The Efficacy of a 12-week Exercise Intervention in 11-16 Year Old Adolescents with Autism Spectrum Disorder

Natalia Neophytou

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Supervisors: Dr Kerith Aginsky and Mrs Natalie Benjamin

Centre for Exercise Science and Sports Medicine,

School of the Therapeutic Sciences,

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DECLARATION

I Natalia Neophytou declare that this thesis is my own work. It is being submitted for the degree of Master of medicine in the branch of Sports and Exercise Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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Natalia Neophytou

25th day of April 2016

Date

DEDICATION

This dissertation is dedicated to my greatly supportive family: George, Helen and Alexander Neophytou, and loving Fiancé Richard Kenneth Barnfield.

PRESENTATIONS ARISING FROM THIS STUDY

1. Part of this study was presented at the 16th Biennial International South African Sports Medicine Conference, on Wednesday the 21st of October 2015 during the Biokinetics session, in Ballroom 4 Sandton City Convention Centre, Johannesburg. The title of the presentation was *"Exercise interventions in children with Autism Spectrum Disorder".*

ABSTRACT

BACKROUND: Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder, which often results in an array of motor impairments. These motor impairments often lead to reduced performance in activities of daily living (ADLs) as well as in societal tasks which require specific motor abilities and skills. Individuals with ASD have also been reported to have significantly lower physical activity levels compared to typically developing individuals. Motor impairments and these lower physical activity levels have led to various health problems including obesity, cardiovascular disease and insulin resistance syndrome. It may therefore be necessary to intervene in the population, to reduce sedentary-related health risks as well as attempt to improve motor impairments. Since exercise has been shown to be an effective therapeutic modality in reducing motor impairments and improving cardiovascular fitness, the efficacy of exercise interventions within the ASD population needs to be established.

OBJECTIVE: To determine the efficacy of a 12 week exercise intervention by assessing the change in posture, body composition, balance, coordination, agility, gait and physical fitness pre- and post-exercise intervention in adolescents with autism aged 11 to 16 years.

METHODS: A randomised control trial was conducted to assess the efficacy of an exercise intervention programme in 27 adolescents with ASD (mental age 5.6 ± 1.8 years). The sample was divided into 2 groups (intervention (n=16) and control (n=11)) using randomisation software. Validation of a 12-week exercise intervention was conducted by an expert panel via an online form. The intervention included an aerobic warm up, upper, core and lower body exercises, balance exercises, agility drills, fine motor skill training and a brief aerobic cooldown. All participants were tested pre- and post-intervention, and the intervention group participated in the exercise intervention bi-weekly for 12 weeks, while the control group received their usual standard care. Posture was assessed using a posture grid, and scores out of 10 were given per body area, where good posture = 10, average posture = 5 and poor posture = 0. Body composition, and physical fitness were assessed using the Brockport Physical Fitness Test (BPFT), and balance and coordination were assessed using the MABC-2 test and checklist. Gait was assessed using Dartfish two-dimensional video analysis, and agility was assessed using a standard agility T-test. Data analysis was performed using Stata version 13.1. Descriptive data were expressed as means and standard deviations. To compare variables during pre-and post-intervention within groups for continuous variables, the Wilcoxon signed-rank test was used. To compare variables during pre and post intervention within groups, for categorical variables, Mc

Nemar's test for symmetry was used. Fisher's exact test was used for categorical variables. Significance was accepted at 95% (p< 0.05).

RESULTS: Overall compliance to the intervention was 88.78%; high functioning individuals demonstrated 97.24% compliance, while low functioning individuals demonstrated 77.89% compliance. **Posture:** there was a significant increase in the overall posture scores (p=0.0004), specifically in the ankle area (p=0.0183) in the intervention group. **Cardiovascular fitness:** the intervention group showed significant decreases in resting systolic blood pressure (p=0.0069), and systolic blood pressure taken one minute following exercise (p=0.0007). A significant decrease in resting Heart rate (p=0.0046), as well as in heart rate taken one minute following exercise (p=0.0096) was also seen. **Anthropometry:** although the intervention groups' weight and body fat percentage did not significantly decrease, there was a significant reduction in BMI (p=0.0130) post intervention. **Strength:** handgrip strength significantly increased in the non-dominant hand only (p=0.0289), yet there was an overall increase in strength in both hands. The intervention group improved significantly in the amount of curl-ups they were able to perform following the intervention (p=0.0094). **Flexibility:** for the majority of the flexibility parameters, no significant changes were seen from pre to post testing besides in the intervention group for the sit and reach test for the non-dominant limb (p=0.0088). **Manual dexterity:** In the MABC-2 test (for age-band 3) there was a significant difference seen in the intervention group (p = 0.200) for the turning pegs item for the non-dominant hand in the intervention group. **Coordination:** a significant difference was seen in the intervention (p=0.0007) and control group (p=0.0112) for the throwing activity. No conclusive information regarding the efficacy of exercise for this component was however noted. **Balance:** the intervention group was able to hold their balance for a significantly (p=0.0028) longer time post intervention (17.0 ± 11.0 s) compared to pre intervention (10.5 ± 9.2 s) in the two-board balance task. **Agility:** there was a significant (p=0.0061) improvement in the agility times from pre (27.4 ± 12.1s) to post (23.0 ± 9.9s) intervention in the intervention group. **Gait:** there were no significant differences seen following the intervention for all gait parameters.

CONCLUSION: A 12 week exercise intervention significantly improved overall posture, cardiovascular fitness, BMI, hamstring flexibility, coordination, balance and agility in individuals with ASD. Handgrip strength and manual dexterity also improved . This therefore suggests that exercise may be a viable therapeutic intervention in the ASD population.

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With sincere appreciation

Natalia Neophytou

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LIST OF DEFINITIONS

Autism Spectrum Disorder: a neurodevelopmental disorder generally presenting early on in childhood and characterized by diminished social communication skills, repetitive behaviours, or a restricted range of interests.(1)

Anatomical position: used as a reference point in describing the relation of body parts and limbs to one another; where the positioning of the body is erect, with the arms at the side, and palms and face facing forward.(1)

Angelman syndrome: a multifaceted genetic disorder that principally affects the nervous system.(2)

Asperger's syndrome: a neurodevelopmental disorder, which is currently, considered one of the autism spectrum disorders. Asperger's characteristically encompasses seriously compromised social skills, repetitive behaviours, and often, a narrow set of interests. It does not however encompass impairments in cognitive and linguistic abilities.(1)

Clumsiness: a deficiency in the level of motor skill impairment, lower than the anticipated level of intelligence, with no known neurological disease- based on motor impairment standardised tests;(3) and movements and actions which are awkward, and performed without skill or refinement.(1)

Cohen syndrome: a hereditary condition that is characterised by intellectual disability, developmental delay, hypertonia and microcephaly.(2)

Copy number variant: when the number of copies of a particular gene vary from one person to the next.(2)

Concordance rate: the probability that two individuals will have the same trait/ characteristic (generally in a pair of twins), given that one of the individuals of the pair has the trait/ characteristic.(1)

Cytomegalovirus: a typically harmless virus, family to the herpes virus, which may elicit severe systemic damage to newborns and immunosuppressed persons.(1)

Dizygotic twins: twins developed from two fertilized ova.[1]

Down syndrome: a genetic disorder in which an individual has an extra chromosome number 21. Typically, individuals with the disorder present with a flatter facial profile, mild to severe mental disability as well as low muscle tone.[1]

Dynamic Balance: an individual's ability to react to, as well as anticipate, changes in balance as their body moves through space.[1]

Fragile X syndrome: a genetic disorder in which an individual has a faulty gene on the X chromosome. Typically, these individuals present with mental retardation.[1]

Herpes encephalitis: encephalitis caused by the herpes simplex virus.[1]

High functioning autism: individuals with an IQ above seventy, and who have an absence of detectable brain damage, biological markers and neurological impairments.[4, 5]

Low function Autism: individuals with an IQ of below seventy, and who have a predisposition for autism due to assimilated or genetically determined biological factors.[6]

Misoprotosol: a medication used when there is insufficient contraction of the uterus to begin labor, induce abortions as well as treat postpartum bleeding.[7]

Monozygotic twins: twins developed from a single fertilized ovum.[1]

Meconium: the primary fecal excretion made up of mucus, bile and epithelial cells released by a newborn child.[1]

Pediatric OMNI scale: a "perceived exertion scale" which is appropriate for numerous types of pediatric patients and physical activity situations.[8]

Phenotype: the physical appearance of an individual following the interaction between the individual's genotype and the environment in which they are found.[1]

Pivotal response training: a form of training aimed at pinpointing essential skills, including: ingenuity initiation and self-management that have an impact on a wide range of behavioral responses. Then training these skills to empower the individual to function in wide-ranging settings.[9]

Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS): a diagnosis made for those who do not meet the criteria for other pervasive developmental disorder diagnoses, or have a less severe presentation of this disorder clinically.[10]

Rett syndrome: a rare genetic disorder that affects the way the brain develops. Typically individuals present with coordination and movement difficulties as well impairments in hand movement and communication.[1]

Stadiometer: a measuring device used to determine the height of an individual.

Sphygmomanometer: an instrument used to measure blood pressure in an artery. Often used with a stethoscope and attached to an inflatable air bladder cuff when used.[1]

Thalidomide: a crystalline composition which was previously used as a sedative which may cause severe limb abnormalities in the developing fetus if taken during pregnancy.[1]

Tragion: a point in the ear, in the depth of the indentation just above the tragus of the ear.[1]

Static balance: an individual's ability to maintain equilibrium as their body remains in a stationery position.[1]

Supine: lying on ones back, facing upwards.[1]

Valproic acid: a carboxylic acid used in individuals to help in the treatment of seizures due to its anti-epileptic properties.[1]

Verbal behavior training: a training method guiding children from basic and sequenced verbal behaviours, to more functional communication skills. Techniques used, often include prompting and errorless teaching.[9]

LIST OF ABBREVIATIONS

A

ADLs: Activities of Daily Living

AS: Asperger's Syndrome

ASD: Autism Spectrum Disorder

ABA: Applied Behaviour Analysis

B

BMI: Body Mass Index

BP: Blood Pressure

BPFT: Brockport Physical Fitness Test

C

CMV: Cytomegalovirus

CNS: Central Nervous System

CNV's: Copy Number Variants

D

DSM-5: Diagnostic and Statistical Manual of Mental Disorders, fifth edition

D: Dominant side

H

HR: Heart Rate

M

M'ABC-2: Movement Assessment Battery for Children (revised edition)

Min: Minute

N

ND: Non Dominant side

O

OCD: Obsessive Compulsive Disorder

P

PECS: Picture Exchange Communication System

PDD: Pervasive Developmental Disorder

PDD-NOS: Pervasive Developmental Disorder Not Otherwise Specified

R

Reps: Repetitions

RM: Repetition Maximum

RS: Rett Syndrome

T

TEACCH: Treatment and Education of Autistic-related Communications- Handicapped Children

TGMD: Test of Gross Motor Development

T1: Trial 1

T2: Trial 2

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CHAPTER 1: PROBLEM IDENTIFICATION

The subtopics that will be covered in this chapter include:

1.1 Introduction and problem

Autism Spectrum Disorder (ASD) is a neurological disorder that may affect children and adolescents in their physical development, cognitive abilities as well as emotional wellbeing.(11) According to the Centre for Disease Control (2014), one in sixty eight people are affected by ASD globally, with 1 in 42 boys and 1 in 189 girls being affected.(12) Although currently, no formal data exists on the incidence of autism in South Africa, it has been suggested that 1 in 88 children are diagnosed with ASD in the country,(13) highlighting the need for intervention within the population.

Individuals with ASD often have an array of motor complications, such as having a predisposition to hypotonia, slower fine and gross motor skill development; having impairments in posture, coordination and gait, as well as having irregularities in motor control, motor imitation and motor planning.(14) These motor impairments tend to be widespread and consistent across both low and high functioning individuals.(14, 15) Furthermore, these motor impairments often lead to reduced performance in activities of daily living (ADLs) as well as in societal tasks, which require specific motor abilities and skills. This reduced performance often has a snowball effect whereby leading to deficient experiences for the child which may consequently disrupt their social, physical and mental well-being.(14)

In addition to having these impairments, the population has been reported to have significantly lower physical activity levels compared to typically developing individuals.(16, 17) Motor impairments, lower physical activity levels and the generally sedentary lifestyles commonly observed within the population, have led to various health problems including obesity, cardiovascular disease and insulin resistance syndrome.(18-20) It may therefore be necessary to intervene in the population, to reduce sedentary-related health risks as well as attempt to improve motor impairments.

With this been said, it is has been estimated that 135 000 South African children with autism are not getting the specialized education and care they need as there are only nine specifically tailored schools for autism in South Africa.[21] The specialised education provided, often includes various forms of therapy such as occupational therapy and physiotherapy, which aids in part, in maintaining and improving physical capacity.[22] The shortage of focused gross motor physical training and the absence of these necessary facilities however, may further impair physical abilities in the population, which therefore highlights a significant issue in therapy provision for the population or a lack thereof.

Previous research has assessed the benefit of targeting motor impairments/deficits in this population through exercise. Exercise has since been reported to be a valuable type of intervention in terms of improving various physical components with several types of interventions being implemented to try and improve physical outcomes. A study done by Pitetti et al. (2007), showed a statistically significant improvement in exercise capacity and caloric expenditure along with a decreased body mass index (BMI) (n=10) after participants followed a nine month treadmill walking programme.[23] A case study by Yilmaz et al. (2004), showed improvements in balance, flexibility and strength (n=1) after a participant partook in a 10-week aquatic training programme.[24] Furthermore, a study done by Elliot et al. (1994), showed that stereotypy (e.g. body rocking), and maladaptive behaviour (e.g. aggression), was significantly reduced after participating in moderate exercise (n=6),[25] and lastly a study conducted by Fragala-Pinkham et al. (2008), indicated that the time required to finish a half mile run/walk was significantly reduced following participation (n=6) in a group aerobic aquatic exercise programme.[26]

Studies also indicate that there is improvement in psychological, physiological, intellectual and social outcomes in young individuals with ASDs as well as improvements in self-esteem, behaviour and happiness with the participation in moderate and vigorous physical activity.[27-29]

However, while exercise as an intervention has been shown to be viable in improving physical outcomes in individuals with ASD, most of the studies have tended to focus on only one or two specific physical components of the individual, for example aerobic function,[23] strength,[30] or motor skills.[31] Thus many studies have failed to provide a holistic and comprehensive view of the various physical components that may be influenced through exercising the individuals.

Furthermore, there is minimal evidence of holistic exercise programme design being used in the various studies conducted, which follow the current exercise programme recommendations specific for autistic populations. These exercise recommendations make precise recommendations for resistance, aerobic, flexibility, and neuromuscular training for individuals with ASD, and include recommendations on the frequency, intensity, time and type of exercises that are safe and beneficial for the population.(32) To ensure safe and efficient exercise and to provide maximal benefit for this population it is important that these guidelines be incorporated when designing exercise programmes.

In addition, there is limited information on the effect exercise may have on other variables related to the individual - for example the mood of the individual,(33-35) as some variables have not been assessed previously.(33-35) Review of the literature also highlights a lack of educational components to accompany exercise interventions to reinforce the importance of exercise and physical activity and this should hence be targeted in future programmes.

Other limitations found in the literature include, studies having small sample sizes,(15, 36) studies not utilizing a control or comparative group,(37, 38) studies not making use of consistent methodologies,(39) interventions comprising of differing durations and intensities; and researchers often using words such as “mild”, “moderate” or “vigorous” to describe exercise intensities without making use of concise operational definitions.(40) These limitations therefore often make comparisons between studies very difficult.

With these limitations in mind, the question for this study is: What is the efficacy of an exercise intervention on various physical parameters such as BMI, physical fitness (aerobic function, muscle strength and flexibility), balance, coordination, gait and agility, of which some have not previously been investigated?

This study therefore aimed to conduct a comprehensive assessment of objectively measured physical parameters and to determine whether a 12-week exercise intervention would positively impact a variety of physical parameters in adolescents with autism. The information gathered can be used by healthcare practitioners, teachers or parents to promote physical activity in adolescents with ASD; can be used to help increase general fitness levels, improve motor deficits, reduce the risk of sedentary-related health problems and help to better manage the core symptoms of autism within the population.

1.2 Aim

To assess the effect of a 12-week exercise intervention programme on body composition, physical fitness, gait and agility in adolescents aged 11 to 16 years with ASD.

1.3 Objectives

1) To formulate and implement a comprehensive model exercise intervention programme in adolescents with autism.
2) To assess posture, body composition and physical fitness pre- and post-exercise intervention in adolescents with autism aged 11 to 16 years.
3) To assess balance, coordination and agility pre- and post-exercise intervention in adolescents with autism aged 11 to 16 years.
4) To assess gait pre- and post-exercise intervention in adolescents with autism aged 11 to 16 years.

1.4 Hypothesis

A 12-week exercise intervention implemented in a group of adolescents with autism aged 11-16, will help improve posture, body composition, physical fitness, balance, coordination, agility and gait in the individuals.

1.5 Structure of dissertation

This dissertation is structured around five chapters (figure 1.1). The contents of each chapter are detailed in the figure below:

Chapter 1
Introduction

- In previous pages, an introduction to the topics of ASD and physical activity was given , the problem was presented and the aims, objectives and hypothesis were defined.

Chapter 2
Literature Review

- A literature review covering the 2 main components of the study namely ASD and physical activity is provided in chapter 2.
- Information on the most recent research available in the field, a critique of previous studies conducted in the field, as well as gaps in the litreature are highilighted in this chapter.

Chapter 3
Methodology

- The objectives of the study are rehashed and methods used to meet each objective are stated.
- Individual tests and tools used in the study are discussed in detail.
- Development, scheduling and implementation of the intervention is described.

Chapter 4
Results

- The results are presented and discussed under each objective of the study by firstly presenting the objectively determined physical parameters assessed; and secondly determining whether the exercise intervention positively influenced each of the parameters.

Chapter 5
Discussion

- Results are discussed and a comparison of the results to other studies is drawn.

Chapter 6
Conclusion, strengths & limitations and recommendations

- The main findings are concluded , stengths and limitations of the study are discussed and future recommendations are stated in this final chapter of the dissertation. A take home message is also provided.

References and appendices follow

Figure 1.1: Structure of the dissertation

CHAPTER 2: LITERATURE REVIEW

The subtopics that will be covered in this chapter include:

2.1 Introduction

2.2 Autism Spectrum Disorder

2.3 Physical activity, fitness and exercise

2.4 Exercise specific interventions

2.5 Summary

"*When I first got my diagnosis, my mother was relieved, because she saw it as something that would be helpful. I mean, teachers don't look at kids who are reading eight grade levels above where they should be and doing complex mathematical proofs in third grade and think they need special help, even if they* are *being teased all the time. The diagnosis helped me get an individualised education programme, which was great, but it also changed things in a bad way." Jacob shrugs. "I guess I expected it to be like this other girl in my grade who has a port-wine stain on half her face. People go right up to her and ask about it, and she says it's a birthmark and that it doesn't hurt. End of story. No one ever asks if they can catch it like a virus, or doesn't want to play with her because of it. But you tell someone you're autistic, and half the time they talk louder to you, like you might be deaf. And the few things that I used to get credit for- like being smart, or having a really excellent memory- were all of a sudden just things that made me even more weird." He was quiet for a moment, and then turns. "I'm not autistic. I* have *autism. I also have brown hair and flat feet. So, I don't understand why I'm always 'the kid with Asperger's".* [41]

2.1 Introduction

The literature regarding physical activity as a means for intervention in adolescents with autism in South Africa is minimal, however internationally, autism studies have shown that physical activity helps improve various aspects of an individual's life. [23, 24, 27-29]

In this chapter, the two core components of this study are reviewed, namely: autism spectrum disorder and physical activity. Firstly, autism spectrum disorder as a whole is shortly reviewed as one needs to understand the fundamental features of the condition. The diagnostic criteria used to diagnose the disorder are covered as these provide understanding to common deficits found within the condition. Due to ASDs being spectrum-type disorders, where individuals may be higher or lower functioning,[42] as well as have various associated conditions,[43] a review of common associated conditions as well as medications used are briefly discussed. These may often influence how individuals may cope with tasks such as participating in exercise programmes, and hence need to be considered in the development and design of exercise programmes. Specifically, motor deficits commonly found within the population are addressed in order to highlight the main areas for concern in the physical capabilities of individuals with ASDs, which would hence need to be addressed in the development of exercise interventions. In the conclusion of this core component of the study, the public health impact of the condition is assessed, highlighting the need for continued therapy, intervention as well as the need for an increase in specialised facilities to cater for those affected by the disorder.

Secondly, physical activity, fitness, and exercise are reviewed, and a brief definition is provided of each. The benefits of physical activity are briefly discussed as well as the activity levels of adolescents with autism as compared to their typically developing counterparts in order to highlight the problem of their sedentary-type lifestyle.(16-20) Exercise recommendations specific to individuals with autism are reviewed as these should be considered in the development of exercise programmes for this population. In the closing of this core component of the study, possible challenges for participation in exercise arising within the population are discussed.

Lastly, exercise specific interventions are reviewed to demonstrate the vast types of therapies tried and tested, as well as to highlight gaps in the field where certain variables have not been previously studied. Taking this theory into consideration, physical activity may be a beneficial intervention for targeting the majority of physical fitness parameters for adolescents with autism spectrum disorder.

2.2 Autism

Autism Spectrum Disorder affects families of all racial, social and ethnic backgrounds(44) and it has been found that boys are generally 4 times more likely to acquire the disorder.(12) ASD is not an emotional disorder but rather principally involves abnormal functioning of the central nervous system, resulting in a behavioural manifestation of a “polygenetic developmental neurobiological disorder”. (45) ASD may affect all areas of the individuals’ life,(46) and may be diagnosed reliably by clinicians in children aged 20 to 24 months.(47) Recently however, it has been suggested that diagnosis may be done even sooner.(48) It should however be noted that atypical autism and pervasive developmental disorder not otherwise specified (PDD-NOS) may not be as accurately diagnosed as early on in development.(48)

ASD is a life-long spectrum disorder where individuals may vary from being low functioning to high functioning. Their symptomology may either stay the same or vary over the course of their life.[42] Symptom variances may depend on the severity of the disorder; on early detection; as well as if any interventions have transpired.[11] Diagnosing ASD in a timely fashion, may be imperative in determining appropriate and effective treatment for the individual. Furthermore, timely diagnosis is important not only in the child's circumstance, but also in the parents, as it allows for counseling, and help with future family planning.[49]

A diagnosis for classical autism, arises from the core diagnostic criteria for autism, which have been termed the 'triad of impairments',[11] and include: "deficiencies in social interaction, communication, and restricted or repetitive patterns of behavior".[11] Not all characteristics of ASD are however covered in the diagnostic criteria, yet may be deemed clinically important; some of these include: "poor postural control, an inability to process sensory stimuli, impaired imitation skills and a low level of attention and arousal".[42] These impairments would therefore all need to be considered if individuals were to participate in any treatment, therapy or intervention.

Autism, PDD-NOS and Asperger's syndrome are sometimes termed autistic disorder instead of Autism Spectrum Disorder,[50] and autism itself may often be termed autistic disorder, infantile autism or childhood autism,[51] hence making autism terminology perplexing. Although initially the term pervasive developmental disorder was proposed to define a specific group of diagnostic labels;[52] and autism spectrum disorder was proposed to link various conditions under a suggested "spectrum" disorder[52] the disorders largely overlap and often these terms are used interchangeably.[53] For clarity purposes, this study will make use of the term ASD when information pertains to all disorders falling on the autism spectrum, and the term autism when referring to a classical autism diagnosis.

Within the broad category of pervasive developmental disorders, various types of autism exist ranging in severity such as Asperger's syndrome, pervasive developmental disorder not otherwise specified (PDD-NOS), autistic disorder, Rett syndrome (RS) and childhood disintegrative disorder (CDD).[54] These are shown in figure 2.1, and are discussed further below.[10]

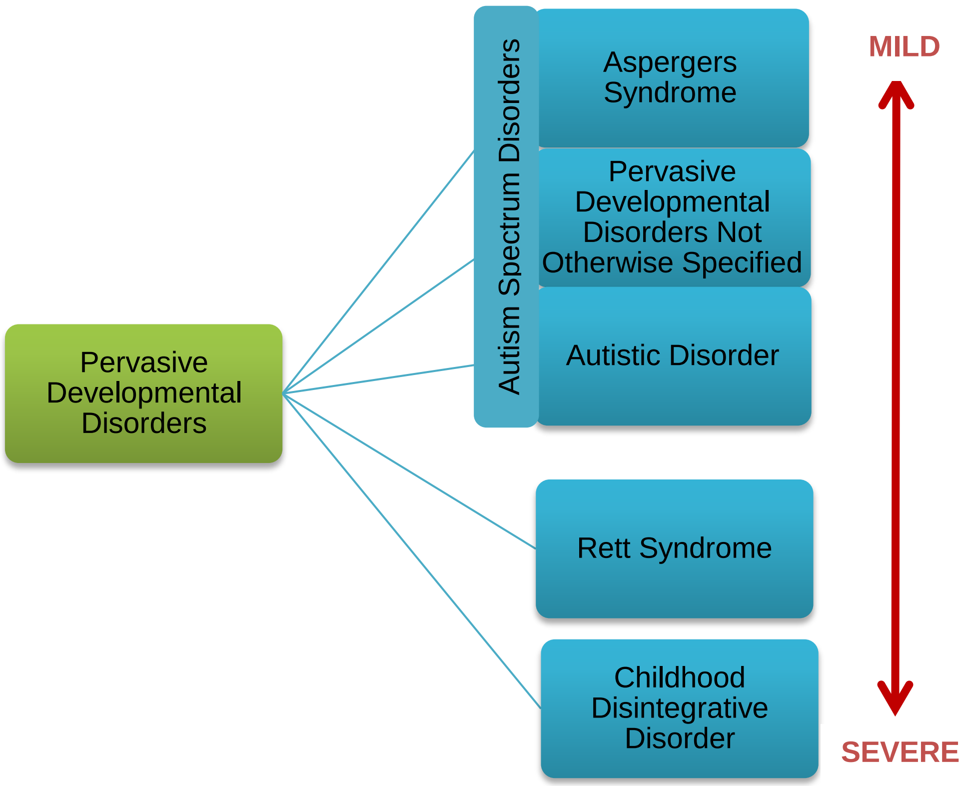


Figure 2.1: Types of Pervasive Developmental Disorders. (Adapted from the Diagnostic and Statistical Manual of Mental Disorders (DSM-5).[10]

Autism is considered to be the core disorder of the autism spectrum disorders, and Asperger's syndrome is considered to be the most alike to autism in terms of presentation and probable causes.[55] A distinct difference between individuals with Asperger's syndrome and those with autism however, is that individuals with Asperger's have normal cognitive and language development.[10, 56] In fact, those with Asperger's generally have above standard cognitive abilities making it easier to work with them in settings where there is an emphasis on cognitive proficiency.

Pervasive developmental disorder not otherwise specified, was established to classify individuals falling short of the autism definition, whereby they lacked certain characteristics of the disorder and or didn't have as many impaired areas of function.[57] These individuals' demonstrate disabilities and problems related to autism, yet are generally higher functioning, and often have superior language skills than the average individual with autism.[57]

Rett syndrome (RS) has been shown to be a separate neurodevelopmental condition to ASD, however there is phenotypic overlap between the two conditions.[15, 58] Increasing spasticity and scoliosis; apraxia, deceleration of head growth and diminished hand skills are hallmark features of RS, with common behaviours including hyperventilation, breath holding and hand stereotypies.[59] These behaviours may be difficult to manage in physical activity settings and should therefore be a consideration in the development for exercise specific interventions within this subcategory of ASD.

One of the main differences between autism and CDD is the pattern of onset, where in CDD a child develops typically within their first two years of life after which there is a regression of skills in numerous areas of development including cognitive, language, social, adaptive play, motor and independence skills.[10, 60] This is unlike autism where the onset of the condition occurs earlier. After the regression of function occurs, CDD presents similarly to autism, usually no additional regression follows and there may even be partial regaining of function.[60] For this subcategory it is therefore imperative to maintain and improve skills through treatment and intervention as soon as possible.

ASD is not considered to be curable, and necessitates chronic management throughout an individual's life. Irrespective of intellectual functioning, changing behavioural characteristics and outcomes that are variable, individuals will commonly continue to fall within the spectrum as adults.[15] Living independently, having functional social relationships and good mental health as well as having optimal employment opportunities, therefore tend be a continuous problem for these individuals throughout their lives.[61]

It is very important for any individual working within this population to understand the differences between the subtypes of the disorder, so that effective interventions may be developed to target certain deficits. For example, it may not be necessary to include cognitive training into an intervention for an individual with Asperger's yet may be paramount for an individual with RS, thus influencing the appropriateness of the intervention for the individual in question. Similarly, when developing exercise interventions for this population, particular attention should be drawn towards pronounced deficits (which may be dictated by the subtype), as these may affect physical activity performance.

2.2.1 Epidemiology of autism

Disease frequency is most appropriately measured using incidence rates; however, it may be challenging to measure these rates in rarer chronic diseases such as ASD.[62] Therefore, in the epidemiology of ASD, period or point prevalence may be more useful than incidence rates as the onset of the condition often begins prior to it being diagnosed. This disparity between onset and diagnosis is influenced by numerous factors unrelated to the risks associated with the disorder. Most research conducted within this population therefore looks at whether there is an increase in period or point prevalence over time, whereas cumulative incidence is generally only made use of in birth cohort studies.[63]

According to the Centre for Disease Control (2014), 1 in 88 people are affected by ASD globally, with 1 in 42 boys and 1 in 189 girls being affected. Furthermore, an annual growth rate of between 10% -17% has been reported.[12] It has been estimated that the incidence of autism in South Africa presently, is 10 per 1000 children, yet no formal data exists to confirm this.[64] Nevertheless, a large amount of individuals are being diagnosed with ASD annually in South Africa and this is a cause for concern.

Furthermore, prevalence estimates have increased dramatically in the last ten years (from approximately 25 in 10000 to over 1 in 1000 when the full spectrum of the disorders is included).[65-67] The increase in prevalence may be due to various reasons. One of the main reasons could be due to the expanding diagnostic criteria as a result of an abundance of research on the autism phenotype. Another reason could be that cases with severe mental retardation and known genetic causes were previously not diagnosed with ASD even though they met behavioral criteria for the condition; these individuals are now being diagnosed with the disorder. In addition, those that fell on the lower end of the spectrum were not tracked and followed up on, if they were able to fit into mainstream schooling systems.[68]

Additionally, prevalence rates may have increased due to changes in the way the diagnostic criteria have been applied over the years; due to entire life span evaluations, increases in experienced and trained clinicians, superior assessment methods, and better funding for screening and research of the condition.[69] One can therefore argue that the reported rise in autism prevalence over time may not be a true reflection of the disorders' incidence but purely as a result of the above reasons.[68, 70] A few years ago, researchers believed that this was an unresolved issue in ASD research,[68, 70] however a recent critical analysis of this rise in prevalence has now concluded that the expanding diagnostic criteria and the awareness and transformation of public attitudes regarding autism have indeed triggered and predominantly account for this upward trend, however the likelihood of a genuine rise in incidence should not be excluded.[71]

Nevertheless, more and more individuals are being diagnosed with this disorder and since no cure exists currently, interventions and targeted therapies should continue to be investigated and implemented within the population.

2.2.2 Diagnostic criteria and relevance for research

Autism is diagnosed based on clinical and behavioral assessments of an individual, as currently, no clear neuroanatomical abnormalities or definite biomechanical indicators define autism.[54] Most recently however, a pilot study conducted by Armand et al. (2015), has identified proteins present in saliva which may be used in the early diagnosis of ASD in the form of a saliva test.[72] However, further research needs to be conducted to confirm whether these protein biomarkers can be used to accurately indicate autism within individuals. Hence traditional diagnosis using the triad of impairments (discussed below), still stands.

The core diagnostic criteria for autism have been termed the 'triad of impairments'.[11] This term has been developed to describe these impairments, which include: "deficiencies in social interaction, communication, and restricted or repetitive patterns of behavior". [11]

According to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) in order for a diagnosis of autism to be made, a child must experience difficulties in each subdivision of the triad, categorized as: "qualitative impairment in social interaction; qualitative impairments in communication and restricted, repetitive and stereotypical patterns of behaviour, interests, and activities".[10]

Furthermore, a child is also categorized according to "delays or abnormal functioning in at least one of the following areas with onset prior to age 3 years: social interaction, language as used in social communication and symbolic or imaginative play".[73] These are defined in figure 2.2 below.[10] Although the validity of the DSM-5 has been previously questioned,[74-79] many recent studies have revealed evidence for good sensitivity and specificity using various instruments for the criteria.[80-82]

“

(I) A Total of six or more items from (A), (B) and (C) , with at least two from (A) , and one from (B) and (C)

A

- **Qualitative impairment in social interaction, as manifested by at least two of the following:**
  - Marked impairments in the use of multiple nonverbal behaviours such as eye-to-eye gaze, facial expression, body posture, and gestures to regulate social interaction.
  - Failure to develop peer relationships appropriate to developmental level.
  - A lack of spontaneous seeking to share enjoyment, interests, or achievements with other people, (e.g. by a lack of showing, bringing, or pointing out objects of interests to other people).
  - Lack of social or emotional reciprocity.

B

- **Qualitative impairments in communication as manifested by at least one of the following:**
  - Delay in, or total lack of, the development of spoken language-individuals with adequate speech, yet marked impairment in the ability to initiate or sustain conversation with others.
  - Stereotyped and repetitive use of language or idiosyncratic language.
  - Lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level.

C

- **Restricted, repetitive and stereotypical patterns of behaviour, interests, and activities as manifested by at least two of the following:**
  - Encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity ,or focus.
  - Apparent inflexible adherence to specific, nonfunctional routines or rituals.
  - Stereotyped and repetitive motor mannerisms
  - Persistent preoccupation with parts of objects.

(II) Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years:

1	•Social interaction
2	•Language as used in social communication
3	•Symbolic or imaginative play ”

Figure 2.2: Diagnostic criteria for Autism Spectrum Disorder as defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). (Information has been reproduced from the Diagnostic and Statistical Manual of Mental Disorders (DSM-5).[10]

Although individuals typically present with one or more of the above impairments illustrated in the previous figure, individuals may also present with other developmental delays outside of this triad which are then termed associated symptoms. These associated symptoms are no less important to be aware of and are in fact, clinically and neurologically important characteristics of the disorder. They may include lower fitness levels, impaired participation behaviours and decreased mental functions which are at a lower level to their typically developing counterparts.[(83)]

Early and correct diagnosis may be imperative for individuals to receive the best and most appropriate treatment. Furthermore, research should be conducted in such a way that the recruitment of qualified specialists is obtained prior to any study taking place to ensure an accurate inclusion/ exclusion of individuals (based on correct diagnosis) for the research, as this is often a downfall/ limitation in many studies. For example, some studies state that only individuals with classic autism will be included into the study, however, individuals with a particular sub-type of autism i.e. RS and or Asperger’s are found within the study. Furthermore, appropriate ASD definitions should be used within studies so that sample populations are clearly and correctly defined.

Importantly, it should be noted that “Autism Spectrum Disorder includes autistic disorder, Asperger’s syndrome and pervasive developmental disorder-not otherwise specified (PDD-NOS)”,[(54)] hence research should specify if individuals from the entire spectrum, or individuals from a particular subdivision of the spectrum are being studied in order to clarify participant populations in research.

In addition, other factors such as mental age need to be considered in order for individuals to be “matched” appropriately in research, for example in randomised control trials. Mental age should be measured for all individuals with ASD when diagnosis takes place so that this information is available for research purposes as well as gives insight into the cognitive abilities of the individuals. Matching for full-scale IQ or global mental age measures may guarantee that a group of study participants have the same average ability as another group, and hence may be compared to one another. It should be noted however that these groups will not be matched for any single ability assessed by the test but rather give an overall level of ability.[(84, 85)]

2.2.3 Causes

Much research has been done to try and define the possible causes of autism, yet this subject is still under thorough investigation.[86] Initially, it was believed that autism was caused by an unloving and hostile mother called the 'refrigerator mother'.[87] This theory, however has since been disregarded, and has been replaced with the idea of an interplay between various factors giving rise to autism.[88]

Figure 2.3 below, illustrates the model known as the "Final Common Pathway" as postulated by Baron-Cohen and Bolton (2002).[88] This model indicates the probable combination of factors which may lead to brain damage and hence result in ASD or mental impairment relative to which area of the brain is affected.[88] The model suggests that genetic factors, viral infections, birth/pregnancy complications and causes such as environmental exposures, and anything that may alter or damage the central nervous system both structurally or functionally are considered possible aetiologies of autism.[42, 54, 88] These aetiologies will now be discussed further.

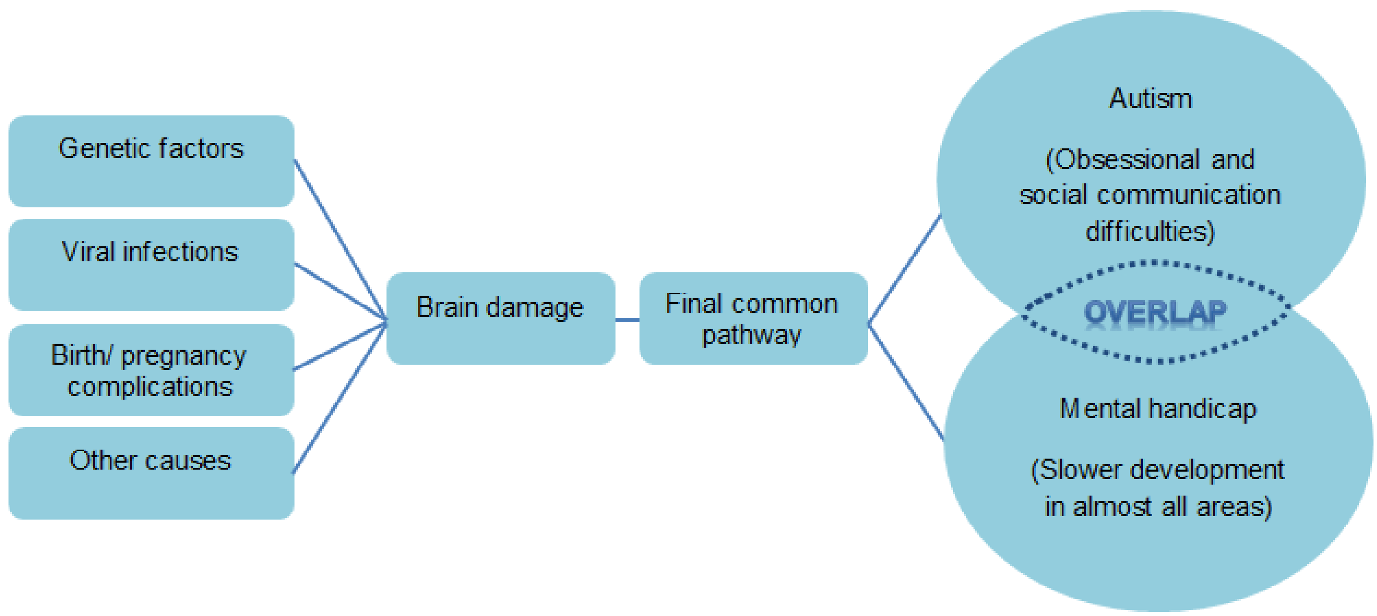


Figure 2.3: The final common pathway in autism. (Adapted from Baron-Cohen and Bolton (2002)).[88]

i) Genetic factors in autism

Genetic and familial factors indisputably play a role in autism causation.[86] Autism has frequently been seen among siblings, twin pairs, and there have been instances where numerous cases have been described within a family.[54] Concordance rates for autism as high as 70% have been reported amongst monozygotic twins,[67] and have come close to 90% where the expansive phenotype of autism is regarded. In dizygotic twins concordance rates do not seem higher when compared to their singleton siblings.[89] Concordance rates amongst singleton siblings with autistic disorder range from two to six percent,[89] whilst siblings of females with autistic disorder have higher estimates (14%).[90] In addition to this, family studies have revealed that approximately 20% of the siblings who were initially studied with ASD generally had slight deviations of the fundamental characteristics of ASDs or ‘autistic traits’. These ‘autistic traits’ collectively called the broad autism phenotype include: being detached or aloof, having a preference for a constant routine, being tactless, having inadequate language skills (both pragmatically and interpersonally) as well as having limited friendships.[51, 91] Furthermore there are numerous genetic conditions in which autism arises, including Down syndrome, Fragile X syndrome, Angelman syndrome,[92] Cohen syndrome and Rett syndrome.[93]

Case-control and family-based candidate gene studies have recognized several candidate loci for the causation of autism on chromosomes 2q, 7q and 15q,[94, 95] and definite mutations linked with ASD have been recognized in the NLGN3/4, SHANK3 and PTEN genes.[92] Abnormalities on chromosome 15q have been noted when conducting cytogenetic studies.[94] One of the more modern genetic investigatory type studies currently being used are genomic wide-association screening studies. These studies have recognized comprehensive genetic deletions, duplications, and copy number variants (CNV’s) linked with ASD and the genes reported to be involved include the CNTN4 and NRXN1 genes[96] with recurrent micro deletions occurring on chromosome 16p.[97]

With gene deletions, gene mutations, CNV’s and other genetic irregularities all having been convincingly associated with autism, it is obvious that genetic factors are important to consider in terms of aetiology.[98] In addition, as genetic research evolves and more genetic causes are revealed, the percentage of autism cases having a genetic factor link will likely increase.[54] However, currently, it is estimated that genetic factors are responsible for only seven to eight percent of all cases of autism, which is a moderately small number[54] and therefore it is has been hypothesized that environmental exposures may also contribute to causation.[95, 99] In addition to this, it has been suggested that the environmental exposures may act together with the genetic vulnerabilities and possibly be responsible for the vast expanses in the autism phenotype.[54, 100]

ii) Environmental exposures

Evidence that environmental exposures may contribute towards the causation of autism arises from two main sources. The first is the recognition that toxic exposures from the environment may have adverse effects on the vulnerable developing human brain.[101] The second, is that studies have shown that there are distinct connections between prenatal environmental exposures and autism.[101]

Numerous chemicals such as mercury, arsenic, manganese, lead, methyl mercury among others have since been directly related to neurodevelopmental disability causation.[54] In addition, it is estimated that children are in danger of being exposed to approximately 3000 different synthetic chemicals,[102] 20% of which have not yet been examined for probable causes of neurodevelopmental toxicity.[103]

The human brain is most vulnerable to injury during embryonic and fetal life, and may be especially vulnerable during the first trimester of pregnancy.[54] It therefore stands to reason that exposure to these chemicals, particularly when the developing brain is susceptible to injury, may influence autism acquisition, particularly if these substances are changing or damaging the central nervous system.

