds. The test was conducted individually under the supervision of a trained assessor. The test has good reliability in children and adolescents with cerebral palsy and has been previously used in DCD research [16,58].

6.2.4.2.5 The 10×5 m Sprint Test-Slalom

This test was recently developed as an agility test [25]. It is very similar to the 10*5 straight test, except that it involves multiple directional changes and requires the participant to run over a curvilinear trajectory. Each participant completed 10 laps and the time taken for this was recorded in milliseconds. Currently, there are no test-retest data for these sprint tests in children and adolescents with DCD.

6.2.4.2.6 The Stair climbing test

The stair climbing task is a subtest of the Functional Strength Measurement (FSM) test [25]. The test involves moving up and down a standardized set of stairs with six steps continuously without rest. Each participant was required to perform this task for 30 seconds and the number of flights completed was recorded. Three trials were conducted, and the best score was used in the analysis. Moderately high reliability is reported for the FSM. Both concurrent and divergent validity have also been reported [56].

6.2.4.3 Participation-based outcomes

To determine the extent to which the interventions influenced participation in activities, two questionnaires were completed by the participants.

6.2.4.3.1 The Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) questionnaire

Since self-efficacy, physical activity and motor performance are related [4,59], studying the effects of motor interventions on self-efficacy is worthwhile. In view of this, we chose the Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) questionnaire to monitor changes in generalized self-

efficacy. The CSAPPA questionnaire was selected because it is validated and has been used previously in research involving children with motor problems [4, 60,61,62,63]. The CSAPPA scale is a 19-item, self-report questionnaire developed to measure self-perceptions of children and their adequacy in and enjoyment of physical activities, physical education and sports [4,62]. The CSAPPA questionnaire was developed in Canada and explores three main factors: Adequacy (confidence), Predilection (enjoyment), and Enjoyment of Physical Education class. On this questionnaire, each child is required to choose a statement that describes his/her physical activity preference from diverse contexts.

For instance, a child is requested to select what most describes them between pairs of statements such as *“some kids think they are best at sports”* but *“other kids think they aren’t good at sports”* and then to indicate whether the selected sentence was either *“sort of true for me”* or *“really true for me”*. It takes approximately 20-minutes to complete the questionnaire [63]. Of the 19 items, seven focused on adequacy, nine was on predilection while three centered on the enjoyment of physical education. All the items are scored 1, 2, 3, and 4 with the least ‘active’ choice being scored as a 1, the most active as a 4. Generally, scores range between 16 and 76, with higher scores indicating greater adequacy in and predilection for physical education and sports [62]. The questionnaire possesses high test-retest reliability ($r = 0.84–0.90$) and has strong predictive and construct validity [63]. Participants completed the CSAPPA questionnaire independently under the supervision of trained research assistants.

6.2.4.3.2 The Participation in Activities of Daily Living for Adolescents’ Questionnaire (PADLA-Q)

To evaluate the effects of the interventions on participation, we administered the participation in Activities of Daily Living for adolescents’ questionnaire (PADLA-Q), a tool developed by the authors for this study. The questionnaire sought to assess participants’ perception of change regarding participation in everyday activities following the intervention period. The participants’ involvement in general sports

and games, physical education, physical activity and sedentary habits were assessed. The questionnaire has 14 items divided across six categories; changes in participation in general sports and games (3 items), participation in household chores (2 items), participation in games and everyday activities (4 items), participation in sports and exercise during physical education (1 item), engagement in sedentary habits (2 items), engagement in physical activity behaviour (2 items). Responses were based on a 5-point Likert scale scoring system ranging from 1 to 5 (1=a lot worse, 2= a little worse, 3= no change, 4= improved a bit, 5= improved a lot). Each participant indicated their perception of change for the various domains by choosing one of the five responses. It took approximately 15-minutes to complete the questionnaire. The questionnaire has not been formally validated but earlier versions were piloted for content, language clarity, feasibility and acceptability in a small group of students who were not involved in the present study.

6.2.5 Statistical Analysis

The Kolmogorov–Smirnov test was used to check the data for normality and Levene's test was used to determine equality of variance for the ANOVA. The appropriate analyses are reported. Differences in age, anthropometric variables and motor performance were computed at baseline using the independent *t*-test. Next, we tested whether muscular strength, motor proficiency, functional performance and self-efficacy changed with training and whether this effect was different between the two interventions using a repeated measure ANOVA with pre and post score as within, and intervention (Wii/TFT) as between factors. For the ANOVA, the estimates of effect size were calculated as partial eta squared. Partial eta squared is to be interpreted as the proportion of the total variability in the outcome variable that is accounted for by the variation in the independent or manipulated variable (in this case intervention and type of intervention). Small, medium and large effects correspond to values of $\eta^2 = 0.01\text{--}0.05$, $0.06\text{--}0.14$ and >0.14 respectively. Effect sizes (Cohen's *d*) were reported per group so the magnitude of the effects is easily understood regardless of the scale that was used

to measure the dependent variable. This would also allow for comparison to be made between the results of the current study and previous ones. Effect sizes are reported with the 95% confidence interval. To test if changes in one outcome co-occurred with changes in another, Pearson correlations were performed only between scores that significantly changed after the intervention to avoid random comparison. Given the number of comparisons, alpha was set at 0.01 for this analysis.

Reported changes in the participation questionnaire (PADLA-Q) were reported as a frequency of the change scores. Chi-square test was used to test if the changes in the PADLA-Q were different between the two intervention groups. The total sample size required was calculated based on an earlier study [24]. Accordingly, it was established that 18 participants per group would be needed to be able to detect a difference between the pre and post-tests with an effect size 0.66, power of 0.8 and at a significance level of 0.05. All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS Inc., version 23) at $p \leq .05$.

6.3 Results

6.3.1 Group differences at baseline

At baseline, the two groups were grade-matched and were all below the 16th percentile of the MABC-2. No differences were found with regards to age, body mass index (BMI) and the MABC-2 total score [Table 6.1]. Most participants (n=38) (TFT=20, Wii=18) were right-handed, whereas 5 (TFT=2, Wii=3) were left-handed.

Table 6.1: Baseline comparison of motor proficiency and anthropometric variables between the intervention groups

Variables	TFT	Wii	<i>t</i> (df=41)	<i>p</i>
	(Mean±SD)	(Mean±SD)		
MABC-2 total standard score (TSS)	61.4±10.4	63.0±5.6	0.604	0.549
Age (years)	14.4±1.05	14.3±1.10	-0.238	0.813
Height (m)	1.6±0.08	1.6±0.06	-0.483	0.632
Weight (kg)	67.6±20.2	68.1±17.4	0.095	0.925
Body mass index (kg/m ²)	26.9±7.4	27.6±6.9	0.317	0.753

Abbreviations: MABC-2= Movement Assessment Battery for Children 2nd edition, TSS= Total Standard Score, TFT Group=Task-oriented Functional Training group, Wii Group= Nintendo Wii Training group

6.3.2 Changes in muscular strength, aerobic endurance, motor proficiency, functional performance, self-efficacy and participation.

Table 6.2 presents the statistics of the main effects of the interventions on all the dependent outcome variables. It can be seen that overall, strength, motor proficiency, functional performance and certain domains of self-efficacy improved. Importantly, no interaction effects were found between type of intervention (TFT or Wii) and any of the outcomes. Changes in performance on all the outcomes for the two groups are presented in Table 6.3. Clearly, there were improvements in impairment and activity-based outcomes as well as generalized self-efficacy regardless of group allocation. Results are discussed in more detail below.

Table 6.2: Effect of Intervention (TFT and Wii) on muscular strength, aerobic endurance, motor proficiency, functional performance and self-efficacy

	Intervention		
	F [1,41]	partial η^2	p
Muscular strength			
Knee extensors (N)	211.192	0.837	0.001
Ankle plantarflexors (N)	519.466	0.927	0.001
Ankle dorsiflexors (N)	296.880	0.879	0.001
Aerobic endurance			
20-meter shuttle run (level)	1.102	0.026	0.300
Motor proficiency (MABC-2)			
Total Standard Score (SS)	95.500	0.700	0.001
Manual Dexterity (SS)	128.555	0.758	0.001
<i>Aiming & Catching</i> (SS)	0.730	0.017	0.398
Balance (SS)	19.579	0.323	0.001
Functional performance			
BOT-2 Running & Agility (SS)	65.815	0.616	0.001
10*5 straight (s)	29.769	0.421	0.001
10*5 slalom (s)	43.886	0.517	0.001
Stair climbing (#)	19.334	0.320	0.001
Generalized self-efficacy			
Total CSAPPA Score	7.008	0.146	0.011
<i>Adequacy</i> Score	3.012	0.068	0.090
<i>Enjoyment</i> Score	0.494	0.012	0.486
Predilection Score	9.263	0.184	0.004

Abbreviations: MABC-2=Movement Assessment Battery for Children 2nd edition; BOT-2= Bruininks-Oseretsky Test of Motor Proficiency second edition, SS=Standard scores

Table 6.3: Comparison of Mean (SD) pre and post Intervention scores on Outcomes for TFT (n=22) and Wii (n=21) groups

	TFT Group					Wii Group				
	Pre	Post	t(df=21)	p	Cohen d (95% CI)	Pre	Post	t (df=20)	p	Cohen d (95% CI)
Muscular strength										
Knee extensors (N)	139.5 (27.1)	263.6 (49.2)	-11.25	0.001	-3.12 (-3.94 to -2.20)	157.9 (22.9)	302.3(68.1)	-9.64	0.001	-2.84 (-3.64 to -1.94)
Ankle plantarflexors (N)	98.9 (17.7)	281.0 (34.5)	-22.21	0.001	-6.64 (-8.01 to -5.04)	109.4 (20.0)	271.0(51.3)	-12.59	0.001	-4.15 (-5.13 to -3.01)
Ankle dorsiflexors (N)	119.3 (17.8)	213.0 (34.9)	-10.84	0.001	-3.38 (-4.32 to -2.41)	128.7 (12.9)	229.4(38.9)	-14.05	0.001	-3.47 (-4.36 to -2.46)
Aerobic endurance										
20meter shuttle run (level)	2.3 (1.5)	2.4 (1.6)	-0.36	0.722	-0.06 (-0.65 to 0.53)*	1.9 (0.9)	2.3 (1.1)	-1.39	0.180	-0.40 (-1.00 to 0.22)*
Motor proficiency (MABC-2)										
Total Standard Score (SS)	61.4 (10.4)	74.0 (10.3)	-6.95	0.001	-1.22 (-1.84 to -0.55)	63.0 (5.6)	78.1 (8.8)	-6.89	0.001	-2.10 (-2.75 to -1.27)
Manual Dexterity (SS)	5.5 (2.1)	8.9 (2.7)	-7.35	0.001	-1.41 (-2.04 to -0.72)	5.9 (1.5)	9.7 (1.5)	-8.77	0.001	-2.53 (-3.29 to -1.68)
Aiming & Catching (SS)	9.0 (2.3)	8.9 (2.5)	0.140	0.890	0.04 (-0.55 to 0.63)*	9.3 (2.6)	10.1 (2.9)	-1.39	0.178	-0.29 (-0.89 to 0.32)*
Balance (SS)	7.0 (2.9)	8.9 (2.6)	-2.92	0.008	-0.69 (-1.29 to -0.07)*	6.9 (2.1)	9.1 (2.5)	-3.34	0.003	0.95 (-1.57 to -0.30)
Functional performance										
BOT-2 Running & Agility (SS)	14.1 (3.9)	18.5 (3.2)	-6.25	0.001	-1.23 (-1.85 to -0.57)	14.4 (2.9)	18.3 (1.6)	-5.25	0.001	-1.75 (-2.43 to -1.01)
10×5m straight (s)	24.8 (3.9)	22.2 (3.0)	3.49	0.002	0.75 (0.12 to 1.34)*	25.0 (3.5)	21.7 (2.1)	4.89	0.001	1.14 (0.47 to 1.77)
10×5m slalom (s)	24.3 (4.1)	22.2 (3.1)	3.52	0.002	0.58 (-0.04 to 1.17)*	24.6 (3.8)	20.6 (2.0)	5.85	0.001	1.32 (0.63 to 1.96)
Stair climbing (#)	67.5 (14.9)	74.8 (10.4)	-2.83	0.010	-0.57 (-1.16 to 0.04)*	72.0 (7.3)	78.0 (7.9)	-3.99	0.001	-0.79 (-1.40 to -0.15)*

Generalized self-efficacy										
Total CSAPPA Score	52.7 (10.7)	55.6 (11.2)	-1.57	0.132	-0.26 (-0.85 to 0.33)*	50.0 (12.8)	53.9 (9.9)	-2.19	0.040	-0.34 (-0.94 to 0.27)*
Adequacy Score	19.8 (4.5)	19.9 (4.9)	-0.108	0.915	-0.02 (-0.61 to 0.57)*	17.6 (5.4)	19.6 (5.4)	-2.27	0.034	-0.37 (-0.97 to 0.25)*
<i>Enjoyment Score</i>	9.8 (2.5)	9.5 (2.2)	0.499	0.623	0.13 (-0.47 to 0.72)*	9.7 (2.5)	9.4 (1.6)	1.23	0.624	0.14 (-0.47 to 0.75)*
Predilection Score	23.2 (6.5)	26.1 (5.9)	-2.540	0.019	-0.47 (-1.06 to 0.14)*	22.8 (7.3)	24.9 (4.3)	-1.76	0.093	-0.35 (-0.95 to 0.27)*

Abbreviations: MABC-2=Movement Assessment Battery for Children 2nd edition, BOT-2= Bruininks-Oseretsky Test of Motor Proficiency second edition, TFT Group=Task-oriented Functional Training group, Wii Group= Nintendo Wii Training group, #= number of steps, N=Newton, SS=Standard score, s=seconds, Note: Outcomes in *italics* showed no significant changes after intervention, * Lower boundary of effect size's 95% confidence interval ≤ 0.20

6.3.3 Impairments-based outcomes

At the end of the training, there were significant improvements in isometric strength of the knee extensors ($p < 0.001$), ankle plantarflexors ($p < 0.001$) and dorsiflexors ($p < 0.001$) [Table 6.2]. However, we found no statistically significant improvements in the running task [aerobic endurance, ($p = 0.300$)].

6.3.4 Activity-based outcomes

6.3.4.1 Motor proficiency

A significant improvement was found on the mean Total Standard Score (TSS) ($p < 0.001$) [Table 6.2]. Further analysis [Table 6.2 and 6.3] indicated that the mean sub-scores of manual dexterity and balance also improved significantly. However, there was no significant change in aiming and catching.

The participants improved in motor performance such that 17 (81%) children in the Wii group and 16 (72.7%) in the TFT group reached normal range scores on the MABC-2 post-intervention. While no participant was identified as impaired on the MABC-2 in the Wii group, only 3 (13.6 %) had scores denoting definite motor impairments in the TFT group.

6.3.4.2 Functional performance

Significant improvements in running and agility ($p < 0.001$), sprint tasks ($p < 0.001$), and stair climbing ($p < 0.001$) were shown after intervention [Table 6.3].

6.3.5 Participation-based outcomes

6.3.5.1 Generalised self-efficacy

The total CSAPPA score improved ($p = 0.01$) as well as the sub-score of predilection for physical activity ($p = 0.004$). There were no significant changes in the following sub-scores; Adequacy in performing physical activity and Enjoyment of physical education class for both groups. Although no significant interaction ($p = 0.12$) from the ANOVA was found, the Wii group seemed to have gained more on the adequacy sub-score.

6.3.5.2 Changes in Participation in Activities of Daily Living for Adolescents

Generally, there was increased participation in some sports after the intervention. Overall, a large number of the participants reported improvements in their participation in games, sports and play ($n=24$) as well as engagement in physical activity behaviour ($n=20$) as displayed in Figure 6.4. Only 9 of the 43 children perceived no positive change in participation in games, sports and play, and engagement in physical activity behaviour. No significant differences were found between the two groups regarding frequency of participation in games, sports and play [$\chi^2 (2) = 4.63, p= 0.20$] and engagement in physical activity behavior [$\chi^2 (2) = .81, p=0.67$].

6.3.5.3 Pattern of change in outcome measures

Although it is known that outcomes at the different levels of ICF are not linearly related, we wanted to explore if changes at one level co-occurred with changes at another level. For instance, we wanted to determine whether increased strength was associated with improved performance on the stair-climbing task. To examine this, we looked at the correlation between the significant change scores. However, no clear pattern of correlations emerged between the variables that improved after the intervention. Only two correlations reached a $p=0.01$ and five had a $p=0.05$ level.

Changes in the two sprint tests (straight and slalom) were related ($r=0.53, p<0.01$). Also, increased strength of the ankle dorsiflexors occurred with increased strength of the knee extensors ($r=0.49, p<0.01$). Increased strength levels around the ankle were related to increased total scores on the MABC-2 (ankle dorsiflexors and plantarflexors both, $r_s=0.35, p<0.02$) as well as the gains in the Predilection and Adequacy subscores of the CSAPPA ($r_s=0.34 p<0.05$). Lastly, improvements in the speed of the straight sprint task and the Manual Dexterity (MD) score on the MABC-2 were interrelated ($r_s=0.34 p<0.05$). These results indicate fairly

independent changes in the different outcomes. Improvements on the level of impairment did not coincide with improvements in skills.