There have been various epidemiological and clinical studies that have linked particular environmental exposures with autism.[54] It has been documented that there is an elevated incidence level of autism when children are prenatally exposed to thalidomide.[104] In addition, prenatal exposure to valproic acid in children reveals somatic defect patterns analogous to those of thalidomide embryopathy and these children may also develop autism.[105] Prenatal exposure to misoprotosol may also increase the incidence of autism as reported in a Brazilian case study showing that of these seven children with ASD, 57.1% had prenatal exposure to this prostaglandin analogue.[106]

iii) Birth/pregnancy complications

Various birth/pregnancy risk factors have been recognised in relation with autism, namely:[88]

- Maternal age of 35 years or more at the time of pregnancy[88]
- Using medication during pregnancy (a few examples are listed below)
    - Serotonin reuptake inhibitors and valproic acid used during the first trimester may modestly increase the risk of ASD.[107, 108]

- Antipsychotics or mood stabilizers taken during pregnancy may increase the risk of a child being born with autism.[109]
    - Taking high doses of misoprotosol in early pregnancy may also increase the risk of having a child with ASD.[106]
- Birth order - children born after previous siblings carry an increased risk.[88]
- The presence of infant stool (muconeum) in the amniotic fluid during labour.[88]
- Bleeding during the last trimester of pregnancy.[88]
- A rhesus incompatibility between the child and mothers' blood group.[88]

iv) Viral infections

Epidemiological and clinical studies have shown a relationship between autism and early pregnancy maternal rubella infection.[110] In these studies, ASD risk seemed highest when infection arose in the initial eight weeks of pregnancy.[108] Herpes encephalitis and cytomegalovirus (CMV) are other infections which have since also been reported to be related with ASD. The mechanism by which viral infection may cause autism is unknown.[111] Mechanisms thought to be involved include the immediate infection of the central nervous system (CNS), infection in another area of the body triggering disease of the CNS, immune response deviation in the mother or her offspring , or an amalgamation of all the above.[111]

v) Vaccines

Over the years childhood immunisation has been under intense enquiry as being a possible cause for autism.[54] A series of studies conducted in America,[112] Europe [113, 114] and Japan[115] addressed this matter, however none of the studies found any plausible data implicating vaccines as a cause of autism.[71] Therefore there is no justification for parents to fear autism development in their children due to vaccinations.[116]

In summary there is no doubt genetics are involved in the causation of autism [86] however, genetics account for a small percentage of autism cases, hence other causative factors must play a role in the development of autism.[54] It is highly probable that the interplay of various factors give rise to the autism phenotype.[88] Thus environmental exposures to various chemicals, as well as viral infections such as rubella, CMV and herpes encephalitis should all be considered possibilities of autism causation. Importantly, it is a misconception that vaccines may cause autism and thus children should always have their necessary immunizations.[31] If an absolute cause of autism was known, interventions tailored towards a cure would help benefit the population, however at this stage we need to rely on new interventions, and proven targeted *therapies to improve the various symptoms of the condition to improve the quality of life of individuals affected with the condition.*

2.2.4 Associated conditions and medications

The absence of a "gold standard" diagnostic tool has hindered the establishment of valid and reliable assessment tools specifically designed to determine comorbidity in developmentally challenged individuals and those with ASD.(117) However, numerous studies have revealed evidence for a number of comorbid diseases in children and adolescents with ASD.(43, 118, 119) Some of the more documented associated conditions include genetic disorders such as uberous sclerosis complex, Fragile X syndrome and Down's syndrome; comorbid psychopathologies such as mood disorders, obsessive compulsive disorder (OCD), anxiety, and phobias; as well as other disorders such as anorexia nervosa, sleep disorders, epilepsy as well as obesity. These will now be discussed further:

i. Genetic disorders

Tuberous sclerosis is a rare "neurocutaneous autosomal dominant disorder" that triggers the growth of "hamartomatous tumours predominantly in the brain as well as in other vital organs".(120, 121) An estimated prevalence of 0.4% of tuberous sclerosis in autism has been reported and it has been suggested prevalence could be as high as 8-14% amid the subgroup of individuals with autism with a seizure disorder.(120, 122) Furthermore it has been reported that between 25% and 61% of individuals diagnosed with tuberous sclerosis have also have been reported to meet the diagnostic criteria for autism, with an even greater fraction presenting attributes of a broader pervasive developmental disorder.(123) This condition requires pharmaceutical management in the case where vital organs are affected; hence this would need to be considered if the individual where to begin an exercise programme.

Fragile X syndrome is the greatest widespread inherited type of mental retardation in people, and it has recently been estimated that the prevalence of Fragile X syndrome in autism is 2.1%.(118) Numerous authors however, have argued that there is no link with Fragile X syndrome and autism in their cohorts,(124, 125) and in some instances it has been reported that the autism prevalence is identical in control groups with idiopathic mental retardation and Fragile X cohort groups.(126, 127)

Mental retardation is most frequently caused chromosomally by Down syndrome.[128] A prevalence rate of between 0% and 16.7% of Down syndrome in autism has been estimated, however once the effects of mental retardation (a risk factor for autism) are eliminated from the equation, the comorbidity of Down syndrome and autism are the same as expected by chance.[129] Hence studies are concentrating on the likely factors related specifically to Down syndrome that may predispose an individual to developing ASD. Risk factors suggested include the commonly found conditions in Down Syndrome infants, such as infantile spasms which lead to poorer mental development and hypothyroidism, which are in themselves risk factors for autism,[11] as well as the disturbance of serotonin development which may be the causal mechanism for the two disorders.[130]

ii. Comorbid psychopathologies

Many types of mood disorders exist, most of which are potentially debilitating for individuals; they may be divided into bipolar disorder and major depression.[131] Pediatric bipolar disorder is both difficult to diagnose and treat [132] and has often been claimed to be comorbid with various conditions including ASD.[133] However the literature is very scarce in this regard, as research has previously predominantly been focused on defining the subtypes of bipolar disorder as well as being solely conducted on adults.[131] A study conducted by Realmuto and August (1991), described a few bipolar features being present in three individuals with autism[134] and only one case has been reported of an individual with Asperger's syndrome having bipolar disorder.[135] Hence further research would need to be conducted to determine appropriate estimates for the comorbidity of bipolar disorder and autism.

In contrast the comorbidity of depression and autism has been studied greatly and the general consensus of studies indicate that depression is a comorbid condition with ASD, being diagnosed in 2% of children studied.[136] Comorbidity rates as high as 30% in children with Asperger's syndrome have also been reported.[137] It has been suggested that the most frequent form of comorbid psychopathology with ASD is depression,[138] and that due to the overall absence of measures for assessing comorbidity in ASD, the above mentioned rates are most likely lower than should be reflected.[138] The level of cognitive function of an individual may influence the presentation of depression in ASD, with more behavioral issues being present in lower functioning individuals, and more traditional depressive symptoms being seen in higher functioning individuals.[139] In addition, the occurrence and development of depression in high functioning individuals tends to increase in adolescence as a result of an increased insight into their differences from others.[140]

Other types of psychopathologies often associated with ASD include OCD, anxiety, phobias, and psychosis. It is estimated that 30% of children with ASDs have concurrent OCD.[141] There is a great concern however about whether ASD and OCD may be separated, as individuals with OCD engage in repetitive acts in order to reduce anxiety which is not unlike symptomatic individuals with ASD.[131] Similarly anxiety seems to overlap with ASD, (in particular depression and ASD), with concerns arising that ASD may not be separated from anxiety, and in addition, that ASD may not be able to be separated from other psychopathologies such as fears, phobias and depression.[131] Research advocating the comorbidity of anxiety and ASD is minimal and no data exists disproving a comorbidity hypothesis.[131] A prevalence of anxiety of between 11% and 84% in children with ASD has been reported, with the problem of the large range being attributed to the differences in study methodology.[142] It is suggested that anxiety symptoms are probably influenced first and foremost by ASD-specific difficulties, followed by the age of the individual, level of cognitive functioning as well as the extent of social impairment.[142]

Limited research has been done concerning phobias as a comorbid psychopathology for ASD, however in a study conducted by Leyfer et al. (2006), the majority of the children with ASD studied (n=109) had phobias of more than one object or situation, with 32% of the children being fearful of needles and crowds.[143] It was also noted that specific phobias which are typically prevalent in developing children such as fears of standing in lines, flying, fears of bridges, tunnels and others occurred at minimal rates in the children with autism, whereas the fear of loud noise which is not a common phobia in typically developing children occurred in 10% of the children with autism.[143] A systematic review of phobias in ASD populations indicated that children with autism had a greater fear of dim spaces, big crowds, thunderstorms, closed places, dark chambers, and going to bed in the dark and that common types of phobias rarely overlapped with their typically developing counterparts.[144]

iii. Other disorders and conditions

High functioning individuals with autism have often been reported to have comorbid anorexia nervosa, however many authors believe this to be a chance association.[145] A study conducted by Wentz et al. (2005), showed that 23% of patients who had anorexia nervosa had been reported to meet the criteria for ASD (n=7).[146] It has been suggested that mutations in serotonin transporter coding genes might be the facilitators for this association.[147]

A common problem conveyed by parents of children and adolescents with ASDs is sleep disorders. Sleep disturbances recounted often include premature morning awakening, late sleep onset, as well as poor sleep maintenance.[148]

Another comorbid condition often associated with ASD is epilepsy, with the onset occurring prior to the age of five or through puberty.[148] The risk of developing epilepsy varies dependent on the age, type of language disorder as well as the cognitive function of the individual.[149] Contributing factors include a high fever or lack of sleep, and epilepsy is more prevalent in females or in those "who have comorbid intellectual disability".[149]

The prevalence of intellectual disability in children with autism has been reported to be between 25% to 70% with the large discrepancy in the range owing to the difficulty in determining intelligence of an autistic individual.[150] It is also estimated that 25% to 75% of children with ASD may have learning disabilities.[151] It should however be noted that that the association between ASD and intellectual disability may not be due to the conditions having common causes, but rather due to the likelihood of both being diagnosed when both conditions are present.[152]

A highly dominant comorbidity in children with ASD which may lead to many major health concerns is obesity,[153] however problems associated with obesity risk and prevention do not seem to be addressed in recent interventions for individuals with ASDs.[32]

Psychoactive medications including antidepressants, antipsychotics, antianxiety drugs and stimulants for behavioral and psychiatric symptoms are frequently prescribed to individuals with ASDs, and often the long term use of these and other prescription medications may contribute to the obesity levels within these populations.[154] Some medications in particular such as risperidrone (an antipsychotic), often leads to significant weight gain.[155, 156] A study conducted by Hellings et al. (2001), showed that a weight gain of 8.2kgs in children, and 5.4kgs in adults was noted following 6 months of risperidrone treatment.[155]

Feeding behaviors are controlled by the brain satiety factor called serotonin, hence the blocking of this factor could cause significant weight gain following increased appetite.[155, 156] It has been suggested that antipsychotics have a potent serotonin-blocking action; that they decrease the “sensitivity of the satiety center to feedback signals from peripheral adipocytes” which lead to overeating and weight gain; as well as desensitize the leptin receptors in the brain.[155, 156]

Furthermore, individuals with autism may have sensory regulation and processing difficulties.[10] It has been suggested that the abnormal processing of sensory information in children with autism can be attributed to the neurological differences when compared to children without autism,[157] with these sensory disturbances being the primary deficits underlying autism.[158] The neurological differences consist of irregularities in the cell structure in areas such as the limbic system and cerebellum: with causal mechanisms consisting of “cell growth deregulation, apoptosis and/or white matter development”.[159] The limbic system and cerebral cortex are generally larger in children with autism, whereas reduced brain development is seen in regions like the cerebellum.[57] Initial brain overgrowth is mainly prominent in the frontal lobes,[159] presenting anatomically, with the head circumference and brain volume of an individual with autism being greater than that of a typically developing individual.

A leading problem in children with autism, is their self-stimulatory behavior.[160] Self-stimulatory behaviour, also known as autistic mannerisms, stereotypic behaviour or repetitive behaviour includes body rocking, hand flapping, spinning, head nodding, gazing at lights, object tapping, and mouthing.[161] This behaviour has been studied extensively in many diverse populations [162-164] and although not all the populations function identically,[165] research has shown that this self-stimulatory behaviour hinders learning as well as positive social behaviour due to its disruptive nature.[33, 166, 167] Interventions have been developed solely to try and reduce these behaviours;[168, 169] however there has been no intervention to date that has completely rid individuals of these behaviours, and hence self-stimulation behaviour needs to be considered when developing other types of future interventions for the population.

In summary, it may be very important to consider the types of medications individuals with ASD are taking to get an understanding of possible hurdles in creating effective exercise interventions. For example, an individual on antipsychotics could potentially gain weight; hence their exercise programme should be adapted to include more aerobic components of exercise to counteract this effect. Associated conditions and comorbidities also need to be taken into consideration as they may affect performance of various tasks in exercise programmes as well as indicate whether certain tasks or exercises may be contraindicated for certain individuals. Since depression seems to be problem in the population, future interventions, whether they be exercise based or not should acknowledge this and account for possible depressive tendencies.

2.2.5 Motor deficits in autism

Over time, the significance of motor functioning in children with ASD has become a growing area of research. Although variations in motor development are not a primary diagnostic category for ASD,[170] there is increased recognition that individuals with ASD experience motor difficulties.[171] In addition, evidence shows that motor impairments tend to be widespread and consistent across both low and high functioning individuals.[15] Impairments tend to affect the fundamental elements of motor control consisting of: posture, gait, coordination and tone.[14] Thus, in order to provide a holistic intervention programme for children with ASD, it is essential to conduct comprehensive developmental assessments that include evaluation of their motor functioning.[15] Various common physical and motor deficits commonly found in individuals with ASDs will now be discussed further.

i. Posture

A fundamental motor skill required for activities of daily life (ADLs) is postural control, which has become a recent key focus in motor research in ASD populations.[172] Postures that are usually deemed challenging for a child with ASD to maintain, include those of a slow and controlled nature, for example: single limb stance, prone extension, supine flexion or standing in a position where their feet are together with their eyes closed and/or tandem stance (heel-to-toe) with eyes closed (Romberg position).[42] These positions should therefore be targeted through interventions for improvement. It has been suggested that reduced postural control could be as a result of inadequate motor modulation for motor and sensory outputs,[173] however there is no consensus on the actual cause. Static posture has often been disregarded in ASD research and no formal data currently exists on the posture profiles of individuals with ASD. Having a good static posture is necessary to prevent undue loading of the spine through maintenance of correct musculoskeletal alignment within the body.The ability to keep and maintain a projected center of mass in the base of support is known as postural stability.[174] A recent study by Memaria et al. (2013), confirmed previous findings reporting children with ASD show poorer postural stability than their typically developing counterparts.[172] Furthermore, a different pattern of directional sway was seen in the individuals with ASD, as well as a positive association with postural sway scores and autism severity.

Previous studies have shown that as typically developing children mature, their postural sway decreases gradually, enabling them to control their body movement,[175] however there is minimal information regarding the effect of age on postural sway in individuals with ASD.[176] In a study by Minshew et al. (2004) a significant relationship between the amount of postural sway and age in individuals with ASD was found, however other studies have indicated that there is no effect of age on postural sway outcomes.[177] There is however a general consensus that individuals with ASD have poor postural stability.[172] A deficiency in postural stability can cause difficulty in performing motor skills and limit movement which could in turn negatively affect the activities of daily living in these individuals.[177] This is therefore an important area that should be addressed in individuals with ASD to help improve ability in ADLs.

ii. Gait

In children with ASD, bilateral movement patterns seem immature and there are often problems with coordination due to the "discrepancy between the actions of the upper and lower limbs".[178] Gait components which may be affected, include: shorter stride length, longer stance times, slower walking pace, increased knee flexion and increased hip flexion at toe off. Irregular gait may lead to joint stress, pain and fatigue which in turn could disturb an individual's quality of life and ADLs.[179] The cause of gait abnormalities in individuals with ASD is a controversial topic, with some believing that the disruption of the cerebellum is the cause, whereas others believe that disturbances in the basal ganglia and frontostriatal regions underlie the abnormalities.[180]

Various studies have investigated gait in individuals with ASD.[181, 182] A study by Venazza-Martin et al. (2005), reported a decreased stride length and an increase in upper body oscillations in nine children with autism as compared to an age-matched control group.[181] Vilensky et al. (1981), reported shorter stride lengths, increased stance phases, increased hip flexion at toe-off, decreased knee extension and altered foot contact patterns in twenty one children with autism, as compared to an age-matched control group.[182] In contrast to these studies, Rinehaert et al. (2006), found that there was no reduced stride length, but rather a variability in increased stride length in ten high functioning individuals with ASD,[180] and in eleven children with autism.[183] However these differing results could be due to the differences in severity of ASD in the participants studied.

A deficiency in thorough and reliable interpretation of gait information in ASD exists[179] and therefore additional research is required for the better understanding of gait within this population. Enhanced understanding of these gait patterns may aid in the design and development of prime rehabilitation plans for those requiring treatment, and in addition lead to effective treatment programmes in helping to increase overall functionality, and lessen health-care expenses.[179]

iii. Coordination

It has been found that individuals with ASD have problems with motor planning (praxis),[14, 184-186] which includes marked impairments in motor coordination interfering with their ADLs. Children with ASD also have poor body awareness which may add to their problems with motor planning in terms of carrying out and planning imitative movement.[187] In addition, these children also experience deficits in motor responses and have shown unusually "slow reaction times for movement preparation".[14] Children with ASD are often mistaken to be generally clumsy due to these deficits[11] and need additional repetition to learn a particular motor plan as they find it difficult to learn new tasks.

Furthermore, the term "kinesia paradoxa" has sometimes been used to define movement disorders in individuals with autism and Asperger's syndrome where individuals who usually struggle tremendously with executing basic movements could unexpectedly execute skilled and complex coordinated movement patterns.[188] A study conducted by Kohen-Raz et al. (1981) described an example of "kinesia paradoxa" whereby their participants with ASD "paradoxically" demonstrated equivalent or superior stability in tougher postural positions, such as standing with obstructed vision on an uneven surface as compared to easier postural positions, such as standing on a stable surface with non-obstructed vision.[176] Another example of "kinesia paradoxa" is seen in individuals with Asperger's syndrome where individuals seem uncoordinated and clumsy, as they struggle with simple everyday tasks such as catching a ball or walking, yet show good dexterity in drawing, playing computer games or model building.[189] It has been suggested that the ability to perform these tasks of greater difficulty could be due to the individual focusing their attention more; either because they become obsessed with the motor task at hand or that the difficult tasks have imbedded cues (e.g. verbal instructions or visual cues).[180] It is well documented that the performance of complex coordinated tasks is better in children with ASD when verbal, physical and visual cues are provided to them.[190] This affirms the importance of cuing the various tasks at hand when working with this population, and should hence be considered when implementing exercise interventions within the population.

iv. Balance

The cerebellum is critical for balance, muscle coordination and fine motor control. It controls the coordination of complex movements in the body and it is believed by researchers that children with autism seem to have a failure of development within this area of the brain.[42] This failure arises within the “first few months after conception or during the first and second years of life”.[42]

In addition to these well-known problems found within the ASD population, other factors such as body composition, aerobic fitness, flexibility, agility and quality of life should also be considered, these will be discussed further.

v. Body composition

Although there has been an increase in the literature regarding the problem with childhood obesity, there is minimal information available for youth with developmental disabilities. In particular the data available regarding the weight status of individuals with ASD is scarce, yet studies have found a variable prevalence of obesity in children and adolescents with ASD.[191-193] Results from these studies indicate that the frequency of obesity in youth with ASD may be similar to the general population or higher, yet many of these studies have no comparative group, have small sample sizes and were conducted more than fifteen years ago.[191] A more recent study however, with a larger sample size and comparative group conducted by Curtin et al. (2005), found that children with ASD have a prevalence of being overweight which is comparable to the general population.[191]

Nevertheless, this population may be susceptible to developing obesity due to their increased prevalence of physical, behavioural and psychosocial difficulties.[191] Atypical physical activity and eating patterns in this population may be closely associated with obesity development.[191] Generally physical activity levels are lower in this population making them prone to obesity, and in addition motor impairments may prevent individuals from participating in physical activities successfully.[191, 194] Furthermore, eating habits in children with ASDs have been reported to be unusual and highly selective.[191] The individuals have been reported to have a preference for soft, sweet and energy dense foods which may contribute to their risk of obesity.[195]

vi. Aerobic fitness

There have been no studies to date, to the researchers knowledge, that have determined whether individuals with ASD have a similar aerobic capacity to individuals of the same age without ASD. It would however be expected that due to the ASD population being less physically active and being more likely to have motor impairments (aiding in the inability to perform certain physical tasks), that they may have reduced aerobic fitness levels. It may therefore be necessary to implement interventions to increase aerobic fitness levels within this population. A study conducted by Lochbaum and Crews (2003), effectively increased aerobic fitness levels in individuals with ASD by between 33% and 55% (n=5) through a cycling (n=3) and resistance training (n=2) intervention.[30] In addition, Pitetti et al. (2007), reported an improvement in exercise capacity and caloric expenditure in 5 individuals with autism who participated in a nine month exercise programme as compared to an age-matched control group.[23] However, both of the aforementioned studies had very small sample sizes.

vii. Flexibility

There have been no studies conducted comparing flexibility profiles in children and adolescents with ASDs to their typically developing counterparts. However many studies have reported deficits in muscle tone and physical activity levels.[14, 38] Generally individuals with ASD lead sedentary lifestyles[38] and this may predispose them to having reduced body flexibility. Furthermore, in individuals who have decreased or low muscle tone (hypotonia), there is an increase in the resting length of the muscle and hence increased flexibility at the joint.[23] However there is no research available showing if individuals with ASD who have low muscle tone have increased joint flexibility.

There have however been some studies looking at how flexibility may be influenced through exercise interventions. Yilmaz et al. (2004), showed an improvement in flexibility parameters in one individual with autism, where the individual participated in an aquatic programme for 10 weeks, 3 times a week for sixty minutes per session.[24] In contrast, a study by Fragala-Pinkam et al. (2008), assessed nine individuals prior administering an aquatic intervention programme (6 with autism and 3 with PPD-NOS) and showed no significant increase in flexibility.[26]

Further research therefore needs to be done in individuals with ASD to determine what their flexibility profiles are in relation to typical individuals to effectively determine firstly, whether flexibility interventions are needed, and secondly, how they could benefit the population.

viii. Agility

Similarly, there have been few studies to date focusing on the agility capabilities of individuals with ASD. In a case study conducted by Yilmaz et al. (2004), it was reported that after a 10-week aquatic training programme, the participant with ASD who participated in 60 minute sessions three times a week, had an improvement in agility.[24] The study made use of an agility thrust test where agility was measured pre- and post-aquatic intervention programme. The individual improved from 10 agility points to 13 points following the intervention. Although there is no data regarding whether individuals with ASD have a deficit in agility capabilities as compared to typically developing individuals, it may be inferred that due to having general motor impairments, individuals with ASD may be prone to being less agile. In addition, in reference to the study by Yilmaz et al. (2004), if agility deficits do occur, implementation of aquatic training and/or other forms of exercise may help improve the deficits within the individuals,[24] however more studies need to be conducted for better understanding.

ix. Quality of life

"Quality of life is a critical measure of treatment outcome for people with mental and physical health concerns".[196] To date there have been no studies that have identified indicators predictive of quality of life for children or adults with ASD. Yet, a possible model for utilizing quality of life indicators to measure and evaluate outcomes for individuals with ASD has been proposed by Burgess and Gutstein (2007).[196] They postulate that measurable indicators may include social support, academic functioning and/or satisfactory employment, family life and self-determination. In addition, they suggest that several considerations should be taken into account when measuring this outcome, such as developing age appropriate measures that are autism specific, multidimensional and clinically useful. The development of interventions, whether they are exercise-based or not, should therefore take into consideration whether an individuals quality of life may be improved following the intervention. If this is not the case an alternative means of therapy which may improve quality of life should be pursued instead.

In summary, it should be noted that there is a dearth of literature regarding various physical parameters in individuals with autism such as agility, flexibility and aerobic fitness levels. Although studies have been conducted, looking at the before-mentioned variables, many questions remain, such as: do individuals with autism generally have lower aerobic fitness levels and different flexibility and agility profiles to typically developing individuals? And would interventions effectively correct these issues? It is also relatively clear that these individuals lead a relatively less active lifestyle compared to individuals without ASD and thus may be at greater risk of obesity and sedentary-related health problems. Further research into these variables is necessary so that there is a greater understanding of how these areas may influence an individual, and so that effective interventions may be implemented to manage these deficits.

2.2.6 The public health impact of autism

While it has been reported that individuals with ASD may have a reduced lifespan, the majority of the public health burden is due to core impairments of the disorder as well as associated co-morbidities which often require additional treatment.[(197)] It has been estimated that the medical expenditures of children with ASD are nine times higher than typically developing individuals and three times higher than those with mental retardation.[(198)] In addition the fee for caring for an individual with ASD is estimated to be between 85% and 550% more than the fee for caring for a neurotypical child, with a typical lifetime community expenditure estimated to be $4.7 million dollars per person.[(199)]

There has been a drive for timely identification in ASD due to the increase in interest in behaviorally-based educational interventions, yet routine screening for ASD does not readily occur and identification rates vary greatly.[(200)] Furthermore, there is little literature regarding the worth and effectiveness of screening tools for the population[(63)] and the number of facilities providing comprehensive evaluations and treatment plans for children suspected to have ASDs cannot meet demands. Statistics in South Africa are limited, yet it is suggested that not nearly enough individuals are receiving the specialized education and treatment they require, as only 9 schools provide these specialized services.[(21)]

In summary, it is clear that ASD has a large public health impact. The public health burden may be reduced if, early identification occurs, effective interventions transpire where individuals become less reliant on costly therapies, and enough facilities become available to administer the specialized care needed. This however is a monumental task and one that will not be achieved without continued research identifying more cost effective strategies for the management of the condition, and more facilities becoming available for the efficient care of the population. A good starting point however would be to start implementing interventions, for example exercise interventions which are not extremely costly.

2.2.7 General interventions / current treatment procedures

The main treatment and intervention goals for individuals with ASD are to reduce the core symptoms and associated conditions of the disorder, reduce family stresses, improve quality of life and maximize functional independence.[(61)] The main components for effective management of ASD include organized educational interventions which include rehabilitative therapy and behavioral strategies. These components should be used together to tackle deficits in social and communication skills, ADLs, play and leisure skills, academic skills, as well as address maladaptive behaviours.[61] Educational interventions have generally been implemented in younger children as research has shown that early targeted intervention results in markedly improved outcomes with a significant influence on behavioural problems and abilities.[45, 61]

Applied behavioral analysis (ABA) therapy is a widely accepted treatment for individuals with ASD.[201] This form of therapy involves reinforcing and shaping positive behaviours e.g. learning to speak and reducing undesirable ones e.g. body rocking. The therapy involves one-on-one child-teacher interaction for up to forty hours per week and through its effectiveness has encouraged the development of like interventions. ABA interventions include pivotal response training and verbal behaviour training.

Other widely accepted treatments for the ASD population include:

- The Treatment and Education of Autistic and related Communication Handicapped Children (TEACHH) programme which focuses on environmental adaption for the child so that they may function more independently (for example: labeling materials needed for everyday living so that the individual may find them more easily). A study conducted by Panerai et al. (2009) reported that TEACCH is a useful treatment programme as individuals with ASD are able to constructively complete tasks in a normal setting.[45]
- The Floortime Model which uses the natural emotions and interests of the child to form significant and healthy abilities and relationships for better functioning.[202]
- Interpersonal synchrony which focuses on education on how to institute and preserve engagement with others through targeting social development and imitation skills.[203]
- Discrete Trial Training which attempts to ascertain learning readiness by coaching foundation skills, comprising obedience, attention, imitation and discrimination learning.[61]
- Speech and language therapy in order to address speech and communication impairments.[61]
- Occupational therapy in order to “promote development of self-care skills and academic skills such as writing and cutting”.[61]
- Sensory integration therapy in order to teach individuals to interact and adapt more effectively with the environment through the improvement of neurological processing deficits and integration of sensory information.[61]

These treatments and interventions are usually rolled out at the home of the child or at childcare centers when individuals are younger than 3 years old after which they may be implemented at schools or other specialized facilities. The interventions and treatments are usually administered by trained clinicians or teachers, yet newer interventions encourage the training of parents to continue therapy at home.

As no sole optimal treatment intervention has been established for children and adolescents with ASD, the American Academy of Pediatrics has listed shared features of successful early intervention programmes.(204) Some of the most important points include: starting an intervention as soon as possible i.e. as soon as the diagnosis has been made; making sure interventions are individualised or rolled out in small groups; monitoring progress along the way and making sure that parents/peers are involved as a form of support.(204)

In addition to the above-mentioned treatments and interventions used within the ASD population, medications are often prescribed for management of the condition. Medications and pharmacological therapies should be considered as supplementary treatments and not cures, and their latent undesirable toxicities and side-effects taken into consideration.(205) The drug treatments however, can be used to lessen symptoms, improve quality of life for the individual as well as render the individual more willing to participate in non-pharmacological treatments and interventions.(206)

Medications that have previously been prescribed for children with ASD include the following:

i. Antidepressant medications

These medications are usually prescribed to reduce repetitive behaviours as well as control anxiety and aggression. There has been debate on whether these medications are useful. For example a study conducted by King et al. (2009), stated that the use of the drug citalopram (Celexa) in children with ASD, had a similar effectiveness to a placebo (sugar pill) at reducing repetitive behaviors suggesting Celexa is not beneficial in the population.(207) Other commonly prescribed antidepressants for the ASD population include fluoxetine (Prozac) or sertraline (Zoloft).

ii. Antipsychotic medications

These medications are commonly prescribed to treat serious mental illnesses such as schizophrenia, as well as aid in the reduction of aggression, repetitive behaviours, attention difficulties, hyperactivity and other serious behavioural problems in children with ASD.(15) One of the most studied antipsychotic drugs (Haloperidol) has shown to be effective in “reducing aggression, self-injurious behaviours, hyperactivity, tantrums, irritability, social withdrawal and stereotyped behaviours”.[207, 208] Similarly, another antipsychotic, Risperidrone, has also proven to be effective in decreasing aggression, irritability, and repetitive behaviours, however there was no effect on social communication variables, and undesirable side effects included increases in weight and appetite, as well as lethargy, tiredness, lightheadedness and drooling.[209] Other commonly prescribed antipsychotics for the ASD population include: Olanzapine (Zyprexa™) and Ziprasidone (Geodon), yet there is minimal research on their effectiveness in reducing similar behaviours.[15]

iii. Stimulant medications

These medications are commonly prescribed to effectively treat individuals with attention deficit hyperactivity disorder (ADHD). Methylphenidate (Ritalin™, Concerta™) has been reported to reduce hyperactivity in neurotypical children and those with ASD; however less individuals with ASD tend to respond to treatment and in addition have more side effects compared to children with ADHD.[9]

In addition to medication, often dietary interventions are used to manage symptoms in the population. Often the foods containing gluten and casein are emitted from the child’s diet in order to reduced maladaptive behaviours. These behaviours are said to be caused by physiological imbalances as a result of “incomplete breakdown and absorption of peptides found in these foods”.[210]

In summary, all medications carry side effects, and hence pharmacological agents and their effects on the individual should be addressed when implementing interventions in children with ASD. In addition, comorbid conditions associated with ASD also need to be considered when developing interventions in the population, as these may hinder performance in various aspects of the individuals’ life and additional medications may be prescribed to manage those conditions.There are minimal facilities in South Africa that offer a variety of teaching methods and assistance for adolescents with ASD,[21, 205] and this is of great concern. It has been shown that the most successful means of rehabilitation for the population is making use of a multidisciplinary team who use a variety of treatment modalities and take care to provide treatment in an individualised manner.[15, 205] Hence, optimal rehabilitation of individuals with ASD in the future may depend on greater access to appropriate facilities and trained personnel that follow the above mentioned principles.

2.3 Physical activity, fitness and exercise

"Kid says to me, "You play baseball? What position? Left out?" and gets a big laugh from the rest of the class. Kid is only one person out of 6.792 billion humans on this planet. This planet is only one-eighth of the solar system, whose sun is one of two billion stars in the Milky Way galaxy. Put it that way, the comment loses its importance".[41]

2.3.1 Definition

According to the world health organization (WHO), physical activity may be defined as "any bodily movement produced by skeletal muscle that requires energy expenditure",[211] and physical inactivity is deemed to be the fourth leading risk factor for global mortality resulting in approximately 3.2 million projected worldwide deaths per annum.[211]

2.3.2 Benefits

Partaking in regular physical activity has been shown to improve the physical condition of individuals with ASD as well as reduce their impaired behavioural patterns.[212] In particular, studies conducted in children with ASD indicate there is an improvement in both psychological and physiological factors with the participation in moderate and vigorous physical activity.[27, 28] It has also been shown that physical activity positively influences intellectual and social outcomes, self-esteem and happiness.[29]

In particular aerobic exercise in individuals with ASD has been shown to reduce their BMI indices, and improve general body conditioning.[23] Furthermore, structured aerobic exercise in various populations has been shown to improve task behaviour, work performance and attention span,[213-215] as well as decrease self-injurious behaviours, aggressive behavior and unproductive and disruptive behaviour.[216, 217]

A leading problem with children and adolescents with ASD is their self-stimulatory behaviour.[160] Self-stimulatory behaviour - also known as autistic mannerisms, stereotypic behaviour or repetitive behaviour - includes body rocking, hand flapping, spinning, head nodding, gazing at lights, object taping, and mouthing.[161] This behaviour has been studied extensively in many diverse populations [162, 163, 218] and although not all the populations function identically,[165] research has shown that this self-stimulatory behavior hinders learning as well as positive social behavior due to its disruptive nature.[33, 166] Various researchers and practitioners have since reported success in using exercise as a modality for treatment in reducing these behaviours.[24, [25, 219] Importantly, the use of exercise has reduced these behaviours in the affected individuals without interfering with academic performance. [25, 213, 220]

In summary, it has been highlighted that physical exercise may be very beneficial in addressing various impairments associated with ASD and therefore should be considered a viable means of rehabilitation for individuals with ASD. Exercise should however be implemented in a safe and efficient manner while following specific guidelines for optimum benefit.

2.3.3 Physical activity levels in autistic vs. typically developing children

Generally, typically developing children are more likely to participate in vigorous and continued physical activity as compared to children with disabilities[221, 222] and studies have shown that children with ASDs in particular, have significantly lower physical activity levels as compared to their typically developing counterparts.[16, 17] Studies have also shown that children with ASDs tend to favour more self-contained physical activities such as swimming and cycling and that there is reduced participation in team and non-team sports.[223] It is speculated that their impaired motor, sensory, social and behavioral domains may be the reason for their reduced physical activity levels, and that possible environmental factors may also influence their participation in physical activity.[32] These will now be discussed further.

i) Motor impairments

Previous studies using standardised motor assessments have reported that more than half of children diagnosed with ASDs exhibit movement difficulties.[224, 225] Impairments in motor abilities such as poor balance, and impaired motor coordination may limit activity choices and give rise to a preference for sedentary-type activities such as playing on the computer or the watching of television.[16, 226] These preferences may in turn lead to more sedentary-type lifestyles which may further inhibit gross and fine motor skill development, as well as lead to obesity.[32] Movement difficulties and inferior motor skills may also hinder the want to participate in physical activity, as individuals may feel inadequate and unable to achieve and excel in physical activity settings. Furthermore, as individuals with ASD lie on a spectrum of impairment, it may be difficult for lower functioning individuals to compete or participate with higher functioning individuals within a particular setting. If this is not considered in interventions/ programmes, individuals may become frustrated in not being able to perform and this may further elicit a negative mind set towards participating in physical activity. It could therefore be suggested that individuals at a similar level of function should exercise together to reduce this possible frustration.

ii) Sensory impairments

Studies have reported incidence rates of between 42% and 100% for sensory processing problems in individuals with ASD, with problems arising in various sensory domains such as auditory, visual and tactile areas.[227-229] These sensory changes may upset an individuals' proficiency in play and in turn lead to avoidance of activities rich in sensory stimulation,[226] further decreasing physical activity levels. Although a study conducted by Bass et al. (2009), reported that sensory skills may be improved with exercise (where an individual engaged in sensory stimulation through riding a horse (hippotherapy));[230] more research is needed in this field to determine what the most appropriate and efficient form of exercise would be to specifically target sensory improvement. This highlights a gap in the body of knowledge encompassing how exercise may be specifically beneficial within the population of ASD in improving sensory impairment, hence reiterating the need for further research in this area.

iii) Social communication impairments

The participation in group activities, such as group physical activities, is often hindered by social communication impairments in individuals with ASD.[16, 226] Communication impairments inhibit the formation of appropriate peer bonds and social enjoyment in participating in tasks, whether it be performing physical activity, or working effectively in a classroom setting. The fulfillment of being part of a team or group and sharing fun experiences may be limited due to these impairments and hence the overall experience may be diminished in individuals with ASD as compared with their typically developing counterparts. This may contribute to the preference for participating in lone physical activities instead of group activities. In addition, behavioural problems may further impair the abilities of individuals with ASD to communicate effectively with one another, and often behavioural problems may irritate those around them further isolating them from participating in a group setting. Individuals with ASD often have highly restricted interests and these may be difficult to share with other individuals, once again leading to lone participation and isolation. Furthermore, individuals with ASD prefer adhering to set routines which are often uncompromising. This often makes it impossible for many individuals to come together and participate at a particular time without disrupting these personal schedules or routines. With this being said, individuals with ASD should still be encouraged to participate in group activities as much as possible to reduce the possibility of further social impairment. A study conducted by Pan (2011), suggested that the participation in exercise may have a positive effect on social communication within individuals with ASD,[231] allowing for greater participation in physical activity. However, further research needs to be conducted as to what the exacting effects of exercise may have on social behaviour.

iv) Environmental factors

Similarly to their typically developing counterparts, environmental factors such as having access to various physical recreation facilities and resources may affect the participation in physical activities in individuals with ASD.(222, 232) In general, individuals who have access to these facilities and resources are more likely to have better physical participation levels compared to those who don't. Furthermore, a lack of time as well as having a poor support system in the family and peer environment often influences the physical activity behaviour of individuals with ASD,(222, 232) which is something that needs to be addressed in the population.

In summary, motor impairments, social communication, behavioral impairments as well as environmental factors may all contribute to lower physical activity levels in individuals with ASD. These impairments and factors should hence be taken note of and improved in the population so that individuals are better equipped to participate in physical activities. Individuals should be assessed so that key areas for improvement are identified to make participation in physical activity easier for them and they should be encouraged to a certain extent to participate in group activities as much as possible. Furthermore, all individuals with ASD should be encouraged to increase their physical activity levels to meet the physical activity recommendations and guidelines set out for the ASD population.

2.3.4 Exercise recommendations for children and adolescents with ASD

It may be very demanding working with individuals with ASDs,(32) thus having a basic knowledge of the exercise recommendations tailored specifically for this population could make exercise prescription more effective and appropriate. Below are guidelines on exercise recommendations for individuals with ASDs. These have been proposed by Srinivasan et al. (2014),(32) who based these guidelines on the principles of contemporary approaches of treatment for individuals with ASDs from TEACHH,(233) PECS(234) and ABA.(235) The guidelines include information on the appropriate environmental structure needed for exercise, specific considerations for exercise as well as how to appropriately provide instruction, feedback and reinforcement to the individuals participating in the programmes.

1. Environmental structure

Exercise sessions should be conducted in the same physical space or area [233] and scheduled in such a way to allow for predictability and familiarity,[32] for example: every Tuesday and Thursday at the same time of the day in the same gym. This allows for routine to be maintained for the individuals where necessary. In addition, it could be added that the same, appropriately qualified, person should be responsible for each session, allowing individuals with ASD to form a bond and trusting relationship with the individual responsible for the sessions.

Careful and appropriate selection of the environment is required, where the specific needs of individuals should be taken into account. For example: intense/ flashing lights, loud sounds and frequent distractions in the environment may not be appropriate for individuals with hypersensitivity.[32] If such distractions exist, they should be removed from the training environment so that individuals may feel as comfortable as possible.

The environment should be thermoneutral as the thermoregulatory systems of children and adolescents are not fully developed.[236] For example: exercising outdoors at midday on a hot day would not be appropriate. Furthermore, if individuals become uncomfortable in a particular environment and ASD symptoms worsen, individuals should be removed from the particular environment in question and taken to an area that they feel comfortable in.

Visual cues may be used to affirm the specific spot where individuals will be exercising and the space that will be available to them, and picture schedules may be used to outline sessions so that individuals may understand how the session may advance as well as to allow for anticipation of the next exercise.[234, 237] For example: handing out of a picture schedule of exercises to be done prior to the session may make individuals feel more at ease and more compliant towards exercises, as they then have a greater understanding of what is expected of them. Furthermore, it could be added that enough time should be allowed for any questions individuals may have regarding the schedule.

With each new exercise prescribed, time should be allowed for adaption to the new task.[32] For example, making sure enough time is set out for the learning of new activities so that sessions do not run over time.

2. Considerations for exercise

When beginning and implementing an exercise programme, the person responsible should according to Srinivasan et al. (2014):[32]

Allow enough time for a suitable warm-up and cool down within a session, and provide adequate breaks and avoid overstimulation throughout the session so individuals do not become overwhelmed.[32] For example: a short jog around the field prior to starting an exercise session as well as when ending off an exercise session may be appropriate for individuals participating in field activities. Furthermore, it can be added that individuals should be allowed to rehydrate whenever necessary throughout an exercise session.

Progress exercises gradually according to individual outcomes, making use of variation and include enjoyable activities to promote success in the individual.[32] For example, modify an exercise an individual enjoys to make it more difficult, yet enjoyable; by possibly using a ball or piece of equipment the individuals enjoys working with.

Utilise adaptive equipment to accommodate for any sensory or motor impairments of the individual such as, making use of a kit which is safe and specially designed for individuals with learning and motor difficulties.[33] If no equipment is availbale of this nature make sure that any substiture equipment is user friendly, safe and age appropriate for the individual.

Monitor exercise performance with heart rate monitors, and use appropriate rate of perceived exertion scales such as the pediatric OMNI scale in individuals who are intolerant or are taking antipsychotic medications, as the medications may affect resting and exercise heart rates and blood pressure.[32, 236, 238] For example: make sure each individual is being monitored throughout an exercise session and take special care to monitor those who are taking medications which may mask the typical exercise response.

Stop activity if the individual has any observed negative-type behavior during the session, such as self-injurious behaviour, tantrums and non-adherence. Obtaining information from caregivers, teachers and parents prior to exercise sessions on possible negative behaviours to be expected, as well as advice on the management thereof is very important.[235] For example: stop exercising if an individual begins to scream and shout and show signs of irritation towards you.

Physical activity should be encouraged by parents, teachers and caregivers not only in its pure form but also in the form of daily chores, games and recreational activities whereby the physical activity becomes part of the individual’s daily routine.(32) Furthermore, emphasis should be placed on participation with others, for example: parents should encourage individuals to go outside and play with others instead of allowing individuals to participate in lone, sedentary-type activities as this may negatively influence their social behaviour.

Understand where on the spectrum the individual lies in terms of function, individuals who are lower functioning may require individual sessions whereas those who are high functioning may do extremely well with group exercise sessions.(32) For example: encourage group activities wherever possible if it is seen that an individual benefits from this type of activity, however if group participation hinders progress this should kept to a minimum or avoided completely.(32)

3. Instruction, feedback and reinforcement

According to Srinivasan et al. (2014), one should:(32)

Be precise in exercise instruction by using short, concise phrases and avoiding long verbal cues; and combine verbal and visual cues for more effective instruction .For example: demonstrate the task while giving instructions or show a picture to the individuals while talking so that concepts are reinforced.(32)

Reinforce verbally, gesture and use rewards such as little stickers, toys or healthy snacks to guarantee adherence to the task at hand. For example: tell the individual that they have done a good job and give them a high five.(32, 235) It should be added that permission be obtained prior to giving individuals food items, whether it be a healthy snack or sweet as an incentive, as some individuals may have very strict dietary requirements.(239)

Provide manual assistance to individuals who struggle with specific motor activities and allow for breaks from activity to perform individual favourite sensory activities.(32) For example: help an individual perform a specific task if it is of benefit to them, otherwise modify said task so that the individual may perform it by themselves.

Encourage exercising with peers or siblings who are of a higher level of function or are typically developing so as to motivate the individual.(32) For example: encourage a lower functioning individual to work with a moderate functioning peer, but be sure not to hinder progress as well as frustrate the higher functioning individuals.

It should be noted that the above guidelines postulated by Srinivasan et al, (2014) are general guidelines, and thus it is still necessary and important to tailor exercise programmes specifically for individuals so that there is maintenance of interest in the programmes being administered as well as to foster long-term adherence to physically active lifestyles.[32]

In addition to following these general guidelines on exercise recommendations for implementing programmes, programmes should also follow a basic standardized outline. The development of exercise programmes for individuals with ASDs need to be specifically tailored for the population so that exercise is safe, stimulating and enjoyable.

Srinivasan et al. (2014) have proposed that an exercise programme for this population should include aerobic, flexibility, resistance training and neuromuscular components so that maximum body composition and fitness gains are achieved.[32] It has been proposed that for children and adolescents with ASD, aerobic exercise should be performed 3 days per week progressing up to 5 days a week at a moderate physical intensity for between 20 to 30 minutes a day accumulated over short bouts of training. Preferred aerobic exercises proposed by Srinivasan et al. (2014) include walking, jogging, cycling swimming and treadmill training amongst others.[32]

According to Srinivasan et al. (2014), resistance training should be performed once a week progressing to twice per week and should be performed at an intensity of 10-15 RM. It is proposed that one set of 6-15 repetitions be done initially, progressing to 2-3 sets of 8-12 repetitions. Initially 2-3 minute breaks between sets should be given and then these should be gradually reduced. The type of resistance training recommended for those under the age of ten are calisthenics type activities where as those recommended for individuals over the age of ten are strengthening programmes targeting the upper and lower extremities as well as the trunk using therabands , free weights and body weight resistance.[32]

Lastly, flexibility and neuromuscular activities should be performed once to twice a week for approximately sixty minutes and should include “muscle stretching exercises for major arm and leg muscles, therapeutic horseback riding, aquatic exercises, yoga and tai- chi”.[33][32]

In addition to the recommendations and above guidelines, it should be noted that children and adolescents spend vast amounts of time at school, thus exercise programmes based at schools may be invaluable in fostering healthy lifestyle practices.[240] Furthermore, it is encouraged that exercise sessions are geared towards being fun and enjoyable and incorporate activities that individuals with ASD have a particular interest in.

In summary, the understanding and implementation of the above proposed recommendations and guidelines aids in familiarization of the population so that appropriate development of exercise programmes may ensue. Individualised programming should be the predominant focus with a move toward group programming if individuals are able to engage and participate effectively in this environment. Individuals should feel safe in their environment at all times and special care should be taken to remove individuals from a situation that elicits a negative response in the individual. There should be appropriate planning of exercise sessions so that there is enough time for individuals to become familiar with the activities at hand, to allow for optimal enjoyment of the sessions as well as to incorporate the majority of physical components such as aerobic, resistance training, flexibility and neuromuscular activities.

2.3.5 Challenges and barriers for participation in physical activity

A challenge or barrier to physical activity can be defined as an "obstacle individuals face in undertaking, maintaining or increasing physical activity".[241] Many such obstacles have been suggested for individuals with ASD, some of which include poor motivation to participate in physical activity, poor motor and organisational skills needed to perform various physical tasks, problems with self-monitoring as well as poor social and behavioural skills.[242] Furthermore it has been suggested that there are only a few physical activities programmes which have been specially designed to cater for the needs of individuals with ASD and that there is a lack in community physical activity programmes available for these individuals. In particular, there are no such programmes currently available for individuals with ASD in South Africa, and this needs to be addressed. Furthermore, in countries where these community activity programmes do exist, they are often too challenging for individuals with ASD to participate in, due to the various deficits and impairments they may have. Thus combined physical activity programmes (with typically developing individuals) may not be a solution, but rather a starting point to encourage physical activity within the population. After which, specialised programmes could be created for individuals with ASD to effectively participate in physical activities.

Another challenge is that individuals with ASD generally don't perform as well as their typically developing counterparts in terms of scoring or achieving particular outcomes,[243] this often makes the individuals feel despondent and inferior, often hindering participation in future events or activities. In order to combat this, constant encouragement may be beneficial. Furthermore, a decrease in group activities is usually noted in this population, due to the complex skill requirements often needed for participation,[242] hence a conscious effort should be made to try and encourage group activity participation within reason.

The Autism Association of America has gone further as to suggest particular risk factors for not participating in physical activity in this population. Highlighted risk factors include: problems in making eye contact with others, the inability for individuals to take turns or engage in imaginative play with others, the inability to share and make friends with others as well as not being able to comprehend social cues.[10] These factors all contribute to the non-participation and isolation of individuals with ASD, which further exacerbates the problem of sedentary-type living within the population. It is necessary to therefore identify these risk factors early on in exercise intervention so as to try and reduce them if possible.

2.4 Exercise specific interventions and outcomes

A range of problem areas in autistic populations have been targeted through various interventions such as occupational therapy, applied behavioural analysis, therapeutic horseback riding and pharmacological treatments to name a few.[167, 244] One of the more current types of interventions uses physical exercise as a modality.[167] The first account of exercise being beneficial in autistic populations was anecdotal in nature, with special education teachers reporting that learners seemed to be more cooperative and attentive following participation in physical activity,[30] this thus lead researchers to explore the benefits of exercise in this population.

Over time it has been showed that , exercise, when incorporated into the daily lives of individuals with ASD improves physical health, intellectual functioning, behaviour, perception and personality.[18, 245]

Studies have shown improvements in exercise capacity and caloric expenditure and a statistically significant decrease in BMI (n=10),[23] as well as improvements in flexibility, strength and balance (n=1),[24] as well as a significant reduction in time taken to complete a half mile run/walk (n=6).[26]

Elliot et al. (1994), reported that following vigorous exercise there was a significant reduction in stereotypy (body rocking), and maladaptive behaviour (aggression) (n=6).[25] Furthermore, in autistic specific populations aerobic exercise has been shown to increase appropriate responses as well as reduce self-stimulatory behaviours in both children and older adults devoid of a decline in academic levels. [25, 219, 246] In addition, studies previously done in children and adolescents with ASD indicate there is an improvement in both psychological and physiological outcomes with the participation in moderate and vigorous physical activity.[27, 28]

Generally, most studies investigating the effectiveness of exercise in ASD populations have looked at conventional types of exercises such as walking, swimming and general strengthening activities, yet recently there have also been studies which have looked at unique forms of physical activity and their benefit in ASD populations. One such study evaluated the effects of a structured therapeutic skating intervention on motor outcomes and functional capacity in two boys with ASD aged 7 and 10 years respectively. The boys participated in three, sixty minute skating session per week for 12 weeks and it was found that they had an improvement in balance, motor behaviour and functional capacity.[247]

Another study investigated the use of dancing as a means of rehabilitation in a 15 year old girl with ASD. She participated in 30-minute sessions of dance therapy twice a week for a year, totalling 120 sessions. She showed marked improvement in her balance where her overall Tinetti balance score improved from 68% to 75%, and her overall motor function measure improved by 27.1%.[248] Following dance therapy, the participant moved from a “severe” ASD diagnosis to a “moderate” ASD diagnosis according to the childhood autism rating scale for the before mentioned parameters,[248] thus making dance therapy an effective physical activity tool in rehabilitating this participant with ASD.

Clearly, no matter the type/ mode of exercise, studies have shown that all types of physical activity may be beneficial for individuals with ASD. Furthermore, overall, there has been a general consensus that physical activity has great value as a means of rehabilitation in populations with ASD; however there are still large gaps in the literature for particular motor variables. For instance, there are no studies available that have generated agility profiles for the ASD population, nor are there any studies assessing whether agility parameters may be influenced by exercise training programmes, and if so, by how much?

Furthermore, a similar problem exists for flexibility variables, where there is very minimal information available regarding flexibility parameters and again a general absence of flexibility profiles for the population.

In addition, there are no studies that look at how exercise interventions may influence many motor variables. Studies generally look at two to three motor variables at a time and hence valuable insight into other parameters may be overlooked. It is therefore essential that future studies look a broader scope of motor variables, when determining the influence of exercise interventions so that researches can hone into which motor skills can be significantly improved and hence target these in therapeutic settings.

In summary, exercise and physical activity has been proven useful as a treatment modality for various impairments and difficulties within the autism population. Although many studies have been conducted to identify where physical activity may be used as a means for rehabilitation there are still many unanswered questions and variables which have not been researched. In addition, large gaps exist where no research has been done to look at how exercise may benefit an individual as a whole i.e. looking at more than one variable at a time and thus further research should strive to look at his.

It has, also been highlighted that there is a great need to increase physical activity levels within autistic populations as they tend to live more sedentary type lifestyles which often hinder further progress of the individuals as well as put them at a greater risk for obesity and heart disease. Therefore, it is essential that holistic interventions, which include exercise as treatment modality, are provided to these populations so that they may benefit maximally.

“

CHAPTER 3: METHODOLOGY

The subtopics that will be covered in this chapter include:

3.1 Introduction

Literature regarding autism and the participation in physical activity provides empirical evidence for health benefits, and improvements in movement impairments within the population. Various assessment tools have been used within the autism population to measure physical activity as no single tool has been developed specifically for use with individuals with autism. Tools do however exist for special needs populations and these may be deemed appropriate for use within the autism population. Some of these tools have been used in the present study and will be discussed following a brief description of the study sample and design.

3.2 Study design

This study was a randomised control intervention trial.

3.3 Site of study

Baseline/ pre-intervention testing, the 12-week exercise intervention, and post-intervention testing were performed at UNICA School for Autism in Pretoria. UNICA School caters for all individuals with ASD (low to high functioning) aged 3 to 18. The school is one of two schools, which caters for children with ASD in Pretoria, South Africa. Letters of permission to conduct this study were obtained from the principal at UNICA School for Autism and the Gauteng Education Department (Appendices A and B respectively).

3.4 Sample population

3.4.1 Selection of subjects

Adolescents aged from 11 to 16 years attending UNICA School for Autism were provided with an information sheet, and invited to participate in this study (Appendix C). The adolescents' parents were provided with a parent information sheet (Appendix D) inviting them, and their child, to participate in the study. Prior to the commencement of testing the parent/ legal guardian signed parental consent (Appendix E) and the adolescents signed a child assent form (Appendix F). Procedures for orientating parents and teachers may be found in Appendix G.

3.4.2 Sample size

Since the prevalence of autism has been documented to be 1 in 88 individuals, the minimum sample required per group for this study was 10, allowing for a clinically acceptable margin of difference of 5%. (α=0.05; β=1.645,p= 80%; δ_0=0.05). The following formula was used to determine the sample size:

$$N= 2 \times \left[\frac{z_{1-\alpha} + z_{1-\beta}}{\delta_0}\right]^2 \times p \times (1 - p)$$

N=size per group; p = the response rate of standard treatment group; z_x= the standard normal deviate for a one or two sided x ; δ_0= a clinically acceptable margin.

A sample of 30 adolescents with autism was therefore recruited from UNICA School for Autism to account for dropout, and participants were randomly assigned into two groups of near equal numbers: the intervention and control groups (procedure discussed below). Although the sample may appear to be small this is the largest exercise intervention study to date to be conducted in this population in South Africa.

The following criteria were used for inclusion and exclusion into the study:

3.4.3 Inclusion criteria

i. A diagnosis of autism.
ii. Be aged from 11 to 16 years old.
iii. Have a tolerance for the gross motor testing. The occupational therapist at UNICA School was consulted about the participants's tolerance levels, and she helped advise on whether certain adolescents could be included in the study. In addition, if during the initial assessment, any participant was unable to perform the gross motor skills required they were not included in the study.

3.4.4 Exclusion criteria

i. Adolescents not in good health, or those who had a disease or impairment (besides ASD) that affected delays in their physical activity.
ii. An impairment in fundamental receptive and expressive communication abilities.

3.4.5 Randomisation

After the recruitment, the participants of the study were stratified into whether they were low, moderate or high functioning. Stratification of level of function was done with the help of the registered psychologist and psychometrist at UNICA School who had previously assessed the participants and had determined their mental ages (Appendix H). It was advised that the participants at the school were generally low functioning as compared to the general population, however the participants still needed to be classified into categories so that control and intervention groups were matched according to level of function. Individuals were classified as low functioning if their mental age was, or fell below the age of 3.5 years, individuals were classified as moderate functioning if their mental age was or fell between the ages of 3.6 - 6.5 years and individuals were classified as high functioning if their mental age was above 6.6 years. After this stratification was complete the individuals were grouped into their categories. The sample consisted of - 15 high functioning participants, 8 moderate functioning participants and 7 low functioning participants. Following this stratification randomisation was then conducted. Online randomisation software, Research Randomizer,[249] was used to divide the participant group into control and intervention group categories. As it so happened there was equal representation of males and females in each group and so male female stratification was not done further.

3.5 Testing procedures and equipment

The objectives of the study and how the objectives were met using the various instruments are described below. An in-depth look at how the study was conducted follows.

1. ***To formulate and implement a model exercise intervention programme in adolescents with autism.***

   A model exercise intervention was developed and validated by an expert panel carefully selected for the study and was implemented over 12 weeks at UNICA school for Autism. Details regarding the intervention are described under point 3.6.

2. ***To assess posture, body composition and physical fitness pre-and post-exercise intervention in adolescents with autism aged 11 to 16 years.***

   Posture was observed and then analysed using a posture grid overlaid on photos taken of the individuals'. Body composition and physical fitness were assessed using the Brockport Physical Fitness Test battery.

3. ***To assess balance, coordination and agility pre-and post-exercise intervention in adolescents with autism aged 11 to 16 years.***

   Balance and coordination were assessed using the MABC-2 test battery and agility was tested in the test battery developed by the researcher using an agility T-test.

4. ***To assess gait pre-and post-exercise intervention in adolescents with autism aged 11 to 16 years.***

   Gait was assessed as part of the researcher's additional test battery using two video cameras per participant, and interpretation was done using Dartfish analysis software.

3.5.1 Testing procedures using selected instruments

Each participant was tested individually. Testing was performed twice, once within 3 weeks prior to the implementation of the intervention, and again within 3 weeks after the 12-week exercise intervention was implemented. Testing in both instances included the use of a standardised Brockport Physical Fitness Test (BPFT) battery; the Movement Assessment Battery for Children-2 (MABC-2); and the testing of posture, gait and agility. Each participant was first tested with the BPFT (the test took approximately about 30 minutes to administer) and posture was recorded simultaneously during this first session. Each participant was then given a 30-minute break before the next test was administered. The participant was then tested with the MABC-2 (this test took approximately 20-30 minutes to administer), after which the participant was given a 30-minute break. The participant then participated in the last testing session which included gait video recordings and agility testing (these tests took approximately 20 minutes to administer).

Results from the pre-intervention testing were compared to those obtained following the intervention to assess the efficacy of the intervention. Results from the pre-intervention testing were recorded on assessment form 1 (Appendix I) and results from post-intervention testing were recorded on assessment form 2 (Appendix J).

All tests were explained and demonstrated to the participants prior to each test being performed. Two trial attempts were given for all relevant tests so that the participants became familiar with the tests. Data from each test was recorded on the relevant data sheet and feedback was given to the participant after each test was performed.

The individual tests and test batteries conducted pre- and post-intervention, will now be discussed in detail:

3.5.2 Brockport Physical Fitness Test (BPFT)

The Brockport Physical Fitness Test is a fitness test battery which is criterion referenced as well as health-related,(250) and is used to test the fitness levels of children and adolescents from the ages of 10 through to 17 who may be impaired both physically and mentally.(250) This test was chosen for the study as it was considered to be appropriate for individuals with ASD due to the population often having impairments both mentally and physically, furthermore it was suitable for the age group selected for the study and was able to test the particular motor fitness components required for the study.

The test consists of 27 items organized into three primary domains, namely: body composition, aerobic function and musculoskeletal function. Musculoskeletal function is further subdivided into strength/ endurance and flexibility. Although it is advised to formulate an individual test battery from the 27 items provided, a standardised test battery was used instead, to allow for consistency in this study.

The tests selected to form part of the BPFT battery are believed to be valid and reliable.(251) Many of the test items in the BPFT are reported to have construct validity,(251, 252) and validity of a logical nature is also claimed for most of the items in the BPFT whether it may be anatomically (for example flexibility tests which are based on anatomically correct manual muscle tests) or functionally (for example the functional speed tests for aerobic capacity). Furthermore, "test-retest reliability coefficients associated with BPFT test items generally reflect at least, minimal levels of acceptability, and several are indicative of items that are highly reliable. Statistics on reliability are unavailable for six items in the battery. Scoring for these items, however, generally seems to be fairly objective, which should help to control that source of measurement error".[252] Individual reliability and validity measures will be described further under each of the subtests. Figure 3.1 below illustrates the subtests that were used in the standardised test battery in pre-and post-intervention testing.

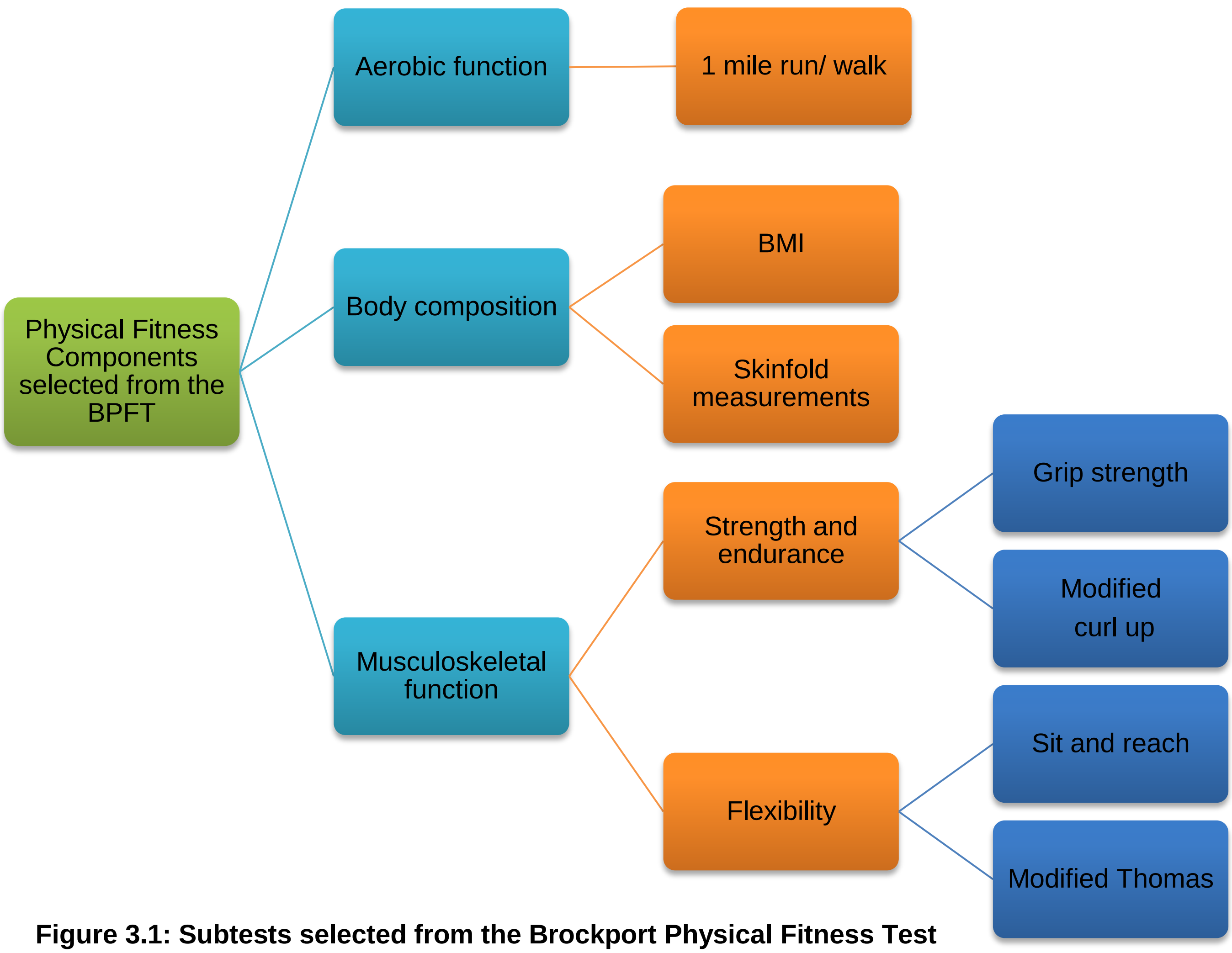


Figure 3.1: Subtests selected from the Brockport Physical Fitness Test

A score for each domain was obtained from the individuals' pre-and post-intervention. Each test component was documented and analyzed separately to provide information on particular possible improvements for the participants and an individual report was given to each participant on their performance after the study was completed. A change in score provided information on the interventions possible effectiveness. The way in which the individual tests from the FPT were carried out will now be discussed further:

a. Aerobic function- 1 mile walk/run test

1. Reason for test: this test provided information on the participants' aerobic function. According to Short and Winnick (2005), the 1 mile walk/run test can be used as a valid and reliable tool for youngsters between 10 and 17 years of age.[(253)] This therefore made this test appropriate for the study population. Test-retest reliability R scores for the 1 mile walk test seem to range between 0.91 to 0.96 in non-disabled adolescent populations.[(254)]
2. Pre-test procedure: resting blood pressure and heart rate were measured, prior to the aerobic test. Blood pressure was measured using an aneroid sphygmamometer and stethoscope. Heart rate was to be measured using a heart rate monitor, however some of the participants were weary of the heart rate belt and refused to wear it, manual HR measures were therefore taken for all participants by feeling for the radial pulse and recording the number of pulses over a 60 second interval.
3. Testing procedure: the participants were instructed to walk around an available concrete track as quickly as possible to complete a mile distance (1.6km). On performing the test some of the individuals refused to complete the full mile-long test, the distance of the test was therefore modified for the participants so that they all completed the same number of laps (6) which equated to a total distance of 480m or completed a maximum of 6 minutes walking time. The researcher shouted "on your marks, get set, go" and began a stop watch as soon as the participant moved away from the start line. The stopwatch was stopped after the full 6 laps were completed or the individual performed a total of 6 minutes of walking time.
4. Post-test procedure: blood pressure and heart rate was measured on completion of the test in the same way as it was measured before the test.
5. Equipment used: concrete playground track, Fastime 3 Event electronic stop watch (AST limited, Leicestershire, England), Sprague Rappaport Type stethoscope (Medi IQ, Johannesburg, South Africa) and aneroid sphygmamometer (Medi IQ, Johannesburg, South Africa).

b. Body composition- BMI (kg/m^2)

1. Reason for test: this test provided information on the participants' body composition. It has been stated that generally the reliability of BMI measures "is very high because the measurement of height and weight is very precise when following a standardised protocol"[(255)] as in this study. Furthermore BMI measures have been reported to have sufficient validity for use with youngsters with disabilities even though further research is needed for some conditions.[(256)] BMI and body fat percentage correlation scores of between 0.7 and 0.82 have been reported in the literature,[(257)] indicating relative validity for this measure.
2. Pre-test procedure: the participants were instructed to remove their shoes, socks and any bulky clothing. A stadiometer was placed against a wall on a level surface.
3. Testing procedure: firstly, the participants' mass (kg) was measured using a SECA 844 scale. For this measure the participants were instructed to step up onto the scale with their feet slightly apart and standing in an upright position whilst looking ahead, a measure was then taken. The participants' height (m) was then measured using a SECA stadiometer. For this measure the participants were instructed to stand up straight against a wall with a stadiometer fitted on it, with their heels and buttocks touching the wall. They were aided by the researcher to stand with their tragion in line with their supra orbital margin. Instructions were simplified for the participants who did not understand, and the researcher positioned them accordingly if they were having difficulty.
4. Post-test procedure: the time of day was noted (this was done so that post-intervention testing could be performed at a similar time to give more accurate height measure comparisons overall). Using the participants body mass and height values, body mass indices (BMI) were calculated using the following formula:

$$\text{BMI} = \text{weight (kg)}/\text{height}^2\text{ (m)}$$

5. Equipment used: SECA 844 Scale (SECA gmbh & Co, Hamburg, Germany), SECA stadiometer 217 (SECA gmbh & Co, Hamburg, Germany), and SECA 491 BMI calculator (SECA gmbh & Co, Hamburg, Germany). Calibration of the SECA 844 scale was performed once prior to all testing as per the SECA manual. According to the manual, calibration only needs to be performed once annually.

c. **Body composition- Skinfold measurements (mm)**

1. Reason for test: this test provided information on the participant's body composition. According to Lohman (1994), acceptable levels of reliability and validity have been reported for the triceps and calf skinfolds measures.[(255)] Lohman (1994), demonstrated concurrent validity to a certain extent, with a 0.88 correlation between a group of parameters (water composition, bone mineral density and mineral content of the body) and the sum of tricep and calf skinfolds in order to measure body fat percentage.[(255)]
2. Testing procedure: measurements of the triceps and medial calf skinfolds were taken twice using a Slim Guide skinfold caliper (mm). The triceps skinfold was measured parallel to the long axis of the right arm over the triceps muscle at the level of the mid-point between the acromiale and the radiale on the mid-line of the posterior surface of the arm.[(258)] The medial calf skinfold was measured with the participant seated so that their knee formed a 90° angle to the ground. The skinfold was measured parallel to the long axis of the right leg at the level of the largest circumference of the calf on the medial side.[(258)]
3. Post-test procedure:body composition was calculated using the following formulas:[257]

% fat (males, aged 6-18) = .735 (TC skinfold) + 1.0 or

% fat (females, aged 6-18) = .610 (TC skinfold) + 5.0

4. Equipment used: Slim Guide skinfold calipers (Slim Guide, USA), SECA 201 measuring tape (SECA gmbh & Co, Hamburg, Germany).

d. Musculoskeletal function- Grip strength (kg)

1. Reason for test: this test provided information on the participants' grip strength. Grip strength measures have been used effectively in young individuals who have physical disabilities as well as in those with mental disabilities,[(259, 260)] and grip strength measures are considered to have good reliability.[(261)] According to Shephard (1990), grip strength has been shown to effectively predict whole upper body isokinetic strength.[(262)]
2. Pre-test procedure: the participants' dominant hand was determined prior to testing by questioning the participant on their dominance, if they were not able to give the information, the researcher asked the participants teacher and/or occupational therapist.

3. Testing procedure: the participant's grip strength was measured on their dominant hand using a spring-type handgrip dynamometer. The participant was instructed to hold the dynamometer in their dominant hand, with their arm at right angles and their elbow at the side of their body. The dynamometer was adjusted if necessary, so that the base of the dynamometer rested on the first metacarpal of the handle while the handle rested on the middle four fingers. It was explained to the participants that they were expected to perform a maximal squeeze, that the squeeze needed to be maintained for 5s and that no other body movements were allowed during the test. The test was performed twice and the highest measurement was recorded in kgs.
4. Equipment used: Lafayette spring-type handgrip dynamometer (Lafayette Instrument Company, Lafayette, Indiana). Calibration for the equipment was not necessary as calibration was done by the company before distribution.

e. Musculoskeletal function – Modified curl-up (number of curl-ups)

1. Reason for test: this test provided information on the participants' core strength. Generally, measures for strength and abdominal endurance are deemed to be reliable, yet according to Short et al. (2005), more data needs to be obtained for the modified curl-up as well as standard curl-up test.[(261)] The reason for the use of the modified curl-up test for this study, as well as the inclusion of this test into the BPFT battery however, was due to the acknowledgement that in general, individuals with physical and mental impairments may be unable to perform standard curl-up tests.[(261)]
2. Pre-test procedure: the participants were instructed to move into a position ready to do a curl-up on a plinth. Starting position required the participant to be lying in supine position with their knees bent at 90 degrees, heels in contact with the ground and with their hands on the front of their thighs. A digital Tempo-Lite metronome[(263)] was played for the participant, and at the same time the participant was passively guided into slowly curling up at the sound of the first beat until their hands reached their knees, and then guided into curling back down into supine position by the sound of the next beat.
3. Testing procedure: the participant was instructed to do as many curl-ups to the beat of the metronome as possible in a minute. The researcher shouted "on your marks, get set, go" and began a stop watch as soon as the participant began his/her first curl-up. The stopwatch was stopped after one minute and the total number of correctly performed curl-ups was recorded. The test was terminated if the participant could not keep the required cadence over a period of three seconds, if they weren't conducting

the test with the correct technique over two repetitions and/or if the participant began to feel unusual discomfort. The metronome was played at 60 beats per minute.

4. Equipment used: plinth (WhecoGroup, Johannesburg, South Africa), Fastime 3 Event electronic stop watch (AST limited, Leicestershire, England), Tempo-Lite digital metronome app (Version 2.0.3) (Frozenape Pte,Ltd).[263]

f. Flexibility- Back saver sit and reach test (cm)

1. Reason for test: this test provided information on the participants' hamstring length. The back saver sit and reach test is a valid measure for hamstring flexibility. [264] The reliability of the standard sit and reach test is well established, and in addition it has been shown that there is a high reliability for the test when used in populations with disabilities.[264] Specifically, according to Patterson et al. (1996), the back saver sit and reach test has interclass reliability coefficients of 0.99 (mean scores over four trials for both boys and girls aged 11-15 years), and R scores ranging between 0.95 and 0.97 for reliability for a single reach which is used in the BPFT.[265]
2. Pre-test procedure: a standard sit and reach box was setup on a flat even surface of the floor, with an exercise mat placed in front of it. The participants were asked to remove their shoes.
3. Testing procedure: the participants were instructed to sit on the floor with one leg stretched out straight, and the other leg in a bent knee position. The sole of the straight foot was placed against the sit and reach box and the knee was locked and pressed flat to the floor (the researcher helped keep the knee in this position where necessary). The participants were then instructed to get their palms to face downwards and put one hand over the other- ensuring that their hands stayed at the same level. The participants were then instructed to reach as far as possible forward along the measuring line of the sit and reach box. The participants were allowed two practice attempts and on the third attempt the participants were asked to hold the position for 2 seconds after which a measure was taken in centimeters (where the fingertips extended on the sit and reach box). The researcher made sure there were no jerky movements during the test. The test was then repeated on the other leg.
4. Post-test procedure: the participants put their shoes back on.
5. Equipment used: Baseline™ Standard wooden sit and reach box (Fabrication Enterprises, New York, USA), and 1x 2m black exercise mat (Medi IQ, Johannesburg, South Africa).

g. Flexibility- Modified Thomas Test (°)

1. Reason for test: this test provided information on the participants' lower limb flexibility. While the Thomas and Modified Thomas tests have regularly been used in adapted physical activity programmes and clinical practice[266, 267] no data presently exists on their reliability.[264]
2. Testing procedure: the angle of hip flexion and knee flexion (°) was measured using a Baseline™ goniometer. The participant was instructed to lie on the very edge of a plinth. The participant needed to roll backwards onto the plinth pulling both knees to his/her chest (to ensure a flat position of the lumbar spine on the plinth as well as keeping the pelvis posteriorly rotated). The participant was then asked to hold one hip in maximal flexion using his/her arms while the opposite leg was lowered towards the plinth (the leg to be tested). Measurements were performed bilaterally and two angles were then measured with the goniometer:

   I: The angle of hip flexion. The stationery arm of the goniometer was aligned with the lateral midline of the pelvis.[268] Then, using the lateral epicondyle as a reference point, the moving arm of the goniometer was aligned with the midline of the femur and the angle was recorded.[268] This angle reflected the length of the Iliopsoas muscles.

   II: The knee flexion angle. Using the greater trochanter as a reference point, the stationary arm of the goniometer was aligned with the lateral midline of the thigh, with the fulcrum of the goniometer being positioned over the lateral epicondyle of the femur.[268] Then, using the lateral malleolus as a reference point, the moving arm was aligned with the lateral midline of the fibula and the angle was recorded. This angle reflected the length of the rectus femoris muscle. [268]
3. Equipment used: Baseline™ goniometer (Fabrication Enterprises, New York, USA) and plinth (WhecoGroup, Johannesburg, South Africa).

3.5.3 Movement Assessment Battery for Children -2 (M'ABC-2)

The Movement Assessment Battery for children-2 (M'ABC-2) includes 2 components: the M'ABC-2 checklist and the M'ABC-2 test.

1. The M'ABC-2 checklist is a complementary tool used with the test battery to aid teachers in establishing the existence of movement difficulties (Appendix K). Although the checklist has been found to have an overall poor sensitivity (41%), it

has a generally good specificity – 88%.[269] Furthermore, according to Schoemaker et al. (2012), the MABC-2 checklist is a valid and reliable tool in assessing the performance of a variety of activities of daily living.[269]

The checklist was sent out to be completed by the participant's parents during baseline testing and again following the completion of the exercise intervention. The researcher followed up with teachers at the school regarding these forms however only one parent sent back the forms to the researcher on completion of the study, group data was therefore omitted from results however a case study is presented in the results for the participant.

2. The M'ABC-2 test is a standardised assessment tool that objectively measures motor impairment in individuals aged 3 years 0 months to 16 years 11 months and is a revision of the Movement Assessment Battery for Children (M'ABC). Each child tested, is required to perform various motor tasks in a specific way. The test may be used for children and adolescents who either have established movement difficulties or have problems in the movement domain. The test is divided into three age bands and within each age band eight tasks are grouped together under three main categories namely: manual dexterity, aiming and catching, and balance. The age bands are defined as follows: age band 1: 3-6 years; age band 2: 7-10 years; and age band 3: 11-16 years.

For the purpose of this study, participants were tested on age band 3 as the age range of the sample population fell between 11 and 16 years. This tool was selected for this study as it was appropriate for the age group selected for the study and has been used without incident in studies with individuals with autism before.[15] Furthermore, the test battery is made up of functional activities which the participants have likely done before and thus is not overly challenging and novel for the participants which was ideal for this population.[270] This test was also selected as it is a valid and reliable tool for evaluating motor impairments in children and adolescents. Specifically for age band 3, a study conducted by Chow et al. (2002), demonstrated that intra-class correlation coefficients varied from 0.92 to 1.00 for interrater-reliability, and test-retest coefficients ranged from 0.62-0.92 in a sample of 31 adolescents.[271] In another study, when looking solely at age band 3, an overall intra-class correlation coefficient of 0.79 for intra-rater reliability was found, while inter rater reliability was found to be 0.79 for the overall MABC-2 total score in a sample of 64 adults.[272]

In addition, according to the MABC-2 testing manual, the tests included in the test battery which are used to evaluate the proficiency of motor domains are appropriate and relevant (according to an expert panel), and hence the test has content validity. Furthermore internal consistency has been found for the MABC-2 test, a=0.90,[273] and in terms of the tests' psychometric properties, it has been reported that the minimal detectable change was 0.28 points and values for the minimal important difference ranged from 2.36 and 2.50.[273] Although it has been suggested that more research is still needed for the validity and reliability of the tool,[274] there is a general consensus that the test is valid and reliable and that it is a clinically useful tool in assessing motor impairments in children and adolescents.

Figure 3.2 below illustrates the subtests used in the test battery for this study. These tests were used during pre-and post-intervention testing, and recorded on the M'ABC-2 record form (Appendix L) in both instances.

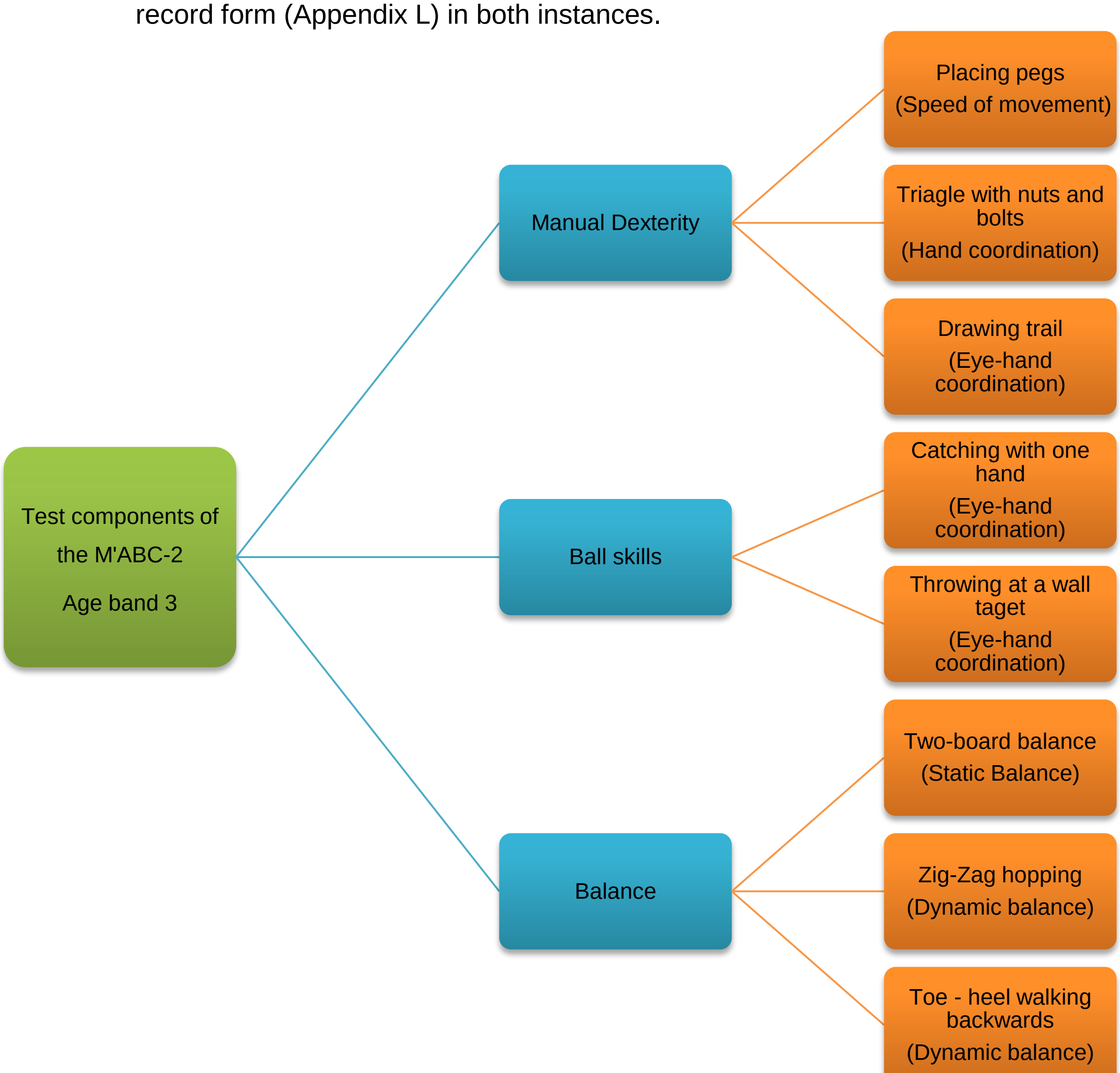


Figure 3.2: Subtests used for age band 3 in the MABC-2 Test

a. Manual dexterity- turning pegs (s)

1. Reason for test: this test provided information on the participants' manual dexterity and in particular their speed of movement ability in performing fine motor tasks.
2. Pre-test procedure: a table was set up with the MABC-2; table-top mat on it and the 12-hole board was then placed on the mat (with the short side facing the child). Twelve pegs were setup in the 12-hole board, (all pegs were placed red side up to start with) and a chair was setup in front of the table, so that the participant's elbows (when bent at 90 degrees) were parallel to the table. The setup is shown in Figure 3.3 below.
3. Testing procedure: to start the test the researcher shouted "on your marks, get set, go" and a stopwatch was started. The participant needed to turn a peg around and fit it into each of the 12 holes using their dominant hand as fast as possible. The participant needed to turn all the pegs around so that at the end of the test, all pegs would be yellow side up. When the last peg got paced in the hole the researcher stopped the stop watch and recorded the amount of time taken to complete the task in seconds. The test was then repeated for the non-dominant hand.
4. Equipment used: 1m high wooden table, chair, MABC-2 table-top mat, MABC-2 pegs (12), MABC-2 12-hole board and a Fastime stopwatch (Fastime 3 Event electronic stop watch (AST limited, Leicestershire, England).