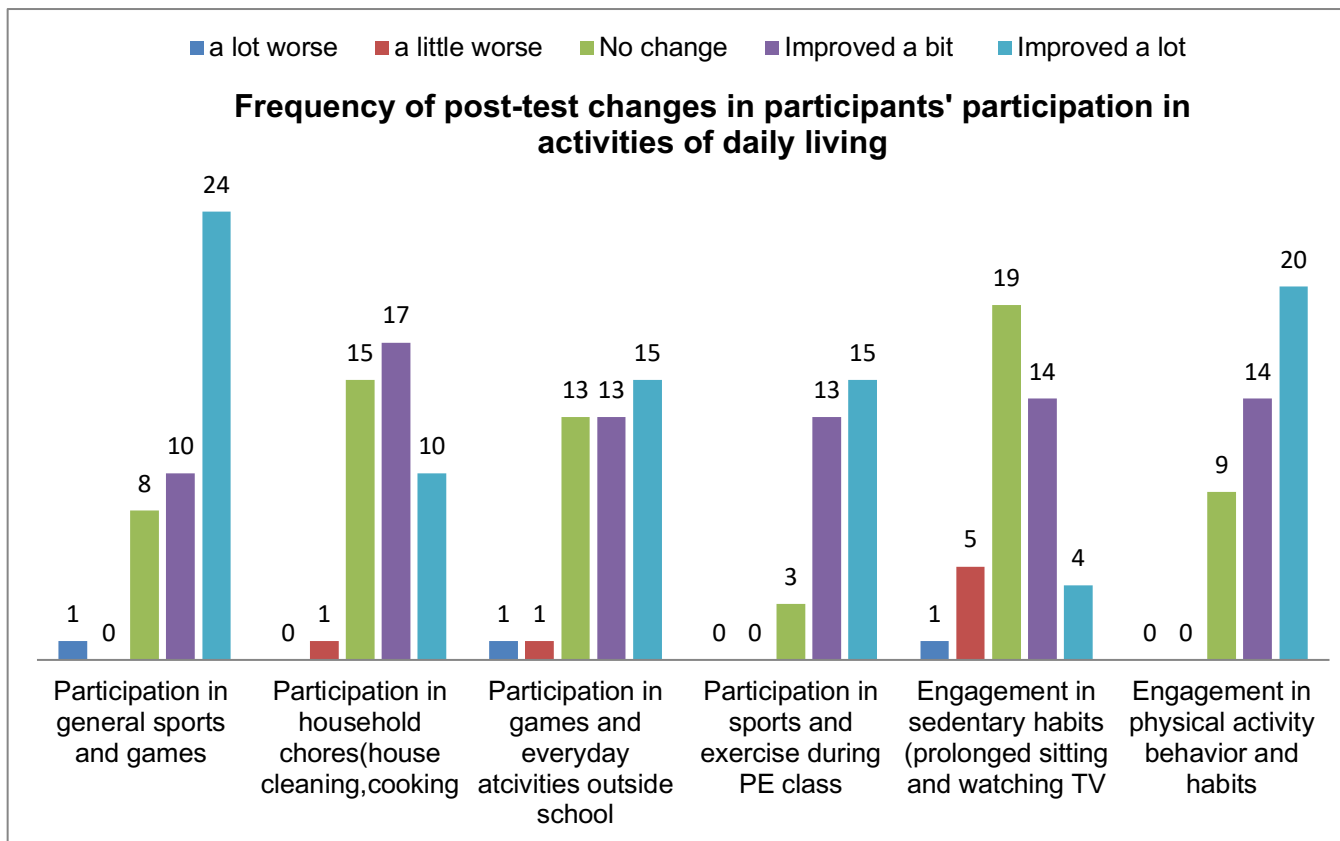


Figure 6.4: Frequency of post-test changes in participants' participation in activities of daily living

6.4. Discussion

The study investigated the efficacy of two activity-based motor interventions in female adolescents with DCD. The participants were randomly assigned to either Task-oriented Functional Training or Wii training and received 45-minutes of supervised training held once weekly for 14 weeks. We elected to implement a 14-week intervention (one session per week) at a moderate intensity based on available resources (school hours, personnel and logistics), data extracted from existing literature [16,17,18,22,24], and the fact that the participants had no prior physical education experiences.

After the interventions, significant improvements in outcomes at all levels of the ICF were found; muscular strength, motor proficiency, functional performance, self-efficacy and participation in ADLs. There was no statistically significant difference in aerobic endurance (running task) between pre and post-test. With regards to self-efficacy, we found significant changes in the participants' predilection for physical activity and their overall self-efficacy score. Additionally, improvements in participation in activities of daily living were observed. However, there were no significant differences in the gains between the two interventions.

The fact that both interventions provided similar short-term benefits is an important outcome and gives practitioners options when planning treatments. In other words, one can decide to use either the Wii or TFT to elicit therapeutic benefits in female adolescents with DCD. This decision should take into account several considerations including the expertise of the trainers and the availability of resources (space, equipment, level of supervision required etc.). The value of the tested interventions lies in their flexibility. They can be easily adapted to conform to the intended intervention goals and the specific needs/expectations of an individual or group. For example, the TFT could be delivered in a group format through collaborative working on the same goals. This could have some time-saving benefits and might be a suitable treatment option for DCD populations in less-resourced settings. Also, administering the intervention in a group format

might enhance peer socialization and improve adherence. Conversely, the Wii protocol requires less space, is easy to set up, and provides online instructions and feedback to users. It could be implemented for one person, in pairs or in small groups. For these reasons, the Wii could also be regarded as a training tool in situations with limited PE facilities as it might increase compliance.

Similar improvements were recorded for both interventions perhaps because of the seemingly common training parameters (time on task, loading effects, training frequency, duration), employed in both training modes. Perhaps the nature of the movement skills used (mainly gross motor skills) and the manner in which training sessions were gradually loaded over time for the two interventions could explain the observed changes. Although the content of the two interventions was different, they shared similar elements. These include similar training goals, common strategies to increase the level of challenge, same duration and frequency, and the participants received verbal encouragement (motivation) during training. Also, the two interventions were administered to the participants who worked in groups in their own natural environment. These factors might have triggered some positive social effects (improved self-efficacy) leading to the improvements seen across the ICF domains for the two groups.

The findings on the task-oriented training of the present study corroborate those of Ferguson and colleagues [16]. In their study involving 46 children, they showed that the mean motor performance of children with DCD improved after undergoing Neuromotor Task Training. Based on our findings, it can be argued that task-oriented interventions potentially work in diverse populations and that its effects seem not to be age-dependent. It should be noted that while Ferguson et al. [16] focused on the teaching and learning of motor skills, the current study was designed to use everyday tasks and games to improve motor skills, strength and conditioning.

Although positive changes in strength and anaerobic performance were found, there was no significant improvement in aerobic endurance for the two groups. This contradicts findings of previous research [15,16] and could be attributed to differences in training goals and other parameters including frequency, duration and type of exercises. Farhat *et al.* [15] reported that motor skills training improved aerobic capacity and exercise tolerance in boys. The exercise intensity of that study was much higher (1 hour per session, 3 times per week for 8 weeks) than that of the present study. Another possible explanation could just be the differences in the gender of the participants who were involved in the two studies, as boys are known to be more physically active than girls.

Concerning motor performance, the participants showed improvements in manual dexterity and balance. These findings are consistent with that of a previous study using Wii training [24]. In that study, it was reported that children improved their balance and stability. Although the focus of our interventions was not on skill training per se, the majority of the games and tasks employed required relatively high levels of dynamic balance and might have contributed to the improvements in balance. Furthermore, the participants increased their performance in activities requiring high anaerobic and power demands, as seen in the improvements in the functional tasks (sprinting and stair climbing).

This raises two important questions, could these have arisen because of improved motor performance or did the participants become better due to increased functional capacity? Our correlation matrix suggests that the gains in motor proficiency, anaerobic capacity and agility are rather independent and confirm task specificity of the training effects [64,65,66]. Although one might think that improvements in sprint tasks would make the participants run faster on the stairs and that increased muscular strength in the ankle would produce better balance, these patterns were not substantially evident in the analysis of the change scores. However, the participants became better at most of the activities trained. The fact that the participants improved on different outcomes does not mean that

improvements in one outcome led to improvements in another for the same participant. In theory, half the participants could improve on variable A and the other half on variable B and we could find significant improvements in variable A and B in the pre-post comparison without any causality or interrelation.

The participants also reported perceived positive changes in participation in activities of daily living. Participation in games, school and community activities are critical for motor development and well-being, particularly during childhood and adolescence. Increased participation could be a positive outcome of enhanced motor proficiency or increased self-efficacy. Although we cannot explicitly explain this observation, it is clear that gains in participation can be explored to minimize physical inactivity and its related consequences. Additionally, the results of the present study indicate that activity-based interventions may potentially influence self-efficacy. This is also an important finding, given that most children and adolescents with DCD have poor self-efficacy [4,67,68]. Our finding differs from previous studies where authors reported no improvements in psychosocial status [19,69].

Generally, the ultimate goal of interventions for individuals with DCD is to enable them to engage in developmentally appropriate activities and to participate in relevant social events. Hence, interventions should be developed to provide multiple benefits to the individual with DCD. Increased participation might lead to increased fitness, enhanced peer socialization and improved self-efficacy. Given that self-efficacy is recognized as a strong predictor of physical activity [70], interventions that offer improvements in self-efficacy could be the best remedy for addressing activity limitations in children with DCD. These findings add support to the effectiveness of task-based interventions for managing individuals with DCD. Task-oriented interventions should be further examined to determine the optimal dosage of training that would provide the greatest benefits to the individual with DCD. The long-term effects of task-oriented interventions on individuals with DCD should also be explored in future studies.

Although the present study is limited by a relatively small sample size leading to large confidence intervals in the effect sizes and no-intervention control group, it provides preliminary evidence of the potential for task-oriented interventions to improve impairments and to minimize activity limitations and participation restrictions in adolescents with DCD. In addition, all the participants were female adolescents and our findings may not be generalizable to other populations and should be interpreted with caution. Although known group validity and responsiveness have been established for most of the outcome measures, others such as the PADLA-Q and the self-report screening tool have not yet been tested for its psychometric properties.

Post-intervention tests were administered shortly at the end of the intervention period. As such, it is impossible to ascertain the degree to which exercise might yield long-term benefits in this population. Lastly, in order to improve knowledge regarding research about the impact of exercises in adolescents with DCD at all levels of ICF, more studies are needed. These studies should involve larger samples if they are intended to show differences between two types of intervention. It would also be useful if such studies could incorporate an active control condition, which would share common attributes with the experimental arm except for the variable being manipulated. Although we compared two interventions in the present study, both interventions had numerous elements (active ingredients) including physical activity, group training, verbal encouragement and augmented feedback.

Due to the above, it is currently unclear whether it is the exercises alone or a combination of the exercises with the other strategies that led to the improvements seen. To overcome this limitation, we recommend that future studies should be designed as randomized controlled trials to compare one specific component of the intervention with a suitably formulated active control group to test if children with DCD only need more time and opportunity to practice in order to improve their

level of performance or if instruction matters. Another consideration for researchers is to manipulate the teaching strategies used by those who deliver such interventions e.g. implicit learning versus teaching explicit problem-solving strategies [71].

6.5 Conclusions

In summary, we have demonstrated that activity-based interventions may yield positive benefits across the ICF levels of functioning in female adolescents with DCD. These two interventions seem to provide similar short-term benefits and can be implemented to enhance functional performance, participation and generalised self-efficacy. Further research is needed to evaluate the effectiveness of these interventions amongst clinical populations with DCD and the sustainability of improvements over time. Given that the use of the two interventions is flexible, they can be adopted as models for school or community-based health programmes to improve motor abilities and decrease sedentary behaviour. Lastly, supervised Wii training could also be implemented as an adjunct to the usual motor-based interventions for adolescents with DCD.

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CHAPTER 7: Benefits of activity-based interventions among female adolescents who are overweight and obese

Abstract

Background: Children and adolescents with high BMI are known to have low motor competence and decreased physical fitness compared to peers with healthy weight. This study compared intervention effects of two exercise protocols in overweight and obese female adolescents, aged 13-16 years.

Methods: Fifty-two female adolescents (average age: 14.4 years) who are overweight and obese participated in this study. Participants were randomly assigned to task-oriented functional training (n=26) or Wii Fit intervention (n=26). Both interventions involved 45-minutes of active training scheduled once weekly for 14 weeks. Outcome measures included motor coordination, physical fitness and self-efficacy. Data was collected before and after the intervention period.

Results: Participants in both groups demonstrated significant improvement in motor coordination and physical fitness but not self-efficacy. However, no between group differences were observed on any of the outcomes.

Conclusions: Activity-based interventions are capable of improving motor coordination and physical fitness in female adolescents who are overweight and obese. Activity-based approaches may help prevent the decline in motor coordination and physical fitness in this population and could be useful tools for promoting neuromotor fitness in high school girls who are overweight or obese.

7.1 Introduction

Obesity is a global health issue affecting a diverse range of populations residing in both developed and developing countries [1,2]. Multiple factors are known to contribute to the development of obesity including genetics, poor dietary habits and reduced physical activity [1]. In South Africa, the prevalence of overweight and obesity in children is high and is thought to be comparable to reports from most Western populations [3]. Of significant concern is that South African female adolescents have a higher prevalence of obesity than males [3,4]. Because of the current trends of obesity worldwide [2], paediatric physical therapists are more likely to encounter children who are obese in clinical practice or school settings [1]. To be able to prescribe better treatments as healthcare providers, it is important for physical therapists to gain more insight about effective obesity interventions.

Children who are overweight and obese tend to have poor motor skills [5]. Studies have shown that children who have obesity demonstrate poorer motor skills than peers with healthy weight [6-8]. In addition, obesity is reported to be inversely related with physical activity and fitness [9]. Apart from the negative impact of obesity on physical skills, obesity may impair psychosocial development [10]. Psychosocial factors such as self-efficacy play a significant role in obesity development and have been found to be negatively correlated with body mass index [11]. Further, compared to peers with healthy weight, individuals with obesity have been found to demonstrate poor motor planning, an attribute which is essential for adapting motor actions [12]. Given that these impairments may preclude participation in physical activity and further increases in body mass index [13], it is necessary to identify effective ways to reduce declines of motor coordination, physical fitness and self-efficacy in this population. Because motor coordination, fitness and self-efficacy influence regular engagement in physical activity [13], and are amenable to intervention efforts, developing interventions to improve these variables in this population may be prudent.

Although there is evidence to support the effectiveness of exercise interventions on improving motor coordination in children and adolescents who are overweight and obese [14], substantial gaps still exist in this area of research. First, to our knowledge, no published intervention study has compared the effects of regular exercise programmes to active video games in children and adolescents who are overweight or obese. In addition, studies testing the impact of interventions on physical and psychological health outcomes in female adolescents who have excess weight are limited. Furthermore, more intervention research needs to be conducted in low and middle-income countries (LMIC) such as South Africa because previous studies were designed and implemented in high-income nations. Testing the effectiveness of interventions designed and implemented by physical therapists would generate knowledge that can guide exercise prescription for children who are overweight and obese, thereby optimizing the benefits of physical therapy.

Activity-based interventions are exercise strategies that use functional tasks as channels to facilitate the learning of motor skills and/or improve performance [15]. These approaches apply the principles of motor learning related to practice, feedback, task and environment to address the needs of an individual or specified group [15]. Activity-based interventions can be delivered in diverse contexts including natural settings and virtual reality environments. In this paper, we report the outcome of a study designed to compare intervention effects of a task-oriented functional programme and Wii Fit training among female adolescents who are overweight and obese. Based on findings from past research [16], we hypothesized that participation in both interventions would lead to improvement in motor coordination and physical fitness. Since the task-oriented functional training uses everyday functional tasks; it was further hypothesized that participants who would receive this type of training would experience greater improvements in outcomes than the Wii Fit training group.

7.2 Methods

7.2.1 Study design and participants

A two-arm parallel randomised controlled trial was adopted. Fifty-two female adolescents (8th-10th graders), aged 13-16 years participated in the study. Physical activity (PA) was assessed by self-report and body mass index (BMI) was used to categorise participants as either overweight or obese using the International Obesity Task Force BMI age-and-gender-specific definitions [17]. To assess PA, participants were asked to indicate the number of days they engaged in at least 60 minutes of moderate-to-vigorous activity, over the last 7 days. Girls with any physical disability (e.g. cerebral palsy, fracture etc.) that prevented participation in assessments and interventions were excluded. Girls who were involved in any kind of formal exercise or fitness programme were also excluded. Written informed parental consent and child assent were obtained before commencement. Ethical approval was granted by the Human Research Ethics Committee (HREC) of the University of Cape Town (ref#: 232/2016).

7.2.2 Sample size calculation

Based on a previous study [16], and using an alpha of 0.05, an effect size of 0.8 and a power of 0.8, a minimum sample size of 19 participants per group was required to detect a statistical difference in the primary outcome (aerobic fitness). Because of potential issues of drop-out and the authors desire to provide intervention opportunities to girls identified as overweight or obese, all 52 eligible participants were randomly assigned to either task-oriented functional training or Wii Fit training groups.

7.2.3 Randomisation

Participants were randomly allocated to receive either a task-oriented functional training (TFT) or Wii Fit training (WFT) after stratification by grade. Pre-generated number codes were used to randomise participants through balloting. This was carried out by an independent person not involved in the study (Figure 7.1).

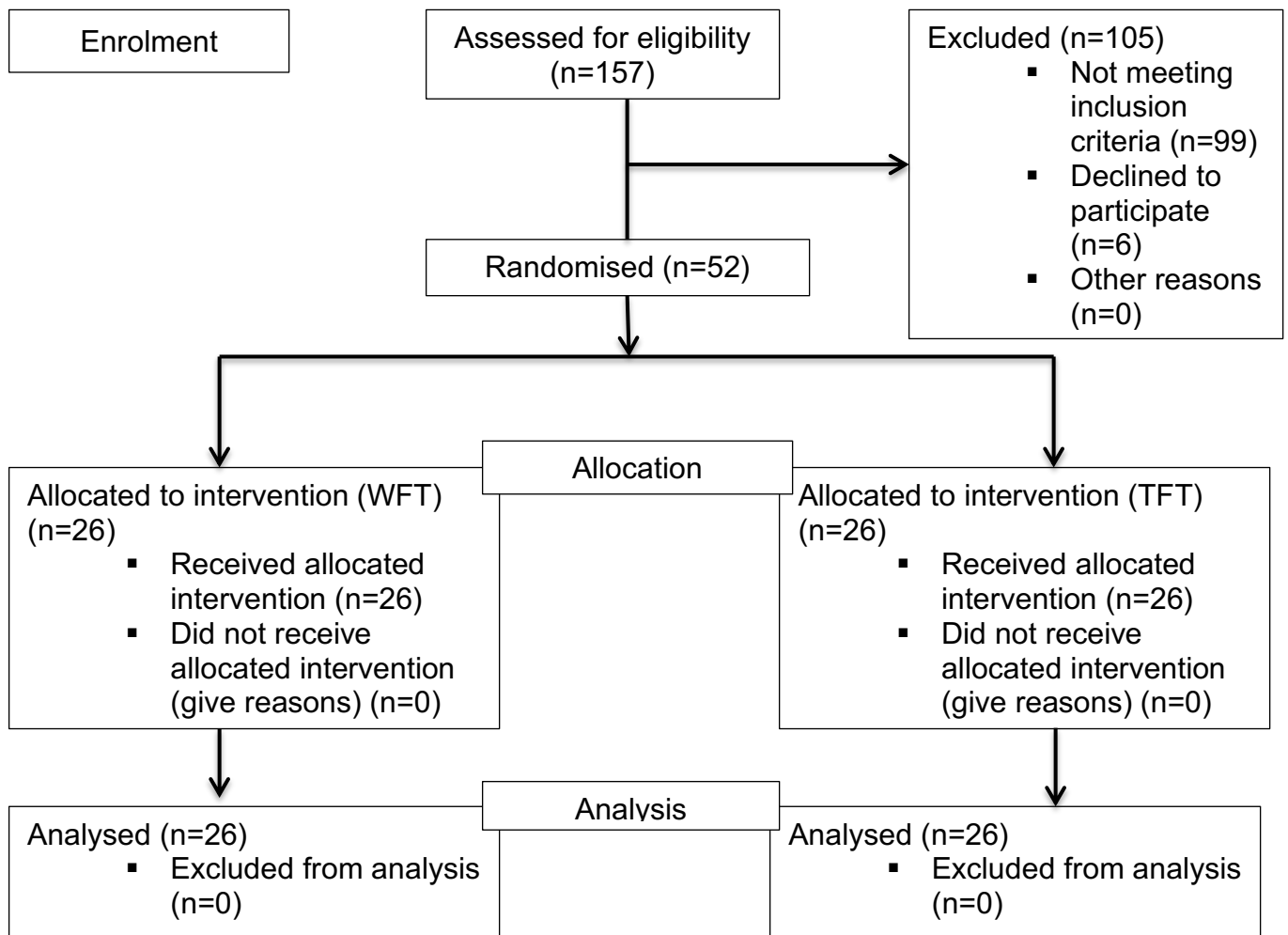


Figure 7.1: CONSORT flow diagram of participants' recruitment and analysis process

7.2.4 Intervention

Two interventions were developed and tested in this study. The development and implementation of the interventions were based on the constraints-based approach proposed by Wilson *et al.* [18], the competence-motivation theory [19] and relevant strength and conditioning training principles [20]. Each intervention was scheduled 45 minutes per session, once weekly for 14 weeks. The interventions were developed and implemented by three paediatric physical therapists. The structure of each intervention has been summarised below.