Figure 3.3: Turning pegs setup

b. **Manual dexterity- triangle with nuts and bolts (s)**

1. Reason for test: this test provided information on the participants' manual dexterity and in particular their hand coordination.
2. Pre-test procedure: a table was set up with the MABC-2 table-top mat, triangle pieces, and nuts and bolts placed upon it. A completed triangle was placed above the mat and all required pieces for building the triangle were placed on the mat as shown in Figure 3.4, lastly a chair was setup in front of the table.
3. Testing procedure: the researcher shouted "on your marks, get set, go" and began the stop watch. The participant needed to build a triangle using the plastic pieces and bolts provided. When the last nut was threaded on the last bolt and the entire triangle was built correctly, the researcher stopped the stop watch and recorded the amount of time taken to perform the task in seconds.
4. Equipment used: 3 perforated plastic pieces, 3 nuts, 3 bolts, chair, table, MABC-2 table-top mat and Fastime stopwatch (Fastime 3 Event electronic stop watch (AST limited, Leicestershire, England).

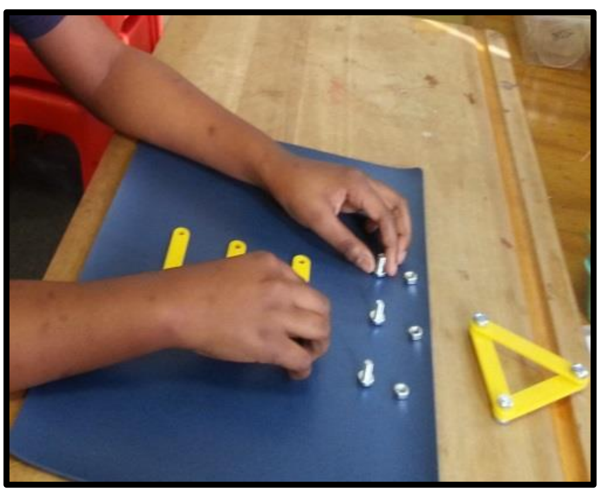


Figure 3.4: Triangle with nuts and bolts setup

c. Manual dexterity- drawing trail (no. of errors)

1. Reason for test: this test provided information on the participants' manual dexterity and in particular their hand-eye coordination.
2. Pre-test procedure: a table was set up with the MABC-2 table-top mat placed upon it. A piece of paper with a drawing trail drawn on it was then placed on the table – the drawing trail for age band 3 may be seen in Appendix L (page 10). A pen was placed next to the paper and a chair was setup in front of the table. The setup is shown in Figure 3.5 below.[275]
3. Testing procedure: the researcher asked the participant to follow the house trail image on the page by drawing a line in between it. This needed to be done without crossing the boundaries of the trail, and without lifting the pen. When the participant came to the end of the trail, the researcher counted and recorded the number of errors the participant made in the test. Errors were defined as the number of times the drawn line crossed the boundary of the trail, as well as ow many times the pen was lifted off the page.
4. Equipment used: chair, 1m high wooden table, MABC-2 ballpoint pen, MABC-2 table-top mat , MABC-2 drawing trail worksheet.

Figure 3.5: Drawing trail setup[276]

d. Ball skills- Catching with one hand (no. of catches)

1. Reason for test: this test provided information on the participants' ball skills and in particular their catching abilities.
2. Pre-test procedure: the researcher measured a distance 2m away from a wall and marked the distance with a stripe of masking tape to form a line, behind which the participant was required to stand for the duration of the test. The setup is shown in Figure 3.6 below.[275]
3. Testing procedure: the researcher asked the participant to throw a standard tennis ball against a wall using their dominant hand, and then catch the ball with the same hand without it bouncing on the floor on its return. The participant needed to do this 10 times and then perform the task again with their non-dominant hand. The researcher recorded how many correctly executed catches the participant achieved out of 10 attempts for each hand.
4. Equipment used: SECA 201 measuring tape (SECA gmbh & Co, Hamburg, Germany), 20 mm thick masking tape and a standard tennis ball.

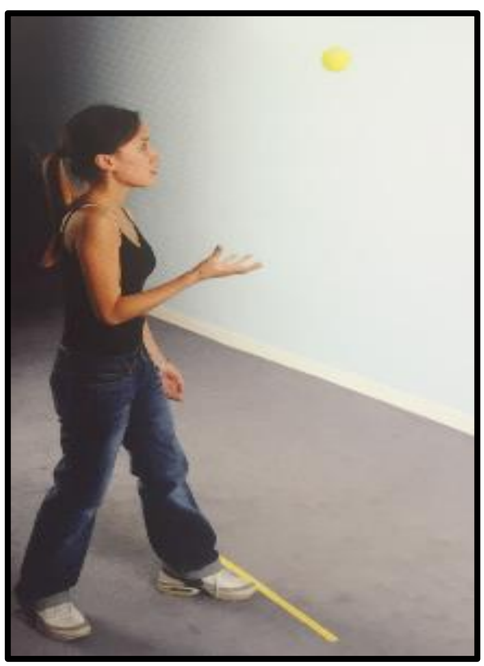


Figure 3.6: Catching with one hand setup[276]

e. Balls kills – Throwing at a wall target (no. of throws)

1. Reason for test: this test provided information on the participants' ball skills and in particular their eye -hand coordination and throwing ability.
2. Pre-test procedure: the researcher measured a distance of 2.5m away from a wall on which a target was placed 1.5m up from the ground. Masking tape was placed at the 2m mark in the form of a line. The participant needed to stand behind this line for the duration of the test. The setup is shown in Figure 3.7 below.[275]
3. Testing procedure: the researcher asked the participant to throw a tennis ball with their dominant hand at the wall target 2.5m away from them. The participant had to do this 10 times and then perform the task again with their non-dominant hand. The researcher recorded how many correctly executed throws the participant achieved out of 10 attempts for each hand. A correct throw was defined as one in which the majority of the tennis ball made contact within the wall target.
4. Equipment used: M'ABC-2 tennis ball, M'ABC-2 red target and SECA 201 measuring tape (SECA gmbh & Co, Hamburg, Germany).

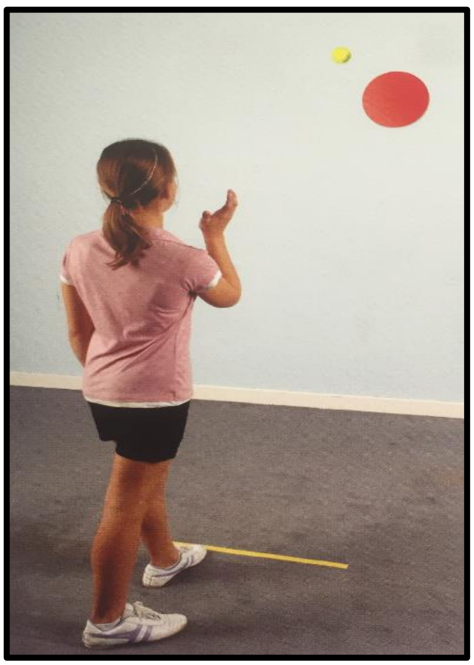


Figure 3.7: Throwing at a wall target setup[276]

f. Static balance- two board balance (s)

1. Reason for test: this test provided information on the participants' static balance ability.
2. Pre-test procedure: the researcher set up the M'ABC-2 balance beams one in front of the other (with the keels facing up) on 2 rubber M'ABC-2 mats on an even surface. The setup is shown in Figure 3.8 below. [275]
3. Testing procedure: the researcher shouted "on your marks, get set go" and began the stop watch. The participant needed to stand with their dominant foot in front of their non-dominant foot on the M'ABC-2 two board balance beam. The participants' hands needed to be placed on their hips throughout the test. The researcher recorded how long (in seconds) the participant could maintain their balance without any errors, and stopped the stop watch after an error was made or after 30s had elapsed. An error was defined as moving away from their original position when the test began, stepping off the balance beam or taking the hands off the hips. The researcher monitored at all times the feet of the participants to make sure their feet were not touching below the keels of the balance boards.
4. Equipment used: Fastime stopwatch (Fastime 3 Event electronic stop watch (AST limited, Leicestershire, England), M'ABC-2 two board balance beam, MABC-2 rubber mats, even and stable surface

Figure 3.8: Two-board balance setup[276]

g. Dynamic balance-zig-zag hopping (no. of hops)

1. Reason for test: this test provided information on the participants' dynamic balance ability.
2. Pre-test procedure: the researcher placed 6 M'ABC-2 jumping mats in a zig zag position on an even surface. The mats were placed in alternating colours of blue and yellow, and ending with a mat with a red target drawn on it. The setup is shown in Figure 3.9 below. [275]
3. Testing procedure: the researcher asked the participant to get into a starting position where they needed to stand balancing on their dominant leg in front of the first mat. The participant needed to perform 6 consecutive hops forward from the starting square to the last square without falling over. The researcher recorded how many correctly executed consecutive hops (maximum 6) the participant was able to achieve without making an error. An error was defined as hopping more than once on one mat, landing outside of a mat, landing with both feet on a mat or falling over.
4. Equipment used: 6 M'ABC-2 colored mats and even surface

Figure 3.9: Zig-zag hopping setup[276]

h. Dynamic balance- walking toe to heel backwards (no. of errors)

1. Reason for test: this test provided information on the participants' dynamic balance and coordination.
2. Pre-test procedure: the researcher measured and marked out (with masking tape) a straight 4.5 meter long line on a flat even surface and placed a cone at the beginning and end of the line. The setup is shown in Figure 3.10 below.[275]
3. Testing procedure: the researcher shouted "on your marks, get set, go" to begin the test. The participant needed to walk on the straight line backwards, placing the toe of one foot against the heel of the other foot with each step they took. The first step was taken by their dominant foot first for each test. The researcher recorded how many errors the participant made throughout the course of the line. An error was defined as stepping off the line at any time during the test or leaving a space between the heel and toe during each step.
4. Equipment used: SECA 201 measuring tape (SECA gmbh & Co, Hamburg, Germany), 2 plastic cones (Medi IQ, Johannesburg, South Africa).

Figure 3.10: Backward walking setup[276]

3.5.4 Posture, gait and agility analysis

Figure 3.11 below illustrates 3 further subtests used in this study that were used in the pre and post intervention testing. A change in score in the following tests provided information on the interventions possible effectiveness.

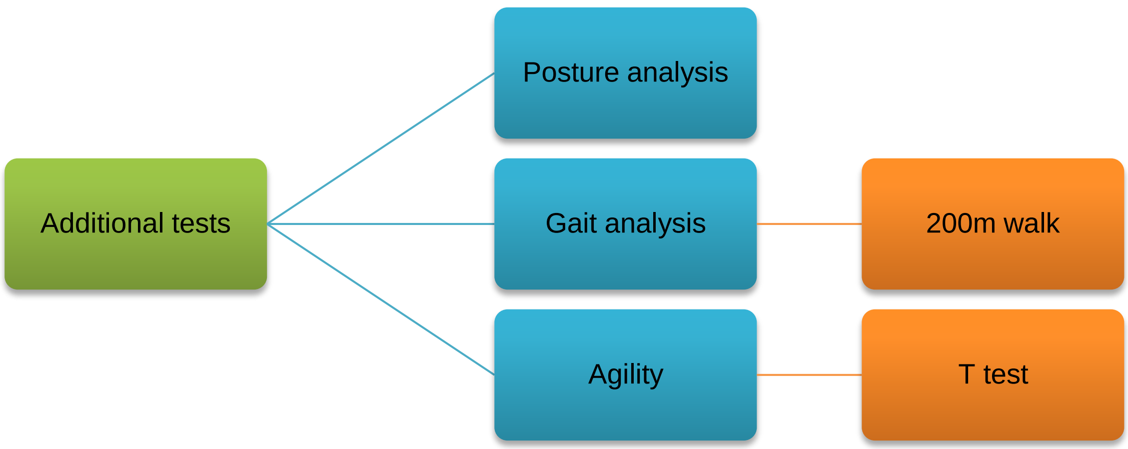


Figure 3.11: Subtests compiled by researcher for further analysis

a. Posture analysis

1. Reason for test: this test provided information on the participants' standing posture.
2. Pre-test procedure: a camera was set up to capture the entire body of a participant in a single frame.
3. Testing procedure: the participant was instructed to stand comfortably in anatomical position as he/she would do in everyday life. The participant was then asked to face the camera, and then turn side-on to the camera. Three photographs were taken in each of the above positions. The best of the three photos were used for further analysis.
4. Post-test procedure: A posture grid was overlaid over each image to objectively determine the participant's posture using Dartfish video analysis software. The participant was then given a score out of 10 for each area of the body using a posture score chart (Appendix M).[75] Good posture was given a score of 10, average posture was given a score of 5 and poor posture was given a score of 0. An overall posture score was then determined by adding up all posture scores for each area of the body, namely: head, shoulders, spine, hips, ankles neck, upper back, trunk, abdomen, lower back.

5. Equipment used: Camera (Sony Handycam, DCR-SX44E, Sony Electronics Inc. San Diego, California), Dartfish video analysis software (Dartfish Pro-suite, version 6.0, Fribourg, Switzerland).

b. Gait analysis

1. Reason for test: this test provided information on the participants' style of walking and his/her temporal distance parameters.
2. Pre-test procedure: two cones were set up on a field. The first cone was to demarcate the beginning of the walking stretch and the second cone was set up 200m away in a straight line from the first cone to demarcate the end of the walking stretch. Two 50fps video cameras were set up behind and side-on to the walking stretch. A meter stick was placed in view of both cameras.
3. Testing procedure: video cameras were turned on and the participant was instructed to walk normally from the first cone to the last cone and then walk back to the starting cone. Two trials were taken of the participant and the best footage was used for analysis.
4. Post-test procedure: Dartfish video analysis was used to analyze the temporal distance parameters being: stride length (m) and step length (m) of the dominant and non-dominant sides measured side-on, and step width (m) of the dominant and non-dominant sides measured from behind. Dominance was determined as the preferred side. Data was analyzed by importing the videos into the dartfish software. Following this, distance was calibrated in the programme using the meter stick in the video and then distances for stride length were measured from the toe of the dominant foot to the heel of the non-dominant foot. For step width, measures were taken between each foot from the center of each calcaneus.
5. Equipment used: two cones (Medi IQ, Johannesburg, South Africa), two 50fps video cameras (Sony Handycam, DCR-SX44E, Sony Electronics Inc. San Diego, California), SECA 201 measuring tape (SECA gmbh & Co, Hamburg, Germany), Dartfish video analysis software (Dartfish Pro-suite, version 6.0, Fribourg, Switzerland).

c. Agility- T-test (s)

1. Reason for test: this test provided information on the participants' ability to change direction and move quickly through obstacles. It has been shown that the agility T-test measures a number of parameters including leg power and speed, and agility and it is deemed to be a highly reliable measure for these components.[276]
2. Pre-test procedure: four cones were set out in a T position as shown in Figure 3.12. The first cone demarcated the beginning of the test. The next cone was placed vertically in a straight line from the start cone 9.14 m away. Then two cones were placed on either side of this cone vertically 4.57m away.
3. Testing procedure: to start the test, the researcher shouted "on your marks, get set, go" and began the stopwatch. The participant was instructed to run as fast as possible forwards from the start cone to the cone directly in front of them at which point they needed touch the top of the cone with their dominant hand. They then needed to move laterally to the left as quickly as possible to the next cone and touch it with their hand. Following this, they needed to laterally shuffle across to the cone at the far right and touch it. They then needed to return to the middle cone, touch it and run backwards back to the start cone- touching it to end the test- at this point the stopwatch was stopped. The time taken to complete the test was recorded in seconds.
4. Equipment used: four plastic cones (Medi IQ, Johannesburg, South Africa), SECA 201 measuring tape (SECA gmbh & Co, Hamburg, Germany), stopwatch (Fastime stopwatch (Fastime 3 Event electronic stop watch (AST limited, Leicestershire, England).

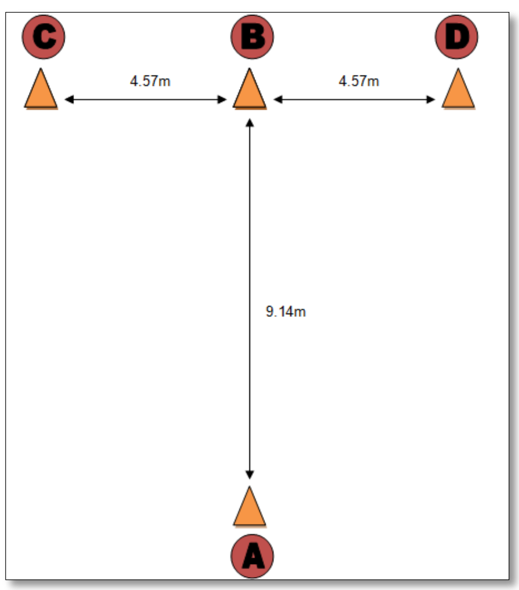


Figure 3.12: Cone setup for agility T-test

3.6 Intervention

Following the initial testing, the exercise intervention programme was designed based on the baseline testing results and the ability of the participants that consented to take part in the study. After the intervention was designed, it was validated by a panel of experts before implementation into the school. Details regarding this are discussed below under point 3.63.

Following the validation, the intervention took place at UNICA School for Autism. The exercise intervention programme was conducted twice a week at the school for 12 weeks.

A 12-week intervention was selected due to the nature of the intervention (i.e having strength, endurance and proprioception variables). Physiologically it takes between ± 6-8 weeks for neural adaptation to occur (which may or may not influence strength), with muscle hypertrophy and strength taking ± 12 weeks to occur [(277)]. Selecting this time frame allowed for various changes to take place which were then measured.

3.6.1 Scheduling of the intervention

Preliminary scheduling of the testing and the intervention was discussed with the school occupational therapists and a few preliminary dates were selected. Final scheduling of the exercise programme times were finalised at the information talk held with the parents of the participants and teachers of UNICA school. The scheduled times needed to suit everyone's needs (including parents, learners, teachers and researcher). Exercise classes were selected on days and times where the participants had free periods as they were not to interfere with the participant's current therapy sessions. Exercise classes occurred every Wednesday and Friday morning at 8:30 am (moderate to high functioning participants) and 9:15 am (low functioning participants). The participants participated in the classes voluntarily and if at any stage the participant or parent wanted to withdraw from the study they were allowed to do so.

3.6.2 Initial proposed intervention

Table 3.1 below shows the initial proposed intervention. This outline served as a basic guide for exercises to be included for various components e.g. aerobic function, strength, endurance, etc. This proposed intervention was expanded upon in an online from (Appendix N) in order to be validated.

Table 3.1: Proposed 12 week exercise intervention outline

	Intervention phase		
Component	**Weeks 1-4**	**Weeks 4-8**	**Weeks 8 -12**
Aerobic function	As part of the warm up and cool down One additional aerobic exercise to be included		
Strength	2 upper body 1 core 1 lower body	3 upper body 2 core 1 lower body	3 upper body 2 core 2 lower body
Endurance	2 exercises	Progress reps and sets	Progress reps and sets
Manual dexterity	2 exercises	2 exercises & progress	3 exercises
Ball skills	3 exercises	Increase speed and distance	Increase speed and distance
Balance	2 exercises	2 exercises (eyes open to closed)	3 exercises (eyes open to closed)
Agility	1 exercise	1 exercise	1 exercise
Gait	2 exercises	Progress exercises	Progress exercises
Posture	Postural corrections for each exercise done and emphasis on correct posture for ADLS		
Flexibility	*Stretching to be done at the end of each session		

Experts invited to validate the intervention included: two biokineticists, a physiotherapist, occupational therapist and expert on autism, a doctor and a parent of a child with autism.

The experts filled out an online form in order to validate the intervention (Appendix N). The main outcomes from the online form were that the experts were happy with the overall outline of the proposed intervention and that no major changes needed to be made. A summary of all the responses may be found in (Appendix O). Two main concerns that were raised were:

1. The extended arm hang may not be suitable for endurance testing/training; it may also be too difficult for individuals with low muscle tone to do, therefore this exercise was subsequently removed from the intervention.
2. Using weights for the bicep curls may be too heavy or not appropriate to begin with. Weights were subsequently not used initially in the intervention and modifications of the exercises also did not make use of weights but rather varying body positions and the use of body weight instead.

3.6.4 Panel reviewed final intervention

After the intervention was reviewed and finalised, it was implemented at Unica School. The intervention was divided into 3 phases lasting 4 weeks each. The exercises were progressed through each phase, and included exercises from all the fitness components tested pre-intervention. The exercise programme was tailored to be fun and enjoyable with exercises that were easy enough for the participants to manage. Exercises were changed from week to week if needed, to maintain interest and also adapted/modified so that participants were able to do the exercise without difficulties.

The intervention group was divided into smaller groups so that the groups were more manageable for the researcher to work with. The sizes of the groups were determined by the final number of participants that agreed to participate in the study. Each group was a maximum of 8 participants. The participants all followed the same basic exercise programme, however small adaptions to exercises were made for individuals who could not perform the exercises- this allowed individuals to perform as many of the exercises as possible. All the information regarding exercises that were included/modified was documented in a journal (Appendix P).

Each exercise class began with a 3-minute talk about exercise and the importance of exercising. This formed a small educational component of the study, and was included to leave a lasting impression with the participants. The participants then began exercising following a short warm up, as per the validated programme.

Classes were initially meant to be 45 minutes long. The moderate to high functioning group coped well with this time frame, yet the lower functioning individuals were not able to exercise for the whole duration partly because of loss of concentration and partly due to fatigue. Therefore the majority of the sessions conducted with the lower functioning individuals were approximately 30-35 minutes long.

During the 12 weeks the participants in the control group continued with their normal weekly occupational therapy sessions and received standard care. Following the study, the intervention programme was offered to the participants that were in the control group, as per the Declaration of Helsinki.[239]

3.6.5 Journal

A daily journal (Appendix P) was kept throughout the duration of the intervention. The journal was used to document notes on the participant's abilities to perform the various exercises and whether any modifications (regression or progression of exercises) were made for specific participants. The journal was also used to document possible reasons for improvement/deterioration of performance, motivators for each child, exercises that the participants particularly liked or disliked, notes for future lesson plans and any other relevant important information. An entry into the journal was made after each exercise session by the researcher and the entry was reflected upon that day in order to plan future exercise sessions. On completion of the intervention, the journal was used to provide additional information on reasons for possible improvement/ deterioration as well as any possible limitations of the study. The journal also allowed for a more holistic look at the intervention in terms of how the participants coped with the sessions and what they liked and disliked. One of the main things noted over the course of the intervention was that the participants began to thoroughly enjoy the classes; they would try and "invent" their own exercises or ask to do more of the exercises they enjoyed, even if the exercises were difficult or the participants were tired. Another interesting finding was that the participants began enquiring about the exercises i.e what a particular exercise was good for, or asking advice for how to strengthen certain parts of their bodies. This indicated that they were becoming more aware of the benefits of exercise and where becoming interested possibly continuing with exercising following the study.

3.6.6 Risk factors and safety precautions

Due to the various impairments the participants may have had, it was possible to overload them with too much information and sensory stimuli, this was monitored throughout the programme. The occupational therapist at UNICA school was involved with the study and information was obtained from her with regards to the participants's specific needs thus helping to create a safer environment for the participants as well as helping to reduce risks associated with exercising this specific population. Exercises were modified and adapted if a participant was not able to perform a specific exercise, and if a participant could not perform a specific task after the modification was made, it was left out for him/her and exchanged with something they were able to perform. For example: one of the participants was unable to perform the supine bridge and so while the other participants were performing this exercise the researcher would sometimes do stretches or crunches with her so that she was not left out.

Exercises were explained carefully; in detail to allow the participants to understand what they were required to do, if an individual struggled to understand the task at hand, the exercise was explained and demonstrated until the participant could perform the exercise in a safe manner. All exercises were demonstrated and performed in a safe environment at Unica School. The participants only used specialised equipment specifically developed for children with motor development problems, thus allowing them to handle the equipment in a safer way.

No major injuries occurred during testing, yet one participant fell during one of the exercise sessions and grazed her knee. Since a first aid kit was on standby at all times, the researcher provided the necessary treatment required as the researcher is qualified in first aid. The participant sat out of the session for approximately ten minutes and then continued to exercise with the other participants as the fall was not severe.

3.7 Ethical considerations

Ethical clearance was obtained prior to conducting this study from the Human Research Ethics Committee of the University of the Witwatersrand (Appendix Q). Due to some of the tests being maximal effort dependent in nature, it was expected that the participants may have experienced local muscle fatigue which could have caused some muscle stiffness in the 24 to 48 hours following the testing. This is a normal physiological response to muscle testing; hence the researcher (being aware of this) included an appropriate warm up and cool down as well as appropriate stretches after testing, which consequently reduced the risk of muscle stiffness. The possibility of muscle stiffness was explained to the participants involved.

Prior to the commencement of testing the parent/ legal guardian signed parental consent (Appendix E) and the adolescents signed a child assent form (Appendix F).

Testing was performed by the same trained clinician and was conducted for one participant at a time, ensuring that testing was safe and reliable. The information that was obtained during the course of the study and during exercise testing was treated as privileged and confidential. All participants were given codes and all data presented in feedback to the school was done as group data. Following the study, individual feedback was given to the participants and the group data provided to the school. The researcher gave a small presentation at the school and gave a basic outline of the exercise programme to the school. As the intervention proved effective the control group was offered a similar intervention on completion of the analysis, and was performed in accordance with the principles of the Declaration of Helsinki (2004).

3.8 Statistical analysis

Data analysis was performed using Stata version 13.1. Descriptive data are expressed as means and standard deviations. Data were checked for normality by drawing histograms. Non parametric tests were used for non-normally distributed variables. To compare variables during pre-and post-intervention within groups for continuous variables, the Wilcoxon signed-rank test was used. To compare variables during pre and post intervention within groups, for categorical variables, Mc Nemar's test for symmetry was used. Fisher's exact test was also used for categorical variables. Data were recorded on a data collection sheets (Appendices I, J, Land M). Statistical significance was accepted at 95% ($p < 0.05$).

CHAPTER 4: RESULTS

The subtopics that will be included in the chapter include:

4.1 Introduction

Results will be presented under three main sections: in section A, the baseline data and demographic information will be presented, as well as the compliance rates for the intervention; in section B, data concerning the appropriateness of the randomisation will be given; and lastly in section C, the objectives for the study and the results corresponding to each objective will be presented, after which a discussion of the results follows.

4.2 Results

A. Baseline Data

i. Participation throughout the study

Participation in the study by the participants is illustrated in Figure 4.1 below. There were no dropouts in the intervention group throughout the study; however two participants that were in the control group left the school during the course of the study, and one further participant in the control group had major surgery in both of his lower limbs which rendered him unable to complete post-intervention testing. The results of these three individuals were hence excluded from the findings of this study.

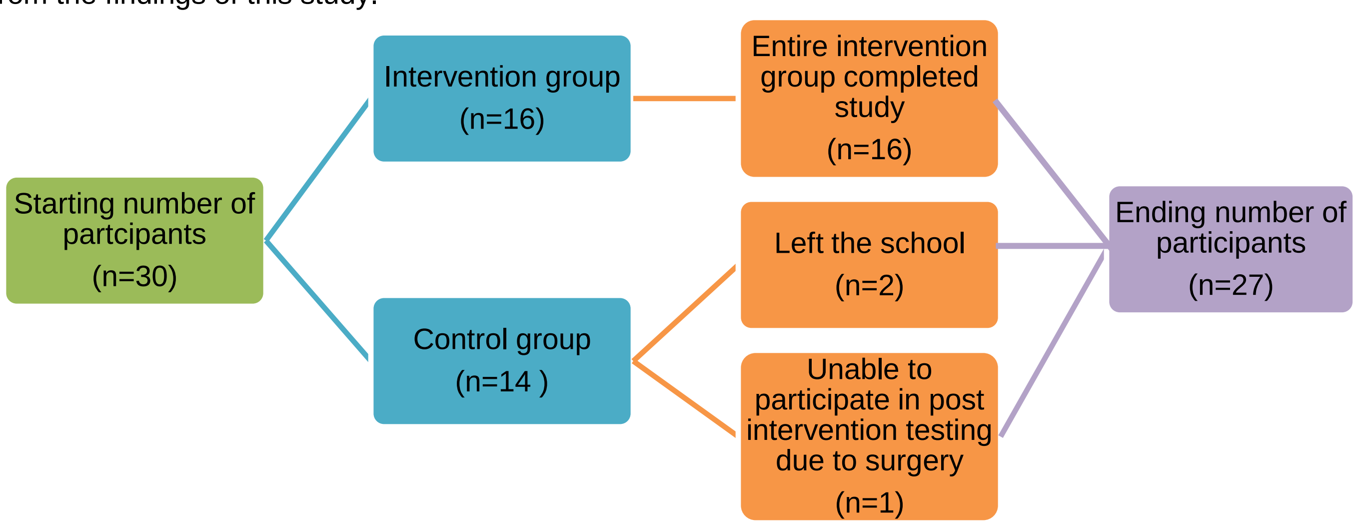


Figure 4.1: Participation of participants

II. Demographic Information

Table 4.1 below shows the mean chronologic and mental ages for the total, control and intervention groups. The mean chronologic and mental age for the total group was 13.0 ± 1.8 years and 5.6 ± 1.8 years respectively. The mean chronologic age for the control group was 12.1 ± 1.7 years whereas the mean chronologic age for the intervention group was 13.6 ± 1.5 years. The mean mental age for the control and intervention group was 5.2 ± 1.8 and 5.8 ± 1.8 years respectively. There was a significant difference in the chronological ages of the intervention and control groups; however the mental age was similar.

Table 4.1: Mean baseline chronologic and mental ages for the total, control and intervention groups of adolescents with ASD (n=27).

Age	Total Group (n = 27)	Control Group (n=11)	Intervention Group (n=16)	P value
Chronologic (years)	13.0 ± 1.8	12.1 ± 1.7	13.6 ± 1.5	0.0223*
Mental (years)	5.6 ± 1.8	5.2 ± 1.8	5.8 ± 1.8	0.3877

*p≤0.05=Significant

i. Posture

The New York Posture Rating chart[278] was used to document the posture of the participants. Posture was rated out of 100, with each body region being scored out of a maximal 10 points and described as being good (10), fair (5), and poor (0).

Table 4.2 below shows the mean posture scores for the total group as well as the divided scores for the control and intervention groups. The overall mean posture score for the total group was 57.2 ± 16.1 and the anatomical region with the highest overall score was the spine (8.3 ± 2.8). The lowest scores were seen in the abdominal area (3.7 ± 3.6) followed by the ankle (4.3 ± 3.6) and lower back (4.8 ± 2.6) areas. There were no significant differences in baseline posture scores between the control and intervention groups pre-intervention. The best score was noted in the spine for both the control (7.7 ± 3.5) and intervention groups (8.8 ± 2.2), while the lowest mean postural score was found in the ankle (4.1 ± 3.8) in the control group and in the abdominal area (3.1 ± 3.1) in the intervention group.

Table 4.1: Mean posture scores per body area for the total, control and intervention groups of adolescents with ASD (n = 27).

Body Parameter	Total Group (n = 27)	Control Group (n = 11)	Intervention Group (n = 16)	P value
Head	6.3 ± 3.3	5.9 ± 4.4	6.6 ± 2.4	0.6205
Shoulder	5.2 ± 1.7	5.5 ± 1.5	5.0 ± 1.8	0.5025
Spine	8.3 ± 2.8	7.7 ± 3.5	8.8 ± 2.2	0.3565
Hips	6.3 ± 2.2	5.9 ± 2.0	6.6 ± 2.4	0.4658
Ankle	4.3 ± 3.6	4.1 ± 3.8	4.4 ± 3.6	0.8445
Neck	5.0 ± 3.7	5.5 ± 4.2	4.7 ± 3.4	0.6033
Upper Back	6.7 ± 3.4	7.3 ± 3.4	6.3 ± 3.4	0.4529
Trunk	6.7 ± 3.7	7.3 ± 3.4	6.3 ± 3.9	0.4875
Abdomen	3.7 ±3.6	4.6 ± 4.2	3.1 ± 3.1	0.3178
Lower Back	4.8 ± 2.6	5.9 ± 3.0	4.1 ± 2.0	0.0673
Overall posture score	57.2 ± 16.1	59.6 ± 18.8	55.6 ± 14.5	0.5454

Upper body

The baseline upper body posture profiles, split into poor, fair and good categories, for the control and intervention groups are shown in Figure 4.2 The majority of the control group had good head posture (45.4%) followed by equal observations for fair and poor head posture (27.3%). The majority of the intervention group (68.8%) had fair head posture followed by good posture (31.2%), and had no observations of poor posture. The majority of the control group (36.4%) and intervention group (56.3%) had fair neck posture. Poor neck posture was seen in 27.3% of the control group and 25% of the intervention group, while good neck posture was seen in 36.3% of the control group and 18.7% of the intervention group. Fifty-four percent of the control group had good upper back posture, followed by fair upper back posture (36.4%) and poor upper back posture (9.1%). Half (50%), of the intervention group for the same body area had fair posture, followed by good (37.5%) and poor posture (12.5%) observations. Similar posture profiles where noted in the shoulder area for both groups where 9.1% of the control group and 6.1% of the intervention group had good posture, and 90.1 % of the control group and 87.5% of the intervention group had fair posture. Furthermore 6.3% of the intervention group where found to have poor posture. Lastly, the majority of both the control and intervention groups had good spine posture (63.6% and 75% respectively) followed by fair (27.3% and 25% respectively) and poor (9.1% and 0% respectively) spine posture.

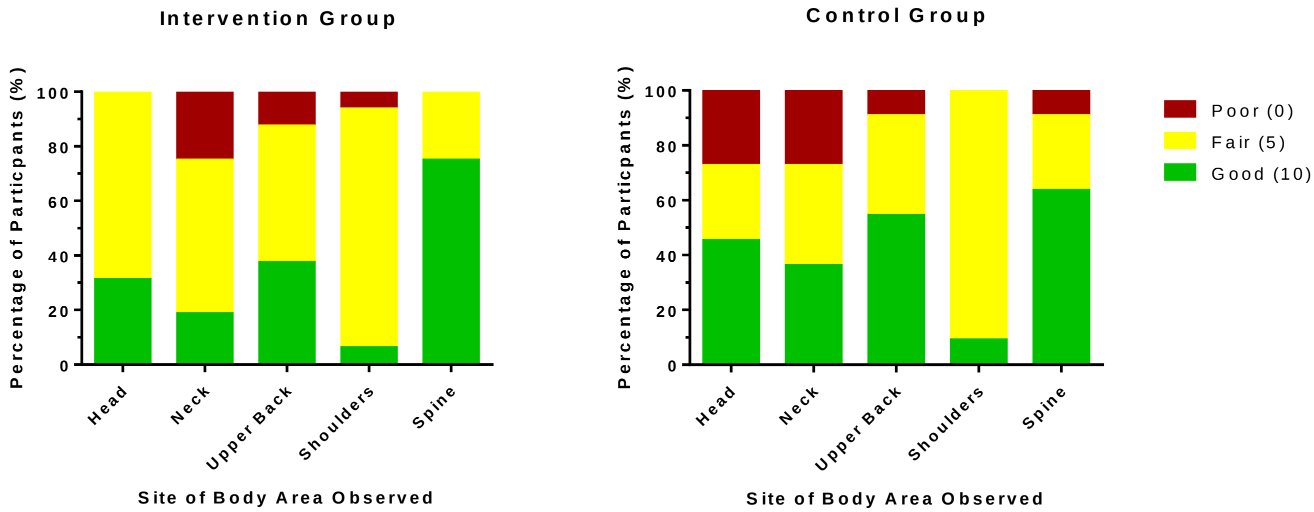


Figure 4.2: Comparison of mean baseline upper body posture profiles for the control and intervention group in adolescents with ASD (n=27).

Trunk, abdomen and lower back

The baseline trunk, abdominal and lower back body posture profiles for the control and intervention groups are shown in Figure 4.3. The majority of the control group had good trunk posture (54.5%) followed by fair trunk posture (36.4%) and poor trunk posture (9.1%). This was also the case with the intervention group where the majority had good trunk posture (43.8%) followed by fair trunk posture (37.5%) and poor trunk posture (18.8%). In terms of the adnominal posture, 27.3% of the control group had good posture, 36.4% had fair posture, and 36.4% had poor posture, while 6.3% of the intervention group had good posture, 50.0% had fair posture, and 43.8% had poor posture. No good posture was noted for the intervention group for the lower back, yet 27.3% of the control group demonstrated good posture in this area. Fair posture was seen in 63.6% of the control group and 81.3% of the intervention group in the lower back area and 18.8% of the intervention group were found to have poor lower back posture.

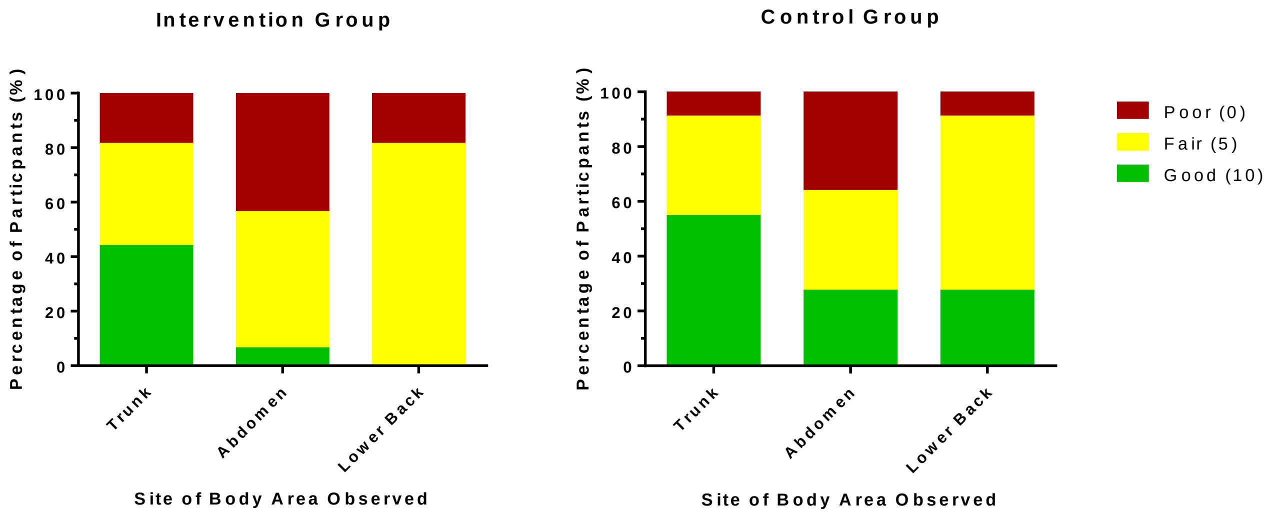


Figure 4.3: Comparison of mean baseline trunk, abdominal and lower back posture profiles for the control and intervention groups in adolescents with ASD (n=27).

Lower body

The baseline lower body posture profiles for the control and intervention groups are shown in Figure 4.4. The posture profiles between the groups were similar for the hip and ankle areas. Most of the participants in both the control and intervention groups had fair hip posture (81.8% and 68.8% respectively) followed by good hip posture (18.2% and 31.3% respectively). Similarly, the control and intervention group showed near-equal category posture observations for the ankle region where 18.2% of the control group and 18.8% of the intervention group had good ankle posture; 45.5% of the control group and 50.0% of the intervention group had fair ankle posture; and 36.4% of the control group and 31.3 % of the intervention group had poor ankle posture.

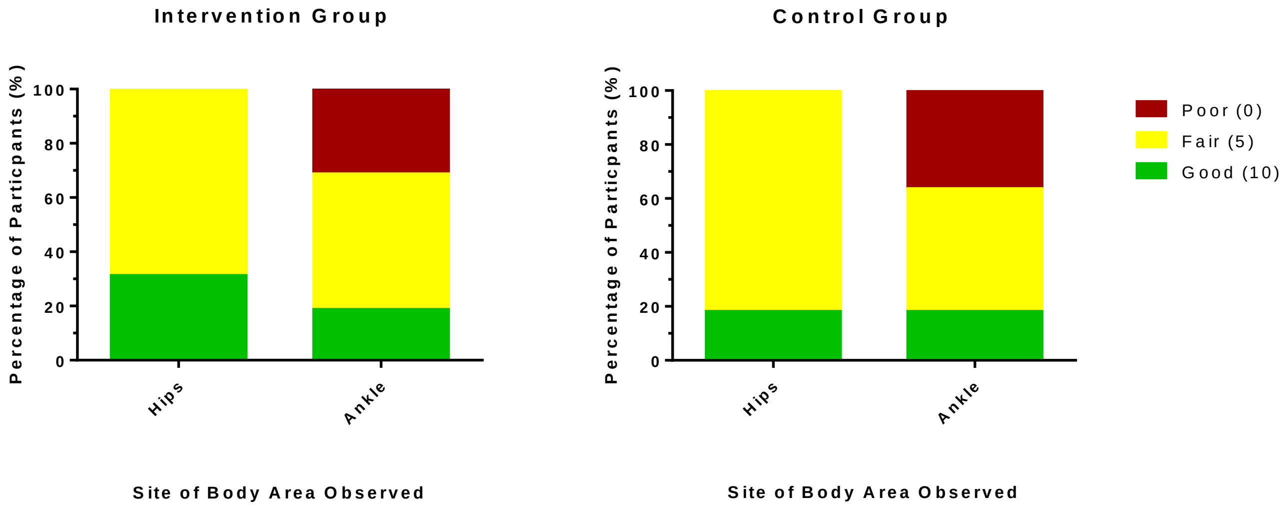


Figure 4.4: Comparison of mean baseline lower body posture profiles for the control and intervention group in adolescents with ASD (n=27).

ii. Brockport Physical Fitness Test

a. Aerobic function

The mean aerobic function parameters for the total, control and intervention groups are shown in Table 4.3. One participant from the intervention group refused to have blood pressure and heart rate taken. The total group had a mean systolic resting blood pressure of 112.8 ±16.7mmHg, and a mean diastolic resting blood pressure of 73.8 ± 10.8mmHg. The mean systolic blood pressure taken one minute after the cessation of exercise increased to 130.3 ± 20.0 mmHg, while the diastolic blood pressure remained similar (73.9 ± 8.7mmHg). Resting heart rate for the total sample was 83.7 ± 18.0bpm, while heart rate taken one-minute post exercise increased to 116.0 ± 18.4bpm. The intervention group had a higher resting systolic and diastolic blood pressure (116.9 ± 17.7mmHg and 74.3 ± 9.2mmHg) when compared to the control group (107.1 ± 14.1mmHg and 73.2 ± 13.2mmHg). Similarly, the intervention group had higher systolic (135.7 ± 19.4mmHg) and diastolic blood pressure one-minute post-exercise (75.3 ± 9.0mmHg) when compared to the control group (120.0 ± 18.0mmHg and 71.3 ± 8.0mmHg respectively). In contrast the control group had significantly higher resting heart rates (92.7 ± 21.6bpm; p=0.0398) as compared to the intervention group (78.0 ± 13.0bpm), and higher heart rates one-minute post exercising (119.8 ± 21.2bpm) as compared to the intervention group (113.8 ± 17.0bpm).

Table 4.3: Mean baseline aerobic function values for the total, control and intervention groups of adolescents with ASD (n=26).

Cardiovascular Parameters	Total Group (n = 26)	Control Group (n=11)	Intervention Group (n=15)	P value
Systolic BP at rest (mmHg)	112.8 ±16.7	107.1 ± 14.1	116.9 ± 17.7	0.1416
Diastolic BP at rest (mmHg)	73.8 ± 10.8	73.2 ± 13.2	74.3 ± 9.2	0.8224
Systolic BP 1 min post exercise (mmHg)	130.3 ± 20.0	120.0 ± 18.0	135.7 ± 19.4	0.0718
Diastolic BP 1 min post exercise (mmHg)	73.9 ± 8.7	71.3 ± 8.0	75.3 ± 9.0	0.2934
HR at rest (bpm)	83.7 ± 18.0	92.7 ± 21.6	78.0 ±13.0	0.0398*
HR 1 min post exercise (bpm)	116.0 ± 18.4	119.8 ± 21.2	113.8 ± 17.0	0.4492

BP= Blood Pressure; HR= Heart Rate; min= Minute; *p≤0.05=Significant

b. Body composition and anthropometry

Table 4.4 shows the mean body composition and anthropometric values for the total sample, control and intervention groups. One participant from the control group was afraid of the skinfold calipers and hence refused to have skinfold measures taken, therefore only 10 participants are reflected for the triceps skinfold, calf skinfold and body fat percentage measurements. The mean height for the participants (n=27) was 160.2 ± 12.6cm, and the mean weight was 61.6 ± 21.8kg. The mean BMI for the total sample (n=27) was 24.2 ± 5.9m/kg^2 while the mean triceps skinfold (n=26) measure was 21.0 ± 9.1mm and the mean calf skinfold (n=26) measure was 18.9 ± 8.4mm. Lastly, the overall body fat percentage for the sample (n=26) was 29.4 ± 12.7%. The intervention group had a mean height, which was greater than the control group (160.9 ± 11.6cm vs 152.1 ± 13.04cm) and a mean weight that was greater than the control group (68.31 ± 22.3kg vs 51.8 ± 17.6kg). The intervention group also had a greater BMI than the control group (25.8 ± 6.0 m/kg^2 vs 21.9 ± 5.2m/kg^2) and a greater body fat percentage when compared to the control group (n=10)(31.9 ± 12.0% vs. 25.4 ± 13.3%).

Table 4.4: Mean baseline body composition and anthropometric values for the total, control and intervention groups of adolescents with ASD (n=27).

Body Composition Parameters	Total Group (n=27)	Control Group (n=11)	Intervention Group (n=16)	P value
Height (cm)	160.2 ± 12.6	152.1 ± 13.04	160.9 ± 11.6	0.0795
Weight (kg)	61.6 ± 21.8	51.8 ± 17.6	68.3 ± 22.3	0.0504
BMI (m/kg^2)	24.2 ± 5.9	21.9 ± 5.2	25.8 ± 6.0	0.0892
Triceps skinfold (mm)	21.0 ± 9.1	18.1 ± 9.2	22.7 ± 8.8	0.2153
Calf skinfold (mm)	18.9 ± 8.4	15.4 ± 9.0	21.1 ± 8.5	0.1142
Body fat percentage (%)	29.4 ± 12.7	25.4 ± 13.3	31.9 ± 12.0	0.2101

Total group for skinfold and body fat percentage measurements: n=26

Control group for skinfold and body fat percentage measurements: n=10

c. Musculoskeletal function

i. Strength and endurance

Table 4.5 below shows the mean strength and endurance parameter values for the total, control and intervention groups. One participant in the control group refused to perform the handgrip tests. One participant refused, and 2 participants were unable to do the modified curl up test in the control group (n=7). Four participants were unable to appropriately perform the modified curl up test in the intervention group (n=12). The total group had mean handgrip strength of 13.4 ± 9.6kg for the dominant hand and a mean 13.4 ± 9.6kg for the non-dominant hand. The whole group (n=19) was also able to perform a mean of 11.6 ± 5.7 curl ups. There were no significant differences between the groups at baseline. The intervention group did however have greater handgrip strength for both the dominant (19.0 ± 11.8kg) and non-dominant hands (17.2 ± 10.3kg), compared to the control group: 13.4 ± 9.6kg and 14.0 ± 8.0kg respectively. Yet, the control group (n=7) was able to perform more modified curl ups (11.6 ± 5.7) as compared to the intervention group (n=12)(10.1 ± 6.6).

Table 4.5: Mean strength and endurance parameter values for the total, control and intervention groups of adolescents with ASD (n=26).

Strength and Endurance Parameters	Total group (n=26)	Control Group (n=10)	Intervention Group (n=16)	P value
Handgrip strength D (kg)	13.4 ± 9.6	13.4 ± 9.6	19.0 ± 11.8	0.2144
Handgrip strength ND (kg)	13.4 ± 9.6	14.0 ± 8.0	17.2 ± 10.3	0.4017
Modified curl up (number of)	11.6 ± 5.7	11.6 ± 5.7	10.1 ± 6.6	0.6258

D= Dominant; ND= Non-dominant

Total group for modified curl up: n=19

Control group for modified curl up: n=7

Intervention group for modified curl up: n=12

ii. Flexibility

The mean sit and reach, and hip and knee flexibility parameter values for the total, control and intervention groups are shown in Table 4.6 and 4.7 respectively. All participants were able to perform the sit and reach test, however one participant in each group (Total: n=25; Control: n=10; Intervention: n=15) were unable to perform the modified Thomas test. The sample achieved a higher distance in the sit and reach test for the non- dominant limb (24.0 ± 8.3 cm), compared to the dominant limb (23.9 ± 8.1cm) and a greater hip flexion value for the dominant limb (7.4 ± 6.9^{o}) compared to the non-dominant limb (5.1 ± 3.7^{o}). Similarly, the whole sample (n=25) had a greater knee flexion value for the dominant limb (18.6 ±13.0^{o}) as compared with the non-dominant limb (17.9 ± 14.3^{o}). There were no significant differences between the groups for all flexibility parameters; however, the control group (n=10) had greater hip flexion in the dominant limb as compared to the intervention group (n=15): 10.6 ± 8.6^{o} vs 5.3 ± 4.7^{o} respectively. This was also noted in the non-dominant limb for hip flexion, where the control group had a mean hip flexion of 5.4 ± 3.3^{o} and the intervention group had a mean hip flexion of 4.9 ± 4.0^{o}. In contrast, the intervention group had superior knee flexion in their dominant limb (19.6 ± 14.8^{o}) compared to the control group (17.0 ±11.2^{o}), while the control group had greater knee flexion in their non-dominant limb (19.5 ± 14.8^{o}) compared to the intervention group (16.9 ± 14.4^{o}). For the dominant limb, the intervention group achieved a greater distance in the sit and reach test compared to the control group (24.8 ± 8.9cm and 22.5 ± 7.0cm respectively), while the control group achieved a slightly greater distance for the non-dominant limb compared to the intervention group for the same test (24.1 ± 7.9cm vs 24.0 ± 8.8cm respectively).

Table 4.6: Mean baseline sit and reach values for the total, control and intervention groups of adolescents with ASD (n=27).

Flexibility Parameters	Total group (n=27)	Control Group (n=11)	Intervention Group (n=16)	P value
Sit and reach D (cm)	23.9 ± 8.1	22.5 ± 7.0	24.8 ± 8.9	0.4878
Sit and reach ND (cm)	24.0 ± 8.3	24.1 ± 7.9	24.0 ± 8.8	0.9996

D= Dominant; ND= Non-dominant

Table 4.7: Mean baseline hip and knee flexibility parameters values for the total, control and intervention groups of adolescents with ASD (n=25).

Hip and Knee Flexibility Parameters	Total Group (n=25)	Control Group (n=10)	Intervention Group (n=15)	P value
Modified Thomas (Hip flexion) D (^{o})	7.4 ± 6.9	10.6 ± 8.6	5.3 ± 4.7	0.0592
Modified Thomas (Hip flexion) ND (^{o})	5.1 ± 3.7	5.4 ± 3.3	4.9 ± 4.0	0.7625
Modified Thomas (Knee flexion) D (^{o})	18.6 ±13.0	17.0 ± 11.2	19.6 ± 14.8	0.6346
Modified Thomas (Knee flexion) ND (^{o})	17.9 ± 14.3	19.5 ± 14.8	16.9 ± 14.4	0.6611

D= Dominant; ND= Non-dominant

iii. Movement Assessment Battery for Children – 2

a. Manual dexterity

Table 4.8 below shows the comparison of the mean baseline manual dexterity items of the MABC-2 test for the total, control and intervention groups. The whole group was able to perform the turning pegs task with their dominant hand in 31.1 ± 9.8s and in 33.1 ± 8.1s for their non-dominant hand. In trial one of the triangle with nuts and bolts task the total group was able to complete the task in 82.1 ± 48.5s and in trial two the total group was able to perform the task in 72.7 ± 31.7s. Overall the total group made 72.7 ± 31.7 errors in the drawing trail task. There was no significant difference between the control and intervention groups for all the manual dexterity parameters. The intervention group performed better in the turning pegs task for both the dominant and non-dominant hands (29.9 ± 9.1s and 33.5 ±11.1s) compared to the control group (33.0 ± 11.0 s and 35.3 ± 8.5s) as they performed the task in a shorter amount of time. The control group performed the triangle with nuts and bolts task in a quicker time (80.0 ± 57.7s and 65.4 ± 36.0s) compared to the intervention group for both trials and the intervention group (83.2 ± 45.0s and 76.2 ± 30.1s) made less errors compared to the control group in the drawing trail task (11.3 ± 9.4 errors vs. 19.6 ± 18.4 errors).

Table 4.8: Mean baseline manual dexterity items of the MABC-2 test for the total, intervention and control groups of adolescents with ASD (n=27).

Manual Dexterity Parameters	Total Sample (n=27)	Control Group (n=11)	Intervention Group (n=16)	P value
Turning pegs D (s)	31.1 ± 9.8	33.0 ± 11.0	29.9 ± 9.1	0.4455
Turning pegs ND (s)	33.1 ± 8.1	35.3 ± 8.5	33.5 ±11.1	0.6401
Triangle with nuts & bolts T1 (s)	82.1 ± 48.5	80.0 ± 57.7#	83.2 ± 45.0	0.8856
Triangle with nuts & bolts T2 (s)	72.7 ± 31.7	65.4 ± 36.0	76.2 ± 30.1	0.4696
Drawing trail (no. of errors)	14.7 ± 14.1	19.6 ± 18.4	11.3 ± 9.4	0.1312

T1= Trial 1; T2= Trial 2; D= dominant hand; ND= Non-dominant hand

Total group for turning pegs ND: n=25

For triangle with nuts & bolts T1 and T2: n=23

Control group for turning pegs ND: n=9

Intervention group for triangle with nuts & bolts T1 and T2: n=15

Control group for triangle with nuts & bolts T1 and T2: n=8

b. Aiming and catching

Table 4.9 below shows the overall mean baseline aiming and catching items of the MABC-2 test for the total, control and intervention groups. The total group was able to catch a mean 6.9 ± 3.2balls with their dominant hand and a mean 6.7 ± 2.8balls with their non-dominant hand. The whole group was also able to throw a mean 5.2 ± 1.5balls correctly at a wall target. There were no significant differences between the control and intervention groups at baseline. The control group was able to make a mean of 5.9 ± 3.1catches out of 10 for the dominant hand and 6.5 ± 3.5catches out of 10 for the non-dominant hand, whereas the control group performed slightly better at baseline- being able to complete a mean of 6.5 ± 3.5catches and 6.8 ± 2.9catches with their dominant and non-dominant hands respectively. The intervention group was also able to throw more balls into a target at baseline (5.2 ± 1.3balls) compared to the control group (5.1 ± 2.0balls).

Table 4.9: Mean baseline aiming and catching items of the MABC-2 test for the total, control and intervention groups in adolescents with ASD (n=27).

Aiming and Catching Parameters	Total Group (n=27)	Control Group (n=11)	Intervention Group (n=16)	P value
Catching with one hand D (number of catches)	6.9 ± 3.2	5.9 ± 3.1	7.6 ± 3.1	0.2492
Catching with one hand ND (number of catches)	6.7 ± 2.8	6.5 ± 3.5	6.8 ± 2.9	0.8534
Throwing at a wall target (number of correct throws) D	5.2 ± 1.5	5.1 ± 2.0	5.2 ± 1.3	0.9137

D= Dominant; ND= Non-dominant

c. Balance

Table 4.10 below shows the comparison of the mean baseline balance items of the MABC-2 test for the total group, and split into control and intervention groups in adolescents with ASD (n=27). Some of the participants performed these tests inappropriately, refused to perform the test or were unable to do the test, data for these individuals were subsequently omitted from the results. The total group was able to perform the two-board balance task for their first trial in a mean 9.0 ± 8.1s and a mean 12.8 ± 11.3s for their second trial. The whole group was able to perform a mean 5.5 ± 0.8 correct zigzag hops for their dominant leg and a mean 5.7 ± 1.1 correct zigzag hops for their non-dominant leg. The group was also able to perform a mean 12.9 ± 4.2 correct steps in the backwards tandem-walking task. There was a significant difference between the control and intervention groups in the second trial of the two board balance activity, yet for all the other balance parameters there were no significant differences between the groups. The intervention group did however perform better in all of the balance activities compared to the control group. The intervention group was able to hold their balance for a mean 10.5 ± 9.2s during the two-board balance test, while the control group could hold their balance for 6.8 ± 6.0s. The intervention group performed worse in their second trial of the test (compared to their first), maintaining their balance for a mean 16.9 ± 11.2s, while the control group maintained their balance for 6.7 ± 8.8s. The intervention group performed more mean steps in the tandem walk test at baseline (13.4 ± 4.4 steps) than the control group (11.8 ± 3.9 steps), as well as performed more hops in both trials of the zig zag hopping test (5.8 ± 0.9 hops and 6.0 ± 1.2 hops) compared to the control group (5.0 ± 0.0 hops and 5.2 ± 0.4 hops).

Table 4.10: Comparison of the mean baseline balance items of the MABC-2 test for the control and intervention groups in adolescents with ASD (n=27).

Balance Parameters	Total Group (n=27)	Control Group (n=11)	Intervention Group (n=16)	P value
Two board balance T1 (s)	9.0 ± 8.1	6.8 ± 6.0	10.5 ± 9.2	0.2742
Two board balance T2 (s)	12.8 ± 11.3	6.7 ± 8.8	16.9 ± 11.2	0.0243*
Tandem walking backwards (no. of correct steps)	12.9 ± 4.2	11.8 ± 3.9	13.4 ± 4.4	0.5210
Zig-Zag Hopping D (no. of correct hops)	5.5 ± 0.8	5.0 ± 0.0	5.8 ± 0.9	0.0328
Zig-Zag Hopping ND (no. of correct hops)	5.7 ± 1.1	5.2 ± 0.4	6.0 ± 1.2	0.1393

T1= Trial 1; T2= Trial 2; D= Dominant; ND= Non-dominant; *p≤0.05=Significant

Total group for zig-zag hopping D: n=19; ND: n=16

Intervention group for zig-zag hopping D: n=12; ND: n=10

Control group for zig-zag hopping D: n=7; ND: n=6

iv. Agility and Gait

The mean baseline agility times achieved in the agility T-test and mean baseline gait parameters for the total, control and intervention groups for the sample are shown in Table 4.11. The whole group had a mean agility T-test time of 30.0 ± 12s. The intervention group performed the agility T test in a quicker time compared to the control group (27.4 ± 12.1 s vs 33.8 ± 11.3 s), yet this difference in time was not significantly different. The whole group had a mean stride length of 1.7 ± 0.4m and a mean step length of 0.9 ± 0.2m for their dominant leg. The group had a mean stride length of 1.7 ±0.5m and a mean step length of 0.9 ± 0.2m for their non-dominant leg. The mean step width for the total group was found to be 0.2±0.0m. The intervention group had a slightly longer stride length for their dominant leg compared the control group (1.8 ±0.2m and 1.6 ±0.5m respectively. The opposite was seen for their non-dominant leg where the intervention had a stride length of 1.7 ± 0.3m m and the control group had a stride length of 1.8 ± 0.5m.and the intervention group had a shorter step width for both their dominant (0.8 ±0.1m) and non-dominant(0.8 ± 0.1m) compared to the control group which had a step length for their dominant and non-dominant legs of 0.9 ± 0.3m and 0.8 ± 0.3m respectively. The intervention group had a mean step width of 0.2 ± 0.0m and the control group had a similar step width of 0.2 ± 0.0m.

Table 4.11: Mean baseline agility times and gait parameters for the total, control and intervention groups in adolescents with ASD (n=27).

Movement Parameters	Total Group (n=27)	Control Group (n=11)	Intervention Group (n=16)	P value
Agility T test (s)	30.0 ± 12	33.8 ± 11.3	27.4 ± 12.1	0.1843
Stride Length D (m)	1.7 ± 0.4	1.6 ± 0.5	1.8 ± 0.2	0.7454
Stride Length ND (m)	1.7 ±0.5	1.8 ± 0.5	1.7 ± 0.3	0.7454
Step length D (m)	0.9 ± 0.2	0.9 ± 0.3	0.8 ± 0.1	0.9774
Step length ND (m)	0.8 ± 0.2	0.8 ± 0.3	0.8 ± 0.1	0.9591
Step width (m)	0.2 ± 0.0	0.2 ± 0.0	0.2 ± 0.0	0.3730

D= Dominant; ND= Non-dominant

B. Randomisation appropriateness

i. Demographic data

The demographic data for the total group, as well as a comparison between the control and intervention groups at baseline are shown in Table 4.12. For all parameters, it is shown that there were no significant differences between the control and intervention groups in terms of level of function (based on mental age), hand and leg dominance as well as in gender. Hence, randomisation for all these components was done optimally.

Table 4.12: Demographic data for the total control and intervention group (n=27).

Demographic Parameters		**Total Group (n=27)**	**Control Group (n=11)**	**Intervention Group (n=16)**	**P value**
			Occurrence (Percentage)	Occurrence (Percentage)	
Function (based on mental age)	High functioning	13(48.1%)	4(36.4%)	9 (56.3%)	0.540
	Moderate functioning	7(25.9%)	3 (27.3%)	4 (25.0%)	
	Low functioning	7(25.9%)	4 (36.4%)	3 (25.0%)	
Hand dominance	Right dominant	22(81.5%	9 (81.8%)	13 (81.3%)	1.000
	Left dominant	5(18.5%)	2 (18.8%)	3 (18.8%)	
Foot Dominance	Right dominant	22(81.5%	10 (90.9%)	12 (75.0%)	0.618
	Left dominant	5(18.5%)	1 (9.1%)	4 (25.0%)	
Gender	Male	21(77.8%)	9 (81.8%)	12 (75.0%)	1.000
	Female	6(22.2%)	2 (18.8%)	4 (25.0%)	

ii. Medications

A variety of medications were used in the population and this needed to be considered for the intervention as the medications taken could have influenced the outcome variables. Four main types of medications were noted in the sample, namely: CNS stimulators, antipsychotics, antidepressants and anti-convulsants. Figure 4.5 below shows the amount of medications taken pre-intervention by the participants for the whole sample. The majority of the individuals 36% (n=10) were taking 1 medication prior to the intervention, 29% (n=8) were taking no medication, 21% (n=6) were taking 2 medications and 14% (n=4) were taking three or more medications.

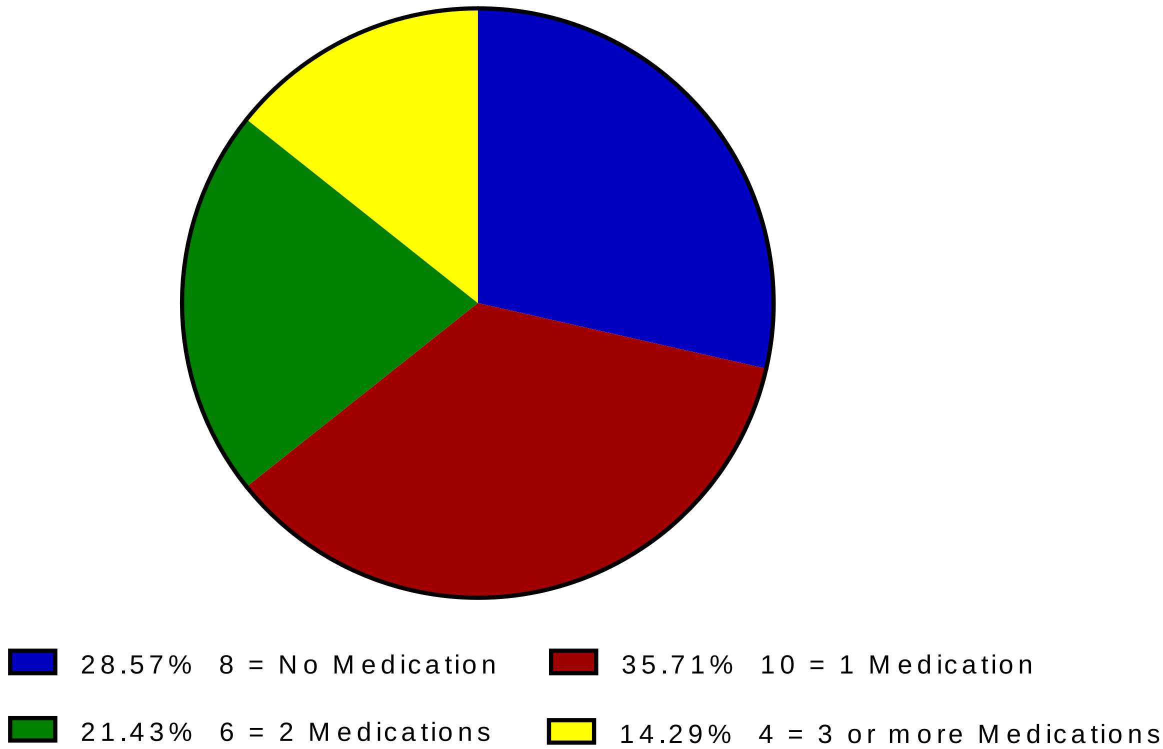


Figure 4.5: Number of medications taken at baseline in adolescents with ASD (n=27).

Table 4.13 shows the comparison of the mean medications taken by the control and intervention groups at baseline. It can clearly be seen that the control and intervention group were balanced in terms of randomisation as there were no significant differences between groups. Fifty-three percent of the control group was taking CNS stimulators while 31.3% of the intervention group was taking CNS stimulators at baseline. The intervention group was taking more antipsychotic (43.8% vs 26.7%) medication and more antidepressant medication (25% vs 20%) compared to the control group at baseline. In contrast the control group was taking slightly more anticonvulsive medication (13.3%) compared to the intervention group (12.5%).

Table 4.13: Comparison of baseline medication levels taken, by group in adolescents with ASD (n=27).

Type of Medication	Number of Medications		P value
	Control Group (n=15)	Intervention Group (n=12)	
	Occurrence (Percentage)	Occurrence (Percentage)	
CNS stimulators	8 (53.3%)	5 (31.3%)	0.213
Antipsychotics	4 (26.7%)	7 (43.8%)	0.458
Antidepressants	3 (20.0%)	4 (25.0%)	1.000
Anticonvulsants	2 (13.3%)	2 (12.5%)	1.000

CNS= Central Nervous System

C. Intervention vs Control Group following Intervention

1) Objective 1

To formulate and implement a model exercise intervention programme in adolescents aged 11-16 years with ASD.

A model exercise intervention was developed and validated by an expert panel carefully selected for the study and was implemented at UNICA school for Autism over 12 weeks.

The intervention was successfully rolled out at Unica school for autism over the course of 12 weeks.

i. Compliance to intervention

The overall percentages of compliance to the exercise intervention for the whole sample, as well as for the 2 exercise groups (moderate to high functioning individuals, and low functioning individuals) are shown in Figure 4.6.The overall compliance for the whole sample of individuals with ASD was high- 88.78 %. The moderate to high functioning individuals with ASD demonstrated an excellent compliance rate to the intervention (97.24%), whereas the low functioning individuals demonstrated a much lower compliance rate (77.89%).

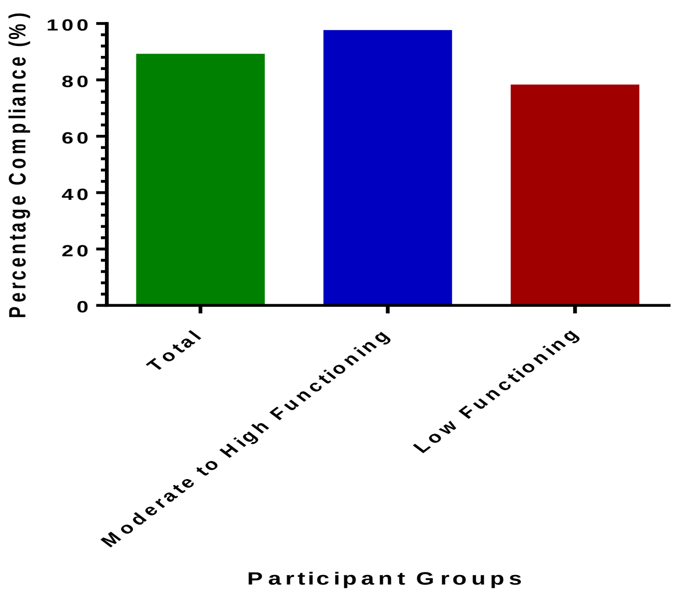


Figure 4.6: Overall percentage compliance for total, control and intervention groups of participants with ASD partaking in a 12-week exercise intervention (n=16).

The overall percentages of participants who took part in each exercise session are shown in Figure 4.7. Out of the 24 sessions, full participation by all 16 participants occurred 5 times (session number 1, 15, 21, 22 and 23). The lowest percentage participation was seen in session number 13 where only 75% of the participants attended the session.

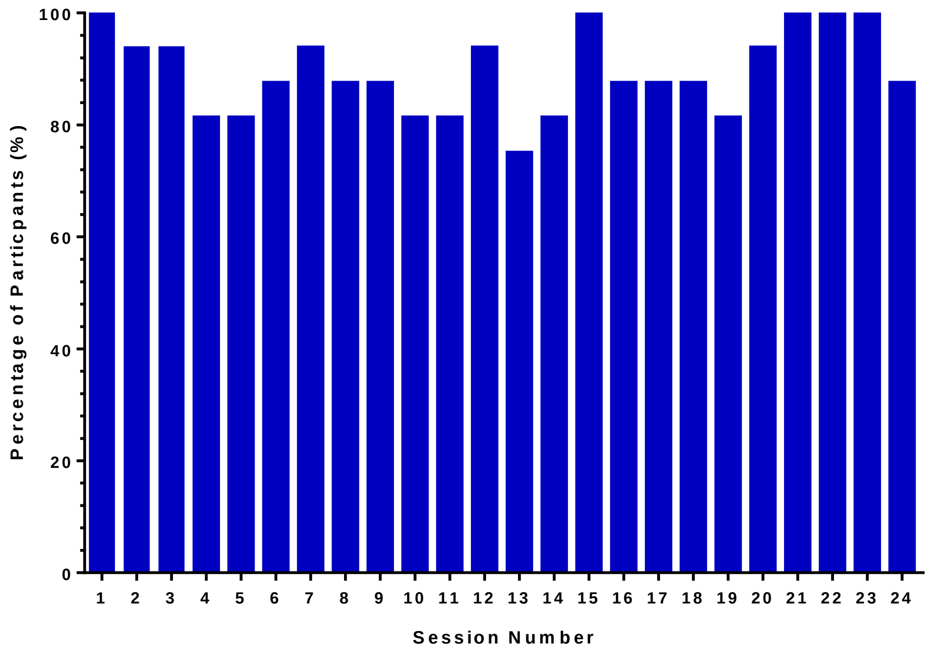


Figure 4.7: Overall percentages of participants with ASD who took part in each exercise session (n=16).

The overall percentages of the 2 groups of participants (moderate to high functioning individuals, and low functioning individuals) who took part in each exercise session are displayed in Figure 4.8. Full (100%) participation was seen in 20 out of the 24 sessions for the moderate to high functioning group, whereas 100% participation was only seen in 5 sessions for the low functioning group. The lowest participation percentage seen for a session was 77.78% (n=12) for the moderate to high functioning group, whereas the lowest participation percentage seen for the low functioning group was 57.14 % (n=4), and this occurred in 4 out of the 24 sessions.

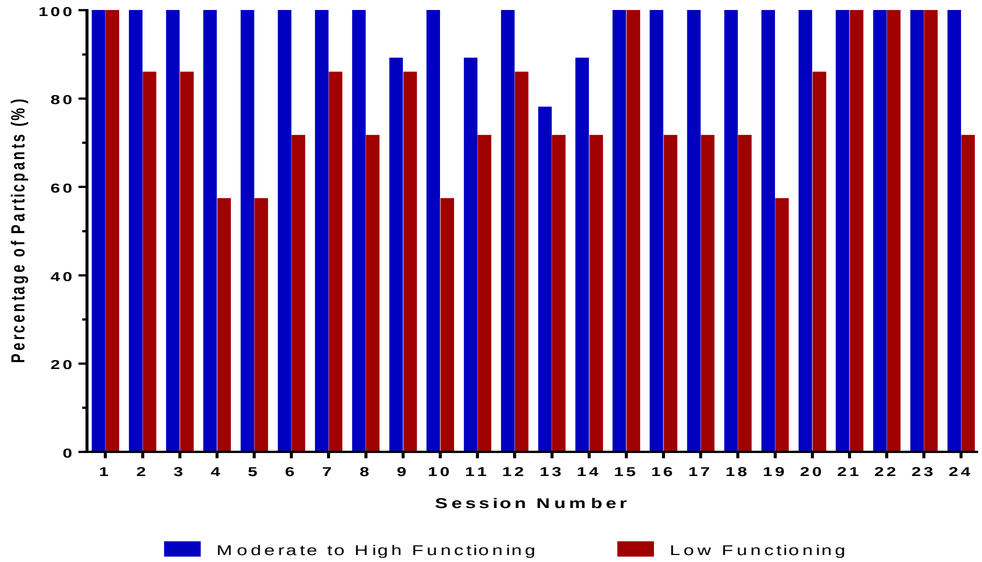


Figure 4.8: Percentage of participants with moderate to high function ASD compared with low functioning ASD partaking in each exercise session throughout the 12 week exercise intervention (n=16).

2) Objective 2

To assess posture, body composition and physical fitness pre-and post-exercise intervention in adolescents with autism aged 11 to 16 years.

Body composition and physical fitness were assessed using the Brockport physical fitness test and posture was analyzed using a posture grid.

i. Posture

The comparison of the mean pre and post intervention total body area scores are shown in Figure 4.9, and the total posture scores in Figure 4.10. There were no significant differences for the majority of the body areas from baseline to post intervention for the control group, yet significant increases in posture scores were noted in the ankle (p=0.0183) and trunk areas (p=0.0907) for the intervention group. Overall ankle posture scores in the intervention group were found to be 4.4 ± 3.6 at baseline as compared to 6.9 ± 3.1 post intervention. Similarly, overall trunk posture scores increased from pre (6.3 ± 3.9) to post intervention (8.1 ± 2.5). Furthermore, there was a significant difference in the overall posture scores in the intervention group seen from baseline to post intervention (0.0004). The intervention group improved in all body areas besides the spine from baseline.

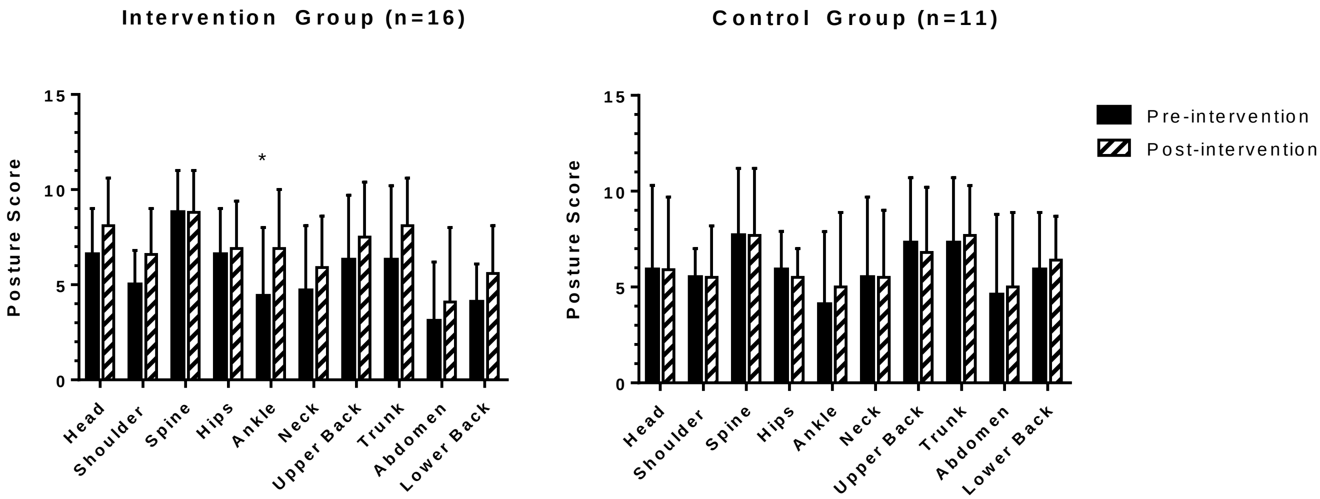


Figure 4.9: Comparison of mean pre vs. post body area posture scores, by group.

**Ankle Score: Intervention Group (Pre vs Post): p = 0.0183*

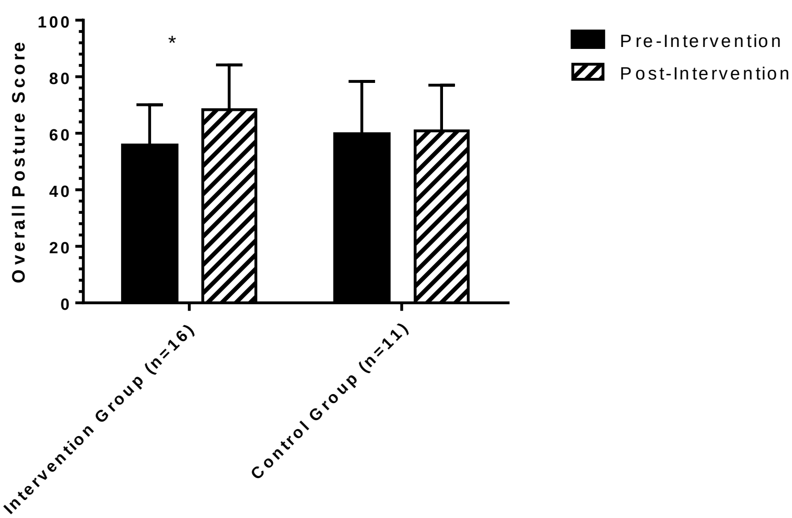


Figure 4.10: Comparison of mean pre vs. post overall posture scores, by group.

**Overall Posture Score: Intervention Group (Pre vs Post): p = 0.0004*

ii. Brockport Physical Fitness Test

a. Aerobic function

Figure 4.11 below shows the comparison of the mean blood pressure and heart rate values for the sample pre and post intervention. Not all the participants had their BP and HR measured in the control and intervention groups (see bottom of figure for group numbers).The intervention group showed a significant decrease in systolic blood pressure post intervention (116.9 ± 17.7mmHg to 102.9 ± 16.5mmHg: p=0.0069).Systolic blood pressure taken one minute following exercise also significantly decreased (p=0.0007), from 135.7 ± 19.4mmHg pre intervention to 115.0 ± 16.5mmHg post intervention.There were also significant differences found in the resting heart rates (p=0.0046) where heart rate decreased from 78.0 ±13.0 bpm to 75.1 ± 9.9 bpm; and heart rates taken 1 minute following exercise (p=0.0096), where heart rate decreased from 113.8 ± 17.0 bpm to 109.5 ± 15.2 bpm.Conversely, there were no significant differences found for systolic BP, diastolic BP or heart rate when tested at post-intervention.

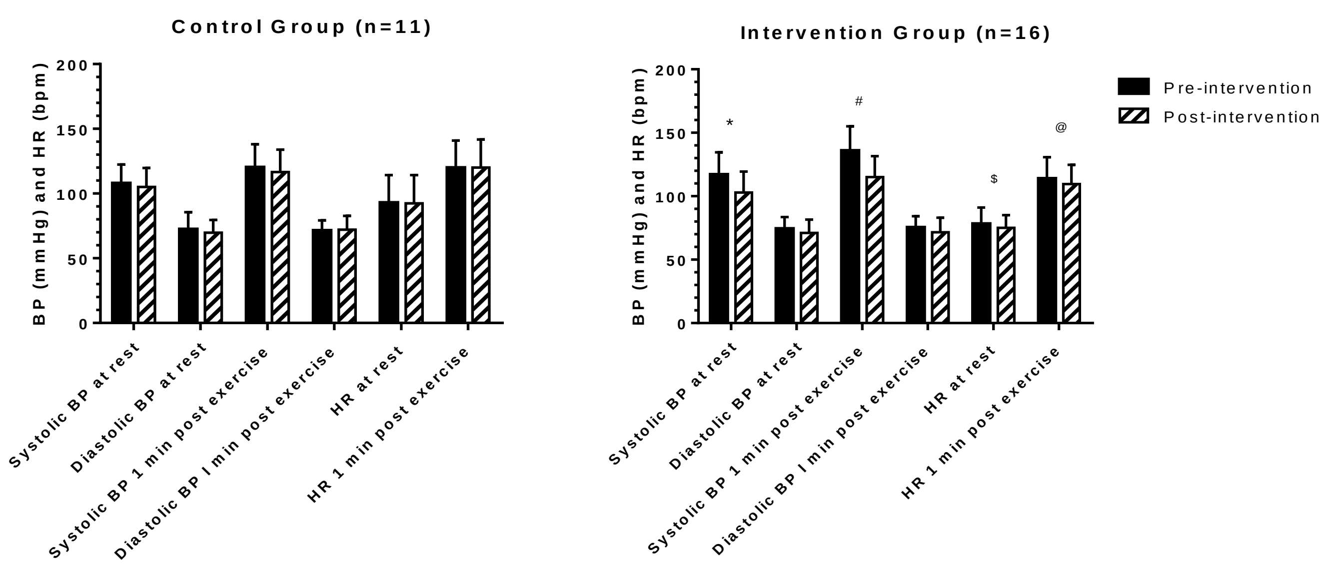


Figure 4.11: Comparison of mean pre vs. post blood pressure and heart rate values by group, in adolescents with ASD (n=27).