7.2.4.1 Wii Fit Training (WFT)

A Wii Fit training programme, called the graded Wii Fit protocol was developed using a variety of games from the Nintendo Wii gaming system. The Wii was chosen as it has been found to increase motor competence and components of fitness in children and adolescents with low motor competence [20,21]. Games that required gross bodily movements were used, as they were thought to be more appropriate for optimizing motor skills and physical fitness. Seven TVs, balance boards, Wii consoles and game accessories were set up in a designated classroom. The workout stations were arranged such that participants (maximum of 6 per group) could not see the screens of their colleagues. The Wii protocol was delivered in three blocks [Block 1 (Weeks 1-5), Block 2 (Weeks 6-10), and Block 3 (Weeks 11-14)]. Each participant played a maximum of eight games per session. During Block 1, participants played the prescribed games with no external adaptations. This was intended to provide participants enough time to become acquainted with the rules of the games and the patterns of movement required for successful game play. Subsequently, the gaming environment was gradually adapted to increase the gaming/task demands using the idea of task loading. Task loading was achieved through the use of backpacks (with specified weights at various time points) and wooden platforms to raise the balance boards, thereby increasing the physiological load of gameplay. Modifications of the gaming

environment occurred during Blocks 2 and 3. Details of the graded Wii protocol has been previously described [22].

7.2.4.2 Task-oriented Functional Training (TFT)

The group-based (6-8 girls per group) TFT had three parts including dance with music, goal-directed activities (e.g. throwing at targets, emptying boxes, walking and running) and culturally appropriate team-based games (e.g. tag, relays, hide-and-seek). Each session included an initial warm up involving a group dance (10 minutes), motor skills instruction (25 minutes), and culturally appropriate games (10 minutes). The tasks used were gradually loaded over time to fit participants' level of tolerance and changes in performance. Simple objects such as sandbags (weighing about 1-3kg), balls, hula hoops, wooden blocks and moveable wooden stairs were used for task adaptations. The rate of task loading of the TFT was similar to that of the WFT and a detailed protocol for the TFT has previously been published [22].

7.2.5 Outcome measures assessed before and after intervention

Data was collected at pre and post-intervention by two different teams of assessors who were blinded to group assignment.

7.2.5.1 Primary outcome measurement

7.2.5.1.1 Aerobic fitness: The 20-metre shuttle run test (20mSRT), a validated and reliable measure of aerobic fitness was used. The test was administered in accordance with standardised protocol [23].

7.2.5.2 Secondary outcomes

7.2.5.2.1 Motor coordination: The Movement Assessment Battery for children test-second edition (MABC-2 test) was used to assess motor coordination. Testing was performed as prescribed in the test manual [24].

7.2.5.2.2 Muscular strength: Lower extremity muscular strength (isometric and functional strength) was assessed using a handheld dynamometer (the MicroFET 2, Hogan Health Industries Inc., USA), and the lower extremity sub-items of the Functional Muscle Strength (FSM) test [25]. Both the handheld dynamometer and FSM have sound psychometric properties [26].

7.2.5.2.3 Anaerobic fitness: The 10×5m sprint tests (straight and slalom) were used to assess anaerobic fitness [27]. These tests have been used in research involving South African children and adolescents with and without motor problems [27].

7.2.5.2.4 Self-efficacy: The Children's Self-perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) questionnaire was used to measure generalised self-efficacy [28]. The questionnaire assesses three domains of self-efficacy; adequacy in physical activity, enjoyment in physical education and predilection for physical activity, and has acceptable validity and test-retest reliability [28].

7.2.5.3 Additional measure assessed at each training session

7.2.5.3.1 Enjoyment: The participants' perception of enjoyment of the two interventions was assessed. After each training session, participants indicated their perceived enjoyment on a previously published enjoyment scale [29]. The scale displays five smiley faces and uses a Likert-type rubric (0-4, 0 means boring; 4 is awesome) to quantify one's perception of enjoyment of an activity.

7.2.6 Statistical analysis

The Kolmogorov-Smirnov test was used to verify normality of the dataset. Descriptive statistics of means and standard deviations were calculated for all variables. An independent t-test was used to compare differences in age, anthropometric measures, motor competence, aerobic fitness and physical activity at baseline. A repeated measure ANOVA was conducted on all outcome measures with time (pre-post) as within-subject variables and type of intervention (TFT or WFT) as between-subject variables. To examine the magnitude of the intervention effects, effect sizes (Cohen's d) were computed for all outcomes. Conventional norms were used to interpret the results of the effect sizes [30]. Level of significance was established at $p < 0.05$. All analyses were performed using the SPSS version 24.0.

7.3 Results

7.3.1 Overview of participant baseline characteristics

A total of 52 girls participated in the study. At baseline, the participants' motor competence, aerobic fitness, and physical activity scores were comparable (Table 7.1).

Table 7.1: Baseline comparison of anthropometric, motor competence, aerobic fitness and physical activity variables

Characteristics	WFT (n=26) (Mean±SD)	TFT (n=26) (Mean±SD)	t (df=50)	p-value
Age (years)	14.3±0.8	14.4±0.9	-0.309	0.758
Height (cm)	158.2±5.6	157.4±7.1	0.478	0.635
Weight (kg)	69.4±9.4	71.3±15.6	-0.527	0.601
BMI (kg/m ²)	27.7±3.9	28.6±5.1	-0.698	0.488
Physical activity (days/week)	3.1±1.1	3.6±1.3	-1.569	0.123
MABC-2 TSS (SS)	9.0±2.1	8.8±2.0	0.333	0.740
20m shuttle run test (level)	2.2±0.9	2.0±1.0	0.577	0.567

Abbreviations: BMI= Body Mass Index, MABC-2= Movement Assessment Battery for Children second edition, TSS= Total Standard Score, TFT =Task-oriented Functional Training Group, WFT = Wii Fit Training Group

7.3.2 Changes in outcomes after the interventions

After the intervention, participants in both groups had significant improvements in aerobic fitness [$F(1, 50) = 5.507, p = 0.023$; Cohen's $d = 0.36$ 90%CI, (0.03 to 0.68)], motor competence [$F(1, 50) = 47.317, p = 0.001$; Cohen's $d = 1.05$ 90%CI, (0.71 to 1.40)], and strength of the knee extensors, ankle dorsiflexors and plantarflexors over time (Table 7.2). There was a significant improvement in lower extremity functional strength for the two groups [$F(1, 50) = 540.279, p = 0.001$; Cohen's $d = 3.60$ 90%CI, (3.09 to 4.13)] (Table 7.2). However, these changes were not different between groups.

With regards to self-efficacy, both groups demonstrated significant improvement on the adequacy sub-score [$F(1, 50) = 6.073, p = 0.017$; Cohen's $d = 0.31$ 90%CI (-0.01 to 0.64)]. However, we observed no significant changes in the overall self-efficacy score as well as enjoyment of physical education (PE) and predilection for physical activity sub-scores (Table 7.2). There were no significant interactions between groups over time for any of the outcomes.

Table 7.2: Effect of intervention (WFT and TFT) on motor competence, aerobic & anaerobic fitness, muscular strength and self-efficacy

Outcomes	WFT [Mean (SD)]		TFT [Mean (SD)]		F	Time	Partial η^2	P	Cohen's d (90% CI)
	Pre	Post	Pre	Post					
Motor competence (MABC-2)									
Manual Dexterity (SS)	8.5 (2.3)	10.8 (2.6)	8.3 (2.6)	10.8 (2.6)	51.035	0.505	0.001	0.96 (0.62 to 1.30)	
Aiming & Catching (SS)	10.2 (2.7)	10.8 (2.7)	10.3 (2.1)	10.9 (2.1)	3.981	0.074	0.051	0.29 (-0.03 to 0.62)	
Balance (SS)	9.1 (2.5)	10.5 (1.7)	9.1 (2.7)	10.3 (2.3)	9.473	0.159	0.003	0.59 (0.26 to 0.92)	
Total Standard Score (SS)	76.3 (7.9)	83.1 (8.4)	75.8 (7.9)	82.4 (9.3)	47.317	0.486	0.001	1.05 (0.71 to 1.40)	
Aerobic fitness									
20m shuttle run test (level)	2.2 (0.9)	2.8 (1.4)	2.0 (1.0)	2.2 (1.1)	5.507	0.099	0.023	0.36 (0.03 to 0.68)	
Anaerobic fitness									
10×5 sprint test-straight (s)	24.3 (3.1)	21.6 (1.9)	24.5 (3.1)	21.5 (1.9)	43.164	0.463	0.001	1.09 (0.74 to 1.43)	
10×5 sprint test-slalom (s)	24.0 (2.7)	20.5 (2.1)	23.1 (5.3)	21.0 (2.2)	28.728	0.365	0.001	0.87 (0.54 to 1.21)	
Muscular Strength (Isometric)									
Knee extensors (N)	160.3 (21.3)	301.1 (55.9)	151.8 (32.2)	295.7 (53.4)	314.970	0.863	0.001	3.32 (2.82 to 3.81)	
Ankle dorsiflexors (N)	128.3 (13.4)	243.1 (43.3)	122.9 (26.4)	223.1 (34.7)	296.270	0.856	0.001	3.36 (2.86 to 3.86)	
Ankle plantarflexors (N)	111.7 (21.8)	273.3 (40.2)	107.4 (24.8)	302.2 (45.0)	674.118	0.931	0.001	5.04 (4.39 to 5.70)	
Muscular strength (Functional)									
FSM Lower extremity total score	-0.3 (1.2)	1.5 (1.3)	-0.3 (1.4)	1.8 (1.5)	540.279	0.915	0.001	3.60 (3.09 to 4.13)	
Self-efficacy									
Adequacy score	18.5 (6.2)	20.3 (5.4)	20.4 (4.4)	21.6 (4.6)	6.073	0.108	0.017	0.31 (-0.01 to 0.64)	
Enjoyment score	10.0 (2.5)	9.4 (2.2)	10.4 (2.0)	10.0 (1.6)	2.336	0.045	0.133	-0.24 (-0.56 to 0.09)	
Predilection score	24.3 (7.5)	25.9 (5.5)	24.5 (6.2)	25.6 (5.7)	1.179	0.023	0.283	0.15 (-0.18 to 0.47)	
CSAPPA Total score	55.7 (14.1)	58.5 (12.3)	59.0 (10.6)	59.6 (9.3)	1.493	0.029	0.227	0.15 (-0.18 to 0.47)	

Abbreviations: MABC-2=Movement Assessment Battery for Children second edition; SS=Standard Score, CSAPPA: Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity, TFT Group=Task-oriented Functional Training Group, WFT= Wii Fit Training Group, CI=Confidence Interval, Note: outcomes in italics are not significant at $p < 0.05$.

7.3.3 Enjoyment scores

As shown in Figure 7.2, the two groups reported high and comparable levels of enjoyment scores. Approximately 63% and 76% of the participants in the WFT and TFT rated the interventions as awesome, respectively. While only 0.5% of girls in the WFT rated the sessions as boring, no participant in the TFT rated it as boring. A chi-square test of independence was performed to determine the differences in enjoyment levels between the two groups and found no significant results [χ^2 (2, N = 52) = 1.584, $p=0.663$].

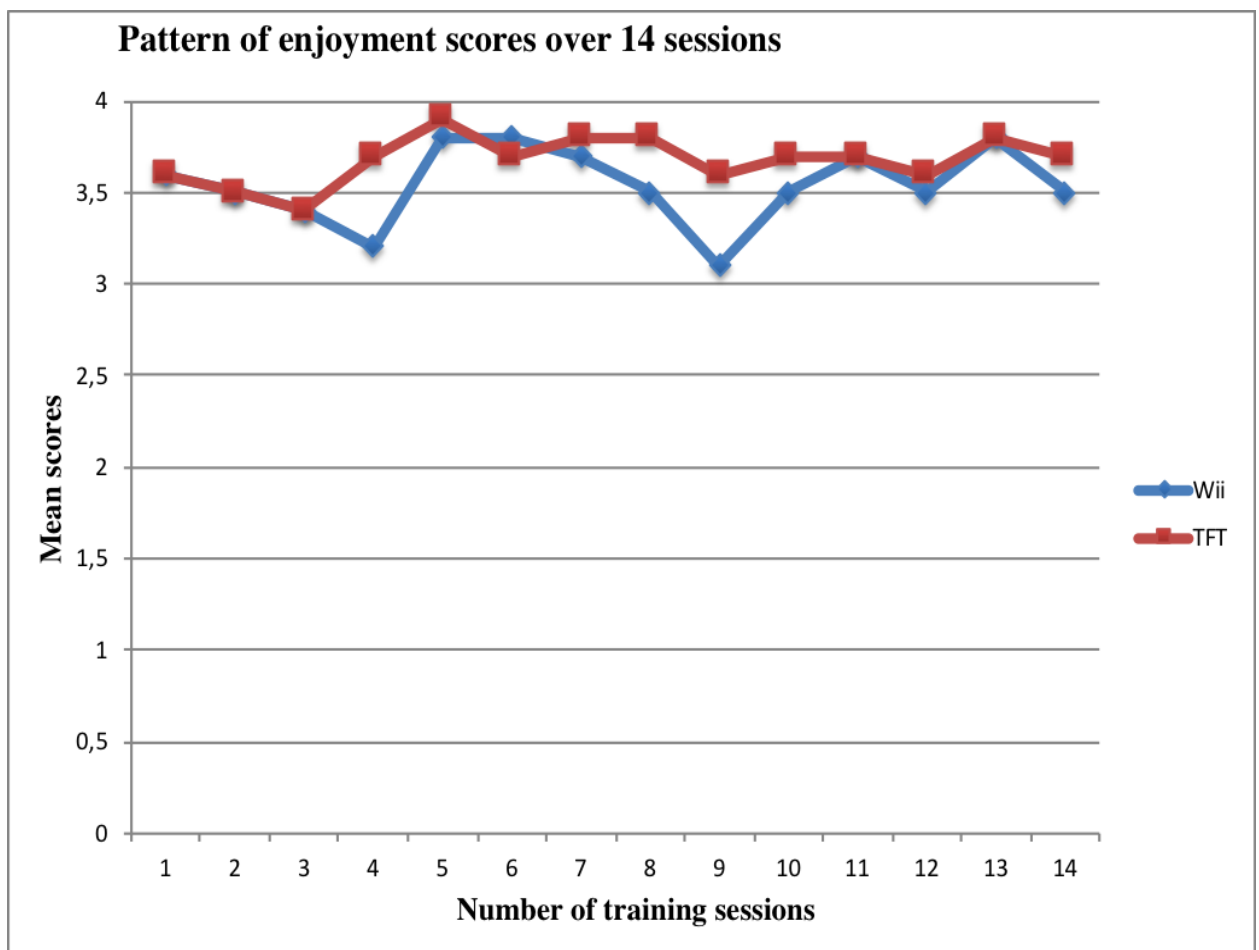


Figure 7.2: Pattern of enjoyment scores over 14 sessions [0=lowest score, 4=maximum score]

7.4 Discussion

The study compared intervention effects of two forms of paediatric physical therapy interventions among female adolescents who are overweight and obese. After the interventions, we observed improvements in aerobic and anaerobic fitness, motor coordination, lower extremity muscular strength and adequacy in physical activity for the two groups. However, there were no differences between the groups for any of the outcomes. Though the groups played different games, the high resemblance in interventions delivery strategies (task loading, time on tasks, reinforcement, amongst others) may partially explain the absence of statistically significant differences between the groups. Because we did not track exercise intensity, we were unable to confirm if the groups trained at similar or different intensities; nor were we able to determine the specific components of the interventions that produced the intervention effects.

Improvements in aerobic and anaerobic fitness were encouraging, particularly considering the relatively low levels of participants' baseline physical fitness. These findings lend support to previous research showing significant changes in health-related fitness among children and adolescents following exercise training [14]. These changes may be attributable to the nature (content and structure) of the interventions. The interventions used in this study involved motor skills instruction, and strength and conditioning components. The interventions were appropriately graded to match the performance levels at various stages during the implementation of the interventions. It is likely that these elements enhanced feelings of enjoyment and motivated the girls to actively engage in training sessions. The fact that participants had decreased fitness at baseline could have contributed to the changes observed. The idea of designing interventions with meaningful activities and at an appropriate level to enhance voluntary participation is well accepted, though the application of these concepts to the development and implementation of interventions for children who have obesity is not well explored. It would seem that when the needs (challenges) of vulnerable groups are placed at the heart of intervention development, such programmes may elicit improved

outcomes. Improvements may be pronounced when programmes are enjoyable, culturally appropriate and delivered by pediatric physical therapists in a challenging but stimulating environment.

Our positive findings on motor coordination corroborate previous research which demonstrated that with effective treatment, overweight and obese children can improve fundamental movement skills [14,15]. For adolescent girls who are overweight and obese, having superior motor coordination may drive participation in physical activity and prevent further increases in BMI. Improving motor coordination may be one of the best means of preventing obesity-related activity decline in this population [14].

With regard to muscular strength, we found positive intervention effects on lower extremity muscular strength. As expected, participants demonstrated greater isometric and functional lower extremity strength. This finding could be due to the use of additional loads for increasing the physiological challenge of the interventions. Though research indicates that children who have obesity have decreased lower extremity strength compared to normal weight peers [14], our findings suggest that impairments in muscle strength could be treated with activity-based interventions.