Systolic and diastolic BP at rest: Intervention group: n= 15; Control group: n=10

Systolic and diastolic BP at 1 min: Intervention group: n= 15; Control group: n=8

HR rest and 1 min post-exercise: Intervention group: n= 16; Control group: n=10

** Systolic BP at rest: Intervention Group (pre vs post): p = 0.0069*

 # Systolic BP 1 min post exercise: Intervention Group (pre vs post): p = 0.0007

$ HR at rest: Intervention Group (pre vs post): p = 0.0046

@ HR 1 min post exercise: Intervention Group (pre vs post): p = 0.0096

b. Body composition and anthropometry

Figure 4.12 below shows the comparison of the mean anthropometric and body composition parameters between the control and intervention group pre and post intervention testing. Due to one participant being afraid of the skinfold calipers only 10 participants in the control group had their tricep skinfold, calf skinfold and body fat percentage measured. The intervention groups weight decreased from 68.3 ± 22.3kg to 67.7 ± 20.5kg, while the control groups' weight significantly increased (p=0.0284) from pre intervention from 53.5 ± 17.6kg to post intervention 54.8 ± 18.1kg. The intervention groups' BMI significantly decreased (p=0.0130) from pre to post intervention from 25.8 ± 6.0m/kg^2 to 24.8± 5.3 m/kg^2 and their body fat percentage also decreased from 31.9 ± 12.0% to 31.6% ± 11.4. In the intervention group the triceps skinfold measure decreased slightly from 22.71 ± 8.77mm to 21.71 ± 8.14, while in the control group the triceps skinfold decreased significantly from 18.1 ± 9.2mm to 15.3 ± 8.6mm. for the calf skinfold measure. In the intervention group, the calf skinfold measure increased slightly from 21.1 ± 8.5 to 21.8 ± 8.2, while in the control group the skinfold measure for the calf significantly decreased from 18.6 ± 8.8mm to 15.4 ± 9.0mm.

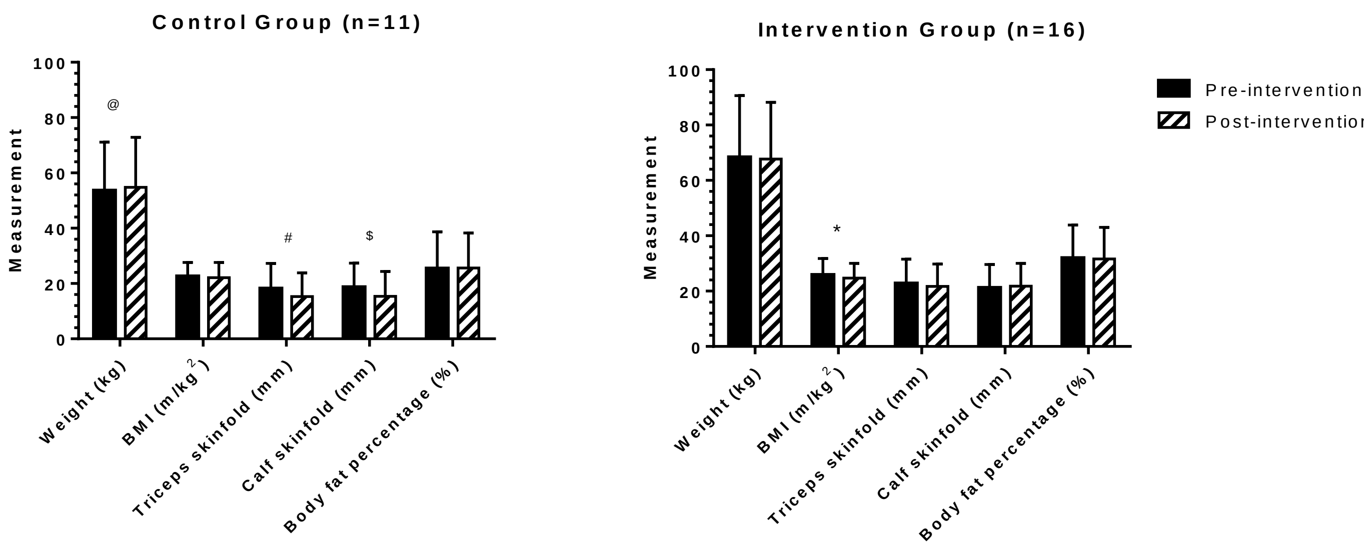


Figure 4.12: Comparison of mean pre vs. post, body composition and anthropometric results, by group, pre and post intervention testing.

Tricep skinfold, calf skinfold and body fat percentage: Control group: n=10

** BMI: Intervention Group (pre vs post): p = 0.0130*

@ Weight: Control Group (pre vs post): p = 0.0284

 # Triceps Skinfold: Control Group (pre vs post): p = 0.0244

$ Calf Skinfold: Control Group (pre vs post): p = 0.0411

c. Musculoskeletal function

i. Strength and endurance

Figure 4.13 below shows the comparison of the mean handgrip strength and number of curl-ups performed for the control and intervention group pre and post-intervention testing. There was a significant mean improvement seen in the intervention group for handgrip strength in the non-dominant hand (p=0.0289) yet no significant changes were seen for handgrip strength and the number of curl ups the participants could do for the control group. It can also be seen that mean handgrip strength in the intervention group increased from 19.0 ± 11.8kg to 20.0 ± 11.0kg for the dominant hand and from 17.2 ± 10.3kg to 18.8 ± 10.4kg for the non-dominant hand, while in the control group it decreased from 13.4 ± 9.6kg to 12.8 ± 9.1kg for the dominant hand and decreased from 14.0 ± 8.0kg to 12.6 ± 7.6kg for the non-dominant hand. The same can be said for the mean amount of curl ups the participants could perform, where the intervention group significantly improved (p= 0.0094) from being able to perform a mean 10.1 ± 6.6 curl ups to a mean of 14.3 ± 4.5 curl ups, while the control group had a decrease in the number of modified curl-ups they could perform (from 11.3 ± 6.2 curl-ups to 8.0 ± 7.1 curl ups).

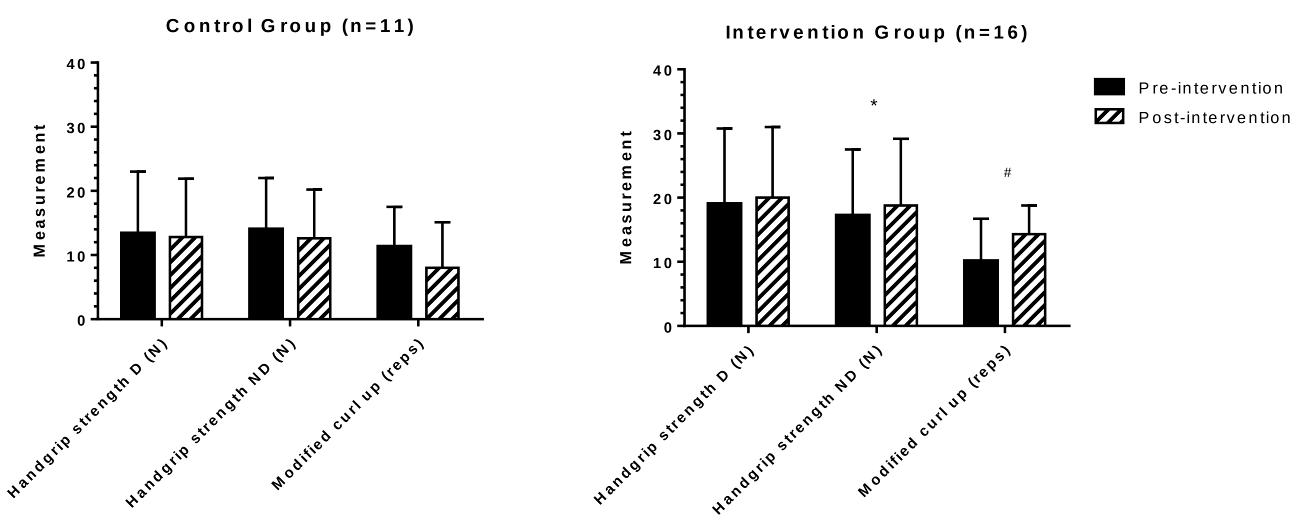


Figure 4.13: Comparison of mean pre vs. post handgrip strength and number of curl-ups performed, by group.

Modified curl up: Intervention group: n=12; Control group: n=7

** ND Handgrip Strength: Intervention Group (pre vs post): p = 0.0289*

 # Modified curl up: Intervention Group (pre vs post): p=0.0094

i. Flexibility

Figure 4.14 shows the comparison of mean pre vs post body flexibility parameters for the control and intervention groups. For the majority of the parameters, no significant changes were seen from pre to post testing besides in the intervention group for the sit and reach test on the non-dominant limb (p=0.0088). In the intervention group flexibility increased for the dominant leg (from 24.8 ± 8.9cm to 27.3 ± 8.6cm), and for the non-dominant leg (from 24.0 ± 8.8cm to 27.8 ± 8.7cm) for the sit and reach test, yet in the control group flexibility decreased in the sit and reach test for both the dominant (from 22.1 ±7.2cm to 19.6 ± 5.8cm) and the non-dominant leg (from 23.6 ± 8.1cm to 20.5 ± 6.2). For the dominant leg in the intervention group, flexibility improved from 24.8 ± 8.9cm to 27.3 ± 8.6cm, and for the non-dominant leg flexibility significantly improved from 24.0 ± 8.8cm to 27.8 ± 8.7cm. Hip flexion for both the control and intervention group decreased from pre to post intervention testing, while for the non-dominant limb, hip flexion decreased in the intervention group (from 4.9 ± 4.0^{o} to 4.1 ± 3.7^{o}) yet improved in the control group (5.0 ± 3.2^{o} to 8.5 ± 9.9^{o}) from pre to post intervention. For both groups knee flexion decreased for both the dominant and non-dominant limbs from pre to post-intervention testing.

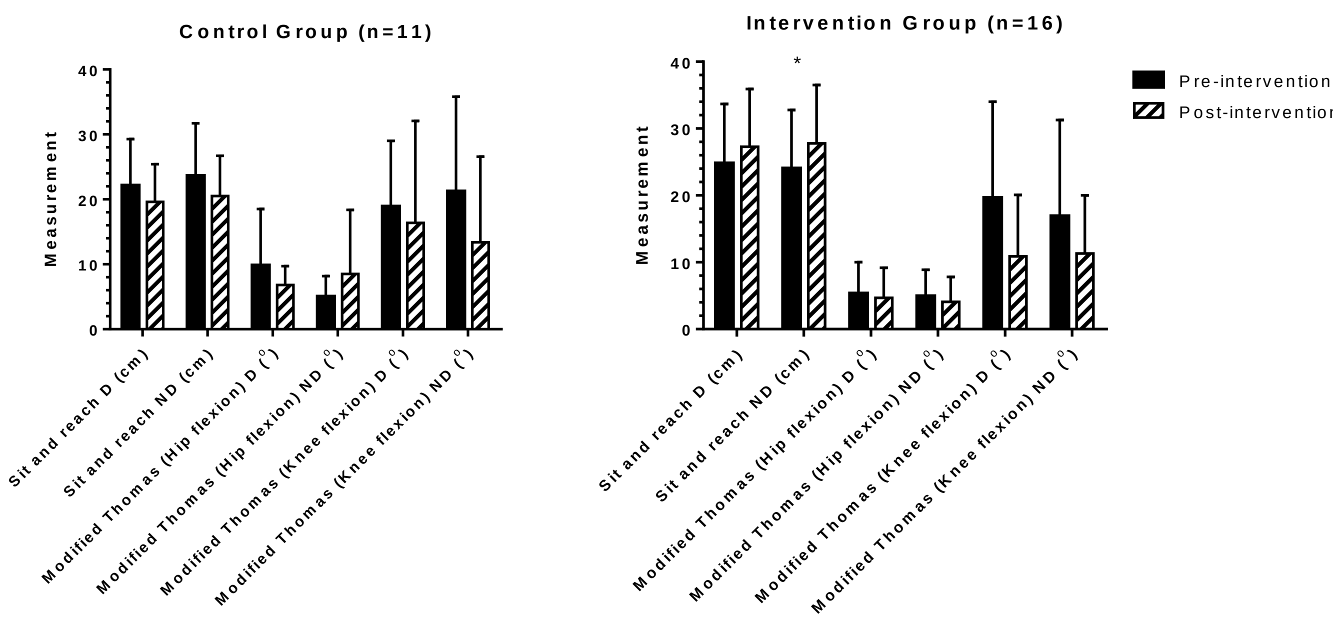


Figure 4.14: Comparison of mean pre vs. post body flexibility parameters by group.

Hip flexion and knee flexion: Intervention group: n=15; Control group: n=9

** ND Sit and Reach: Intervention Group (pre vs post): p = 0.0088*

3) Objective 3

To assess balance, coordination and agility pre-and post-exercise intervention in adolescents with autism aged 11 to 16 years.

Balance and coordination were assessed using the MABC-2 test battery and agility was tested in the test battery developed by the researcher using an agility T test.

i. Movement Assessment Battery for Children – 2

a. Manual dexterity

The comparison of the mean pre vs post manual dexterity items of the MABC-2 test by group are shown in Figure 4.15. There was a significant difference seen in the intervention group (p=0.0200) for the turning pegs item for the non-dominant hand in the intervention group, where the group was able to turn all the pegs around in 33.5 ±11.1 s pre intervention and then much quicker (29.6±10.8s) post intervention. In comparison there were no significant differences for the control group pre and post intervention for any of the manual dexterity items of the MABC-2 test.

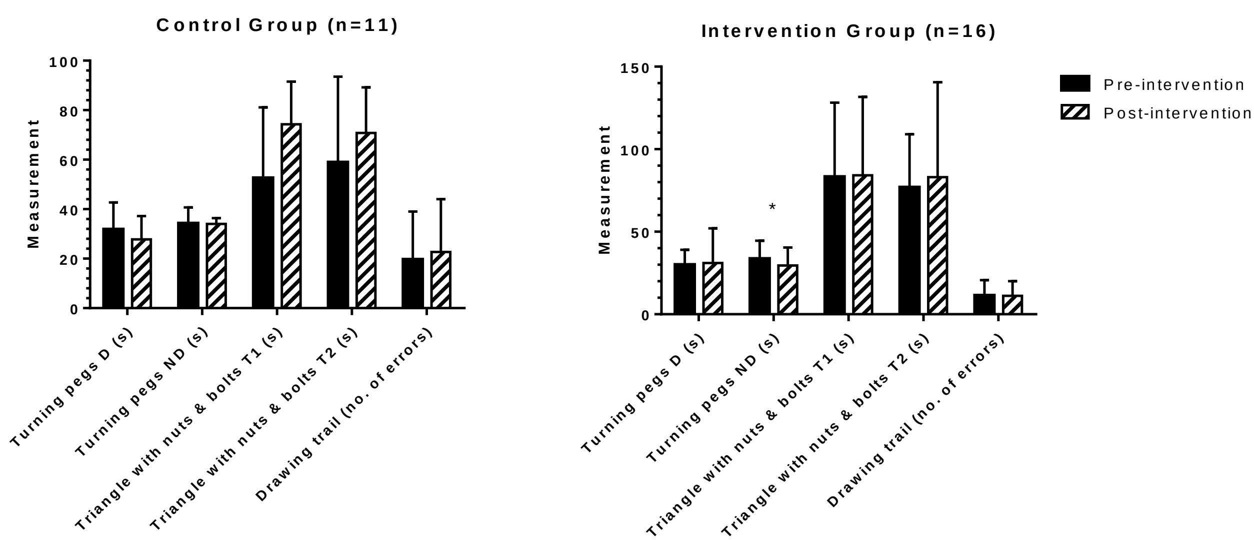


Figure 4.15: Comparison of mean pre vs. post manual dexterity items of the MABC-2 test, by group.

Turning pegs ND: Intervention group: n=16; Control group: n=9

Triangle T1 and T2: Intervention group: n=15; Control group: n=8

**Turning pegs ND: Intervention Group (pre vs post): p = 0.0200*

b. Aiming and catching

Figure 4.16 below shows the comparison of the mean aiming and catching results for the MABC-2 test in the control and intervention group pre and post intervention. There was a significant difference (p=0.0007) in the intervention group for the throwing activity, where the group increased in the number of throws they were able to get inside the target following the intervention (5.2 ± 1.3 balls to 8.9 ± 1.5 balls). A significant difference was also seen in the control group (p=0.0112), where the group increased in the number of throws they were able to get inside the target following the intervention (5.1 ± 2.0 balls to 8.4 ± 1.5 balls). No other significant differences were seen in the control group or intervention group between pre and post intervention testing.

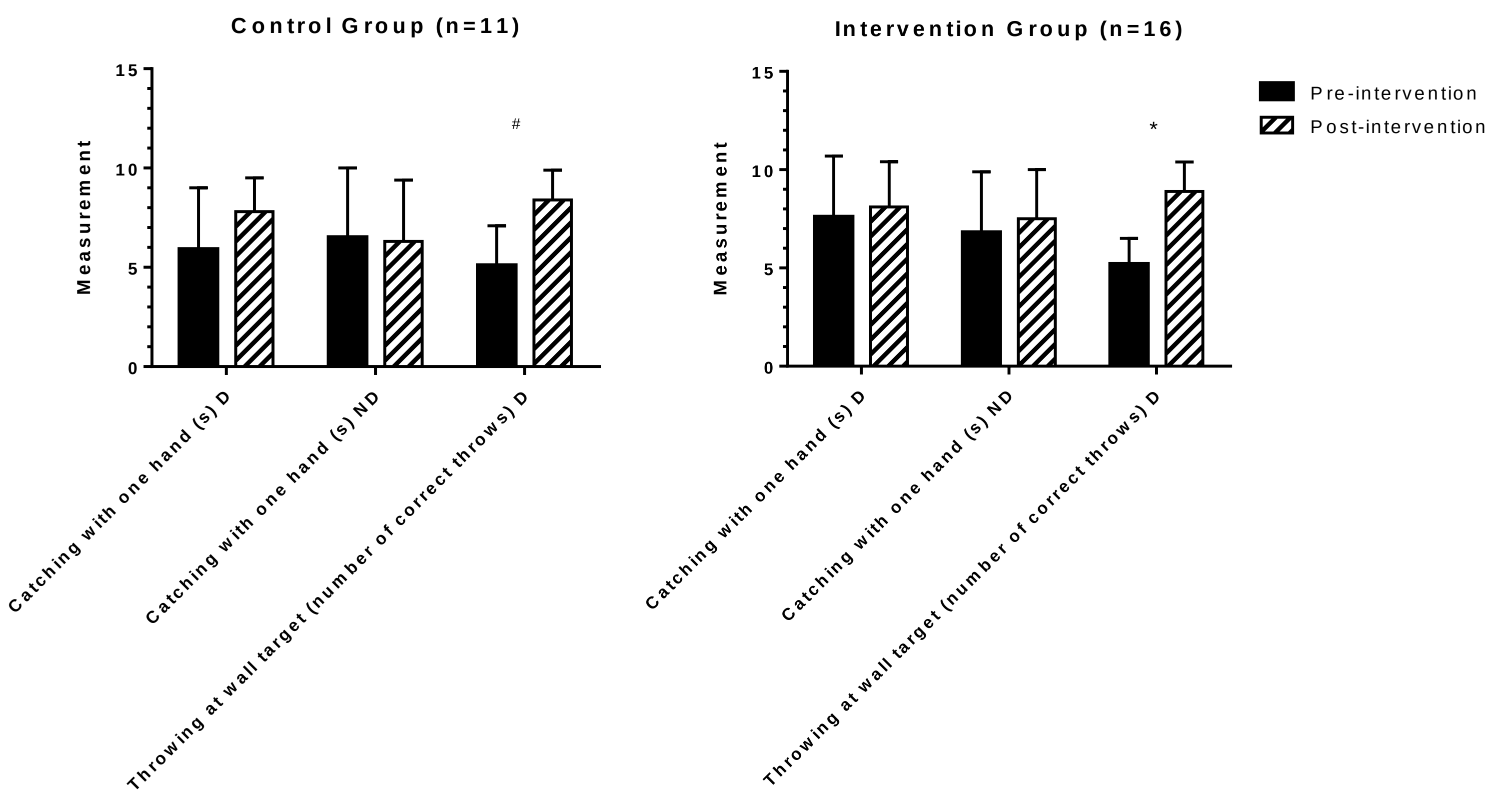


Figure 4.16: Comparison of mean pre vs. post aiming and catching items of the MABC-2 test, by group.

*Throwing at wall target D: Intervention Group (pre vs post): p = 0.0007

Throwing at wall target D: Control Group (pre vs post): p = 0.0112

c. Balance

The comparison of mean pre vs post balance items are shown in Figure 4.17 for the MABC-2 test items. The intervention group was able to hold their balance for a significantly (p=0.0028) longer time post intervention (17.0 ± 11.0 s) compared to pre intervention (10.5 ± 9.2 s). No other significant differences were found for the intervention group for the balance items. The control group demonstrated no statistically significant changes in any of the balance items of the MABC-2 test from pre to post intervention.

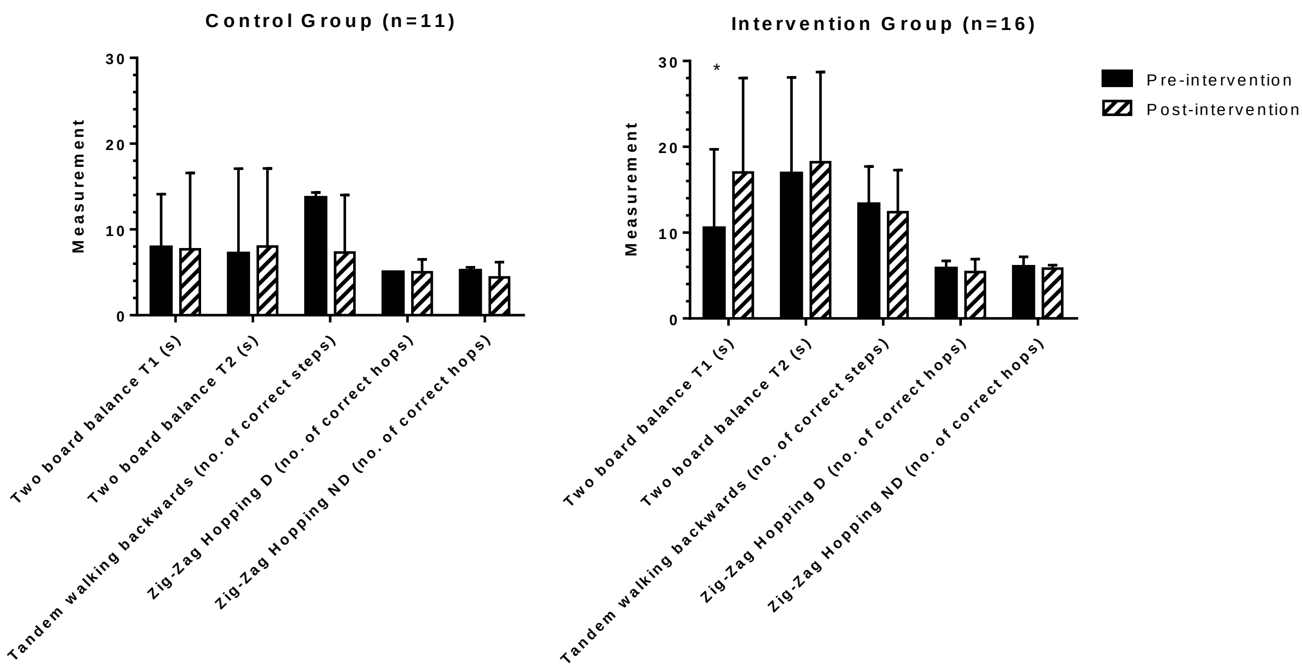


Figure 4.17: Comparison of mean pre vs. post balance items of the MABC-2 test, by group.

Zig-zag hopping D: Intervention group: n=12; Control group: n=7

Zig-zag hopping ND: Intervention group: n=12; Control group: n=6

*Two board balance T1: Intervention Group (pre vs post): p = 0.0028

ii. Movement Assessment Battery for Children – 2 Checklist

Since only one parent returned the MABC-2 checklists back to the researcher, data for the whole sample was not available and thus a case study is presented for this component of the study.

CASE A

Case A, was a 16 year old girl, who had a mental age of 7.5 years. She was deemed to be high functioning and hence participated in the advanced group in the exercise intervention. She attended all 24 exercise classes and was always very enthusiastic in participating in the programme.

Figure 4.18 below illustrates her MABC-2 checklist component scores. Case A had no change in scores pre and post intervention. The scoring for the checklist is such that the best score is 0 points where as the worst score is 36 points per section, with an overall perfect score being 0 and overall worst score being 180. Case A's overall motor scores for the first and second sections of the MABC-2 checklist were 6 points. These measures looked at her motor proficiencies in a context where she was stationary and her environment was stable; and when she was moving and her environment was stable, respectively. Her motor score for the third section of the MABC-2 checklist was 10, and was measured in a context where she was stationary and her environment was changing. Her motor score for the 4th section was 13 points which was measured in a context where she was moving and her environment was changing. And lastly she scored 10 points for section 5, which looked at her behavioral problems related to her motor difficulties. Overall she obtained a checklist score of 45 points.

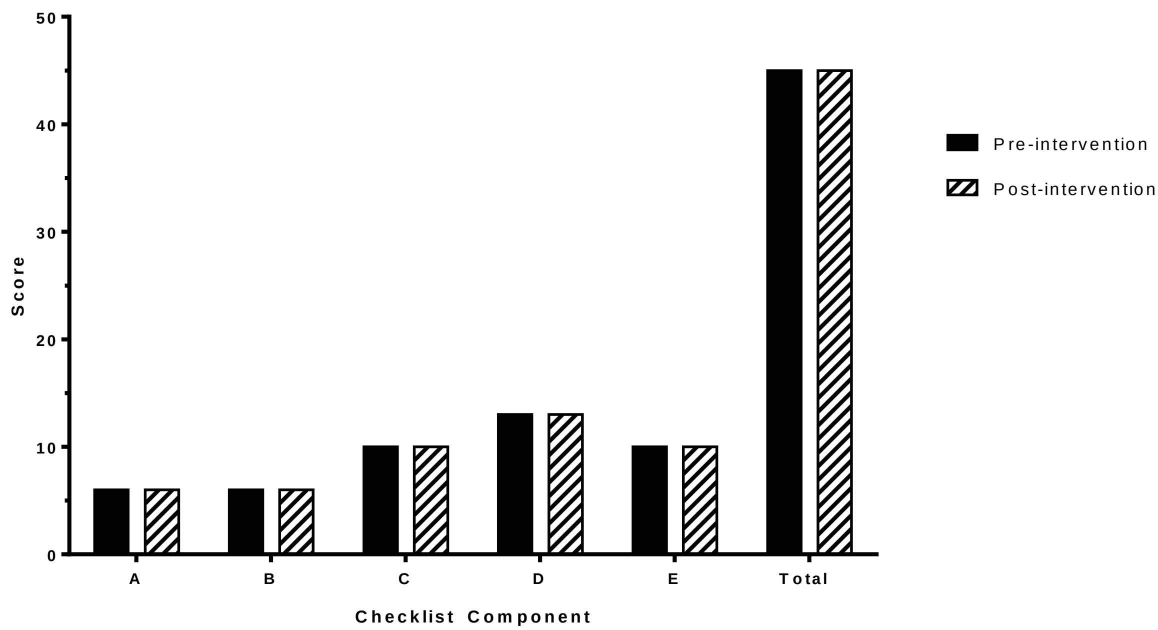
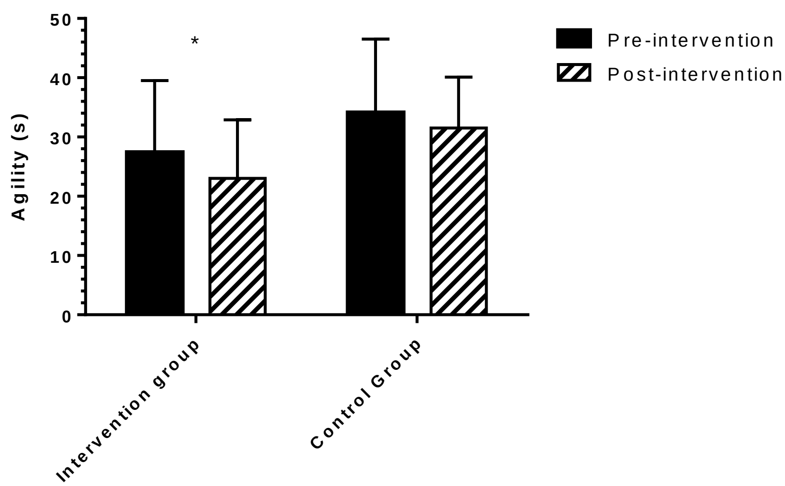


Figure 4.18: CASE A: MABC-2 checklist pre and post intervention scores

A= Child stationary/environment stable; B= Child moving/environment stable; C= Child stationary/environment changing; D= Child moving/environment changing; E= Behavioral problems related to motor difficulties.

iii. Agility

The comparison of mean pre vs post intervention agility times for the control and intervention groups are shown below in Table 4.19. There was a significant decrease in the agility times from pre to post intervention in the intervention group (p=0.0061). The intervention group obtained a mean time of 27.4 ± 12.1s in the agility T test pre intervention and a mean time of 23.0 ± 9.9s post intervention. There was no significant difference between the control group pre and post intervention (p=0.1094), where the agility test times decreased slightly from pre (34.1 ±12.44 s) to post (31.5 ±8.6 s) intervention.



*Agility: Intervention Group (pre vs post): p = 0.0061

Figure 4.19: Comparison of mean pre vs. post intervention Agility T test scores by group.

4) Objective 4

To assess gait pre-and post-exercise intervention in adolescents with autism aged 11 to 16 years with ASD.

Gait was assessed as part of the researcher's additional test battery by conducting a gait analysis using video cameras for each participant, and interpretation was done using Dartfish analysis software.

i. Gait

Table 4.20 shows the comparison of the mean gait parameter values pre and post intervention, by group. There were no significant differences seen following the intervention for all gait parameters. Stride length for the dominant leg remained similar in the intervention group from pre to post intervention (1.8 ±1.7m and 1.8 ±1.7m respectively), while in the control group stride length decreased slightly from 1.9 ± 0.4m to 1.6 ±0.5m. For the non-dominant leg, stride length increased from 1.7 ± 0.35m to 1.9 ±0.5m in the intervention group, and decreased in the control group from 2.0 ±0.5m to 1.6 ±0.4m. In the intervention group, step length increased from 0.9 ± 0.1m to 1.0 ± 0.3m for the dominant leg and increased from 0.8 ± 0.1m to 1.0 ± 0.4m for the non-dominant leg following the intervention. In the control group, step length decreased in both the dominant (from 1.0 ± 0.2m to 0.8 ± 0.2m) and non-dominant (from1.0 ± 0.2 to 0.8 ±0.3m) legs from pre to post intervention. Lastly, step width remained unchanged following the intervention in both groups, who were found to have a step width of 0.2 ± 0.0m.

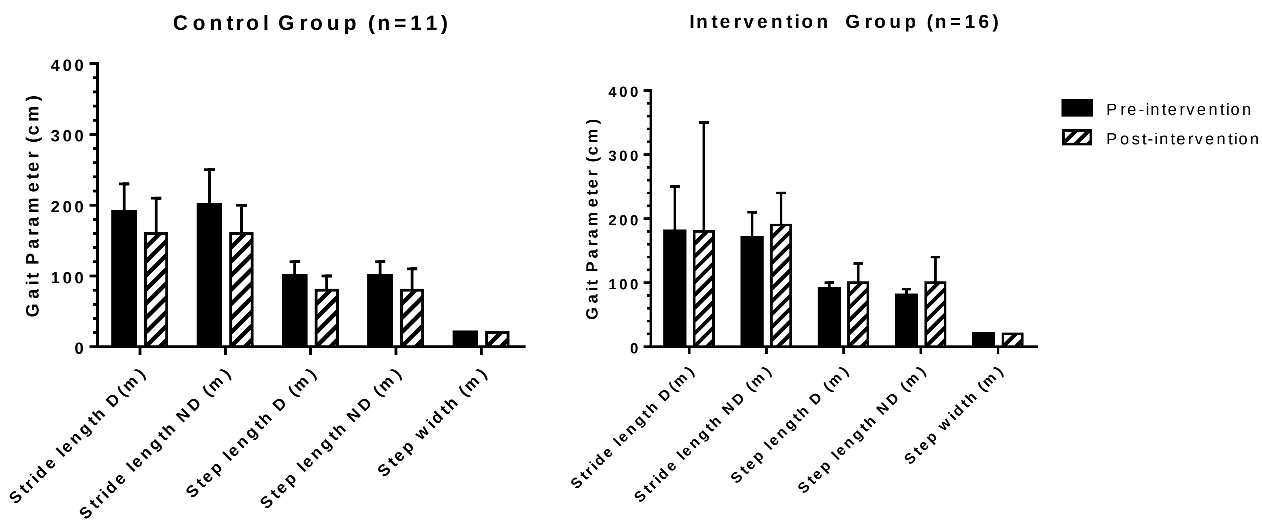


Figure 4.20: Comparison of mean pre vs. post gait parameters by group.

5) Medications

Although the change in the amount of medications taken by the participants was not an objective for the study, this variable was documented pre and post intervention as this may have influenced the outcomes of this study. The results for the comparison of the pre and post medication levels taken, by group, are shown in Table 4.14 below. There was no statistically significant change that occurred in the number of medications taken by the individuals following the study. It can be seen however that more individuals in the intervention group took less CNS stimulators (31.25% as opposed to 18.8%) and anticonvulsants (6.3% as opposed to 0%) following the intervention, while more participants in the control group took less antipsychotics (26.7% compared to 20%) and antidepressants (20% compared to 13.3%). Further research should be done to investigate these findings.

Table 4.14: Comparison of pre vs. post medication levels taken, by group.

Type of medication	Medication status	Number of medications					
		Control Group (n=11)			Intervention group (n=16)		
		Pre	Post	P value	Pre	Post	P value
CNS stimulators	Not taking	7(46.7%)	7(46.7%)	1.000	11(68.75%)	13(81.3%)	0.1573
	Taking	8(53.33%)	8(53.33%)		5(31.25%)	3(18.8%)	
Antipsychotics	Not taking	11(73.3%)	12(80%)	0.3173	9(56.3%)	9(56.3%)	1.000
	Taking	4(26.7%)	3(20%)		7(43.8%)	7(43.8%)	
Antidepressants	Not taking	12(80%)	13(86.7%)	0.5637	12(75%)	12(75%)	1.000
	Taking	3(20%)	2(13.3%)		4(25%)	4(25%)	
Anticonvulsants	Not taking	13(86.7%)	13(86.7%)	1.000	15(93.8%)	16(100%)	0.3173
	Taking	2(13.4%)	2(13.4%)		1(6.3%)	0(0%)	

CNS= central nervous system

CHAPTER 5: DISCUSSION

5.1 Introduction

The primary purpose of this study was to determine the efficacy of a 12-week exercise intervention in adolescents with ASD aged 11-16 years. For this study efficacy was defined as a significant improvement in one or more of the variables measured, which included posture, physical fitness, body composition, flexibility, gait, agility, balance and coordination. The discussion that follows will address the efficacy of the intervention and will be presented in three main sections: in section A, the baseline data and demographic information will be discussed; in section B, data concerning the appropriateness of the randomisation will be discussed; and lastly in section C the results per the objectives for the study will be discussed. Compliance rates for the intervention will be discussed under objective one.

5.2 Discussion

A. Baseline Data

i. Demographic Information

Although there remains debate on whether to age-match individuals with ASD in intervention studies,[85] in this study, the mean chronologic age for the total group was more than double the mental age (13.0 ± 1.8 years vs 5.6 ± 1.8 years), which highlights how imperative it is to consider both variables when working within this population. Compared to other literature this is the largest study, which has looked at this particular age group of individuals with ASD in an exercise intervention context, making this study's findings valuable. A study by Magnusson et al. (2012), assessed a similar age group of individuals with ASD (9-15 years), however they had a much smaller sample size with only 6 participants,[279] and their study predominately focused on the effects of high intensity interval training. Nevertheless, the study demonstrated that exercise in the form of high intensity training is beneficial in this population.

ii. Posture

This study found that the mean posture scores at baseline, were good for all areas besides the ankle and abdominal areas, according to the New York Posture Rating chart. Generally, most of the individuals had abdominal obesity, which likely contributed to the low scores noted in the abdominal area; and poor ankle posture may have been attributed to the generally low muscle tone and poor flexibility of the lower limbs seen in the majority of participants. It is recommended that further research be undertaken to confirm these possible links.

Good posture is important not only in protecting individuals from injury, but also in improving the efficiency of performance to maximal capacity.[(280)] In addition, a postural control system which is immature may restrict typical development of other motor skills, may become a barrier for the development of optimal mobility and manipulation skills and may disrupt quality of life.[(177)] It is therefore important to be able to assess posture and improve postural deficits where necessary in individuals. Many studies have determined that individuals with ASD have increased postural sway and decreased postural stability[(281)] as well as "impaired or immature control of posture",[(177)] however, no formal data currently exists regarding posture profiles in the population, and in particular, the effect exercise may have on their posture profiles. This study therefore provides novel insight regarding posture profiles in individuals with ASD.

It is difficult to compare the results of this study to existing literature due to the scarcity of literature in the ASD population. There have been a few studies however, which have documented posture in these individuals. A study by Rinehart et al. (2006), refers to specific sites of poor posture seen in ASD individuals.[(180)] In the study, they observed gait and posture in 10 high functioning autism participants, 10 Asperger's participants and 10 control participants. Seven experienced physiotherapists observed gait and posture and scored these variables on a visual analogue scale constructed for the study and a mean score from the seven observers was recorded. It was found that both clinical groups showed abnormal arm postures, yet only the Asperger's' group differed significantly in head and trunk posture compared to the control group.

A further study by Parsons (2006), reported that a child with autism was made aware of their "bad posture" through watching video footage of themselves,[(282)] however no information was given regarding what was seen per body area with regards to their "bad posture", making comparisons problematic.

iii. Brockport Physical Fitness Test

a. Aerobic function

The mean resting systolic and diastolic blood pressures for the total group was considered to be normal (≤120/80mmHg), however 37% of the participants had a high systolic blood pressure (>120mmHg), while 7.4% had a high diastolic blood pressure (>90mmHg), which are cause for concern in this young population. Individuals with raised blood pressure are at a higher risk for developing kidney disease, heart failure and stroke.[(283)] It has been reported however that individuals with disabilities and cognitive impairments, including individuals with ASD, don't have regular blood pressure assessments and often don't receive the much needed hypertensive treatments they may require.[(284)] An extensive literature review conducted for this study confirms this, and revealed that there is minimal information regarding blood pressure and heart rate profiles within this population.

Lin et al. (2012), assessed blood pressure profiles of 833 adults with a mild to moderate level of disability, including individuals with ASD.[(285)] Similarly, to the present study it was found that the group had normal ranges, with a mean systolic blood pressure of 127.4 ± 20.3mmHg and a mean diastolic blood pressure of 76.5 ± 12.7mmHg. Yet 23.4% of the participants had high systolic blood pressure compared to the 37% found in this study, and 14.9% of participants presented with high diastolic blood pressure which was near double what was found in this study.[(285)] The differences could be explained by the fact that Lin et al's group of participants comprised not only individuals with ASD, but included people with other disabilities. Nevertheless, it seems that this population is indeed at risk for developing high blood pressure, and thus regular health screenings should be performed.

Furthermore, it has been documented that children and adolescents with ASD tend to have a higher mean blood flow, elevated heart rate (HR) and decreased peripheral vascular resistance compared to their typically developing counterparts.[(286)] Although mean blood flow and peripheral resistance weren't measured in this study it was indeed found that individuals with ASD had an elevated resting HR.[(287)] Similarly, Minga et al. (2005), reported that individuals with ASD (who presented with or without autonomic dysfunction symptoms) had a higher mean HR compared to typically developing children. In that study, it was found that children with autism who presented with and without symptoms (n=30) had a mean heart rate of 102.5 ± 16.0bpm whilst children who were typically developing had a lower mean heart rate of 84.9 ± 10.2bpm (n=17).

The assessment of blood pressure and HR after aerobic exercise, showed that the systolic blood pressure increased substantially, while diastolic blood pressure remained similar after the test which are typical responses to exercise.[288] In typically developing individuals, during exercise, the heart's workload increases to allow more blood to be pumped with each contraction so that muscles may be supplied with oxygen, this therefore increases systolic blood pressure. In contrast diastolic blood pressure remains similar or decreases slightly due to the dilation of blood vessels in the working muscles. Similarly, it was found that the resting HR increased post-exercise in the participants, which is also a normal response to exercise.[288] Typically HR increases to compensate for a greater need of blood and oxygen delivery to muscles. No similar aerobic tests have been performed in individuals with ASD therefore the findings of this study can only be compared to the normal physiological response of the exercising individual and not typical responses in individuals with ASD.

b. Body composition and anthropometry

Individuals with ASD were found to be overweight, with the total group having a relatively high BMI and an extremely high body fat percentage. These results compare to other studies showing that children with autism were found to be obese.[193, 289] In contrast, a study with a sample of 13 individuals with Asperger's, were reported to have a low BMI. [290] However, there does seem to be a consensus that this population is at a higher risk for being overweight and obese, compared to their typically developing counterparts. Obesity, and being overweight is a global problem, and it has been reported that in developed countries, obesity and being overweight is prevalent in approximately 31.8% of typically developed children and adolescents.[291] Similarly individuals with ASD are more often reported to be overweight or obese,[191], with the overall prevalence of being overweight in the population being reported to be 19%.[191] For this reason, it should be a priority for healthcare workers to try and reduce this risk, whether it be through nutritional strategies or other effective interventions - perhaps exercise interventions, so that potential associated comorbidities with obesity are prevented.

c. Musculoskeletal function
    i. Strength and endurance
        1. Grip strength

It was found in this study that 26 participants had equal grip strength in both their dominant and dominant hands (13.4 ± 9.6kg); and although the handgrip strength of these individuals was not compared to their typically developing peers, information regarding their baseline grip strength provides information regarding the extent to which muscle weakness may occur in this population. Few studies exist which have determined handgrip strength in individuals with ASD compared to their typically developing peers. In one such study by Kern et al. (2013), who assessed 33 children, aged 2 to 17 years with ASD, and 33 gender-, race-, and age-matched neurotypical controls with a handgrip dynamometer,[292] it was found that the participants with ASD had a mean hand grip strength of 39.4 ± 17.7kPa, which was significantly lower ($p < 0.0001$) than the typically developing controls who had a mean handgrip strength of 65.1 ± 26.7kPa. It was therefore suggested in the study that children with ASD have muscle weakness to a certain extent, and that future studies were needed to determine the extent of this weakness and how this could inhibit the lives of individuals with ASD. Unfortunately, the mean handgrip strengths found in the individuals with ASD in that study can't be compared to the present study as strength was measured in two different units (kPa vs kgs). Thus further studies should strive to be more consistent in their measurement and units of handgrip strength in the future.