Regarding self-efficacy, participants reported relatively high levels of adequacy in physical activity at the end of the intervention. In addition, all the participants thought the interventions were enjoyable. Typically, when exercises are made harder or strenuous, it decreases enjoyment. However, in the present study, this was not evident. Though the task demands were gradually increased over time, these adaptations did not degrade participants' perception of enjoyment. Apart from the interventions being enjoyable, other factors might have influenced engagement in the interventions and contributed to the changes observed. Firstly, the fact that the interventions were designed to address the specific needs of this demographic group (i.e.: poor motor skills, low physical fitness and reduced self-

efficacy) enhanced compliance. Traditionally, physical education (PE) in high schools does not focus on the motor skills development. Rather, PE classes for adolescents tend to emphasize the acquisition of sports-specific (complex) skills without focusing on deficits in motor skills [12]. Secondly, it is also possible that the girls benefited from the interventions just because of peer motivation and their desire to demonstrate improvement in functional performance.

Moreover, we observed no improvement in enjoyment of a physical education (PE) class, a subscale score on the CSAPPA. This is probably because until the start of this study, physical education was not offered as an academic requirement in the school. Similarly, there were no significant changes in the predilection for physical activity score and the generalised self-efficacy total score for the groups. Perhaps the dosage of the interventions was not adequate enough to affect overall self-efficacy.

A major limitation is that due to the multiple layers of the intervention, it was not possible to identify the specific component that led to the improved outcomes. Further, due to logistical constraints, we were unable to determine the intensity of the exercises and the sustainability of the benefits cannot be confirmed as there was no follow-up. Future research could explore the optimal dosage required for improved outcomes. Evaluating the sustainability of improvements in outcomes may be worth considering. As the study was conducted in a low-income community, generalization of results to populations in affluent environments should be done with caution. Future studies should involve diverse samples (both boys and girls) and be conducted in differently resourced settings.

7.5 Conclusions

The findings demonstrate that short-term task-oriented functional training and a Wii Fit programme may improve motor coordination and physical fitness in female adolescents who are overweight and obese. Depending on available resources and individual preferences, either of the two interventions could be used to promote motor development and physical fitness in this demographic group. Given

the pervasive nature of video games, manipulating the gaming environment could provide unique opportunities for increasing motor coordination and physical fitness. These protocols could be suitable alternatives for physical education classes among female adolescents who are overweight and obese and reside in low socio-economic environments.

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CHAPTER 8: Effects of task-oriented functional training on fitness performance among female adolescents with varying weight status

Abstract

Background: Adolescent obesity impairs physical fitness. Examining how high school girls with different weight status respond to physical training might be important to inform intervention development. This study investigated if changes in fitness performance following task-oriented functional training might differ among female adolescents with varying weight status.

Methods: Adolescent girls (n=48) were divided into two body mass index (BMI) groups [a low BMI group (n=23), and a high BMI group (n=25)] based on BMI values. Both groups participated in a 45-minute exercise session held once weekly for 14 weeks. Balance, running speed and agility, aerobic and anaerobic power were measured before and after training.

Results: Significant gains in fitness outcomes were observed in both groups. However, participants with low BMI demonstrated greater changes in specific outcomes compared to peers with high BMI. This was confirmed by an interaction effect (Time×Group interaction) on aerobic power [$F(1,46)=4.293$, $p=0.044$, $\eta^2=0.085$], stepping sideways over a balance beam [$F(1,46)=4.345$, $p=0.043$, $\eta^2=0.088$] and two-legged side hopping [$F(1,46)=6.784$, $p=0.012$, $\eta^2=0.129$].

Conclusions: Findings indicate that changes in fitness performance following task-oriented functional training differ among girls with low and high BMI. Differences in changes in performance are more pronounced on agility tasks. Interventions targeting girls with high BMI should focus on enhancing their capacity to coordinate body segments in circumstances requiring greater displacement of the centre of mass and fast directional changes. Programmes that are adapted to the biomechanical constraints of these children should be promoted as options for increasing physical fitness.

8.1 Introduction

Obesity in young children is recognised as a common health problem worldwide [1]. A high prevalence of obesity has been documented among children and adolescents in South Africa. Among adolescents aged 13–19 years, the prevalence of overweight is 6.9% for boys and 24.5% for girls, and obesity rates are twice as high in girls (5.3%) compared to boys (2.2%) [2]. Apart from genetic predisposition, energy imbalance is frequently cited as a major cause of obesity [3]. Essentially, energy imbalance occurs when calorie intake exceeds energy expenditure [3]. It is now well accepted that regular physical activity is important for restoring energy balance [3]. However, it appears that most interventions are generic in nature and do not give considerable attention to variability in performance and/or weight status. Given that children with a high body mass index (BMI) have greater constraints in performing routine motor tasks compared to peers with low BMI [4], it is important to determine if these categories of individuals would respond differently to specified exercise training. Knowledge gained from this research may aid the development of effective interventions for people with varying weight status.

Children with increased BMI tend to demonstrate poorer motor performance compared to those with low BMI [4,5]. Additionally, they experience greater deficits in postural control, coordination, agility, lower extremity muscle strength, and aerobic power than peers with low BMI [3,6-11]. Body weight is a major predictor of postural control explaining about 52% of the variance in postural sway exhibited by people with overweight or obesity, especially during weight-bearing activities [12]. Excess body mass causes greater displacement of the centre of mass (COM) leading to increased demands on postural control in individuals with overweight and obesity [12]. The additional load creates biomechanical constraints making it difficult for children with overweight or obesity to succeed on tasks requiring constant changes in the COM. This idea has previously been described as the morphological constraint hypothesis [13]. Further, children with a high BMI have slower walking speed [14] and poorer running ability compared to low BMI peers

[15]. This has been attributed to the metabolic cost associated with locomotor activities. Research has shown that people with a high BMI tend to expend greater energy to accomplish motor tasks compared to those with a low BMI [16-18]. The increased cost of energy is more pronounced in activities with high speed requirements [16]. Unfortunately, the metabolic cost of movement and increased inertia experienced by children with overweight and obesity tend to negatively impact physical activity. Reduced physical activity may lead to poor motor skills, and unhealthy weight [19].

Although the benefits of school-based physical activity interventions are well-established [20-23], prescribing exercises to children without considering differences in morphological characteristics may not be helpful. It is possible that children with different weight status may respond differently to the same intervention. However, less research has been performed to examine how girls with varying weight status respond to physical training. Little is known about changes in fitness performance experienced by girls with a low and high BMI following exercise intervention.

Therefore, the purpose of this study was to determine if changes in fitness performance among adolescent girls with a low and high BMI would differ following task-oriented functional training. Given that excess body mass produces greater displacement of the COM leading to increased demands on postural control, we hypothesized that girls with a higher BMI would experience less changes in fitness performance, particularly on tasks requiring fast directional changes, than those with low BMI after participating in task-oriented functional training.

8.2 Methods

8.2.1 Study design and participants

A two-group pre-post experimental design was implemented. Participants were high school female adolescents (13-16 years) attending a public school within the Western Cape Province of South Africa. Girls who scored above the 5th percentile on the Movement Assessment Battery for Children test (second edition) (MABC-2) test were included [24]. Participants who reported any medical condition (e.g. fracture) that hindered their participation were excluded. After baseline assessments, participants were assigned to either a low BMI or high BMI group based on their BMI scores. Twenty-five participants were identified as having a high BMI (n = 25) whereas twenty-three girls had a low BMI (n = 23) (Figure 8.1).

Ethical approval was obtained from the Human Research Ethics Committee of the University of Cape Town (HREC #232/16). Parents and participants provided written informed consent before commencement. Permission was obtained from the Education Directorate of the Western Cape Province and the principal of the school. To detect significant differences in outcomes over time (pre and post), a power analysis was performed using the G-Power software and findings from previous research [25]. The outcome of the power analysis indicated that 18 participants per group were required to identify differences between pre and post-tests with an effect size of 0.66, power of 0.8 and at a significance level of 0.05.

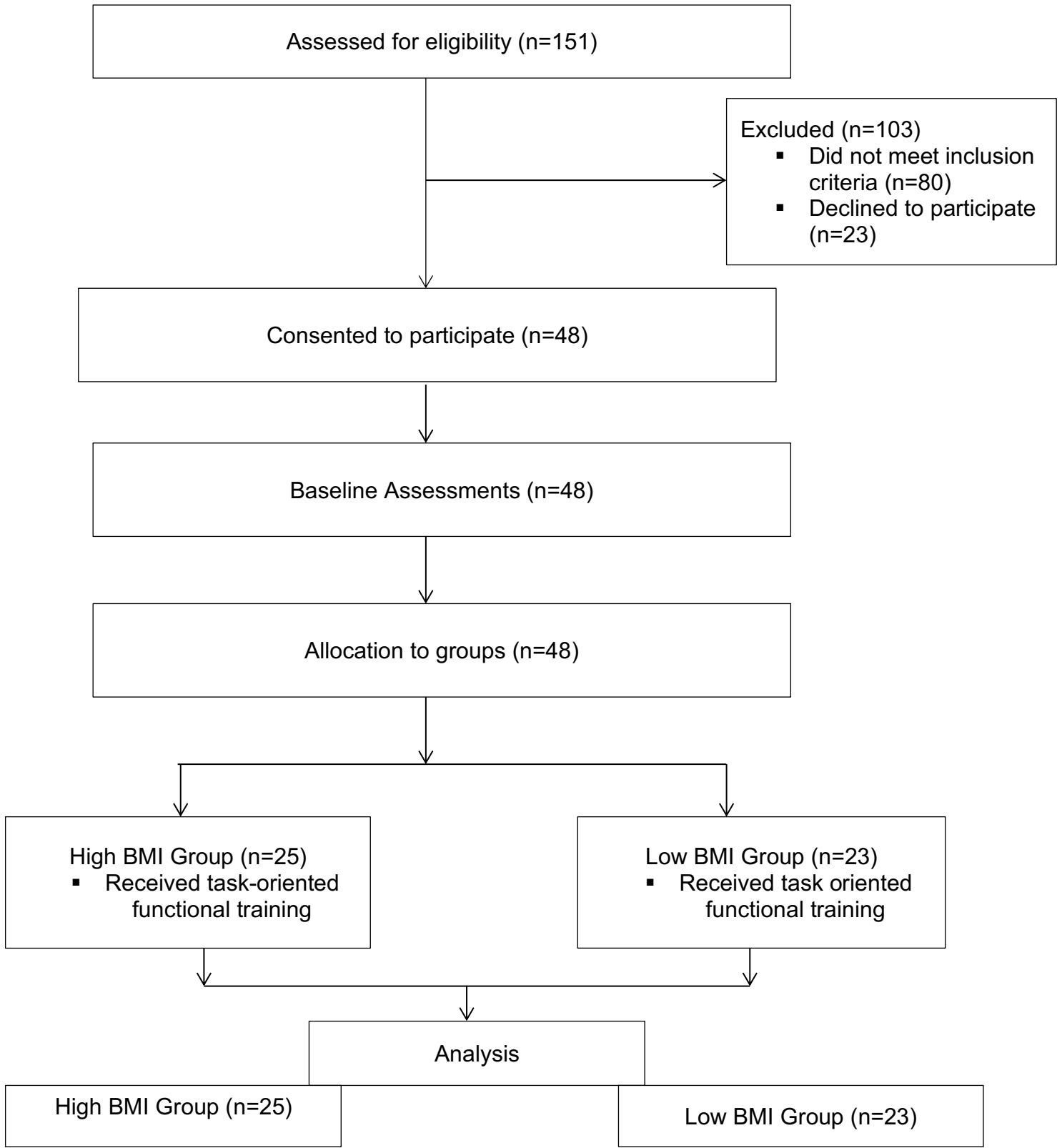


Figure 8.1: Flow chart for participant recruitment

8.2.2 Assessments

8.2.2.1 Body composition measurements

8.2.2.1.1 Body mass Index

Height and body mass were assessed using a standard protocol. Similar protocol from previous chapters in the thesis was used. Participants were assessed in light clothing without shoes. Body mass index was determined by the equation [weight (kg)/height (m)²]. BMI was defined as low and high using the International Obesity Task Force (IOTF) age-and gender-specific BMI cut-off points [26]. In line with the IOTF definitions, participants with BMI below 25kg/m² were identified as low BMI whereas girls whose BMI was at or above 25kg/m² were categorised as the high BMI group.

8.2.2.1.2 Waist circumference

To confirm central obesity, trained research assistants measured waist circumference using a tape measure. Waist circumference was measured in the horizontal plane midway between the lowest ribs and the iliac crest. Two measurements were taken and the best score was recorded [26].

8.2.2.2 Outcome measures

Outcomes were assessed before and immediately after the intervention. Outcomes were assessed by two different groups of assessors who were blinded to pre and post data, and group allocation. Outcomes included balance, running speed and agility, aerobic and anaerobic power. To avoid testing participants in the state of fatigue, testing was spread over two weeks at both pre and post-interventions.

8.2.2.2.1 Balance

8.2.2.2.1.1 The balance items of the Movement Assessment Battery for Children, second edition test (MABC-2)

The MABC-2 test is a norm-referenced test used to assess motor performance in children aged 3-16 years [24]. Children in three age bands (3-6, 7-10, 11-16 years) completed eight test items divided into three components: manual dexterity, aiming and catching, and balance. The three balance items used in this study included two-board balance, walking toe-to-heel backwards and zig-zag hopping. Raw scores for each item are converted to standard scores, which are then added to produce total standard scores (TSS). Next, the TSS is used to generate a percentile score, which provides an idea of the child's motor proficiency. The TSS was used to determine participants' motor performance (>5th percentile) and standard scores of the balance items for age band 3 (11-16 years) were used for the analysis. The MABC-2 test has acceptable reliability and validity [24]. Since no norms exist for the South African population, the Dutch norms were used. These norms have been applied to South African children in earlier studies [27-28].

8.2.2.2.1.2 The Nintendo Wii Fit standing knee Yoga test

The standing knee pose, a yoga balance task of the Nintendo Wii Fit was used to measure static balance [29]. The task required participants to assume a one-leg standing on the balance board while flexing the knee of the other leg. Participants are expected to maintain this pose for 30 seconds and to focus their postural sway (from the COM) in a designated space shown on the television screen. The time taken to maintain this pose and the amount of postural sway produced are combined to generate a point score for each leg (maximum of 50 points). Three trials were conducted per leg, and the best score was recorded. The mean score of the two legs was used for the analysis.

8.2.2.2.2 Running, speed and agility

The running, speed and agility sub-test of the Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2) was used to measure running, speed and agility performance [30]. The running, speed and agility sub-test comprises of one sprint activity and four dynamic balance tasks. To determine overall performance, each raw score is converted into a point score. Following this, all the point scores are summed up to produce a total point score for each sub-test. Based on sub-test values, the total point scores are converted into sub-test scale scores according to sex-and-age-specific norm tables. In this study, we used individual raw scores and sub-test scale scores for females in the analysis. Inter-rater reliability for the scale scores are reported to be high for running, speed and agility [30]. Due to the absence of norms for the South African population, we used the normative values from the United States of American (USA). The USA norms have been used within the South African context [27].

8.2.2.2.3 Aerobic and anaerobic power

8.2.2.2.3.1 Aerobic power

Aerobic power was measured using the 20-metre shuttle run test (20mSRT) and the six-minute walk test (6MWT). The 20mSRT was performed following standard procedures [31]. Participants ran from one end of the track to another end, 20m apart while keeping pace with a pre-recorded audio signal [32]. They were encouraged to keep up with the cadence for as long as possible and the number of levels completed was recorded [32]. The 6MWT was also performed in accordance with standard procedures [33-35]. Each participant walked from one marker to another, 20m apart at self-selected pace. Participants were instructed to walk as far as possible and the distance covered in six minutes was recorded [36]. Participants completed two trials and the average score was used in the analysis [36]. Test-retest reliability has been reported to be good with an intra-class correlation coefficient (ICC) value of 0.99 [37].

8.2.2.2.3.2 Anaerobic power

The Muscle Power Sprint Test (MPST) was used to assess anaerobic power [38]. Participants performed six quick runs at a top speed over a 15-metre course. The time taken to complete each run was measured. Power output for each sprint was calculated using participants' body mass and their sprinting times via the formula; $\text{Power} = [(\text{total mass} \times 15^2)/\text{time}^3]$ [38]. Anaerobic power was defined as peak and mean power. While peak power is the highest calculated power output among the six sprints, mean power represents the average power output of the six sprints. Greater mean power indicates the ability to maintain power output over time and translates into higher anaerobic power. Test–retest reliability of the MPST has been reported to be adequate with an ICC value of 0.98 [39].

8.2.3 Intervention

The task -oriented functional training was designed to enhance physical fitness and motor competence. The intervention was developed based on a combination of theories including the competence motivation theory [40], the multi-component theory of motor performance [41], the youth physical activity promotion model [42] and relevant strength and conditioning training principles [43]. The intervention involved a 45-minute exercise session held once weekly for 14 weeks. Training sessions started with a group dancing (for 15 minutes) requiring whole body rhythmic movements attuned to popular local and foreign music. This was followed by skills acquisition practice (25 minutes) of ball skills, dynamic balance drills, and locomotive tasks designed to improve motor skills. Each session ended with culturally appropriate games (5 minutes) such as netball, hopscotch, tagging and games intended to provide affordances for participants to apply their acquired skills in real-life learning contexts. These were administered by a team of paediatric physiotherapists on the school's soccer field. Whenever participants demonstrated improvement in physical performance, exercise sessions were progressively increased using simple objects like sandbags, and balls of different shapes and sizes. Whenever participants demonstrated mastery over tasks, the

physiotherapists provided them with positive feedback and encouragement. This was intended to increase their perception of competence and to motivate them to better engage in the activities. The intervention has been described in detail elsewhere [44].

8.2.4 Statistical analysis

For baseline data, an independent t-test was used to determine the differences in age, anthropometric variables and motor coordination between the low-and-high BMI groups. Next, we tested if various outcomes changed with training, and if this effect was different between the groups using a repeated measures ANOVA with pre and post scores as within-subject variables, and weight status (low vs. high BMI) as between-subject factors. Estimates of effect size were calculated as partial eta squared. Partial eta squared was interpreted as the proportion of the total variability in the outcome variable that is accounted for by the variation in the independent or manipulated variable (in this case - weight status). Small, medium and large effects correspond to values of $\eta^2 = 0.01-0.05$, $0.06-0.14$ and > 0.14 , respectively [45]. Post-hoc testing was performed in case of an interaction effect per group using a paired t-test. Z-scores were computed for differences in all outcomes, and these values were used to generate a graph to illustrate changes in mean z-scores after the intervention. All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS Inc., version 24) at $p < 0.05$.

8.3 Results

8.3.1 Comparability of the groups

Table 8.1 summarizes baseline characteristics of participants. Apart from weight, BMI and weight circumference, participants did not differ on any of the measures assessed at baseline. All participants attended all training sessions.

Table 8.1: Comparison of baseline characteristics between participants with low and high BMI

Variables	Low BMI Group (n=23) (Mean±SD)	High BMI Group (n=25) (Mean±SD)	t-value	p- value
Age (years)	14.9 ± 0.8	14.92± 0.9	0.100	0.920
Height (cm)	159.0 ± 6.7	157.7 ± 7.0	0.650	0.520
Weight (kg)	52.7 ± 7.4	72.1 ± 15.5	-5.575	0.001
Body mass index (kg/m ²)	20.8 ± 2.3	28.9 ± 5.2	-7.070	0.001
Waist circumference (cm)	73.2±7.9	89.9±11.7	-5.731	0.001
MABC-2 Total Standard Score (SS)	8.7 ± 1.6	9.0 ± 1.9	-0.670	0.510

Abbreviation: MABC-2-Movement Assessment Battery for Children second edition, SS-Standard Score

8.3.2 Balance

Both groups showed improved performance on the MABC-2 balance component score [F (1,46) =4.185, p=0.047]. Similar trend was evident for the Yoga balance test [F (1,46) =8.071, p=0.007] (Table 8.2). Due to a ceiling effect on the balance item of the MABC-2, participants with low BMI had no room for further improvement compared to the high BMI group (mean balance score was 10.9 and maximum score was 11).

8.3.3 Running, speed and agility

With regards to running speed and agility, we observed improved performance for both groups on the BOT-2 running speed and agility sub-set scale score [F (1,46) = 126.857, p=0.001] (Table 8.2). However, compared to the girls with high BMI, participants in the low BMI group had greater improvements on two sub-items; stepping sideways over a balance-beam task [Interaction Time x Group: F (1,46) =4.345, p=0.043, $\eta^2=0.088$], and the two-legged side hopping [Interaction Time x Group: F (1,46) =6.784, p=0.012, $\eta^2=0.129$].

8.3.4 Aerobic and anaerobic power

Though aerobic power improved for both groups (Table 8.2), girls with low BMI again had greater changes on the shuttle run test [Interaction Time x Group: $F(1,46) = 4.293$, $p=0.044$, $\eta^2 = 0.085$]. In addition, both groups demonstrated significant gains in anaerobic power; mean power [$F(1,46) = 9.925$, $p=0.003$], peak power [$F(1,46) = 5.344$, $p=0.025$]. There were no differences in the improvements in anaerobic power between the groups.

Table 8.2: Intervention effects among low (n=23) and high BMI (n=25) groups

Variables	Low BMI Group		High BMI Group		Intervention effects		
	Pre (Mean±SD)	Post (Mean±SD)	Pre (Mean±SD)	Post (Mean±SD)	F	P	η ²
Balance (MABC-2 balance test & Yoga balance task)							
MABC-2 Balance (SS)	10.4±1.9	10.9±1.8	9.1±2.7	10.2±2.3	4.185	0.047	0.083
Mean Yoga score	37.5±7.2	41.4±5.8	33.3±11.2	36.5±7.8	8.071	0.007	0.149
Running, speed and Agility (BOT-2 subtest 6)							
Shuttle run score (s)	9.0±1.3	8.3±0.8	9.6±1.3	9.2±1.2	9.526	0.003	0.172
Stepping sideways over a balance beam score#	33.1±9.1	64.8±6.4	32.7±9.8	57.6±8.3	300.879	0.001	0.870
One-legged stationary hop score	37.1±5.5	40.9±5.9	37.8±3.6	38.4±4.6	5.784	0.020	0.112
One-legged side hop score	29.5±8.7	37.2±4.5	27.9±7.2	33.1±6.1	36.403	0.001	0.442
Two-legged side hop score#	32.6±5.8	40.3±6.5	32.8±4.1	36.4±4.3	49.593	0.001	0.519
Running & agility total scale score	37.6±3.6	43.6±2.3	36.6±3.0	41.3±2.7	126.857	0.001	0.734
Aerobic power							
20m shuttle run test (level)#	2.6±1.4	3.8±1.4	2.0±1.0	2.2±1.1	9.927	0.003	0.177
Mean six-minute walk distance (m)	434.3±58.3	518.6±63.7	444.6±68.7	491.1±61.2	28.425	0.001	0.382
Anaerobic power							
MPST-Mean Power (Watts)	223.6±92.3	319.3±147.1	286.2±119.1	342.5±189.2	9.925	0.003	0.177
MPST-Peak Power (Watts)	336.5±128.3	440.9±227.5	460.5±282.7	537.8±347.5	5.344	0.025	0.104

Time by Group Interaction effects significant at p<0.05, MABC-2-Movement Assessment Battery for Children, second edition, BOT-2-Bruininks-Osteretsky Test of Motor Performance, second edition, s-seconds

8.3.5 Pattern of intervention effects

Overall, there were significant improvements in fitness performance in both groups. However, girls with a low BMI had larger changes in performance compared to peers with a high BMI as illustrated in Figure 8.2. The z-scores used in Figure 8.2 below were based on the average improvement of all participants, which was defined as zero. This implies that negative values represent improvement that is less than the mean.

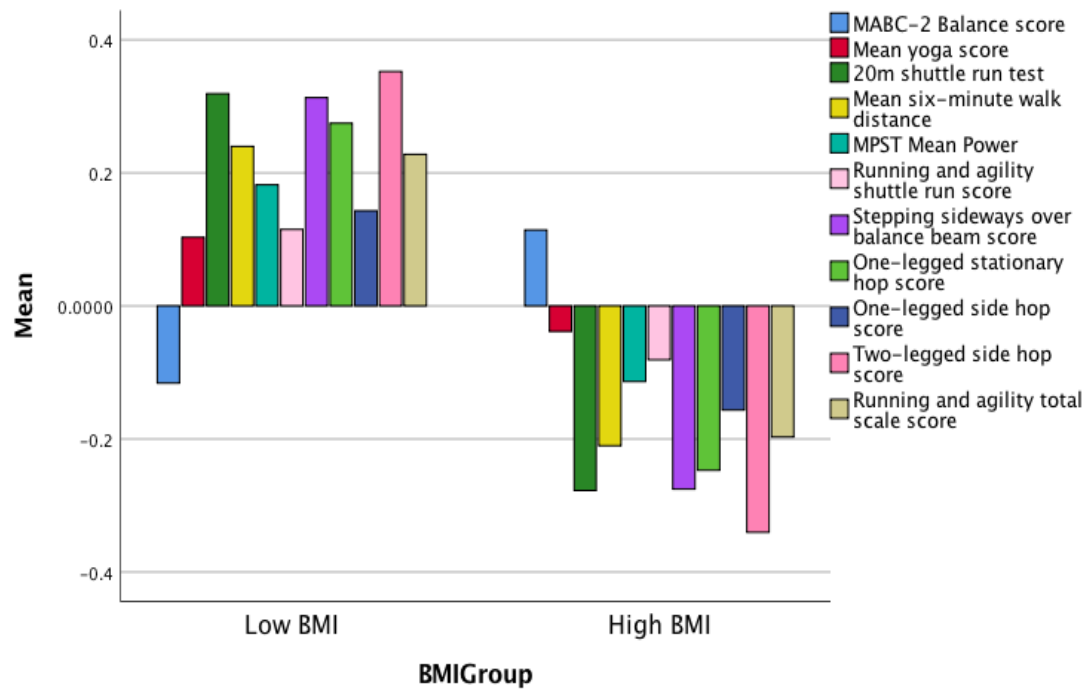


Figure 8.2: Pattern of changes in the z scores of outcomes after training

8.4 Discussion

This study sought to determine if adolescent girls with a low and high BMI would respond differently to the same exercise protocol. In general, both groups demonstrated large improvements in all outcomes over time, with some very large effect sizes (mean η^2 0.33, range 0.87-0.08). However, with the exception of the balance item on the MABC-2, girls with a low BMI showed larger changes in fitness performance than those with a high BMI. Importantly, the low BMI group demonstrated significantly larger changes in performance scores on the hopping and running tasks as compared to peers with a high BMI. Our findings confirm the morphological constraint hypothesis [13] indicating that children with a high BMI have greater challenges in performing tasks requiring medial-lateral movements or forward propulsion. In addition, the low levels of aerobic power observed in girls with a high BMI could be explained by increased metabolic costs associated with running in this group [18]. As can be seen, both groups improved at similar rates on the walking task (6MWT) but showed different changes in performance on running, although both activities are aerobic in nature. Further, it seems girls with a high BMI may need to generate greater muscle power to enhance their speed to be able to succeed in everyday motor actions as compared to those with a low BMI. Girls with a high BMI had more power compared to their peers with a low BMI at baseline but were slower on the BOT-2 shuttle run test. This may confirm the negative impact of the high energy cost on physical performance in this group.

Our results show that improvements in fitness performance following task-oriented functional training were less on some outcomes among female adolescents with high weight status. As predicted, changes in agility and performance on the 20mSRT differed between the two groups. Specifically, we found a significant difference in performance on two running and agility items; stepping sideways over a beam and two-legged hopping. These tasks seem to be very difficult for children with excess body mass due to the reduced ability of these individuals to restore medial-lateral deviations as compared to peers with BMI. Surprisingly we observed no differences in changes in balance between the groups. This might be explained

by the ceiling effect of the test. In addition, it does appear that excess weight in itself is not the problem when it comes to the performance of skilled actions in static positions. The real challenge as shown by the data is that girls with a high BMI find it harder to move and to restore their balance while moving. Therefore, the impact of excess weight on functional performance is far less in stationary postures. Since movement problems encountered in everyday life are unpredictable, it may be necessary to train girls with overweight and obesity to be able to overcome motor challenges in situations requiring greater displacement of the body or faster changes in direction. As a result, programmes should be adapted to provide them with the skills required to deal with the specific functional problems that they face on a daily basis.

The fact that both groups improved on all outcomes confirms the fitness benefits of exercise training [45]. However, girls with a high BMI lagged behind girls with a low BMI particularly in weight-bearing tasks. Plausible explanations include increased mechanical load and inertia. In addition, increased body mass poses greater challenge to tasks that require high speed demands and/or fast directional changes [45]. As such, girls with a high BMI would require greater resources to control the additional body mass to be able to successfully perform these tasks.

The positive results of this study may be explained by nature of the intervention. Basically, the intervention consisted of tasks that were progressively adapted to participants' physical performance. Also, activities such as jumping, and running were not included in the protocol due to participants' poor performance on the shuttle run test at baseline. In addition, the pattern of responses observed in the present study and the level of attendance could be attributed to the strategies employed during the planning and implementation of the intervention. The protocol was designed to be enjoyable, and meaningful (involved the use of familiar tasks). Besides, the intervention was administered in a collegial atmosphere that promoted positive social interactions. Secondly, task complexity was gradually increased over time taking into account participants' increased performance levels.

A limitation of this study is that we could not assess the physical activity levels of participants due to logistical constraints. Due to the multi-component nature of the intervention, we were unable to identify the specific element of the intervention that contributed to the changes that were seen. Although the assessors were blinded to pre and post data, it was still possible for them to identify participants' group allocations by looking at their body size. Due to logistical constraints, we were unable to measure maturity status of participants. Future studies should assess maturation to determine its impact on these fitness outcomes. Though BMI is not considered as an accurate measure of body composition, it has been proven to be a useful indicator in several studies. Given that differences in height were non-significant between the two groups, the use of BMI to classify participants may be appropriate.

8.5 Conclusions

Our results indicate task-oriented functional training is capable of improving fitness performance in female adolescents with a low and high BMI. However, compared to girls with a high BMI, participants with a low BMI demonstrated greater changes in performance on most outcomes. Importantly, changes in performances on agility tasks and those requiring fast directional turns were significantly different between girls with a low and high BMI. These findings have implications for planning and designing interventions for children with a high BMI. It may be important for interventions targeting children with a high BMI to focus on improving efficient coordination of body segments, especially on tasks requiring greater displacement of the COM and faster directional changes. Interventions specifically designed to train whole-body agility skills, muscle power and running ability may be promoted as key aspects of fitness promotion programmes in populations identified as overweight or obese.

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PART III: Discussion and Conclusion

CHAPTER 9: Discussion and Conclusion

9.1 Introduction

This chapter discusses the major findings of the studies in this thesis. In addition, the chapter will provide practical implications of findings and highlight the strengths and limitations of this research. Finally, future research directions and conclusions drawn from the results will be summarised.

9.2 Summary of main research findings

The research evaluated the efficacy of motor-based interventions among adolescent girls with low socio-economic status. Participants were drawn from a high school located in a township community of Cape Town, South Africa. A total of one hundred and fifty-one girls met the eligibility criteria and were subsequently recruited into the first part of this two-phased project. Phase 1 involved testing of participants to gain insight into their physical and psychological health problems. Data collected at this stage were reported in Studies 1 and 2. In the second phase, different interventions were tested to determine their efficacy in separate subsamples with defined characteristics. A summary of the key findings of each of the studies has been presented in table 9.1.

Table 9.1: Summary of major findings of each study in this thesis

Study number	Study title	Study objective	Main research findings
1	Relationship between body mass index, cardiorespiratory and musculoskeletal fitness in South African adolescent girls.	To determine the relationship between body mass index, cardiorespiratory and musculoskeletal fitness among South African adolescent girls living in low-income communities.	<ul style="list-style-type: none"> ▪ High body mass index correlates with decreased cardiorespiratory fitness and poor musculoskeletal fitness. ▪ Girls with increased BMI had low cardiorespiratory fitness. ▪ Girls with increased BMI had decreased lower extremity muscle strength.
2	Association between body mass index, motor competence and self-efficacy in adolescent girls.	To determine if motor competence and self-efficacy, are significant predictors of body mass index in adolescent girls.	<ul style="list-style-type: none"> ▪ Higher levels of motor competence are associated with greater self-efficacy and low BMI. ▪ Balance skills, adequacy in physical activity and enjoyment in physical education are major predictors of BMI.
3	“Not just another Wii training” – a graded Wii protocol to increase physical fitness in female adolescents with probable developmental coordination disorder.	To examine the impact of a graded Wii Fit protocol in adolescent girls with probable developmental coordination disorder.	<ul style="list-style-type: none"> ▪ Adolescent girls with probable developmental coordination disorder had increased aerobic and anaerobic fitness after receiving 14 weeks of a graded Wii intervention. ▪ Participants reported high

			enjoyment and low ratings of perceived exertion over time.
4	The efficacy of two activity-based interventions among adolescents with developmental coordination disorder.	To evaluate the efficacy of two activity-based motor interventions among adolescent girls with developmental coordination disorder.	<ul style="list-style-type: none"> ▪ Participants demonstrated improvements in motor competence, muscular strength, running and agility performance, predilection for physical activity and overall self-efficacy at the end of the interventions. ▪ There were no group differences in any of the outcomes.
5	Benefits of activity-based interventions among female adolescents who are overweight and obese.	To compare intervention effects of two exercise protocols among adolescent girls who are overweight and obese.	<ul style="list-style-type: none"> ▪ Following 14 weeks of intervention, both groups showed significant but comparable improvements in aerobic and anaerobic fitness, motor competence, lower extremity muscular strength, and adequacy in physical activity. ▪ Both groups reported high enjoyment scores for the interventions. ▪ However, overall self-efficacy did not improve over time for any of the groups.

6

Effects of task-oriented functional training on fitness performance in female adolescents with varying weight status.

To determine whether changes in fitness performance following exercise training would differ between adolescent girls with low and high BMI.

- There was no time by group interaction effects on any of the outcomes.
 - Both groups (low and high BMI girls) demonstrated improvements in outcomes over time.
 - Overall, changes in fitness performance were greater in girls with low BMI compared to those with BMI.
 - Specifically, low BMI girls showed larger changes in aerobic capacity, sideways stepping and two-legged hopping performance than those in the high BMI group.
-

9.3 Interpretation of research findings

This section attempts to provide answers to the research questions that were formulated *a priori*;

1. Is there a relationship between BMI, motor competence, physical fitness and self-efficacy among female adolescents?
2. Can a graded Wii Fit training increase physical fitness among female adolescents with probable DCD?
3. Will participation in activity-based motor interventions result in positive changes in motor competence, physical fitness and self-efficacy among female adolescents with DCD?
4. Will participation in activity-based programmes result in positive changes in motor competence and physical fitness among female adolescents who are overweight and obese?
5. Will there be differences in changes in fitness performance between female adolescents with high and low BMI after participating in functional exercise training?

9.3.1 Association between Body Mass Index, Motor Competence, Physical Fitness, and Self-efficacy

The aim of the initial part of the thesis (Phase 1) was to examine the relationship between BMI, motor skill competence, physical fitness and self-efficacy. Secondly, the study compared motor competence, physical fitness and self-efficacy among BMI groups (i.e.: normal weight, overweight and obese). The results showed an inverse relationship between BMI, cardiorespiratory and musculoskeletal fitness in this cohort. Their BMI was also negatively associated with motor competence and self-efficacy among the adolescent girls. As expected, there were significant differences in motor competence, self-efficacy and components of physical fitness (i.e.: cardiorespiratory and musculoskeletal fitness) among normal weight, overweight and obese adolescent girls. Findings of this study demonstrated clear differences in the measured physical and psychological variables between the three groups. Therefore, girls classified as normal weight had higher levels of motor skill competence, cardiorespiratory and musculoskeletal fitness, as well as

self-efficacy than overweight and obese peers. These findings agree with previous studies that investigated the relationship between BMI and these constructs and documented differences in motor skills, physical fitness and perceptions of physical abilities among normal weight, overweight and obese children and adolescents [1-18]. Prior research showed an inverse relationship between BMI, cardiorespiratory and musculoskeletal fitness in children and adolescents [1-5]. In addition, motor competence, and measures of psychological health such as self-esteem, perceived motor competence and self-efficacy have been shown to be negatively correlated with BMI [6-17]. Growing evidence has also highlighted the differences in motor skills, fitness and psychological factors in children and adolescents with varying weight status [6,8,9,10,12,13,16].

Moliner-Urdiales *et al.* [19] investigated the relationship between physical fitness, central and total body fat among 363 Spanish adolescents using both sophisticated [dual energy x-ray absorptiometry (DEXA)] and simple assessment techniques (such as BMI). The authors reported that cardiorespiratory fitness and lower body strength were negatively associated with body fat after controlling for age, puberty status and physical activity. They also found that participants with high BMI had greater upper extremity strength than those with normal-weight. Malina *et al.* [20] examined the association between fatness, motor and health-related fitness in Belgian girls aged 7-17 years and reported that larger body size was negatively associated with cardiorespiratory fitness, balance, strength and speed. Another study showed that obese Flemish youth demonstrated poorer performance on tests requiring propulsion of the body than non-obese counterparts [2]. However, the obese group had greater grip strength than non-obese peers.