Nevertheless, a study to which the present results may be compared to is one by Hardan et al.(2003), where the grip strength of 40 individuals with ASD was compared to 41 typically developing controls. It was found in that study that participants with ASD had significantly weaker handgrip strength compared to the control group.[293] The mean strength for the dominant and non-dominant hands in the participants with ASD was found to be 24.1 ± 13.2kg and 22.4 ± 13.0kg respectively. These measures were considerably higher than what was found in the present study.

In summary, it may be concluded that individuals with ASD have generally lower grip strength compared to typically developing controls. Importantly, it has been reported that reduced grip strength and hence, reduced muscle tone and muscle weakness may limit the performance of daily activities in individuals with ASD,[154] thus it is important that these deficits be managed and where possible strength increased so that these limitations are kept to a minimum.

2. Modified curl up

Participants were able to perform 11.6 ± 5.7 modified curl ups in one minute at baseline. There are no current normative data to compare these values to, however general population normative data dictate that individuals should be able to perform 25 curl ups in a minute. It can therefore be seen that the individuals with ASD are able to perform much fewer curl-ups compared to the general population. In a study by Ferguson (2010), 3 individuals with ASD were tested before and after a 20-week, tri-weekly adapted physical activity intervention was administered. It was found that the three participants were able to perform 0,1 and 4 curl-ups at baseline respectively,[(15)] which is again far less than what the general population should be able to achieve.

In order to effectively perform a modified curl up, good abdominal strength (core strength) as well as trunk and abdominal coordination is required. Therefore, individuals with these attributes are generally able to perform more modified curl-ups than those who don't. The reason therefore that individuals with ASD may be unable to perform as many curl ups compared to typically developing individuals may be due to the lack in proficiency in the above attributes. It has been well documented that these individuals have poor coordination - which extends to abdominal and trunk coordination, and thus this may reduce their ability to perform curl-ups. In addition, it has been reported in a study by Ehleringer (2010), that many individuals with ASD have low muscle tone and minimal core strength,[(294)] which again could inhibit the ability to perform many curl-ups.

Furthermore, it was noted in this sample that many of the participants had abdominal obesity. In a study by Brunet et al. (2007), the BMI and waist circumference as well as the performance of various physical tests (1- minute sit-up test, standing long jump and speed shuttle run) was measured in 1140 children.[(295)] It was found in that study, that there was a significant negative correlation between BMI and waist circumference, and the performance in all physical fitness tests in the children ($-0.16 \leqslant r \leqslant -0.45$, at least $P < 0.05$). This suggests that children with a greater waist circumference i.e abdominal obesity, struggle to perform various physical tests including sit-ups. Further research will need to confirm whether this is also the case in individuals with ASD, however, anecdotally, the researcher can confirm that through observing the participants in the present study, the participants with a higher abdominal obesity did indeed struggle more in performing the curl up test compared to those who did not have abdominal obesity.

ii. Flexibility

Firstly, as all the participants were able to perform the sit and reach test, yet some struggled with the modified Thomas test it may be said that the sit and reach test may be more appropriate for use in the ASD population to measure flexibility. Furthermore, although the modified Thomas test measures different flexibility parameters perhaps a better test could be developed for use in this population. At present there are no studies (as far as the researcher is aware) which has used the modified Thomas test in the ASD population and it is suggested that if future studies select it for testing, the test should be modified further, otherwise a different test should be considered. The reason for this is that some of the participants found the test extremely difficult to perform, and most stated that the test was uncomfortable for them.

Nevertheless, at baseline, the sample in this study was found to have a mean hip flexion measure of 7.4 ± 6.9^{o} for the dominant limb, which was greater than the non-dominant limb (5.1 ± 3.7^{o}). In terms of knee flexion, the sample had a mean value of 18.6 ± 13.0^{o} for the dominant limb, and a mean value of 17.9 ± 14.3^{o} for the non-dominant limb. No norms or data currently exist in this population that these findings may be compared to.

In a study by Pan (2014), a comparison of motor results of 31 individuals with ASD, compared to 31 typically developing individuals was conducted.[(296)] In the study, it was found that the mean sit and reach test results for the dominant limb for the ASD and the control participants was 21.65 ± 11.47cm and 29.89 ± 8.66cm respectively. It can therefore be seen that individuals with ASD had reduced flexibility in their dominant limb. The same was found in the non-dominant limb where the individuals with ASD could reach to 21.13 ± 10.92cm while the control could reach to a mean 29.65 ± 8.66cm. [(296)]

In comparison, it was found that the individuals in this study had similar flexibility measures (dominant leg = 23.9 ± 8.1cm, non-dominant = 24.0 ± 8.3 cm), and that there was greater flexibility in both instances for the non-dominant limb compared to the dominant limb. Since the sit and reach test predominantly, measures hamstring flexibility, the reason behind the individuals having reduced flexibility in their dominant limb could be purely due to, increased muscle bulk, and hence decreased flexibility of the limb purely due to favoring that limb (dominance).

iv. Movement assessment battery for children-2

a. Manual dexterity

In the present study, it was found that all the participants were able to perform the turning pegs and manual dexterity task in a quicker time with their dominant hand (31.1 ± 9.8s) compared to their non-dominant hand (33.1 ± 8.1s).This was to be expected, since in general individuals are more proficient in tasks performed with their dominant limbs.

It has been suggested by Whyatt et al. (2012), that when assessing and making inferences about the manual dexterity capabilities and general motor impairments in individuals with ASD, it may be necessary to not only consider their status of function (low, moderate or high), but also their cognitive and speaking ability as this may influence, to some extent, their performance in these tasks.[(297)] Thus, it was noted in the present study that the majority of the individuals did not have speech difficulties/impediments yet did have cognitive impairments, which could have therefore influenced the results. Nonetheless, compared to the study by Whyatt et al. (2012), in which 18 participants with ASD obtained an overall standard score of 7.7 ± 2.0 for the turning pegs task, [(297)] the participants in the present study, obtained a slightly lower standard score of 1, indicating poorer manual dexterity proficiency for the task, which could be attributed to a possible lower cognitive function of the participants.

For the second task, (triangle with nuts and bolts) in which the participants were required to put together a triangle as quickly as possible, it was found that the group where able to complete the task in 82.1 ± 48.5s in trial one and 72.7 ± 31.7s in trial 2. These times relate to an overall standard score of 1 for both tasks, which is far less than the score obtained (7.5±2.2) in the study by Whyatt et al. (2012).[(297)]

Lastly, in the present study the group made 72.7 ± 31.7 errors in the drawing trail task at baseline, and since typically developing individuals make close to 0 errors for the same task, this number of errors is extremely high, indicating a severe impairment in this component of manual dexterity, which was also noted in the study by Whyatt et al. (2012).[(297)]

The consistent manual dexterity deficits seen a cross the board in individuals with ASD in this study and others, suggest that manual dexterity needs to certainly be addressed in the population to improve daily function. [(297)]

b. Aiming and catching

The participants in this study were able to catch more balls with their dominant hand (6.9 ± 3.2), as compared to their non-dominant hand (6.7 ± 2.8), which was to be expected, since (as mentioned previously) it is well documented that individuals perform tasks better with their dominant limbs. The group was also able to throw a mean 5.2 ± 1.5 balls correctly at a wall target. It has been suggested in other studies that individuals with ASD have poor coordination and in particular have poor hand-eye coordination which is often as a result of their poor proprioceptive capabilities. They have thus, sometimes been compared to individuals with developmental coordination disorder since often, there is a lack of research to compare individuals with ASD to.

In a study by Utley et al. (2006), 8 children (mean age: 7.4 ± 3.0 years) with developmental coordination disorder where observed performing the catching task of the MABC-2 and compared to age-matched controls.[(298)] The individuals with developmental coordination disorder were able to catch 3.3 ± 1.3 balls , in the first trial, 4.8 ± 2.4 balls in their second trial and 4.4 ±1.8 balls in their third trial out of a possible 10 catches. The age-matched controls on the other hand performed much better with the participants catching 6.8 ± 1.4 , 8.3 ± 1.3 and 9.0 ± 1.2 balls per trial respectively.[(298)] The individuals were however asked to catch the ball with 2 hands. Nevertheless, it was seen in the present study that the individuals with ASD performed far better than the individuals with developmental coordination disorder, yet performed similarly in the first trial, but much worse in the last two trials compared to the typically developing individuals.

Although the present study did not compare individuals with ASD to typically developing individuals, when the baseline results were compared to the study by Utley et al. (2006), it was confirmed that individuals with ASD have problems with catching activities, and the reason for this has been thought to be due to the individuals having impaired learning, and poor application of motor skills.[(298)] The same may be said for throwing activities in individuals with ASD. It has been reported that individuals with ASD often have problems in controlling the direction and force of the ball when throwing which often hinders their performance in throwing tasks.[(299)]

In a study by Whyatt et al. (2012) The MABC-2 was used to assess the motor skills of 18 individuals with ASD compared to controls. In the study it was found that the individuals with ASD achieved a standard test score of 6.0 ± 1.8 compared to receptive vocabulary controls (n=6) who scored 10 ± 3.6, and nonverbal IQ controls who scored 9.6 ± 1.8 (n=11). This confirms that individuals with ASD do indeed have problems with catching objects. Similarly, for the throwing task in the same study, it was found that individuals with ASD obtained a lower score of 5.6 ± 2.0 compared to 7.0 ± 3.2 and 7.0 ± 3.5 for the receptive vocabulary and nonverbal IQ control groups respectively, again highlighting their motor impairments in these specific tasks.

Overall, it would seem that individuals with ASD struggle to effectively throw and catch items and this may hinder their activities of daily life and possibly prevent them from engaging in social physical activities where these skills are required. These deficits therefore need to be addressed in the population to try encourage social play and better the performance of everyday activities, which in turn could aid in improving the quality of life of the individuals.

c. Balance

1. Static balance

In this study the participants were able to perform the two-board balance task for their first trial in a mean time of 9.0 ± 8.1s and for their second trial, in a time of 12.8 ± 11.3s. Although, no norms specifically exist for the ASD population regarding the performance of this test, there has been a study, which compared individuals with ASD to typically developing individuals using the MABC-2 test battery. In the above mention study by Whyatt et al. (2012),[297] it was found that the individuals with ASD had comparable levels of balance control compared to the two control groups using the standard score of the MABC-2 test for the balance parameters, however it was also found that when the balance parameters were compared on a sub-test level the individuals with ASD had a significant impairment in the static balance task.[319] Since typically developing individuals are deemed to be able to hold their balance for a minimum of 30s for this static task it may be said that the individuals in the present study also had reduced balance control in the static balance test, similar to what was seen in the study by Whyatt et al. (2012). It has been suggested that poor balance control, as well as other motor deficits such as a reduction in manual dexterity and ball skills in the population may be due to primary "deficits in perception–action coupling, vital for the production of coherent, controlled movement". [297]

It should be noted that, the way in which researchers are required to score the MABC-2, is to generate a sub category score (standard score) per parameter whether it be balance, aiming and catching or manual dexterity. This standard score is made up of between 2 or 3 sub tests, hence if an individual performs extremely well in one task, and poorly in another, the good performance may mask a deficit in performance in standard score when tests are combined or vice versa, which is what was described in the study by Whyatt et al. (2012).[297] In the study it was found that dynamic balance control was relatively similar to the control group, yet static balance was significantly poorer, while the standard score revealed that the individuals had comparable balance control. The study therefore suggested that it is very important to consider the results per sub category when analyzing data. For this reason, in the present study, individual test scores are documented as opposed to standard scores.

In a different study by Yilmaz et al. (2004), an individual with ASD participated in a swimming education programme over 10 weeks, three times weekly for 60 min per each session. Static balance was tested eyes open, and eyes closed for both the dominant and non-dominant leg, and it was found that the participants at baseline could maintain their balance with their eyes open for 12.9s on the right leg and 8.9s on the left leg, which was slightly longer than what was observed in the present study in trial one, yet fairly similar to trial 2. Although the test used in the study (stork test) is different from the two-board balance test used in the MABC-2 both tests observed static balance control. In both instances, it can be seen that static balance seems to be impaired compared to typically developing individuals which is consistent with other research done in this field.

2. Dynamic balance

In this study, the participants were able to perform a mean 5.5 ± 0.8 correct zig-zag hops for their dominant leg and a mean 5.7 ± 1.1 correct zigzag hops for their non-dominant leg. No evident reason exists to why the group performed better on their non-dominant limb. Nevertheless, the majority of the participants struggled extensively with this task, most of whom found it difficult to keep in the jumping squares and maintain balance on one leg while jumping without putting their other foot down. This finding is similar to what was found in a study by Noterdaeme et al. (2002), who reported that individuals with ASD struggled to perform dynamic hops and in particular were less able to perform dynamic hops compared to individuals who were typically developing.[300]

Furthermore, in the present study it was found that the participants were able to perform a mean 12.9 ± 4.2 correct steps in the backwards tandem-walking task, again with some individuals struggling to perform the task. Since dynamic balance requires good neuromuscular coordination, it may be postulated that the general difficulties experienced in individuals with

ASD in preforming dynamic balance tasks may be due to an impairment or lack of neuromuscular coordination, further research is needed to further investigate this link.

It does however seem that although individuals with ASD struggle to perform dynamic balance tasks, such as the zig-zag hopping task or backward tandem walking task, static balance remains a far greater challenge for them, and should therefore be targeted through interventions to improve balance control within the individuals.

v. Agility and gait

a. Agility

At baseline, it was found that the participants in this study had a mean agility T test time of 30.0 ± 12s. Little information exists regarding agility levels in this population and thus baseline comparison of this sample to other samples of individuals with ASD is difficult. There has however been one study which looked at agility in individuals with ASD compared to their typically developed siblings. In the study by Hilton et al. (2011), the "motor impairment of sibling pairs from 67 ASD-affected families comprising 29 concordant pairings and 48 discordant pairings were assessed using the Bruininks Oseretsky Test of Motor Proficiency, 2nd Edition, a standardized measure of motor proficiency".(301) In the study it was found that overall, motor skills were considerably impaired in the participants with ASD and the motor impairments were highly correlated with the severity of autism as well as IQ, while in the typically developing participants, motor skills were found to be normal. In particular, the study found that (for the strength and agility component of the test) the participants with ASD had a much lower mean score (37.8± 14.0) compared to their typically developed siblings (54.6 ±8.1).

Additionally, if one were to compare the results of the present study to typically developing adolescents, it would predominantly be seen that the individuals with ASD perform the agility test slower compared to their peers. For example in a South African study by Nieuwenhuis et al. (2002), it was found that 25 female adolescent hockey players had a mean agility test time of 25.89 ±3.37s which is far quicker than what was found in the present study.(302) Similarly in another study which observed 113 amateur football players (mean age 21.2 ± 3 years), it was found that the participants were able to perform the same agility test in 16.28± 0.57s, again much faster than the sample in the present study.(303) The reduced agility scores in individuals with ASD compared to typically developing individuals may be due to their coordination difficulties and poor muscle tone,(294) which could inhibit quick and agile movement. This may interfere with their activities of daily life and thus this deficit should be targeted through effective intervention.

b. Gait

Participants had an overall stride length of 1.7 ± 0.4m and 1.7 ± 0.5m for their dominant and non-dominant legs respectively. This finding was much higher than what was found by Rinehart et al.(2006) who compared the gait of 11 individuals with ASD to 11 age, sex and IQ-matched controls, and found that the individuals with ASD had a mean stride length of 1.0 ± 0.14m for their dominant leg.(183) Unfortunately, no information regarding the non-dominant limb was provided in that study. A reason for the vast difference seen between the stride lengths in the studies may be due to the slight difference in ages, where the present study's sample had a mean chronologic age of 5.6 ± 1.8 years, while in the other study the mean chronologic age was 5.1 ± 0.9 years. A More likely reason for the differences seen between the studies was due to a difference in the level of impairment between the participants, where those who were lower functioning had exaggerated stride length deficits.

The present study participants were found to have a step width of 0.2 ± 0.0m which is contrast to findings by Rinehart et al.(2006) where the participants had a smaller step width of 0.1 ± 0.18m,(183) again this could be due to the differences in level of function between the samples.

Lastly, in the present study, the sample was found to have a mean step length of 0.9 ± 0.2m for their dominant leg, and a mean step length of 0.9 ± 0.2m for their non-dominant leg. Vernazza Martin et al. (2005), assessed step length in 9 individuals with ASD, compared to 6 typically developing children. It was found that the participants with ASD had a significantly reduced ($p<0.001$) mean step length of 0.67 ± 0.14m compared to 0.73 ± 0.09m found in the typically developing participants. This finding indicates that individuals with ASD may have smaller step lengths compared to their typically developing peers. It has often been described that these individuals have parkinsonian-like gait,(304) whereby they have reduced stride length, and a general slowness of movement often thought to be due to coordination difficulties as well as low muscle tone.

It has been reported that many gait variations have been found in the ASD population(181) and due to the lack of comprehensive gait studies being done there is no consensus as to whether ASD individuals typically present with increased or decreased gait parameters. Making a diagnosis of autism purely based on gait discrepancies should therefore be avoided.

B. Randomisation appropriateness

i. Demographic data

It should be noted that due to ASD being a spectrum disorder, individuals with the condition vary greatly in terms of their motor abilities and general function. Therefore, the intervention and control groups could not be balanced for all outcome variables. The groups differed significantly at baseline in their chronologic age (p=0.0223) which was to be expected as the sample was balanced according to mental age and not chronologic age. The groups also differed significantly in their resting heart rates (p=0.0398) and in their two board balance tests in trial 2 (p=0.0243). For these variables further comparisons between pre and post intervention findings were interpreted with caution. For all other variables the control and intervention groups were not significantly different at baseline, hence randomisation was performed optimally in terms of generating balanced groups for the majority of the variables.

ii. Medications

Medications taken by the participants were documented throughout the study as they may have influenced the outcome measures. Randomisation was done appropriately, as no significant differences were found at baseline between groups. In general, the amount of prescription medication taken in ASD populations is known to be extremely high,[305] as was the case in this study. The majority of the participants (71%) were taking prescription medication, while some were taking multiple medications, which was of great concern. Although medication is often used as an adjunct therapy in the ASD population, the amount of medication taken in this sample seemed to be high compared to others, as it has been reported that approximately 50% to 66% are on at least one type of prescription medication, while approximately 45% of individuals with ASD are prescribed psychotropic medications.[306]

Studies have shown that antidepressants, stimulants and antipsychotics are the most commonly prescribed psychotropic medications for individuals with ASD,[307, 308] as was the case in this study group. The four main types of medications taken in the group included CNS stimulators, antipsychotics, antidepressants and anticonvulsants. Anticonvulsant medications were taken by 12.5% of the participants at baseline, which is higher than has been reported in a study by Witwer and Lecavalier, (2005), which stated that anticonvulsant medication is only prevalent in approximately 5% of children with ASD.[309] In that study, it was however found that the older the participants were, the more anticonvulsant medication they were taking [x^2 (3, n = 344) = 10.65; p = 0.014].[309] , and thus the possible reason for the increased use of anticonvulsants in the present study might be due to the participants being of a higher age. The study by Witwer and Lecavalier, (2005), however reported the chronological ages and associated level of mental retardation and not the mental ages of the participants, thus a comparison cannot be made to see whether the participants in the present study were in fact older.

C. Discussion per objective

1) Objective 1

An exercise intervention was successfully developed, validated and rolled out at Unica School for Autism over the course of 12 weeks.

i. Exercise selection

A variety of different exercises were selected for the exercise intervention based on the recommendations made by Srinivasan et al. (2014) mentioned in Chapter 2.[32] The reason for selecting specific exercises and their contribution towards the various physical fitness variables are discussed below. In-depth notes on every session may be found in Appendix P (exercise intervention journal).

a. Aerobic function: an aerobic warm-up and cool down was selected for the study, which included exercises such as jumping jacks, jogging and dancing. These exercises were selected, as they were thought to be fun and easy to execute as well as taxing on the cardiovascular system. Furthermore, these exercises had been selected for use in other studies for the ASD population before and were used without incident.[15, 23] A jumping Jack dance was originally going to be taught to the adolescents, with them adding some moves to the dance, however the dance was eventually removed from the intervention due to lack of enjoyment and participation, instead a jumping jack lap of 40m was added into the programme.

b. Strength: upper body exercises included bicep and triceps curls, tug of war and seated rows. Of these exercises, it was found during the intervention that the tug of war exercise was not conducive for use in the individuals with ASD as the participants became aggressive, and the exercise became too chaotic to manage, this exercise was subsequently removed from the intervention and arm punches and lateral arm raises were included instead. Core exercises included bridges and crunches, and these exercises were specifically selected as they could be done on the floor so that the whole exercise programme was not in a position of standing. This also allowed the researcher to observe how the individuals could transition from a standing position into a lying down position so that further coordination information could be documented. One participant struggled tremendously with the bridge and crunch exercise and for this individual the exercises were adapted. In the opinion of the researcher these exercise worked well in individuals with ASD and did not need to be changed. Lower body exercises included sit to stands (selected to improve quadriceps, hip flexor and core strength), step up and downs (selected to improve quadriceps strength, balance and coordination) and jumping squats (selected to improve lower limb strength ballistically) which the participants called "frogs". The participants thoroughly enjoyed all these exercises and it seemed that there was a vast improvement in the performance of these exercises from pre- to post-intervention. The researcher would highly recommend these exercises for future use in ASD populations.

c. Endurance: the extended arm hang exercise as well as the standing march exercise were selected for endurance for this population as it was thought that these exercises would tire out the upper and lower body muscles in a short period of time which was needed in the relatively short sessions with the participants. Unfortunately, the participants were not able to perform the extended arm hang exercise due to a lack of available equipment, the arm circle exercise was subsequently added in place of this exercise. Standing marches were performed in every session. Both of these exercises were found to be appropriate for individuals with ASD.

d. Manual dexterity: to improve manual dexterity, a pasta task was developed for the participants. This task involved threading macaroni onto a spaghetti – it was developed to improve fine motor coordination without the risk of the participants swallowing small beads/parts often used in manual dexterity tasks. This activity was thoroughly enjoyed and is highly recommended for future exercise programmes.

e. Ball skills: the exercise selected to improve ball skills and coordination included passing a ball in a variety of different positions, throwing and catching a ball to one another as well as kicking a ball to one another. The participants struggled tremendously in the ball passing tasks and managed extremely well in the catching, throwing and kicking tasks. Although the participants struggled with the passing ball tasks, the exercise was left in to challenge the participants. A drawing task was initially going to be included in the intervention, however due to time constraints this exercise was omitted from the intervention.

f. Balance: tandem walking, one leg standing and walking on a balance beam were the predominant balance exercises chosen for the intervention. They were selected, as they required minimal equipment, and were relatively easy to execute. Furthermore, these had also been used in previous studies in individuals with ASD, and deemed appropriate in improving balance within the population. It was found that the participants preferred the static balance tasks (standing on one leg) compared to the dynamic balance task as some participants had a fear of falling. This would need to be considered in future exercise studies.

g. Agility: agility was targeted through a variety of agility drills. The agility drills included participants running around tires set up in a straight line, running and jumping over tires, running around other participant's setup in a pattern, and combination agility drills where agility tasks would lead onto or follow after some of the other exercises selected for this intervention. The majority of the participants thoroughly enjoyed this component of the exercise programme. It was however noted that two of the low functioning participants struggled tremendously with some of the agility tasks. It is suggested that future exercise studies may need agility tasks categorised by level of difficulty or modified agility drills per the level of function in individuals with ASD so that these drills may be effectively performed by all individuals with ASD. Nevertheless the drills selected for the intervention were deemed appropriate for the majority of the participants.

h. Gait: the exercises selected to improve gait were the actions of walking on toes and walking on heels- again these were chosen as they were easy to perform and required no equipment. The participants managed these exercises well and these exercises may therefore be seen to be appropriate for individuals with ASD.

i. Flexibilty and posture: quadriceps, hamstring, glute and upper body stretches were performed in every session throughout the exercise intervention. The most favoured stretch was the hamstring stretch where the participants needed to touch their toes, they also enjoyed the diamond stretch. The participants found it difficult to do the upper body stretches (such as the door pectoralis stretch and posterior shoulder capsule stretch) without help.

j. Posture: throughout the exercise intervention, the participants were made aware of their posture as well as the correct position their bodies needed to be in to perform the exercises. Often the researcher would demonstrate how a poor posture could influence the effective execution of the exercise, which in turn got the participants questioning the researcher about whether they were in the right position for their exercises.

ii. Compliance to intervention

Although many interventions and treatment options exist to help manage ASD, compliance to these therapies has reportedly been a problem.[310] Yet, there seems to be minimal documentation of this, as studies conducted in this field often fail to provide specific information regarding the compliance rates to therapy and interventions provided which a) makes comparisons between studies difficult and b) leaves one wondering as to how much therapy individuals did in fact receive throughout the course of treatment.

In this study, the overall percentage of compliance to the exercise intervention for the total sample was 88.8%. This was higher than a study conducted by Fragala-Pinkam et al. (2008), which saw a compliance rate of 80% towards an aquatic therapy programme in which 16 children with ASD participated twice a week for 14 weeks.[26] As mentioned above it is difficult to compare compliance rates of interventions to one another, for example, in a study conducted by Pitetti et al. (2007), 10 adolescents with autism participated in a 9 month treadmill programme, and a very clear in-depth methodology is provided in terms of the what the control and intervention group did over the course of the 9 months, however no information is given regarding how many sessions the individuals attended.[23]

Although the compliance rate in this study was relatively high, it was noted that compliance was much higher in the moderate to high functioning participants (97.2%) compared to those who were lower functioning (77.9%). This may be due to the higher functioning individuals being less sickly thus not missing sessions due to doctor visits, or having less impairments, therefore requiring less additional therapies, which may have interfered with the exercise classes. However further research would need to establish the reason for the difference in compliance between these groups.

Furthermore, it was documented that full (100%) participation was seen in 20 out of the 24 sessions for the moderate to high functioning group, while full participation was only seen in 5 sessions for the low functioning group. It was also noted that, full participation was seen in the first 8 consecutive sessions and then in the last 10 consecutive sessions for the high functioning group, with a decline in participation between the 8th and 15th week. There is no evident reason as to why this may have been, however it may have been due to some individuals attending additional therapy or new classes during those weeks. This however, was not the case for the lower functioning group, which seemed to have erratic participation levels throughout the intervention. Again, the erratic participation levels seen in the lower functioning group may be attributed to them having more/more severe general impairments compared to the higher functioning individuals causing them to need additional therapies and hence leading them to miss certain classes and in this case the exercise sessions. This will however need to be confirmed with further research.

2) Objective 2

In this study when comparing the control and intervention group posture scores, it was noted that no significant differences were found between the groups, and thus clear inferences could be made regarding the efficacy of the exercise intervention when comparing the groups' scores post intervention.

There was an improvement in the posture of all body areas post-intervention, with exception of the spine, in the intervention group compared to the control group. Significant improvements in scores were seen in the ankle area ($p=0.0183$) and in the overall posture score ($p=0.0004$). Conversely, the control group's posture scores did not change, confirming that the changes in the intervention group were as a result of the exercise programme. It has been shown that individuals who participate in regular exercise, with good technique, improve their coordination and muscle function, and in turn better their posture.[311] The significant increase in ankle posture improvement may be due to the focus placed on lower limb activities throughout the exercise intervention, as individuals performed many lower limb strengthening, flexibility and balance activities targeting the lower limbs.

As mentioned above no changes in spine posture occurred for both the intervention and control group. In a study conducted by Kuo et al. (2009), a similar result was found, where there was no improvement in both standing and sitting spine postures in 34 (typically developed) adults who participated in a Pilates-based exercise programme twice weekly for 10 weeks. It was however found in this study, that some of the participants had slight decreased thoracic flexion in standing, and slight increased lumber extension in sitting immediately after participation in the programme.[312] The lack of improvement in posture following exercise programmes in the spine, therefore needs to be further researched, particularly in the ASD population. In the meantime, future exercise interventions could target this specific body area through focused strengthening and flexibility exercises to possibly improve posture.

Although statistically significant changes were not seen for all the body areas in the participants, the fact that the overall posture score increased significantly in the intervention group, makes these findings clinically significant. It can therefore be said that a 12-week exercise intervention is effective in improving posture in adolescents with ASD, and further research could look at determining the extent to which posture may be improved through exercise within an ASD population.

i. Brockport Physical fitness test

Since one of the objectives for this study was to determine whether physical fitness was improved following an exercise intervention in adolescents with ASD, aerobic function, strength and endurance as well as flexibility variables were measured so that a holistic idea of the individual's fitness was obtained.

a. Aerobic function

This study found that the intervention group showed a significant decrease in resting systolic blood pressure (116.9 ± 17.7mmHg to 102.9 ± 16.5mmHg: p=0.0069) and systolic blood pressure taken one minute following exercise (135.7 ± 19.4mmHg to115.0 ± 16.5mmHg: p=0.0007) following the exercise intervention. Conversely, no significant changes were seen in the control group, which suggests that the exercise itself caused this change, therefore endorsing exercise an effective means of decreasing systolic blood pressure in ASD individuals.

This finding may be clinically significant, as it has been well documented by the prospective studies corporation (2002), that a reduction in blood pressure may significantly reduce the risk of having a stroke or myocardial infarction regardless of age, or whether blood pressure is already within the normal range.[(313)] In fact, it has been found that for every 20mmHg decrease in systolic blood pressure and every 10mmHg decrease in diastolic blood pressure, a risk reduction of 50% for strokes, coronary artery disease and vascular complications occurs. [(313)] Since the ASD population is at an already higher risk for these conditions[303)] this type of intervention (exercise) may be highly beneficial for them, and might be useful as a preventative strategy to reduce the risk of developing these conditions.

Furthermore, it was found in the present study, that there was a significant decrease in the resting heart rate (p=0.0046) and heart rate taken one minute following exercise (p=0.0096), which again did not occur in the control group. Generally, a lower resting heart rate suggests the heart muscle is better adapted and therefore more efficient in maintaining bodily functions,[(314)] thus the reduction in HR seen in this sample following exercise may be clinically significant as there is less stress on the participants hearts. The reduction in HR after one minute of exercise also suggests that the participants were able to recover from exercise quicker suggesting improved cardiovascular fitness in the sample. It may therefore be concluded that exercise as an intervention is indeed effective in improving cardiovascular fitness in individuals with ASD.

b. Body composition and anthropometry

In this study it was found that the participants who participated in the 12-week exercise intervention had a significant reduction in their BMI measures (p=0.0130) and a reduction in their body fat percentage (although not statistically significant). Similarly, in a study by Pitetti et al. (2007), where participants with severe ASD participated in an 9 month treadmill walking protocol, a significant reduction in BMI was observed from 33.0 ±7.82 to 30.2± 6.33.[(23)] Therefore, it seems that exercise is indeed an effective modality in reducing the BMI in individuals with ASD.

Alarmingly, the control group who did not participate in the exercise intervention, significantly increased their weight (p=0.0284). It would be beneficial for future research to document the nutritional intake of the participants to determine if this was a contributory factor.

When observing the skinfold measures in this study, conflicting results were noted. It was found that the intervention group had a slight decrease in the triceps skinfold, which was to be expected since their overall body fat percentage decreased, yet there was an increase (non-significant) in the calf skinfold, which may have been due to testing error, however no evident reason exists for why this occurred. Furthermore, although it was found that the control group had a significant increase in their weight, it was noted that there was a significant decrease in their triceps and calf skinfold measures. At baseline testing, a few of the individuals (specifically in the control group) refused to remove their clothing, and thus skinfolds measures for some of these individuals were taken over their clothing. This clothing was however, accounted for by subtracting 1mm from the specific individual's results however, this may not have been appropriately accounted for and may certainly be the reason in the significant decrease in scores from pre to post testing.

a. Musculoskeletal function

i. Strength and endurance

1. Grip strength

In the present study, it was found in that in the intervention group, grip strength improved in the dominant hand, and significantly improved in the non-dominant hand following the intervention. This was not the case for the control group, where handgrip strength was seen to decrease in both the dominant and non-dominant hand over the 12 weeks of standard care. The improvement seen in grip strength in the intervention group, may be attributed to the exercise intervention, signifying that exercise may be effectively used in the ASD population to improve this outcome measure. This may be clinically significant since grip strength is an important component of performing everyday tasks, and the improvement in grip strength may aid in improving manual dexterity and fine motor coordination.

Furthermore, it was found by Kern et al. (2011), that the severity of autism is related to handgrip strength.[(315)] Therefore, handgrip strength should be documented in the initial assessment of individuals with ASD. Although there are minimal studies and reports documenting handgrip strength in individuals with ASD, there have been some studies which have observed the effects on handgrip strength following intervention.

In a study by Yilmaz et al. (2004), a participant aged 9 with ASD, participated in 10 weeks of hydrotherapy using the Halliwick method, three times a week for 60 minutes per session, and their grip strength improved from 9.4 kg to 12 kg. However no information regarding the reason for the improvement was given, and information regarding whether the improvement was significant was not given.

Further research needs to be conducted to determine the extent to which handgrip strength may be improved in the population and what the exacting effect the improvement may have on an individual's activity of daily living as well as their quality of life.

2. Modified curl up

In the present study, it was found that there was a significant improvement in the intervention group ($p= 0.0094$) for the number of curl-ups the participants were able to perform (10.1 ± 6.6 to 14.3 ± 4.5). In contrast it was noted that the control group were able to perform less curl-ups over the same period of time. The reason for the increase in performance in the intervention group was likely the result of the regular performance in core strengthening exercises done in the exercise intervention indicating that exercise may significantly improve the strength and coordination of muscles needed to perform a curl-up (i.e: core muscles). There is no evident reason for the reduction in performance seen in the control group, yet it may be hypothesized that these individuals were not actively being stimulated to engage the muscles needed to perform a curl-up (core muscles) in their everyday routine and hence strength in these muscles may have declined.

Core strength is a vital motor skill needed to perform every day fundamental tasks.[(316)] It has been well documented that having good core strength helps improve balance and stability,[(316)] and since individuals with ASD have notoriously been observed to have poor balance and postural stability, improving core strength in this population may be highly beneficial and clinically significant.

Furthermore good core strength also promotes good posture, and although not many individuals in this particular study had many postural deficits, the improvement in core strength could have contributed to the significantly improved overall posture scores ($p=0.0004$) seen in the sample.

Overall, it would seem that exercise is indeed effective in improving core strength in individuals with ASD. It also seems that the improvement in core strength could lead to and build on other motor improvements such as balance, stability and posture making this finding clinically significant.

ii. Flexibility

In this study, it was found that there was a significant improvement (p=0.0088) in flexibility in the sit and reach test for the non-dominant limb (24.8 ± 8.9cm to 27.3 ± 8.6cm), and an overall improvement in the dominant limb (24.0 ± 8.8cm to 27.8 ± 8.7cm) in the intervention group following the exercise intervention. This was likely due to the regular lower limb stretching conducted in the intervention- particularly the straight leg raise stretch, which specifically targets hamstring flexibility (which is what the sit and reach test, tests for). Similarly, Yilmaz et al. (2004), found that an individual with ASD improved in the sit and reach test (from -5 cm to 0 cm) following and exercise intervention.[(24)]

In contrast it was noted that the control group in the present study had an overall decline in performance for both limbs in the sit and reach test, suggesting that over a period of time, the muscles in individuals with ASD, particularly the hamstring muscles, become generally tighter if no intervention occurs.

It is important for individuals (including those with ASD) to have good hamstring flexibility as this may aid in an improved knee extension and overall increased hamstring force production,[(317)] which in turn could improve an individual's gait cycle (particularly, improved knee extension at heel strike and during stance phase). The finding in this study- that exercise may effectively improve hamstring flexibility in individuals with ASD maybe be clinically significant as there is a general consensus that these individuals more often than not, have gait discrepancies which may now (as suggested by this study) be improved through exercise.

In contrast, in the present study it was found that overall hip and knee flexion decreased in both the control and intervention groups (besides the in the control group for the non-dominant leg which improved slightly). Since it was also found that there was an improvement in muscle strength, (as determined by the grip strength test and modified curl up test), it may be hypothesized that some muscles may have become tighter over the course of the intervention. In particular, since the exercise intervention predominantly targeted the lower limb and no specific stretches targeting knee and hip flexibility were included in the intervention, lower limb muscle tightness could certainly have occurred.

Similarly, to having good hamstring flexibility, good hip and knee flexibility is needed to better perform activities of daily living. Therefore, future exercise interventions, should incorporate specific exercises to improve these flexibility parameters as it seems that a general exercise programme may increase tightness in these muscle areas.

Overall the exercise intervention implemented for this study seemed to effectively improve hamstring flexibility, yet decrease knee and hip flexibility.

3) Objective 3

i. Movement Assessment Battery for Children – 2

a. Manual dexterity

There was a significant improvement seen in the intervention group ($p = 0.0200$) for the turning pegs item for the non-dominant hand, yet there were no other significant differences found for both the intervention and control group pre and post intervention for any other of the manual dexterity items of the MABC-2 test. In fact in the turning pegs task for the dominant hand and in the triangle building task for both hands, the participants took longer to complete the task in the intervention group. Moreover, although there was a reduction in the amount of errors seen in the drawing trail task, (from 11.25 ± 9.40 to 11.18 ± 8.8) the participants only improved slightly following the intervention.

The significant improvement in the turning pegs task for the non-dominant hand could have certainly been due to the participants practicing their fine motor coordination and control in the threading spaghetti exercise in the exercise intervention. It should however be noted that the participants predominately practiced this exercise with their dominant hand, and if this was the case there should have also been a large improvement seen in their dominant hand following the intervention.

Furthermore, the lack of improvement in the building a triangle task, could have perhaps been due to the task requiring different fine motor coordination skills (twisting of fingers and sequenced building) compared to what was targeted in the exercise intervention (threading items). This suggests that specific manual dexterity tasks might only be improved through specific task exercise training, and that perhaps general exercise programming may not be as effective in improving manual dexterity as would tailored exercises geared towards improving this particular motor skill. Nevertheless, it seems that manual dexterity/fine motor coordination can be targeted through exercise.

Since it has been reported that individuals with ASD have significant impairments in manual dexterity compared to typically developing individuals,[297] and exercise might be an effective means or rehabilitation for this parameter in this population , exercise as a modality for therapy should be considered, and possibly implemented to try improve manual dexterity in these individuals. With this being said, further research regarding the extent to which manual dexterity can be improved , as well as which specific exercises are most beneficial in improving manual dexterity should certainly be carried out.

b. Aiming and catching

In the present study, there was a significant improvement in the intervention group (p=0.0007), and the control group (p=0.0112) for the throwing activity following the intervention. This suggests that the exercise intervention did not solely influence the throwing activity task and that perhaps the standard care the participants where receiving helped to improve this motor skill, however further research needs to confirm this. Although no significant improvements were seen in the catching tasks in the participants, it was found that they did indeed improve in how many catches they were able to make out of ten following the intervention. Again however, an improvement was also seen in the control group for their dominant hand (yet not for their non-dominant hand), suggesting no direct/sole influence by the intervention.

It therefore seems that no conclusive information may be drawn for the effectiveness of exercise as an intervention for this component of the study. No clear reason is evident for why ball skills/ gross motor coordination where not substantially improved in all activities following the intervention and further research will need to be conducted to ascertain this. The present exercise intervention could perhaps be improved by implementing more ball skill activities so that individuals become more comfortable with these tasks which could aid in improved task performance. In addition a variety of ball skill exercises could be implemented in future studies and compared, so that the most effective and appropriate ball skill activities are selected for further research.

c. Balance

The intervention group’s balance improved, as seen by them being able to hold their balance for a significantly (p=0.0028) longer time post intervention compared to pre intervention (17.0 ±

11.0s vs 10.5 ± 9.2s) for the two board balance task. No other significant differences were found for the intervention group for the other balance items, namely the zig–zag hopping and backward tandem walking tasks. In fact, it was found that there was a slight decrease in the number of correct steps the individuals where able to take in the tandem walk test (from 13.3 ± 4.4 steps to 12.4 ± 4.9steps). Similarly there was a slight decrease in the in the hopping task for both the dominant and non-dominant limb. In contrast, the control group showed similar results pre- and post-intervention, which therefore suggests that the exercise intervention was effective in improving static balance, yet was not effective in improving dynamic balance in the sample.

The reason for this may be that there was more focus on the static component of balance in the intervention as compared to dynamic balance. Furthermore, it was noted by the researcher that the participants favoured the static balance tasks and often refused to perform the dynamic balance tasks due to a fear of falling. In addition, particularly in the balance beam exercise in the intervention, participants would help each other to complete the task, while this was not the case in the static balance tasks. This may have influenced the participant's progression in dynamic balance, as they would rely on their peers to complete the task instead of effectively activating their dynamic motor control systems. It was however difficult for the researcher to prevent the participants from helping each other, as the researcher wanted to foster team building, and not exacerbate the fear of falling in the participants .