The relationship between BMI, motor competence, physical fitness and self-efficacy may be explained by physiological and mechanical factors [21,22]. From the physiological perspective, excess weight is believed to affect musculoskeletal form and function during ontogenic development [23]. In addition, growth and

maturation influences changes in physical fitness, physical activity and body composition [22]. High BMI is associated with impairments in musculoskeletal structures and abnormal mechanics of body parts [23], resulting in muscle deconditioning and decreased strength [21]. From a mechanical perspective, it has been shown that the inertia properties of additional mass create more biomechanical inefficiencies in overweight and obese children, which in turn limits muscular function and lowers cardiorespiratory endurance [21]. According to the biomechanical constraints theory [24], motor competence is an emergent property that is influenced by the physical and psychological properties of an individual, task requirements and environments conditions. This implies that changes in each of these would impact the evolution of motor skills. Since body weight is considered as part of the physical characteristics of the individual, changes in weight (overweight and obesity) have a high tendency of influencing motor competence, and vice versa. Another explanation for these observations may relate to the high energy cost required by individuals with excess weight to transport their bodies during anti-gravity activities. Moreover, low levels of physical activity in children with high BMI could also explain the results. Mamabolo *et al.* [25] reported that girls in South African townships are less physically active than those with normal weight.

The associations between BMI, physical fitness, motor skill competence and self-perceptions found in this study have several implications in this context. First, it emphasizes the need for early screening and intervention for motor skill development and fitness promotion in girls schooling in low-income contexts of South Africa. Secondly, it may be extremely useful for schools to allocate more hours for structured physical education with a special focus on promoting healthy weight status, motor competence, fitness and psychological well-being. Finally, interventions for adolescent girls with high BMI should include activities that would enhance motor skills and fitness as key elements. These may help alleviate the burden of excess weight gain and facilitate participation in PA.

9.3.2 Efficacy of Motor Interventions in Female Adolescents with DCD

Motor coordination problems show persistence through adolescence and adulthood [26,27]. Yet, we still know little about the effectiveness of interventions among adolescents with DCD. For children and adolescents living in low-income settings, the consequences of DCD on physical, psychological and social life may be dire since treatment services are virtually unavailable. In Chapters 5 and 6, two studies that investigated the impact of different programmes in female adolescents with DCD were presented. Results showed that motor programmes are capable of addressing deficits in impairments, activities and participation. Specifically, the outcome of the pilot study indicated that a graded Wii Fit training could improve specific aerobic and anaerobic fitness in this population. In addition, significant enjoyment was reported by the majority of the participants. Similarly, Chapter 6 demonstrated that activity-based interventions elicit significant results in female adolescents, with DCD especially, in the areas of motor competence, muscle strength, agility performance, predilection for physical activity and overall self-efficacy. However, there were no statistically significant differences between the two interventions on any of the outcomes. These findings reveal that task-oriented functional training and AVGs may be equally effective and feasible to implement in low-income schools. The choice of either of the two protocols may be based on personal preferences or available resources. Since these interventions require relatively little resources, each of them represents a cost-effective strategy for improving motor skill performance, and physical fitness among high school girls with motor difficulties.

The results, in part, support reports of previous studies that examined closely related programmes [28-30]. Ferguson *et al.* [28], compared the effects of Wii Fit training and Neuromotor Task Training (NTT) in elementary school children with DCD. The researchers found improvements in most outcomes for the two groups. However, children who participated in the NTT had significantly greater improvement in motor competence (effect size (ES): 4.3), functional strength (0.97) and cardiorespiratory fitness (1.15) compared to the Wii Fit group. The ES

(0.5) of motor competence for the Wii study of Ferguson *et al.* [28] was lower than what was reported in the present study. The results of the current study showed improvements in motor performance (ES $d=2.1$), isometric strength, functional strength and cardiorespiratory fitness over time for both groups, but there were no between group differences. Another important finding was that participants in both groups demonstrated improvements in self-efficacy. This is promising given that children with DCD are known to experience more psychological problems than typically developing peers. The differences in results between the previous research and the current investigation could be due to variations in intervention design factors and differences in age of the participants. While, participants in the present study recorded 630 minutes (45min/per week over 14 weeks) on tasks, the children who participated in the Ferguson *et al.* [28] study, had 540 minutes (30 min per session, 3 times per week 6 weeks) on the Wii Fit playing a free choice of thirteen games throughout the training period without any additional loading or grading. The additional loading of tasks introduced in the current study might explain why participants in this study had a greater ES than those of Ferguson *et al.* [28]. Additionally, the objective of the interventions in the work by Ferguson *et al.* [28] was to increase motor skill competence. In the present study, we focused on motor skills, physical fitness and related outcomes. Finally, the present study focused on older girls whereas the earlier paper included elementary school children. It is easier to motivate and engage younger children than female adolescents.

Although this study did not investigate the mechanisms underlying the changes observed, neural adaptations [30-35], performance factors and intervention characteristics [28] might be responsible for the changes in outcomes. It is acknowledged that changes in the nervous system (i.e. changes in cortical re-organisation, increased motor unit recruitment, increased firing frequency, and increased synchronization) could explain short-term gains in motor performance and strength following training [30-35]. Though this may be speculative, it is possible that the loci for neural adaptations to skill acquisition and strength and

conditioning may share common characteristics. It is also possible that improvements in coordination associated with increased neural drive stimulated performance leading to improved strength and coordination [29,34]. Secondly, the use of design factors such as variation, progressive overload and specificity of training may have contributed to the acute improvements in performance. These strategies may be considered as effective elements of the interventions. Though, it was impossible to identify the specific element that was responsible for the significant results, the inclusion of various activities, games and motor learning strategies such as feedbacks that fostered for engagement and voluntary participation. It was not surprising that high levels of compliance and retention were recorded. Increased enjoyment of the interventions could potentially be a mediating mechanism behind the changes in performance. Typically, progressive adjustments of exercises impair motivation and performance. However, in the case of the current study, there was no reduction in motivation or enjoyment as confirmed by the high enjoyment scores. From specificity of the training viewpoint, the improvements in strength and conditioning were expected. The tasks, games and external loads that were incorporated into the interventions were meant to induce adaptations in strength and conditioning.

With these results, this study has demonstrated how simple tasks and off-the-shelf AVGs could be manipulated to address movement difficulties. The outcome of this study corroborates the existing evidence about the effectiveness of functional programmes in the management of DCD.

9.3.3 Efficacy of Motor Interventions in female Adolescents who are overweight and obese.

Exercises have been identified as promising strategies for preventing and treating obesity in children and adolescents [36]. However, there is a paucity of data on the effectiveness of exercises as tools for promoting motor skill competence and fitness in female adolescents. The results of the study presented in Chapter 7 of

this thesis suggest that activity-based programmes provide motor skills and fitness benefits among adolescent girls with overweight and obesity.

Our findings demonstrate that activity-based programmes elicit similar but significant effects on motor coordination, physical fitness and self-efficacy. In particular, we observed that overweight and obese girls who received either task-oriented functional training or Wii fit training increased their motor coordination, aerobic and anaerobic fitness, lower extremity strength and adequacy in physical activity over time. There were no differences observed on outcomes between the two groups. Again, this finding demonstrates the multiple benefits of task-oriented training. Previously, it was assumed that task-oriented training could only benefit neurologically impaired people. However, this thesis has shown that such interventions are effective in overweight or obese populations. To our knowledge, this is one of the first studies to compare the effects of AVGs and functional exercises among overweight and obese girls and demonstrated promising results. It may be essential for people working with overweight and obese children to consider these interventions in promoting motor performance in obese children and adolescents. The advantage of this approach to intervention is that it requires fewer resources and can accommodate for specific needs of the child with overweight or obesity. Clearly, our data show that these interventions are enjoyable and attractive to girls with a high BMI.

Our findings are consistent with previous studies showing increased motor competence and improvements in physiological health among obese youth following exercise training [36-41]. Studies have suggested that physical exercise may be effective in increasing motor skills [40] and improving cardiovascular fitness and muscle strength in children and adolescents with obesity [37,42-44]. Given that overweight and obese children exhibit poor movement skills [45-47], increasing motor skills and fitness help them improve their physical skills.

As indicated earlier, a combination of factors might explain the effects of the interventions. Theoretically, the multi-component nature of the interventions may

be responsible for the improvements seen in various outcomes. Both interventions involved multiple components as evident by the variety of activities used. In addition, the task difficulty was gradually increased over time in both interventions. Further, strategies such as feedback, encouragement and support from peers and instructors might have contributed to the success of the programmes. It is probable that increments in neural drive, increases in coordination and performance adaptations might potentially explain these changes. Collectively, these strategies might have enhanced perceptions of competence, and enjoyment. Children are more likely to engage in activities that are enjoyable [48] and provide opportunities for success. In summary, our results demonstrate that adaptable exercises are capable of providing numerous physical health benefits in high school girls and could be promoted as options for physical training in low-income schools.

9.3.4 Changes in fitness performance following a functional training intervention among female adolescents with low and high BMI.

In Chapter 8, we described a study that looked at changes in fitness performance among adolescent girls with varying weight status. It was observed that adolescent girls with different weight status experience positive changes in fitness parameters after participating in exercise training. However, changes in fitness performance were larger in participants with low BMI compared to those with higher BMI.

Anatomical and physiological differences in exercise capacity and motor control between these groups may explain the observations. The mechanical and energy requirements of anti-gravity and balance tasks may make it harder for girls with high BMI to be as successful as peers with low BMI on tasks with high stability and agility demands [21]. These findings suggest that it may be important to prescribe different programmes to girls with different weight status. Girls with high BMI may be better prepared to catch up with their peers who have low BMI when they are exposed to programmes that address abnormalities in body mechanics.

The fact that the two groups respond differently to the same training should be an important consideration when planning and designing interventions for overweight and obese populations.

9.4 Consolidating the findings to develop a model to explain emerging neurobehavioural problems among youth in low-income settings.

Based on the several lines of evidence derived from this thesis, it is unequivocal that motor performance of high school girls in low socio-economic environments is influenced by multiple factors. Specific factors that are more influential in this cohort and how interventions can be used to address these issues have been provided in the model below (Figure 9.1). From the data in this thesis, it can be postulated that poor motor skills, excess weight, poor psychosocial factors and low physical fitness and activity may interact to produce deficits in movement behaviour that is being referred to as an “Acquired Movement Deficiency Syndrome” (AMDS). The AMDS can be defined as a group of “physico-psychosocial” conditions (decreased motor coordination, high BMI, poor self-efficacy, and low fitness or activity) that lowers motor ability and increases one’s risk for adverse health complications. Though the origin of this syndrome was not investigated in this thesis, the data shows that individuals with high BMI are more likely to have poor motor skills, which in turn could lead to low fitness and activity and decreased self-efficacy. In a similar vein, people with poor motor skills tend to avoid physical activity, thereby developing excess weight, which could impair their perceptions of competence. It appears that the clusters of symptoms that form this emerging syndrome being described in this section are usually acquired not inborn. The fact that AMDS is an acquired syndrome indicates it may be heavily influenced by behavioural and environmental factors, and not so much by genetics. More importantly, the present data provides evidence showing that AMDS might be preventable and treatable but could persist (if not treated). The big questions are: when should this emerging problem be prevented (developmental time)? where in its evolution process should we tackle the locus of attention in terms of symptoms? and which setting should prevention and treatment be provided? These are important issues that need further research. However, based on the data obtained from this thesis, it is suggested that preventative efforts

should be initiated to prevent poor motor skills and social exclusion and must involve peer and family support as well as support from health and education professionals and stakeholders. It may be advantageous to stop children with low motor skills from lagging behind their peers, prevent isolation and reduced participation so as to ensure healthy weight. Further, interventions should be made available to all those with at least one of these symptoms following identification or assessments. As shown in this thesis, multi-factorial interventions are capable of producing acute improvements in physiological and behavioural states. Additionally, such interventions may be useful for enhancing social inclusion (active participation in social roles) and/or protecting against long-term health complications. Interventions that are multi-faceted in nature such as the ones used in this study are more likely to be successful. It may be helpful to develop intersectorial strategies integrating the expertise of government officials, health workers, education experts, parents and community leaders for preventative and intervention efforts. More research is needed to explore the effectiveness of these measures on both a short and long-term basis.

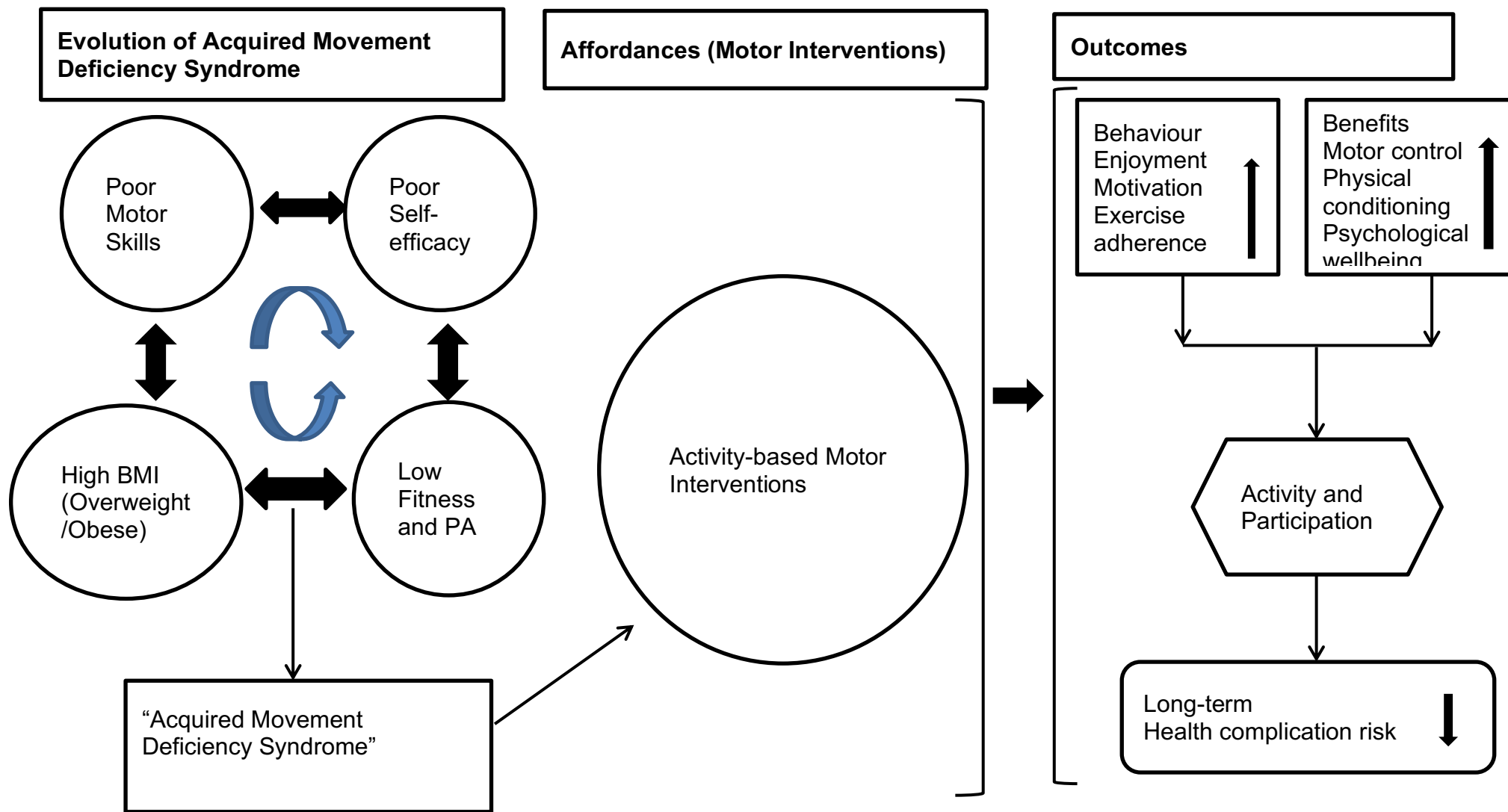


Figure 9.1: Proposed model for the evolution of the “Acquired Movement Deficiency Syndrome” (AMDS)

9.5 Strengths and limitations of this research

The studies in this thesis were conducted with the goal to evaluate interventions and to highlight the need for more translational intervention research in naturalistic settings. The primary aim was to provide evidence to support the need for a shift in focus from the current generic approach of exercise prescription towards adaptable interventions particularly in resource-constrained settings. The use of a variety of methods and instruments allowed us to generate important lines of evidence that have significant relevance for research, policy and school health practices in contexts and populations that have historically received little research attention. Another unique strength is that many of the studies (Chapters 3,4,6,7 and 8) had relatively large samples. Further, two of the developed interventions reported in this thesis used randomised controlled designs, which is an approach that is deemed to have a high level of rigour in experimental research. In addition, the interventions were developed on the basis of evidence-based recommendations. For example, the interventions tested in this thesis were grounded in the constraints-based theory, a framework that has been extensively studied. Finally, many objective measures (including the MABC-2 test, handheld dynamometer, functional strength measurement, and the 20-metre shuttle run test) with relevant validity and reliability were used in this research.

Despite these strengths, several methodological limitations need to be identified. First, the study was conducted in one setting and involved only female adolescents. This implies that the findings cannot be generalized to other populations that exhibit different characteristics such as males, and children in high socio-economic environments. Extending the results to female adolescents with similar characteristics would be prudent. However, the conclusions drawn from this thesis cannot be extended to adolescent boys, neither can they be applied to populations in affluent communities. Nonetheless, these findings may be relevant in most deprived communities around the world where resources for promoting health in schools are limited. More specifically, the findings might be

useful to children, parents, schools and health systems within the South African low-income context and other places with limited resources.

Second, variables such as enjoyment of activities and participation in activities of daily living (ADL) were assessed using self-reported measures, and some of them have not been validated. The use of these measures might have affected the results due to possible threats of recall bias and social desirability. However, due to logistical constraints and the fact that this study was intended to develop interventions with high ecological value, the use of subjective measures was not inappropriate. Another limitation relates to the components and structure of the interventions. The two interventions involved multiple components (e.g. dance, motor skills, culturally appropriate games, tasks, environmental adaptations, etc.) and were administered using a variety of strategies (e.g. group-based delivery format, different feedback schemes, progressive overload, etc.). Because of this, it was impossible to identify the specific components that were responsible for the changes observed. Hence, it is unclear if other mechanisms contributed to these results. That notwithstanding, the findings provide first-hand evidence supporting the effectiveness of activity-based interventions for improving motor performance and physical fitness. Another limitation is the lack of follow-up assessments and the absence of a control group in most of the studies reported in this thesis. While the findings add to current knowledge in DCD and childhood obesity research, this thesis has only demonstrated short-term benefits of activity-based interventions. The long-term impact of the interventions is still unknown and further investigations are required to fill this research void.

9.6 Future research directions

This thesis has shown that activity-based interventions can be useful for improving motor competence and physical fitness in older girls. It has also revealed that such interventions are feasible to administer in low-resourced settings. While the findings have practical implications for people who work with girls with poor motor coordination and those with overweight and obesity, this work opens up several

lines of enquiry for further research. Some of these issues have been highlighted in the section that follows.

9.6.1 Is there any causal relationship between BMI, motor competence, physical fitness and self-efficacy among adolescent girls in low income settings?

The association between BMI, motor competence, fitness and self-efficacy in children and adolescents had been demonstrated in previous studies in most developed countries. In this thesis, the nature of the relationship between these factors has been described in a sample of female adolescents. However, because this observation was made using a cross-sectional design, it was not possible to draw causal inferences. There is the need for longitudinal data to establish the causal relationships between these measures. Additionally, future studies should explore the influence of confounding factors such as maturation and gender in the relationship between these factors. Further, the potential mechanisms underlying these relationships should be further investigated.

9.6.2 Will these interventions be effective in different populations and contexts?

As indicated previously, findings cannot be generalised to other populations because this study was limited to only girls. Therefore, it is necessary to investigate the effectiveness of these interventions in different populations or ethnic groups.

9.6.3 What is the minimum dosage of interventions that is more likely to deliver optimal improvements in adolescent girls with DCD and those with overweight and obesity?

The main findings from two intervention studies in this thesis suggested that activity-based interventions are efficient among adolescent girls with motor problems. Additionally, task-oriented interventions have been shown to be effective in improving motor performance in children with DCD. Our results seem to lend support to current evidence in the literature. Follow up work should now focus on determining appropriate dosage parameters (e.g. frequency, intensity,

types of exercises and duration) required to produce positive effects on motor coordination and physical fitness among adolescent girls. It may also be needful to investigate questions relating to when to intervene (early, middle or late adolescent), in which environment it should take place and who should intervene using these interventions.

Since we have demonstrated that both task-oriented functional training and Wii Fit training are feasible and effective in overweight and obese adolescent girls, more work is needed to establish minimum dosage requirements that would produce optimal and long-term benefits. Investigations into appropriate volumes of these interventions including intensity, frequency and duration are urgently needed to inform intervention planning and development.

9.6.4 What components of activity-based interventions are responsible for the improvement in outcomes observed in this demographic group?

Multi-component interventions are thought to be more effective than those with singular elements. The interventions presented in the various studies of this thesis consisted of several elements making it difficult to ascertain specific components that were responsible for the changes in performance. It is therefore necessary for future research to investigate the specific components that contributed the most to the improvements observed in the various groups of girls.

9.6.5 Are the improvements in outcomes observed for task-oriented functional training and graded Wii Fit training in adolescent girls sustainable?

The short-term effects of task-oriented functional training and graded Wii Fit training among adolescent girls in low-income settings were reported in this thesis. Future studies should demonstrate the long-term effects of these interventions. This kind of implementation would help clarify the stability of improvements in outcomes reported in the various studies in this thesis. This is an important subsequent step as little is known about the long-term effects of multi-component interventions such as those used in the current study.

9.7 Conclusions

This research investigated the association between BMI, motor competence, physical fitness and self-efficacy, and tested the effects of exercise programmes among adolescent girls. Overall, BMI was found to be negatively associated with each of the other variables in this cohort. However, it was impossible to determine the directionality of these relationships. With regard to the effectiveness of the interventions, promising results were obtained. Generally, it was demonstrated that the task-oriented functional intervention and Wii Fit training may yield significant results in motor competence and fitness in girls with DCD and those who are overweight and obese. However, there were no group by time intervention effects among the two groups in the different sub-samples (DCD, overweight or obese girls). This observation suggests that motor-based interventions developed and implemented based on the constraints-led approach are efficacious in female adolescents with motor problems as well as those with excess weight. Further, the study revealed differential intervention effects between adolescent girls with low and high BMI after they have received the same form of training. Participants with low BMI demonstrated larger changes in fitness performance as compared to peers with high BMI. The data showed that girls with high BMI improve less in balance tasks and activities requiring rapid directional changes than those with low BMI.

The study makes significant contributions to the extant literature by showing the connection between BMI, motor control, physical fitness and self-efficacy in a high-risk group that has received little scientific attention. Importantly, evidence derived from this research supports the feasibility and efficacy of motor interventions in addressing motor problems and obesity-related impairments in high school girls residing in low-income settings. This thesis has generated valuable knowledge that can be used to improve the physical health of female adolescents. In addition, this study provides empirical evidence on interventions that can be adopted to promote motor development and enhance fitness in schools within the South African low-income context and other communities with similar characteristics.

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Appendices

Appendix A: Details of the graded Wii protocol administered over 14 sessions

Week #	Names of the selected games	Number of repetitions per session	Game adaptations
1	Jogging (short distance)	2	Familiarization phase. No add-on
	Single leg extension	10	
	Lunge	1	
	Hula hoop	1	
	Soccer heading	1	
	Ski slalom	1	
	Warrior	1	
	Half moon	1	
2	Jogging (short distance)	2	Familiarization phase. No add-on
	Hula hoop	2	
	Rowing squat	1	
	Torso twist	1	
	Penguin slide	1	
	Perfect 10	1	
	Obstacle course	1	
	Sun salutation	1	
3	Jogging (short distance)	2	Familiarization phase. No add on
	Rhythm cycling	2	
	Single leg twists	10	
	Jack knife	1	
	Boxing	1	
	Penguin slide	1	
	Table tilt	1	
	Warrior	1	
4	Jogging (short distance)	2	Familiarization phase. No add on
	Basic steps	2	
	Lunge	1	
	Rowing squat	10	
	Boxing	1	
	Soccer heading	1	
	Penguin slide	1	
	Half moon	1	
5	Jogging (short distance)	2	Familiarization phase. No add on
	Island cycling Short	2	
	Basic steps	10	

	Single leg extension	1	
	Torso twists	1	
	Ski slalom	1	
	Perfect 10	1	
	Sun salutation	1	
6	Jogging (Long distance)	2	The games were graded by making participants carry a backpack with 1 kg load while gaming. The height of the balance board remained unchanged.
	Hula hoop	2	
	Rowing squat	2	
	Single leg twist	10	
	Obstacle course	2	
	Penguin slide	2	
	Half moon	2	
	Tree	2	
7	Jogging (Long distance)	2	The games were graded by making participants carry a backpack with 1 kg load while gaming. The height of the balance board remained unchanged.
	Basic steps	2	
	Kung Fu	2	
	Single leg extension	10	
	Table tilt	2	
	Soccer heading	2	
	Warrior	2	
	Half moon	2	
8	Jogging (Long distance)	2	The games were graded by making participants carry a backpack with 1 kg load while gaming. The height of the balance board remained unchanged.
	Basic steps	2	
	Rowing squat	2	
	Single leg twist	10	
	Penguin slide	2	
	Obstacle course	2	
	Tree	2	
	Palm tree	2	
9	Jogging (Long distance)	2	The games were graded by making participants carry a backpack with 1 kg load while gaming. The height of the balance board remained unchanged.
	Hula hoop	2	
	Rhythm boxing	2	
	Single leg extensions	10	
	Lunge	2	
	Sun salutation	2	
	Palm tree	2	
	Just Dance	1 song	
10	Jogging (Long distance)	2	The games were graded by making participants carry a backpack with 1 kg load while gaming. The height of the balance board remained
	Hula hoop	2	
	Torso twists	2	
	Table tilt	2	

	Ski slalom	2	unchanged.
	Sun salutation	2	
	Half moon	2	
	Just Dance	3 songs	
11	Jogging Long	2	The load was increased from 1kg to 3kg. Each participant carried the new load (3kg) during gameplay. Also, the height of the balance board was raised with a 25cm high elevation (wooden platform).
	Step Basics	2	
	Kung Fu	2	
	Rowing squat	2	
	Single leg extension	20	
	Obstacle course	2	
	Half moon	2	
	Just Dance	5 songs	
12	Jogging (Long distance)	2	The load was increased from 1kg to 3kg. Each participant carried the new load (3kg) during gameplay. Also, the height of the balance board was raised with a 25cm high elevation (wooden platform).
	Step Basics	2	
	Rhythm boxing	2	
	Rowing squat	20	
	Soccer heading	2	
	Ski slalom	2	
	Half moon	2	
	Just Dance	5 songs	
13	Jogging (Long distance)	2	The load was increased from 1kg to 3kg. Each participant carried the new load (3kg) during gameplay. Also, the height of the balance board was raised with a 25cm high elevation (wooden platform).
	Basic steps	2	
	Single leg extension	20	
	Lunge	2	
	Penguin slide	2	
	Tree	2	
	Palm tree	2	
	Just Dance	5 songs	
14	Jogging Long	2	The load was increased from 1kg to 3kg. Each participant carried the new load (3kg) during gameplay. Also, the height of the balance board was raised with a 25cm high elevation (wooden platform).
	Step basics	2	
	Single leg twist	20	
	Table tilt	2	
	Kung Fu	2	
	Sun salutation	2	
	Half moon	2	
	Just Dance	5 songs	

Appendix B: Ethical Approval letter



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee



Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925

Telephone [021] 406 6492

Email: sumayah.ariefdien@uct.ac.za

Website: www.health.uct.ac.za/fhs/research/humanethics/forms

03 May 2016

HREC REF: 232/2016

Dr G Ferguson
Health & Rehab Sciences-
Physiotherapy
Suite F45 Room 78
OMB

Dear Dr Ferguson

PROJECT TITLE: MOVEMENT PROGRAMME TO ENHANCE PHYSICAL FITNESS AND MOTOR COMPETENCE IN GIRLS LIVING IN LOW INCOME AREAS: A RANDOMIZED CONTROLLED TRIAL-PhD-candidate-E Bonney)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 May 2017.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

We acknowledge that the student, Emmanuel Bonney will also be involved in this study.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637

HREC 232/2016

Appendix C: Permission from the Western Cape Education Directorate

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20160331-9099

ENQUIRIES: Dr A T Wyngaard

Mr Emmanuel Bonney
Division of Physiotherapy
Department of Health & Rehabilitation Sciences
Suite F-45, Room 78 Old Main Building
Groote Schuur Hospital
Observatory
7925

Dear Mr Emmanuel Bonney

RESEARCH PROPOSAL: MOVEMENT PROGRAMME TO ENHANCE PHYSICAL FITNESS, MOTOR COMPETENCE IN HIGH SCHOOL GIRLS LIVING IN LOW-INCOME COMMUNITIES OF CAPE TOWN, SOUTH AFRICA

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **18 April 2016 till 30 September 2016**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards. Signed: Dr Audrey T Wyngaard, **Directorate: Research DATE: 31 March 2016**

Appendix D: Informed Consent for Parents/ Guardians in Phase 1

Title: Levels of physical fitness and motor coordination in female learners

Name of student: Emmanuel Bonney (BNNEMM002)

Name of Institution: Division of Physiotherapy, Department of Health & Rehabilitation, Faculty of Health Sciences, UCT.

Name of Supervisors: Dr. Gillian Ferguson, Dr. Theresa Burgess, Professor George Asare, Prof. Dr. Bouwien Smits-Engelsman

Part I: Information Sheet

Introduction

My name is Emmanuel Bonney, a physiotherapist, studying towards a PhD degree at the Division of Physiotherapy, University of Cape Town. We are doing a research on fitness, movement and body composition in young girls living in township communities of Cape Town. This is because it is now known that these girls have low levels of physical activity and carry a greater risk of becoming obese in future. We are asking your permission to allow your child to join our research. This research is likely to provide more information on your child's physical abilities.

Purpose of the Research

Physical inactivity (not doing exercises) and overweight are known health problems of children in South Africa. Physical inactivity leads to poor fitness which affects motor skills. Motor skills are skills that children use to move their bodies and to interact with the world around them. Examples of motor skills are walking, running, hopping, and throwing. We still do not know much about these skills in girls living in low income areas. We want to know more so we can provide better solutions to those who may have any difficulties.

What is involved in the study?

We will check your child's levels of body composition (weight, height etc.), fitness, physical activity and coordination (how skilful she is with movement) by having her perform various tests. Tests will involve simple activities like standing on different platforms, walking and running. We think this will take about 45 minutes and will

be divided into 3 separate visits because we do not want to disrupt your child's school (learning) activities.

During the first visit, your child will be asked to provide personal information such as age, and grade. Your child will also have physical examination including her height, weight, girth (waist size). Your child's physical examination will be done by female physiotherapists or trained research assistants. On your child's second visit, we will ask your child to stand on a wooden beam, walk and run in an open space to know how fit your child is. This will also allow us to know how skilful she is with movement. During her last visit, we will have your child run on a track to see how fit she is. We do not wish to interrupt your child's learning at all. Therefore, we will negotiate with her teachers to perform testing at convenient times. At the end of the study, we will contact you with a letter to tell you about your child's performance.

Participant selection

We are inviting children (females) aged 13-16 years attending high school in Khayelitsha, Cape Town. You are being asked for this permission because your child is a learner in the selected school.

Voluntary Participation

Your decision to allow your child to participate in our research is entirely voluntary. It is up to you to decide whether or not to allow your child to join. You may choose to change your mind later or ask your child to stop participating, even if you agreed earlier, and your child will not be punished in any way. If your child chooses to participate, she will be asked to sign a form to show that she also agreed on her own. Your child may choose to stop participating at any point. If your child stops, she will not be penalised or lose any benefits.

Risks

By participating in this research, it is likely that your child may experience some level of discomfort such as feeling slightly tired during testing or later. Tiredness should disappear few hours after testing. Your child will be allowed enough rest between tests to ensure her safety and comfort. We will also stop the test when necessary to protect your child from any harm.

If something unexpected happens such as falling or injury, we will provide treatment (physiotherapy) at no charge. We will carefully monitor your child and ensure that her welfare is protected. We will also protect your child from others who may pick on her in school. We will always be there to support and provide professional assistance in case of any unexpected situation. We will also provide water and fruit to your child after testing.

Benefits

By participating in this study, your child will have the following benefits: she will be screened and informed about her performance on all tests. You will receive a report about your child's performance in routine activities like walking and running. If we pick up any problems, you will be advised on how best to support her. Your child will receive free treatment (physiotherapy) at the physiotherapy unit in her school, where available. We will also advise you and your child on services and support of other professionals and provide you with a letter that you can take to an appropriate health care provider.

The knowledge gained in this study will become useful to future generations. It will provide information that will help us design programmes to promote active lifestyles among learners in several schools in South Africa. The results will be used to make good plans for children in South Africa.

Confidentiality

Your child's personal information and assessment findings (results) will remain confidential. Your child's name will not be disclosed when results are reported. A report on your child will be issued to you at the end of the study. As researchers,

we may not be able to maintain confidentiality in situations where abuse is suspected. For example, if we are given information about incidents of deliberate neglect, physical, sexual or emotional abuse, we may report it to relevant authorities such as child welfare.

All information (data)—electronic and hardcopies will remain the property of the primary investigator, Dr. Gillian Ferguson. This means that the data will not be used, transported or transferred to anyone else without her written permission. Data files will be kept in locked cabinets at Dr. Ferguson's office at UCT.

Knowledge gained from the study will be shared with you, your child and her teachers before it will be reported elsewhere. Data will be used for obtaining my PhD degree, shared with other professionals at scientific meetings and to write articles for publication. No names will be mentioned. We may submit the raw data to certain academic journals, which may require checking if our results are fine. Every effort will be made to protect the privacy and confidentiality of your child at all times. The results will also be sent in the form of a report to the Western Cape Education Department and to the principal of your child's school.

Will your child be paid for taking part in the study?

We are not offering any money to you or your child for taking part in this research study. Your child will receive a bottle of water and a snack (fruit) at the end of testing (screening).

What if Something Goes Wrong?

The University of Cape Town (UCT) has insurance cover for the event that research-related injury or harm results from your participation in the trial. The insurer will pay all reasonable medical expenses in accordance with the South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI) in the event of an injury or side effect resulting directly from your participation in the trial. You will not be required to prove fault on the part of the University.

The University will not be liable for any loss, injuries and/or harm that you may sustain where the loss is caused by;

- The use of unauthorized medicine or substances during the study.
- Any injury that results from you not following the protocol requirements or the Instructions that the researcher may give you.
- Any injury that arises from inadequate action or lack of action to deal adequately with a side effect or reaction to the study medication.
- An injury that results from negligence on your part.

By agreeing to participate in this study, you do not give up your right to claim compensation for injury where you can prove negligence, in separate litigation. In particular, your right to pursue such a claim in a South African court in terms of South African law must be ensured. Note, however, that you will usually be requested to accept that payment made by the University under the SA GCP guideline 4.11 is in full settlement of the claim relating to the medical expenses.

An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the researcher 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.

If you would like further information, please contact:

Mr. Emmanuel Bonney, 0797356943, Email: bnnemm002@myuct.ac.za or Dr. Gillian Ferguson, 0214066045/0829743924, Email: Gillian.ferguson@uct.ac.za

If you will like to speak to UCT Human Research Ethics Committee, please contact:

Prof. Marc Blockman (Chairman of the University of Cape Town Human Ethics Research Committee tel: 021406338. Email marc.blockman@uct.ac.za)

Part II: Parent/Legal Guardian Declaration

I(name and surname) **am the parent/guardian of**

.....(name and surname of your child) **in grade.....**

at..... (name of school)

I have read through the attached information letter and I understand what is required of me and my child. I do not feel that I am forced to have my child participate and I am doing so out of my own free will. I know that I can withdraw my child at any time that I so wish. I understand that withdrawal will have no consequences on my child.

PLEASE INDICATE YOUR CHOICE BY TICKING ONE BOX BELOW AND SIGNING NEXT TO THE BOX.

Make a mark in the box to indicate your choice	Parent Signature	Witness signature
YES, I AGREE that my child takes part in this research.		
NO, I DO NOT AGREE that my child takes part in this research.		

If someone else has helped you read and complete this form: please write their name here:

Appendix E: Child Assent for Participants in Phase 1.

Title: Levels of physical fitness and motor coordination in female learners

Name of student: Emmanuel Bonney (BNNEMM002)

Name of Institution: Division of Physiotherapy, Department of Health & Rehabilitation, Faculty of Health Sciences, UCT.

Name of Supervisors: Dr. Gillian Ferguson, Dr. Theresa Burgess, Professor George Asare, Prof. Dr. Bouwien Smits-Engelsman

Part I: Information Sheet

Introduction

My name is Emmanuel Bonney, a physiotherapist and PhD student at the Division of Physiotherapy, University of Cape Town. We are doing a research to know how fit and skilful you are with movements. We are also interested in knowing your body dimensions (height, weight, waist size) and how active you are. I want to tell you more about our research and ask you to join if you want to. If you join, you will help us to learn more about the physical abilities of children (girls) in your school.

What is Research?

Research is something we do to gain more knowledge about people and how things work. Research makes us understand the world better. It also gives us information, so we can tell people about better ways to live. If we do research in your school, it may give us information that may help us to make children enjoy active lifestyles.

Purpose of the Research

We are doing this work to learn more about your body, how you move and how you do everyday activities like walking and running. This is because most children have now become inactive. But we do know that inactivity is not good for health. It makes people to become big (fat). Big (fat) people easily get diseases and may die early. We do not want children to suffer from ill health and die. We want to see

children happy and strong. Staying fit will make you healthy and make you enjoy life without illness.

What is involved in the study?

If you agree to join our research, we will ask you questions about your age, grade, and daily activities (things you do in a day) like walking. We want to know more about you and how active you are in school and at home. The questions we ask you are only about you. There is no right or wrong answers because this is not an exam (tests). Your answers are only going to help us know more about the things we don't know much about.

We will also check how fit and skilful you are with movements, by having you to do some simple games (tests). For example, we will ask you to stand, walk or run to see how best you perform these activities. We will check your body weight and height too. Female physiotherapists and trained research assistants will do all tests with you. You can always talk to them and ask questions.

We will give you enough time to rest so you do not get very tired. We will do the checks on several days, so you do not miss a lot of lessons in school. Feel free to ask questions about our research at any time. You can tell us to stop the test at anytime if you do not want to finish. When we finish testing, we will show you how good you were. We will also give your test results to your parents and talk to them about how good you were.

Participant selection

We need children (girls) who attend your school to join our research. We feel you can help us to learn more.

Voluntary Participation

If you want to join, it is up to you. No one will be angry with you if you do not want to do so or if you change your mind later. You can tell us if you want to join or not. We will be happy to work with you.

Risks

If you agree to be part of our work, you may feel tired when you do the tests. We will allow you to take enough rest to make sure you are safe and comfortable. We will always make sure nothing bad happens to you while you do the tests (standing, walking, and running).

If you hurt yourself, we will take care of you by giving you free treatment (physiotherapy). If you become anxious at any point, we will advise you on how best you can cope and get people to look after you properly. We will always be there to support you and make you happy if anything unpleasant happens to you. We will give you water and fruit after the tests.

Benefits

Joining our study will give you the chance to know more about yourself. You will get to know things you may not know. For example, you will get to know how fit and skilful you are with daily activities such as walking, throwing and running.

We will also give you a report on your movement abilities (performance) and tell you how best you can move more and stay strong. If we see anything that needs medical attention, we will send you to the best person who can help you and tell your parents about it too. If we work with you, what we learn will help us answer many questions about movement that we don't know. This may help us to plan new exciting games to get girls to move more, stay fit and avoid illnesses.

Confidentiality

We will not tell anybody about what you tell us. The things you will say (information) will be locked in a cabinet and be kept safe. We will not mention your name to people or in our reports.

We may tell your parents about problems that we will find about you during the tests. This is to help them take better care of you, so you can enjoy life and be happy.

As researchers, if you tell us you are being abused or mistreated in any harmful manner, we may report it to relevant authorities (e.g. child welfare). These authorities will be able to protect you and ensure nothing or nobody worries you. We will also give a copy of our research report to your teachers, parents and to the Western Cape Education Department so they can make good plans for you and your peers.

Will you be paid joining this study?

We will not give you money for joining our research. We will give you water and fruit when you finish the tests.

What if Something Goes Wrong?

The University of Cape Town (UCT) has insurance cover for the event that research-related injury or harm results from your participation in the trial. The insurer will pay all reasonable medical expenses in accordance with the South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI) in the event of an injury or side effect resulting directly from your participation in the trial. You will not be required to prove fault on the part of the University.

The University will not be liable for any loss, injuries and/or harm that you may sustain where the loss is caused by

- The use of unauthorized medicine or substances during the study
- Any injury that results from you not following the protocol requirements or the instructions that the researcher may give you
- Any injury that arises from inadequate action or lack of action to deal adequately with a side effect or reaction to the study medication
- An injury that results from negligence on your part

By agreeing to participate in this study, you do not give up your right to claim compensation for injury where you can prove negligence, in separate litigation. In particular, your right to pursue such a claim in a South African court in terms of

South African law must be ensured. Note, however, that you will usually be requested to accept that payment made by the University under the SA GCP guideline 4.11 is in full settlement of the claim relating to the medical expenses.

An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the researcher 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.

If you would like further information, please contact:

Mr. Emmanuel Bonney, 0797356943, Email: bnnem002@myuct.ac.za or Dr. Gillian Ferguson, 0214066045/0829743924, Email: Gillian.ferguson@uct.ac.za

If you will like to speak to UCT Human Research Ethics Committee, please contact:

Prof. Marc Blockman (Chairman of the University of Cape Town Human Ethics Research Committee tel: 021406338. Email marc.blockman@uct.ac.za)

Part II: Learner Assent Statement

I agree to show the researchers how I do everyday activities like walking, throwing and running. I may be tired after the tests. I understand that I do not have to do all the things, I can stop at any time and no one will be upset with me. I understand that the researcher will tell my parents how well I performed so that plans can be made to help me if necessary.

If you understand and agree to show us how you do some of these activities, please write your name in the box below.

If you understand and DO NOT want to show us how you do these activities, please write your name in the box below.

Appendix F: Informed Consent for Parents/Guardians in Phase 2

Research Title: The efficacy of movement programmes on improving motor competence and physical fitness in girls.

Student Investigator: Emmanuel Bonney.

Institution: Division of Physiotherapy, Department of Health and Rehabilitation,
Faculty of Health Sciences, UCT.

Supervisors: Dr. G. Ferguson, Dr. T. Burgess, Professor George Asare,
Professor Bouwien Smits-Engelsman.

Part I: Information Sheet

1. Purpose/Description of the Research

Your child is being asked to participate in research at her school. The primary purpose of the research is to increase physical fitness in children (only girls) living in low income areas in Cape Town. We also want to see if participating in these training will increase your child's fitness levels.

Lately, physical inactivity (not doing any movement) and overweight are known problems in children (especially adolescent girls) in South Africa. These children have reduced physical activity and unhealthy lifestyles. This study will examine how increased fitness will result in changes in their motor abilities, fitness and self-efficacy. Self-efficacy is one's belief in one's ability to accomplish a task.

Your child is being considered as a potential candidate because she is between the ages of 13 and 16 years and has specified characteristics. Full participation involves receiving 45-min exercise training, once weekly for 14 weeks. Training will occur at her school and will be organized during life orientation/physical education lessons and after school. Physical fitness, motor coordination and self-efficacy will be assessed before and after training. Your child will be assigned to participate in one of two exercise programmes; Wii Fit or functional training. The Wii Fit is an active video game which allows the child to interact with wireless

sensors and move in response to sensory feedback (information on what to do). Your child will be required to play various games each week for 14 weeks. The training will be supervised by a physiotherapist.

The functional training involves everyday movement activities including walking, jumping, running and dancing. Games like netball, tagging etc. will also be part of this training. Your child will work with her peers in a group. Your child will be supervised by a physiotherapist.

2. Conditions of Participant's Involvement

By signing this informed consent form, you agree to allow your child to join this research and to participate in either Wii Fit training or functional training.

The purpose of the research is to allow us to know which of the programmes will be most effective to increase motor skills and physical fitness. It is expected that participation in the exercise programmes will lead to increased fitness and change your child's movement behaviour. Apart from the researchers, nobody will have access to your child's information. Your child's information will be kept confidential. Your child will not be individually identified, except by a participant number that is known only to the researchers. Data obtained during this study will be stored as paper files or on a computer storage device and will be kept in a locked cabinet at Dr. Ferguson's office at the University of Cape Town. Your child's name will not appear in any subsequent report that will be written after the study.

If your child suffers from a physical injury as a direct result of this research, your child will receive treatment (physiotherapy) at no cost. If your child should require additional medical treatment, you will be responsible for the cost. You are free to withdraw your child from the study at any time without any penalty.

3. Risks and Benefits

POSSIBLE RISKS: Your child may feel a little tired after testing and training. She may experience little discomfort in the form of bodily pain after each training session. This will however subside or disappear after a few days. There is a minimal risk that your child could trip/fall while playing the games. We will observe

your child closely and ensure she doesn't fall or trip. We will provide water and snacks (fruits) at the end of each training session.

POTENTIAL BENEFITS: There is no direct benefit to your child for participating in this research. We hope that the results of this research will benefit other children in future. Knowledge gained from this study may inform the planning of physical education curriculum in schools within low income areas.

4. Financial Considerations

There will be no financial reward for allowing your child to participate in this study. You or your child will not receive any money for being part of this research.

5. Contacts

If you have any questions about this research, you can contact either the student, Emmanuel Bonney, 0797356943, Email: bnnem002@myuct.ac.za or the principal investigator, Dr. Gillian Ferguson, at 0214066045/0829743924, Email: Gillian.ferguson@uct.ac.za

If you have any questions or concerns regarding the rights of individuals who agree to participate in this study, you can **speak to the Chairperson of UCT Human Research Ethics Committee,**

Prof. Marc Blockman at 021406338. Email marc.blockman@uct.ac.za)

Part II: Parent/Legal Guardian Declaration

I (name and surname) **am the parent/guardian of**

..... (name and surname of your child) **in grade.....at..... (name of school).**

I have read the above information and understand what is required of me and my child. The purpose, procedures, risks and benefits of this study have been explained to me. I have discussed the research with my child and have agreed to allow my child to join. I do not feel that I am forced to have my child participate and I am doing so out of my own free will. I know that I can withdraw my child at any time without penalty.

PLEASE INDICATE YOUR CHOICE BY TICKING ONE BOX BELOW AND SIGNING NEXT TO THE BOX.

Make a mark in the box to indicate your choice	Parent Signature	Witness signature
YES, I AGREE that my child takes part in this research.		
NO, I DO NOT AGREE that my child takes part in this research.		

If someone else has helped you read and complete this form: please write their name here:

Appendix G: Child Assent for Participants in Phase 2 (Wii Fit Training group)

Research Title: The efficacy of movement programmes on improving motor competence and physical fitness in girls

Student Investigator: Emmanuel Bonney.

Institution: Division of Physiotherapy, Department of Health and Rehabilitation,
Faculty of Health Sciences, UCT.

Supervisors: Dr. G. Ferguson, Dr. T. Burgess, Professor George Asare,
Professor Bouwien Smits-Engelsman.

Part I: Information Sheet

We would like you to help us learn about exercise programmes that we have made for adolescent girls. Mr. Emmanuel Bonney is the person in charge of this project. Emmanuel is a physiotherapist and now working towards a PhD degree at the Division of Physiotherapy, University of Cape Town.

Keeping fit is good for your health and may help you to live longer. We want to see if our exercise programmes can increase your fitness and/or change your motor abilities and physical activity behavior. We hope to use the knowledge we gain to help other girls to keep fit and strong. Your parents or legal guardians know about this and have agreed to let you join, but the final choice is yours. It is all up to you.

1. What types of activities will you do?

If you decide to help us, there are some different things we will ask you to do. We would like to measure your height, weight, waist size, motor abilities (how active you are with activities like walking and running), fitness (how fit you are to perform movement activities) and self-efficacy (how confident you with sports and activities like running and jumping). You will be tested by female physiotherapists and trained research assistants. The tests will take about 30 minutes. We will discuss with your teacher and perform the test at a time that will be okay for you. We do

not want to disturb your school activities. We will also check how best you perform activities such as running, walking and jumping.

Once we finish (testing), you will be assigned to a training programme known as the Wii Fit training. It is an active video game that helps you to move your body in response to feedback (information you receive) on a screen (TV). You will be expected to perform movements that you see on a TV that will be placed in front of you. You must move your body exactly like what you see on the screen.

You will be expected to select and play different games with your arms, legs and whole body. The games will have three levels of difficulty-low, medium and high and you will be expected to start from the low level until you are able to move to the next level. The games you will play include aerobics (e.g. walking, running), strength (e.g. lunges), yoga and balance (shifting your body from side to side). These games will help tone your body and increase your fitness. You will be required to play the games for 45 mins, once weekly for 14 weeks. The training will take place during life orientation/physical education lessons and after school. You can also choose any time that will be convenient for you to train and we will be happy to work with you. You will be supervised by trained instructors (physiotherapists). You are free to ask questions if you do not understand anything and we will be ready to answer you.

2. Are there good things and bad things about the study?

We hope to find some good things. With your help, we will be able to tell if the games are good enough and can be used to increase fitness among adolescent girls. We are unable to tell whether our exercises will help you or not.

Young children have tried these programmes, but we do not know if adolescents like you will find them enjoyable and beneficial. You might get tired after playing these games. We will allow you to have enough rest in order to ensure your safety. We will give you water and fruit at the end of each training.

3. Will you have to do everything you are asked to do?

We would like you take part in all training sessions, but you can stop at any time if you do not want to do any more. This will not affect you in any way and no one will be upset with you.

4. Who will know that you are in the study?

When we are done, we will write a paper about what we learned. The things you do and anything we write about you will not bear your name. No one will know that you were part of this study unless you tell them. We are the only people who will see how you performed.

5. Do you have to be in the study?

No one will get angry with you if you do not want to play these games. Just tell us if you don't want to do it anymore. You can change your mind later and stop at any point if you feel you are no longer interested. No one will be upset with you.

6. Do you have any questions?

You can ask questions at any time. You can ask now, or you can ask later. You can talk to us or you can talk to someone else when you want to. Here are the telephone numbers and email addresses to reach us.

You can contact the student investigator, Emmanuel Bonney, at 0797356943, Email: bnnemm002@myuct.ac.za or the supervisor, Dr. Gillian Ferguson, at 0214066045/0829743924, Email: Gillian.ferguson@uct.ac.za

If you have any questions regarding your rights and welfare as a research a participant, you can **speak to the Chairperson of UCT Human Research Ethics Committee,**

Prof. Marc Blockman at 021406338. Email marc.blockman@uct.ac.za)

Part II: Learner Assent Statement

Participant's Code _____ **Grade:** _____

I agree to join this research and to participate in the testing and Wii Fit training. I have read the above information and wilfully agree to join. I understand that I do not have to do all the things, I can stop at any time and no one will be upset with me. I understand that the researcher will tell my parents how well I perform so that plans can be made to help me if necessary.

If you understand and agree to join the training, please write your name in the box below.

If you understand and DO NOT want to join this study, please write your name in the box below.

Appendix H: Child Assent for Participants in Phase 2 (Functional Training Group)

Research Title: The efficacy of movement programmes on improving motor competence and physical fitness in girls.

Student Investigator: Emmanuel Bonney.

Institution: Division of Physiotherapy, Department of Health and Rehabilitation, Faculty of Health Sciences, UCT.

Supervisors: Dr. G. Ferguson, Dr. T. Burgess, Professor George Asare, Professor Bouwien Smits-Engelsman.

Participant's Code _____ **Grade:** _____

Part I: Information Sheet

We would like you to help us learn about exercise programmes we have made for adolescent girls. Mr. Emmanuel Bonney is the person in charge of this project. Emmanuel is a physiotherapist and now working towards a PhD degree at the Division of Physiotherapy, University of Cape Town.

We are interested in seeing stay fit and strong. Keeping fit is good for your health and may help you live longer. We want to see if our exercise programmes can increase fitness and/or change your motor abilities and physical activity behaviour. We hope to use the knowledge we gain to help other girls to keep fit and strong. Your parents or legal guardians know about this and have agreed to let you join, but the final choice is yours. It is all up to you.

1. What types of activities will you do?

If you decide to help us, there are some different things we will ask you to do. We would like to measure your height, weight, waist size, motor abilities (how active you are with activities like walking and running), fitness (how fit you are), self-efficacy (how confident you are with sports and activities like running and jumping). You will be tested by female physiotherapists and trained research assistants. The tests will take about 30 minutes. We will discuss with your teacher and perform the test at a time that will be okay for you. We do not want to disturb

your school activities. We will also check how best you perform activities such as running, walking and jumping.

Once we finish testing, you will be assigned to a training programme called Functional training. The functional training aims to help you perform everyday activities and tasks in a more coordinated manner. The training involves role-play of routine tasks (e.g. walking), dancing and games that may increase your fitness.

You will be required to participate in this training once per week for 14 weeks. Each session will last for 45 minutes. You will be supervised by physiotherapists.

2. Are there good things and bad things about the study?

We hope to find some good things. With your help, we will be able to tell if our exercises are good enough for girls. We are unable to tell whether our exercises will help you or not.

Young children have tried this programme, but we do not know if adolescents like you will find them enjoyable and beneficial. You might get tired from all after playing these games. We will allow you to have enough rest in order to ensure your safety.

3. Will you have to do everything you are asked to do?

We would like you take part in all training sessions, but you can stop at any time if you do not want to do any more. This will not affect you in any way and no one will be upset with you.

4. Who will know that you are in the study?

When we are done, we will write a paper about what we learned. The things you do and anything we write about you will not bear your name. No one will know that you were part of this study unless you tell them. We are the only people who will see how you performed.

5. Do you have to be in the study?

No one will get angry with you if you do not want to play these games. Just tell us if you don't want to do it anymore. You can change your mind later and stop at any point if you feel you are no longer interested. No one will be upset with you.

6. Do you have any questions?

You can ask questions at any time. You can ask now, or you can ask later. You can talk to us or to someone else about this study. Here are the telephone numbers and email addresses to reach us.

You can contact the student investigator, Emmanuel Bonney, at 0797356943, Email: bnnem002@myuct.ac.za or the supervisor, Dr. Gillian Ferguson, at 0214066045/0829743924, Email: Gillian.ferguson@uct.ac.za

If you have any questions regarding your rights and welfare as a research participant, you can **speak to the Chairperson of UCT Human Research Ethics Committee,**

Prof. Marc Blockman at 021406338. Email marc.blockman@uct.ac.za)

Part II: Learner Assent Statement

I agree to join this research and to participate in testing and Neuromotor task training. I have read the above information and wilfully agree to fully participate. I understand that I do not have to do all the things, I can stop at any time and no one will be upset with me. I understand that the researcher will tell my parents how well I perform so that plans can be made to help me if necessary.

If you understand and agree to join the training, please write your name in the box below.

If you understand and DO NOT want to join this study, please write your name in the box below.