Nonetheless, it has been shown in another study that balance in an individual with ASD improved following an exercise intervention. In the study by Yilmaz et al. (2004), an individual with ASD participated in a swimming education programme over 10 weeks, three times weekly for 60 min per each session. Static balance was tested eyes open, and eyes closed for both the dominant and non-dominant leg. The participant improved in the single leg standing times with their eyes open for both the right (from 12.9s to 46.19s) and left (from 8.92s to 21.16s) leg and also with their eyes closed for the right (from 12.72s to 16.59s) and left(from 2.33s to 10.69s) leg. The researchers did not however give a possible reason for the improvement in balance and there was no dynamic balance test conducted in the study, which could be compared to the present study.

Nevertheless, it seems that static balance can undoubtedly be improved through exercise in individuals with ASD, whether it be water-based or land-based, however the effect exercise may have on dynamic balance requires further research.

ii. Movement Assessment Battery for Children – 2 Checklist

The M'ABC-2 checklist is a complementary tool used with the M'ABC-2 test battery to aid teachers in establishing the existence of movement difficulties as well as assessing the performance of a variety of activities of daily living.[269] Since only one parent returned the forms to the researcher, a case study was presented in the results section. It was found for this participant that no changes were seen for any of the checklist items from pre to post intervention. It was however found that the individual performed tasks particularly well when they were in a stable environment (whether they were moving or not). The individual found it the most challenging to perform tasks in an environment that was changing and themselves needing to move. Overall however the participant scored 45 out of a possible 180, where 0 is the best possible score achievable and 180 is the worst.

iii. Agility

In this study it was shown that agility can be improved through exercise in adolescents with ASD. In fact, agility times significantly improved in the intervention group (p=0.0061) following the 12 week exercise programme. It was however also noted that the control group had a slight improvement in agility times with standard care. The improvement in the agility times in the intervention group may be attributed to the participants' increase in balance, coordination, and muscular strength, which all play a role in agility. Since this is the first study to document this improvement clearly, further research needs to be conducted to confirm these results.

Although minimal information exists regarding the agility profiles in individuals with ASD, there has been one other study, which documented whether agility can be improved through an exercise intervention. In that study, one participant partook in a hydrotherapy intervention 3 times a week for 12 weeks and it was found that the individual's agility improved. At baseline the individual scored 10 points and following the intervention the individual scored 13 points.[24] It is however very unclear what the agility test (thrust test) for the individual comprised and how it was performed or scored. The study however clearly states that agility was improved in the individual.

Improved agility may be extremely beneficial in individuals who have motor impairments, and could allow them to better perform activities of daily life, hence if exercise can efficiently be used to improve agility in individuals with ASD, exercise as a therapeutic modality to improve agility should be pursued.

4) Objective 4

i. Gait

In this study, although overall there were no significant differences seen following the intervention for all gait parameters, some parameters changed following the intervention. It was seen that stride length for the dominant leg remained similar, and increased in the non-dominant leg in the intervention group from pre- to post intervention, and in addition, it was seen that step length increased in both the dominant and non-dominant legs in the intervention group.

It has been suggested that individuals with ASD tend to compensate in terms of their gait parameters, by having shorter stride and step lengths so that they may keep their center of gravity within a wider base of support provided by a general increase in step width. This may be due to them having balance, coordination and proprioceptive problems.(304) The overall increase in step length, and increase in stride length in the non-dominant leg seen in the participants of this study could suggest that they had become more stable in their base of support, allowing them to compensate less in terms of their gait patterns.

It could therefore be said that the exercise intervention was effective in influencing step length (as there was an overall increase in step length), and to a certain degree stride length in the participants. On the other hand step wdith remained the same for both the control and intervention groups throughout the study, and thus the intervention did not seem to influence this parameter.

Although there is limited data on the gait patterns of individuals with ASD, the following parameters have been observed in a few studies: step length, step width, stance time, cadence, and velocity. (317)

The findings of the present study are consistent with a review paper by Kindregan et al. (2015), which highlighted that there is much variation between gait pattern findings in individuals with ASD.(304) The review paper found that six studies had documented that individuals with ASD had significantly reduced step length and stride length, compared to typically developed controls.(181, 182, 318-321). In contrast however, the review paper highlighted that 5 other studies had shown that there was no significant difference in stride length in children with ASD compared to typically developing controls,[179, 180, 183, 322, 323] and in two other studies it was shown that stride length was significantly increased.[319, 323, 324]

Overall, due to no significant differences being seen in the gait parameters in the present study, and due to some parameters increasing and some remaining the same, one cannot clearly state whether exercise, as an intervention in improving gait in individuals with ASD, is entirely effective or not. It would however seem that exercise can indeed alter gait patterns, and thus further research should be conducted to develop gait specific exercise training programmes to determine whether changes in various gait parameters could become significant over a longer period of time.

5) Medications

The intervention group took less CNS stimulators and anticonvulsants following the 12 weeks of exercise, and although this reduction in medication was not statistically significant, it may be clinically significant. The reason for this group taking less medication could have been due to the influence of exercise, where some of the impairments were reduced in the participants, which may have necessitated a reduction in medication according to their doctors who were monitoring them. This would need to however be confirmed with further research.

Esbensen et al. (2009), reported that the number of medications taken in a population of 286 adolescents with ASD, significantly increased over time from 70% of the sample taking medication to 81% of the sample taking medication.[305] The study however, looked at the amount of medication taken over a 4.5 year period (without exercise intervention), compared to 12 weeks in this study (with exercise intervention), suggesting that individuals with ASD generally tend to take more medication over a longer period of time, particularly if there is no intervention within the group. It has been suggested that this general increase may be due to a lack of alternative effective treatments, [305] and although these medications may have positive effects, some also have severe side effects and hence should be kept to a minimum.

Further research will need to confirm whether there is a relationship between participation in exercise and specifically the amount of CNS stimulators and anticonvulsant medications taken in individuals with ASD, as no current literature exists. If exercise can effectively decrease medication levels in this population, a steady increase in medication usage could be prevented and quality of life for these individuals may be improved, thus making exercise a possible effective intervention regarding medication usage.

CHAPTER 6: CONCLUSIONS, STRENGTHS & LIMITATIONS AND RECCOMENDATIONS

The subtopics that will be included in this chapter include:Conclusions
6.2 Limitations of study
6.3 Strengths of study
6.4 Recommendations
6.5 Take home message

6.1 Conclusions

Compliance to this 12-week exercise intervention was relatively high, with a compliance rate of 88.8%. It was found that the exercise intervention was effective in improving the majority of the motor variables tested:

The exercise intervention was effective in improving overall posture, and in particular ankle posture. Furthermore, the exercise intervention was effective in decreasing resting systolic blood pressure and systolic blood pressure taken one minute post exercise post intervention. There was also an improvement in the resting heart rates, and heart rates taken one minute post exercise for those participants who participated in the intervention. Since this population is at a high risk of developing cardiovascular related problems this improvement was deemed to be clinically significant.

In terms of the participant's body composition, the intervention groups' weight and body fat percentage did not improve following the intervention, however the exercise intervention effectively decreased the BMI in individuals with ASD. Clinically this is an important finding as a reduction in BMI could lower the risk of developing comorbid health problems associated with obesity and being overweight.

Furthermore, the intervention was effective in improving grip strength in the dominant and non-dominant hands as well as in the amount of curl-ups the individuals could perform, suggesting an overall improvement in hand grip, core strength as well as trunk coordination in the participants, which are all important skills required for the activities of daily living.

The exercise intervention was effective in improving the performance in the sit and reach test, suggesting that hamstring flexibility may indeed be improved in this population through exercise. In contrast, it was found that following the intervention, hip and knee flexion had decreased, yet this may have been due to an overall improvement in strength seen in the participants, which may have elicited this muscular tightness. Furthermore, the intervention was effective in improving throwing in both the intervention and control groups, with no conclusive information regarding the efficacy of exercise for the ball skills/ gross motor coordination components in this study.

The exercise intervention was extremely effective in improving agility and static balance in the intervention group following the 12 week exercise programme, while the majority of the gait parameters remained the same following the intervention. There was however an increase in the intervention groups' step length for both the dominant and non-dominant limb as well as an increase in stride length in the non-dominant leg and this could suggest that they had become more stable in their base of support, allowing them to compensate less in terms of their gait patterns.

Therefore the original hypothesis of whether "a 12-week exercise intervention implemented in a group of adolescents with autism aged 11-16, will help improve posture, body composition, physical fitness, balance, flexibility, coordination, agility and gait in the individuals" may be accepted with the exception of the improvement in hip and knee flexion, and some gait variables.

6.2 Limitations of study

- During the pre- and post-intervention testing, participants were asked to take off their shoes and socks as well as any bulky clothing, and some of the participants refused to do this whilst others were unable to do so without assistance, this often led to a delay in testing. For the individuals who refused to remove clothing items they had to be tested as they were, as to not trigger an undesired behavioural response. For the purpose of standardisation, these individuals were tested pre- and post-intervention in the same manner.

- The M'ABC-2 checklist is a complementary tool used with the test battery to aid teachers in establishing the existence of movement difficulties. The checklist was sent out to be completed by the participants' parents during baseline testing and again following the completion of the exercise intervention. The researcher followed up several times with teachers at the school regarding these forms. The researcher was not permitted to contact the parents directly, yet the teachers assisted the researcher in sending out reminder emails to the parents to send back the forms, however only one parent sent back the forms to the researcher on completion of the study, hence a case study was presented in the results for the participant. Future studies could possibly incorporate the filling out of these forms at the first and last meeting with the parents when discussing the study.
- During testing some participants did not like to be pinched by the skinfold calipers , have the blood pressure cuff tighten on their arm (in order to take blood pressure), or wear a heart rate monitor, as they were afraid of the equipment and/ or did not like to be touched. Future studies need to be cognizant of this, and possibly make use of other equipment where necessary i.e taking blood pressure and heart rate manually instead of using a blood pressure cuff and heart rate belt.
- The participants struggled in performing the 1 mile walk/ run test and so this test had to be modified for the sample so that all participants were tested in the same way. This however meant that the standard 1-mile test from the Brockport was adapted and this made it difficult to compare these results to other studies making use of the same test.
- Some individuals refused to perform certain tests, were unable to do certain tests or performed certain tests inappropriately. Therefore some tests do not reflect the full samples' results in the results section. This was, however out of the researcher's control.
- It was noted that the individuals who were lower functioning on the ASD spectrum tended to be less compliant to the exercise intervention. This was predominantly due to the individuals missing school, partly because of sickness and/ or going for additional therapy. This may have hindered the extent to which their motor skills improved in the intervention. In light of this, future studies could make provision for those who are unable to attend sessions by adding "make up sessions" on alternate days.
- The participants struggled with the "tug of war" activity which was meant to form part of the strengthening exercises in the intervention- this activity had to be removed from all sessions and was replaced by better suited exercises. More information regarding adaptations to exercises may be found in the journal (Appendix P).

6.3 Strengths of study

- Although the sample size used in the study may be considered small by general standards, this is the largest exercise intervention study to date conducted in South Africa in individuals with ASD, and hence may provide invaluable information in rehabilitating these individuals.
- This study looked at a plethora of motor variables unlike most other exercise intervention studies that have been conducted. This study also measured how an exercise intervention may influence all of these variables, making this study unique, as it provides a holistic view of how individuals may benefit from exercise in the physical domain. It provided information as to which variables are more likely to improve following an exercise intervention as compared with others. This information may be useful in understanding which motor areas may be targeted effectively through exercise and which may need further/added intervention.
- This study provided a small educational component as part of the intervention which taught the participants about the benefits of exercise and therefore could have made a lasting impression on the individuals. Future studies should incorporate educational aspects as part of the exercise intervention as this may lead to better compliance and a possible commitment to further participate in physical activity.
- This study added to the minimal body of information available on flexibility and agility profiles in individuals with ASD and highlighted the need for further research in these areas.
- The study documented the effects exercise may have on medication usage within the population, data of this kind is extremely limited in the population.

6.4 Recommendations

i. Based on the findings of this study

- Physical activity for adolescents with ASD is of benefit and healthcare providers and caregivers should be educated about this, and activity should be encouraged.
- Exercises should be simple, modifiable as well as enjoyable. It is recommended that participants add or suggest exercises that that enjoy into the programme as that improves compliance towards the programme and further adds to the enjoyment of the classes.
- When exercising with adolescents with ASD, group exercise should be encouraged yet, groups larger than 8 for high functioning individuals should be avoided, and groups larger than 5 for low to moderate functioning individuals should be avoided. It becomes

difficult in effectively demonstrating and conducting group exercise classes if groups are too large.

ii. For further research

- Agility and flexibility profiles in individuals with ASD need to be further investigated.
- A standardised motor skill testing battery including a comprehensive list of motor variables should be developed specifically for individuals with ASD so that tests are appropriate, and so that existing tests do not need to be modified. This will also make it easier to compare findings between studies and allow for a standardised level of motor skill testing.
- The effect exercise interventions may have on the amounts of medications taken by individuals, and the link between the two need to be established.
- Lastly, future studies should determine whether there is retention of improved performance variables over time following an exercise intervention and what the lasting benefits may include.

6.6 Take home message

1. Exercise is indeed a good form of rehabilitation for those with ASD for a variety of motor variables, and hence physical activity should be extensively promoted in this population.
2. Exercise interventions should target a variety of motor variables so that individuals with ASD may maximally benefit from exercise interventions. These exercises should be simple yet challenging, as well as fun and enjoyable to promote compliance.
3. Exercise interventions should include an educational component to promote compliance and foster an overall willingness to partake in physical activity.

"It's never the differences between people that surprise us. It's the things that, against all odds, we have in common." [41]

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LIST OF APPENDICES

Appendix A: Permission letter from UNICA School for Autism

UNICA SCHOOL FOR CHILDREN WITH AUTISM

P.O. BOX 35182, MENLO PARK, 0102
CECILIA ROAD, NEW HOPE CAMPUS, ASHLEY GARDENS
TEL: 012 460 6539 / 012 346 1103
FAX: 012 460 6324
HOSTEL: 012 329 0647

REG NO: GDE 211177 TS D4

PRINCIPAL: DR J.C. LOMBARD DEPUTY: J. PERUMAL

10 June 2013

Dear Natalia Neophytou

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT UNICA SCHOOL BY THE ABOVEMENTIONED

TOPIC*: Effects of a model exercise intervention on a autistic population*

We herewith give permission to conduct the proposed research at our school as we have received the following information:

- GDE Permission.
- Interview Schedule: Parents
- Interview Schedule: Teachers
- Research Proposal

Thank you for your interest in our school. We kindly request that a bound copy of the research project as well as any articles be made available to Unica School upon completion.

Sincerely

Lombard

Dr J.C. Lombard
Principal

Appendix B: Permission letter from the department of education

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. D2014/118

GDE RESEARCH APPROVAL LETTER

Date:	**21 June 2013**
Validity of Research Approval:	**21 June 2013 to 20 September 2013**
Name of Researcher:	**Neophytou N.**
Address of Researcher:	**P.O. Box 1552**
	Cresta
	2118
Telephone Number:	**011 717 3383 / 084 847 977**
Fax Number:	**011 717 3379**
Email address:	**natalia.neophytou@wits.ac.za**
Research Topic:	**The efficacy of a 12-week exercise intervention in 11 to 15 year old adolescents with Autism**
Number and type of schools:	**ONE Primary School**
District/s/HO	**Tshwane South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

2013/06/21

1

Making education a societal priority

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Dr David Makhado
Director: Education Research and Knowledge Management

DATE: 2013/06/21

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.g

Appendix C: Child information sheet

Jumping Jacks

My Name is Natalia Neophytou, and I would like to invite you to participate in my study ☺

What will we be doing?

We will be doing exercise tests and having fun in an exercise programme called the JUMPING JACKS!

The exercise tests

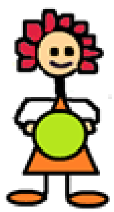
We are going to do these tests before the exercise programme starts and after the programme is finished.

We are going to test:

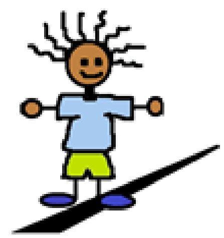
- How fit you are
- How flexible and strong you are
- How good your balance and coordination is
- How good your waking and posture is
- And how quick you can move through obstacles

Your parents are going to help me as well by filling in a questionnaire and a checklist about your everyday tasks.

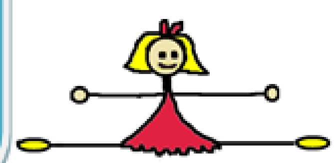
Standing on one leg



Catching and throwing balls



Walking on a balance beam



Stretching & many more!!

The exercise programme

The exercise programme we are going to do together is called Jumping Jacks. It is a fun programme where we will be doing some cool exercises like walking on a balance beam and catching and throwing balls. This programme is going to try teach you how good exercise is, and will try help improve your fitness balance and coordination !

Some exercises we will be doing

It would be great if you would like to participate in my study!

If you have any other questions about what we will be doing, you can ask me and I will explain everything to you.

You can also ask your parents as I will explain everything to them as well, or you can contact me on:

(011) 717 3383 or 084 847 2977

Or email me at natalia.neophytou@wits.ac.za

Thank you ☺

Appendix D: Parent information sheet

UNIVERSITY OF THE WITWATERSRAND
CENTRE FOR EXERCISE SCIENCE AND SPORTS MEDICINE
PARENT/LEGAL GUARDIAN INFORMATION SHEET

Hello,

My name is Natalia Neophytou and I am currently completing my Master's degree in Biokinetics at the University of the Witwatersrand. As part of my degree, I am conducting a study to evaluate the effectiveness of a physical activity programme in adolescents with autism and I would like to ask your permission to include you and your child to participate in the programme. This study has been approved by the Human Research Ethics Committee of the University of the Witwatersrand. Research has shown that exercise interventions in autistic populations can be beneficial in reducing some of the core symptoms of autism.

TITLE

The title of my study is: The Efficacy of a 12-week Exercise Intervention in 11 to 16 year old Adolescents with Autism.

PURPOSE OF THE RESEARCH

The specific aims of the study are to look at the effects a physical activity programme may have on physical fitness (aerobic function, muscle strength, endurance, and flexibility), gross and fine motor skills (balance, co-ordination, agility, ball skills and manual dexterity), gait, posture as well as quality of life in individuals affected by autism spectrum disorder. This holistic look at the various components in physical activity and quality of life will help provide insight into how exercise can be used as a tool to positively influence the lives of adolescents with autism.

PROCEDURES

Site of study

The study will take place at UNICA School for Autism

Number of participants

If you and your child would like to participate, your child will be one of 40 children selected to participate in this study- 20 of which will form the control group and 20 of which will form the intervention group. The control group will be tested before and after the exercise programme is implemented, however the group will not participate in the exercise programme- they will however receive standard care as per normal. The intervention group will be tested before and after the exercise programme is implemented and will participate in the exercise programme. The selection to be included into either group will be done randomly and in an unbiased manner.

Exclusion criteria

Children may be excluded from this study if:

1. They are not in good health, or have a disease or impairment (besides ASD) that may affect delays in physical activity or
2. Have impairment in fundamental receptive and expressive communication abilities.

Testing

Each child who participates in the study will be tested before and after the physical activity programme is conducted. Testing will be done at consistent and convenient times and won't interfere with the children's regular programme. The first set of testing will give an idea of your child's baseline values of fitness, motor performance, gait and posture. I would like to ask you, as the parent, to also help me fill out a quality of life questionnaire and movement checklist about your child prior to the programme being conducted and again after the programme has been conducted so we can establish whether other areas of your child's life have also been positively influenced.

The physical activity programme will be carefully developed to ensure all components of physical fitness and motor performance that were tested for, will be incorporated and progressed throughout the programme to help improve those outcomes in your child. The programme will be presented in 45 minute sessions twice a week for a period of 12 weeks. I will be the instructor for all of these sessions and will ensure that the physical activities offered to your child are appropriate and manageable.

After the 12 week programme has been implemented, a second set of testing, as well as filling out of the questionnaire and checklist will occur for all the participants. The results from the tests and the questionnaire will be compared to the baseline testing results.

<u>The following tests will be done in both the pre and post phases:</u>

- A 1 mile run/walk test
- Grip strength test
- Modified curl up test
- Sit and reach test
- Modified Thomas test
- Agility test
- The child's movement will be assessed by conducting a few balance, manual dexterity and ball skill tests
- Posture and gait will be assessed and lastly,
- Skinfold measurements will be taken along with BMI measurements

Tests will be conducted in a safe environment and will be broken up into 30 min sessions with adequate rest periods for the children and may be split up over a few days.

BENEFITS

Benefits include learning about the importance of physical activity in daily life as well as possible improvement in terms of physical fitness, balance, ball skills, coordination, posture and gait. If the exercise programme proves beneficial, children in the control group will be offered the chance to participate in the exercise programme at the conclusion of the study.

POTENTIAL RISKS AND DISCOMFORTS

When children participate in physical activity programmes there may be risks of injury (e.g. tripping, falling etc.), however should your child be a participant in the exercise programme, this risk will be greatly reduced as I will be working with the children in small manageable groups so that I can effectively control what is happening in the activity sessions as well as being able to provide one-on-one guidance if needed. Additionally only appropriate equipment will be used in the activity programmes, which will also decrease the risk of potential injuries and allow the children to effectively handle and work with the equipment.

I am qualified in first aid, as well as basic life support training and will be able to provide the appropriate attention if needed

CONFIDENTIALITY

The information that is obtained during the course of the study and during exercise testing will be treated as privileged and confidential, with only the researcher and supervisors having access to the information. The information will be used for statistical analysis and scientific purposes with your right to privacy retained. No mention will be made of any identifying information such as your child's name or his/her school in order to protect his/her anonymity- all information will be coded.

PARTICIPATION AND WITHDRAWAL

If you would be willing, as well as allowing your child to participate in this study, it should be understood that you may withdraw yourself and your child from the study at any time without reason, and without prejudice.

ENQUIRIES

If you have any further questions or concerns regarding the research, please feel free to contact:

Principal Investigator: Natalia Neophytou
Centre for Exercise Science and Sports Medicine, University of the Witwatersrand
Tel: (011) 717 3383
Cell: 084 847 2977
Email: natalia.neophytou@wits.ac.za

Supervisor: Dr Kerith Aginsky
Centre for Exercise Science and Sports Medicine, University of the Witwatersrand
Tel: (011) 717 3368
Email: kerith.aginsky@wits.ac.za

Supervisor: Ms Natalie Benjamin
Physiotherapy, University of the Witwatersrand
Tel: (011) 717 3731
Email: natalie.benjamin@wits.ac.za

Chair of Ethics Committee: Professor P Cleaton-Jones
Tel: (011) 717 2301/1234
Email: peter.cleaton-jones@wits.ac.za

Thank you for reading this information sheet.

Natalia Neophytou
Intern Biokineticist, BHSc (Hons)

Appendix E: Parental/Legal Guardian Consent Form

UNIVERSITY OF THE WITWATERSRAND

CENTRE FOR EXERCISE SCIENCE AND SPORTS MEDICINE

PARENTAL/LEGAL GUARDIAN CONSENT FORM

I,………………………………………………………….. (print name) hereby confirm that:

- I have been informed of the study by Natalia Neophytou, and I agree that I am aware of the testing procedures, the nature of the intervention and the risks involved.
- I have read and received a copy of the written information regarding the study and have had the opportunity to discuss the details, and ask questions (which have been answered to my satisfaction) with the principal researcher.
- I am aware that the results of the study will be anonymously processed into a study report and that these details may be submitted to scientific conferences and written up in academic publications. In view of the requirements of the research, I agree that the data collected during the research, including photographs taken during the assessments and intervention procedures described, may be used for the advancement of knowledge as described.
- I am fully aware that I may, at any stage withdraw my consent as well as the consent of my child, without prejudice, from further participation in the study.

I hereby consent of my own free will, to participate as well as allow my child:
………………………………….............................. (print child's name) to participate in this study.

____ _____/_____/_________

SIGNATURE OF PARENT OR LEGAL GUARDIAN DATE

____ ______/______/__________

SIGNATURE OF RESEARCHER DATE

____ ______/______/__________

SIGNATURE OF WTINESS DATE

Appendix F: Child Assent Form

UNIVERSITY OF THE WITWATERSRAND

CENTRE FOR EXERCISE SCIENCE AND SPORTS MEDICINE

CHILD ASSENT FORM

I, …………………………………………………………(print name) confirm that:

- I have been informed of the study by Natalia Neophytou, and I agree that I understand what exercise tests will be done and why they will be done.
- I understand that I will be doing an exercise programme with Natalia. And that she will be helping me do the exercises safely and in a fun way.
- I have read the information sheet and I understand it. I was able to ask any questions I wanted and all the questions were answered so that I fully understood everything.
- I understand that I can stop being part of this study if I want to, for any reason.

I give my permission to participate this study.

_______________________________________ _____/_____/_________

SIGNATURE OF CHILD (Sign or print name) DATE

_______________________________________ _____/_____/_________

SIGNATURE OF RESEARCHER DATE

_______________________________________ _____/_____/_________

SIGNATURE OF WITNESS DATE

Appendix G: Procedures for orientating teachers and parents to the study

Procedures for orientating teachers and parents

i. Initial meeting with teachers

The principal of UNICA School for Autism requested the researcher work in conjunction with the occupational therapists at the school. An initial meeting was set up prior to testing with the two occupational therapists at UNICA School for Autism. The meeting was setup to provide a detailed explanation of the study to the teachers and to select a few preliminary dates for testing and the intervention to take place.

ii. Initial invitation to participate

With the help of the occupational therapists at UNICA School of Autism a bulk email was set up and all invitations to participate, information documents, consent and assent forms were sent out to the parents by the school. Physical packs of documents were sent home with each child in the 11-16 year age category so parents could familiarize themselves with the study prior to the information talk and/or consent if they were happy to participate in the study without any further information given.

iii. Presentation for parents/ information talk

An information session was held at UNICA School for Autism prior to the commencement of the study to follow up with parents after having been sent the invitations to participate. The information session allowed for further recruitment of parents that may have been previously hesitant in participating in the study or had questions that needed to be answered before giving consent. Parents were also welcomed to be part of the expert panel for the intervention review. Scheduling of the intervention was discussed with parents and a final consensus was reached as to when exercises classes were to occur.

iv. Final invitation to participate

All documents were sent out again to the parents 2 weeks after the information talk occurred. The occupational therapists put together a cover page allowing the study for be done at the school for the document packs and the packs were sent home with the children. This allowed for more parents to participate in the study.

v. Thank you letter and additional forms

A thank you letter was sent out to the parents of the children (control and intervention group) who gave consent to participate in the study (may be produced on request). The letter also included information on the intervention implementation and when they would be receiving individual reports for each child.

Appendix H: Mental ages of the participants as determined by the registered psychologist and psychometrist at Unica School for Autism

PARTICIPANT CODE	MENTAL AGE
A2	54
A4	78
A9	39
A11	78
A12	69
A16	41
A17	35
A20	96
A27	77
A31	84
A33	36
A1	**86**
A3	**96**
A6	**73**
A8	**84**
A10	**41**
A13	**90**
A14	**78**
A15	**36**
A18	**81**
A19	**83**
A22	**58**
A23	**82**
A24	**96**
A25	**52**
A26	**33**
A29	**50**
MEAN	**66.8888889**
SD	**21.6374557**

Appendix I: Assessment Form 1 (Pre-intervention testing)

ASSESSEMENT FORM 1 (Pre-intervention testing)

Date: ___________________ Time:_____________________

Code: _________________________________ Age: _____________________ M / F

Dominance: Hands : L / R Feet : L / R

History

Letter from clinical psychologist: Y / N

Categoristation:____

Current medications:

Name of medication	Dosage

Brockport Physical Fitness Test

Test	Result
Resting BP (mmHg)	
Resting HR (Bpm)	
Aerobic function 1 mile walk/run test (seconds)	
BP after 1 min (mmHg)	
HR after 1 min (Bpm)	
Height (m)	
Weight (kg)	
BMI	
Skinfolds Triceps (mm)	
Skinfolds Calf (mm)	
Grip strength	
Extended arm hang (seconds)	
Modified curl up (no.)	
Sit and reach (cm)	
Modified Thomas Hip flexion angle (degrees)	
Modified Thomas Knee flexion angle (degrees)	

Further Test battery –Compiled by researcher

Test	Result
Gait analysis Done Y/N______________________________	Video analysis Done Y/N______________________________
Posture analysis Done Y/N______________________________	Photograph analysis Done Y/N______________________________
Agility T-test (seconds)	

Additional notes

____

____

____

____

____

Appendix J: Assessment Form 2 (Post-intervention testing)

ASSESSEMENT FORM 1 (Pre-intervention testing)

Date: ___________________ Time:_____________________

Code: _________________________________ Age: _____________________ M / F

Dominance: Hands : L / R Feet : L / R

History

Letter from clinical psychologist: Y / N

Categoristation:____

Current medications:

Name of medication	Dosage

Brockport Physical Fitness Test

Test	Result
Resting BP (mmHg)	
Resting HR (Bpm)	
Aerobic function 1 mile walk/run test (seconds)	
BP after 1 min (mmHg)	
HR after 1 min (Bpm)	
Height (m)	
Weight (kg)	
BMI	
Skinfolds Triceps (mm)	
Skinfolds Calf (mm)	
Grip strength	
Extended arm hang (seconds)	
Modified curl up (no.)	
Sit and reach (cm)	
Modified Thomas Hip flexion angle (degrees)	
Modified Thomas Knee flexion angle (degrees)	

Further Test battery –Compiled by researcher

Test	Result
Gait analysis Done Y/N____________________________	Video analysis Done Y/N____________________________
Posture analysis Done Y/N____________________________	Photograph analysis Done Y/N____________________________
Agility T-test (seconds)	

Additional notes

Appendix K: MABC-2 Checklist

MOVEMENT ABC

Movement Assessment Battery for Children

Checklist

Compiled by Sheila E. Henderson and David A. Sugden

Code: Date of test ....

Date of birth ....

.... Age .... Grade/year ....

School .... Assessed by ....

Section 1	Section 2	Section 3	Section 4	Total	Section 5	Full Movement ABC assessment required
____ + ____		____ + ____ +		____	L M H (circle one)	yes no (circle one)

Section 1: Child Stationary/Environment Stable

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Put on and take off articles of clothing without assistance (shirt, sweater, socks). ....
2. Stand on one leg in a stable position (when putting on trousers, skirt). ....
3. Tie shoelaces, buckle belt, fasten a zipper/buttons. ....
4. Demonstrate competence in personal hygiene (wash hands, brush/comb hair). ....
5. Demonstrate good posture when sitting or standing (at a desk/table, on a chair, in line). ....
6. Hold instruments using proper tension and grasp (scissors/pencil/pen/paintbrush). ....
7. Cut/draw/trace with precision/accuracy. ....
8. Form letters, numbers and basic geometric shapes that are accurate and legible. ....
9. Pick up small objects (blocks, beads, puzzle pieces). ....
10. Use blocks, beads, puzzle pieces to complete appropriate task. ....
11. Turn the pages of a book, hand out individual sheets from a stack of paper. ....
12. Recognize own body parts and differentiate between left and right. ....

Section 1 Total ☐

Section 2: Child Moving/Environment Stable

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Walk around the classroom/school avoiding collision with stationary objects/persons. ....
2. Carry objects around the classroom/school avoiding a collision with stationary objects/persons. ....
3. Run and then stop to avoid stationary objects/persons. ....
4. Skip or gallop a distance of 15 feet (4.5 m). ....
5. Hop in a controlled manner on either foot. ....
6. Jump across/over obstacles that might be found in the play environment (blocks, low hurdles, ropes). ....
7. Use fixed playground/gymnasium apparatus such as climbing frame, slide and/or low balance beam. ....
8. Maneuver through/around an obstacle course appropriate to age and ability. ....
9. Throw an object (ball, bean bag, ring) into a container using an underarm action, while on the move. ....
10. Throw an object (ball, bean bag, ring) into a container using an overarm action, while on the move. ....
11. Run to kick a large stationary ball. ....
12. Demonstrate an understanding of directional commands by moving forward/backward; over/under; around/through; in/out; to the left/right. ....

Section 2 Total ☐

Section 3: Child Stationary/Environment Changing

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Pass objects down a line from one child to the next (passing books or pencils along the row). ....
2. Maintain a stable position within a physical group activity (leap-frog, holding a hoop steady for others to throw a bean bag through). ....
3. Intercept and stop a moving object (toy train or car, ball) as it approaches/enters the field of reach. ....
4. Catch a large approaching ball (bouncing or in flight) using two hands. ....
5. Catch a small approaching ball (bouncing or in flight) using one hand. ....
6. Kick an approaching ball using the foot rather than the shin. ....
7. Hit/strike a moving ball using a bat, racket or stick. ....
8. Roll a ball for a moving child to stop or catch. ....
9. Throw a ball/bean bag for a moving child to catch. ....
10. Continually bounce a large playground ball while standing still. ....
11. Turn a rope with sufficient force and accuracy to allow another child to jump or skip. ....
12. Keep time to a musical beat by clapping hands or tapping foot. ....

Section 3 Total ☐

Section 4: Child Moving/Environment Changing

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Move around the classroom/school while avoiding collision with other moving persons. ....
2. Use non-stationary playground/gymnasium apparatus such as swings unassisted. ....
3. Ride moving vehicles such as pedal cars, tricycles, scooters and bikes (as appropriate for age). ....
4. Push/pull wheeled vehicles such as wagons, library and mat trolleys. ....
5. Participate in chasing games (tag, Mr. Wolf). ....
6. Run to catch an approaching ball. ....
7. Run to kick an approaching ball. ....
8. Run to hit/strike an approaching ball using a bat, racket or a stick. ....
9. Use skills of striking, kicking, catching and/or throwing to participate in a team game. ....
10. Move around keeping control of a bouncing ball. ....
11. Move to enter a turning jump rope. ....
12. Move in a variety of directions, styles and speeds while keeping time to a musical beat. ....

Section 4 Total ☐

Section 5: Behavioral Problems Related to Motor Difficulties

0	1	2
Rarely	Occasionally	Often

The child is:

1. Overactive (squirms and fidgets; moves constantly when listening to instructions; fiddles with clothes). ....
2. Passive (hard to interest; requires much encouragement to participate; seems to make little effort). ....
3. Timid (fearful of activities like jumping and climbing; does not want to move fast; constantly asks for assistance). ....
4. Tense (appears nervous, trembles; fumbles with small objects; becomes flustered in a stressful situation). ....
5. Impulsive (starts before instructions/demonstrations are complete; impatient of detail). ....
6. Distractible (looks around; responds to noises/movement outside the room). ....
7. Disorganized/confused (has difficulty in planning a sequence of movements; forgets what to do next in the middle of a sequence). ....
8. Overestimates own ability tries to change tasks to make them more difficult; tries to do things too fast). ....
9. Underestimates own ability (says tasks are too difficult; makes excuses for not doing well before beginning). ....
10. Lacks persistence (gives up quickly; is easily frustrated; daydreams). ....
11. Upset by failure (looks tearful; refuses to try task again). ....
12. Apparently unable to get pleasure from success (makes no response to feedback; has a blank facial expression). ....

Section 5's overall estimated contribution to movement difficulties (High, Medium or Low) ☐

Appendix L: MABC-2 test battery record form for pre and post intervention testing

Movement Assessment Battery for Children – 2

Test Record Form Age Band 3 (11-16 years)

Name: Gender: M / F

Home address:

School:

Assessed by:

Code:

Referral source:

Preferred (writing) hand:

	Year	Month	Day
Date tested			
Date of birth			
Chronological age			

Movement ABC-2 Checklist completed? Y / N

Item Scores and Equivalent Standard Scores

Item code	Name of item	Raw score (best attempt)	Item Standard Score
MD 1*	Turning Pegs preferred hand		
	Turning Pegs non-pref hand		
MD 2	Triangle with Nuts and Bolts		
MD 3	Drawing Trail 3		
A&C 1*	Catching with one Hand – best hand		
	Catching with one Hand – other hand		
A&C 2	Throwing at Wall Target		
Bal 1	Two-Board Balance		
Bal 2	Walking Toe-to-Heel Backwards		
Bal 3*	Zig-Zag Hopping best Leg		
	Zig-Zag Hopping other Leg		
Total Test Score Sum of 8 item **standard** scores:			

*For Turning Pegs, Catching with One Hand and Zig Zag Hopping, look up standard score for each limb, add these and divide by 2. If the result is above 10, round up; if below 10, round down.

Three Component Scores†

Manual Dexterity^ MD 1 + MD 2 + MD 3

Component score	Standard Score	Percentile

Aiming & Catching^ A&C 1 + A&C 2

Component score	Standard Score	Percentile

Balance^ Bal 1 + Bal 2 + Bal 3

Component score	Standard Score	Percentile

^In each case sum the item standard scores

Total Test Score	Standard Score	Percentile Rank

†For confidence intervals, see Examiner's Manual p139 (Chapter 7)

1

Manual Dexterity 1: TURNING PEGS

Record: Preferred hand: R / L (should be same as for Drawing Trail); Time taken (secs); **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)

Preferred hand		Only administer a second trial if the first trial takes longer than the time stated below:							Non-preferred hand		Only administer a second trial if the first trial takes longer than the time stated below:						
Trial 1			11:0-11:11	12:0-12:11	13:0-13:11	14:0-14:11	15:0-15:11	16:0-16:11	Trial 1			11:0-11:11	12:0-12:11	13:0-13:11	14:0-14:11	15:0-15:11	16:0-16:11
Trial 2			25 secs	22 secs	22 secs	22 secs	22 secs	22 secs	Trial 2			31 secs	26 secs	26 secs	26 secs	26 secs	26 secs

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds head too close to task ☐
- Holds head at an odd angle ☐
- Does not look while manipulating pegs ☐
- Does not use pincer grip to pick up pegs ☐
- Exaggerates finger movements in releasing pegs ☐
- Does not use the supporting hand to hold board steady ☐
- Does extremely poorly with one hand (asymmetry striking) ☐
- Changes hands or uses both hands during a trial ☐
- Hand movements are jerky ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Misaligns pegs with respect to holes ☐
- Uses excessive force when inserting pegs ☐
- Is exceptionally slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐
- Other ____________________

Comments: ____________________

Manual Dexterity 2: TRIANGLE WITH NUTS AND BOLTS

Record: Time taken (secs); **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)

No. of seconds		Only administer a second trial if the first trial takes longer than the time stated below:						
Trial 1			11:0-11:11	12:0-12:11	13:0-13:11	14:0-14:11	15:0-15:11	16:0-16:11
Trial 2			55 secs	48 secs	48 secs	48 secs	48 secs	48 secs

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds materials too close to face ☐
- Holds head at an odd angle ☐
- Does not look at hole while inserting bolt ☐
- Does not use pincer grip to hold nuts and bolts ☐
- Finds it difficult to hold bolt with one hand and screw nut on with the other ☐
- Changes hands during a trial ☐
- Hand movements are jerky ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Sometimes misses hole with tip of bolt ☐
- Gets muddled in the construction sequence ☐
- Is exceptionally slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐
- Other ____________________

Comments: ____________________

Manual Dexterity 3: DRAWING TRAIL 3

Note: Bic Atlantis pen to be used

Record: Hand used: R/L/Both; No. of errors; **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)
Number of errors should be counted after testing using scoring criteria provided in Appendix A of the Manual.

	No. of errors
Trial 1	
Trial 2	

Do not administer a second trial if the child completes the first trial perfectly (i.e. no errors).

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds head too near paper ☐
- Holds head at an odd angle ☐
- Does not look at trail ☐
- Holds pen with an odd/immature grip ☐
- Holds pen too far from point ☐
- Holds pen too close to point ☐
- Does not hold paper still ☐
- Changes hands during a trial ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Progresses in short jerky movements ☐
- Uses excessive force, presses very hard on paper ☐
- Is exceptionally slow ☐
- Goes too fast for accuracy ☐

Other ____________________

Comments: ____________________

Aiming & Catching 1: CATCHING WITH ONE HAND

Record: Number of correctly executed catches; **R** for refusal; **I** if inappropriate (note reasons below)

Right Hand Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total: ________

Left Hand Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total: ________

Qualitative observations

Posture/body control

- Standing posture is poor ☐
- Does not follow trajectory of ball with eyes ☐
- Turns away or closes eyes as ball approaches ☐
- Holds hand out flat with fingers stiff as the ball rebounds ☐
- Hands and arms held wide apart, fingers extended ☐
- Arm and hand do not 'give' to meet impact of ball ☐
- Fingers close too early or too late ☐
- Does extremely poorly with one hand (asymmetry striking) ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Does not adjust body position for catching ☐
- Does not adjust position of feet as necessary ☐
- Judges force of throw poorly (too much or too little) ☐
- Does not adjust to height of rebound ☐
- Does not adjust to direction of rebound ☐
- Does not adjust to force of rebound ☐

Other ____________________

Comments: ____________________

Aiming & Catching 2: THROWING AT WALL TARGET

Record: Hand used: R / L / Both; Number of successful hits; **R** for refusal; **I** if inappropriate (note reasons below)

Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total:________

Qualitative observations

Posture/body control

- Balance while throwing is poor ☐
- Does not keep eyes on target ☐
- Does not follow through with the throwing arm ☐
- Releases ball too early or too late ☐
- Changes hands from trial to trial ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Errors are consistently to one side of the target (asymmetry striking) ☐
- Control of direction is variable ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- **Other** ________

Comments: ________

Balance 1: TWO-BOARD BALANCE

Record: Time balanced (secs); **R** for refusal; **I** if inappropriate (note reasons below)

	No. of seconds
Trial 1	
Trial 2	

Do not administer a second trial if the child maintains balance for 30 seconds

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Sways wildly to try to maintain balance ☐
- Does not hold head and eyes steady ☐
- Makes no or few compensatory arm movements to help maintain balance ☐
- Exaggerated movements of arms and trunk disrupt balance ☐
- Cannot hold feet in a straight line ☐
- **Other** ________

Comments: ________

Balance 2: WALKING TOE-TO-HEEL BACKWARDS

Record: Number of correct consecutive steps from the beginning of the line; Whether entire line was walked successfully; **R** for refusal; **I** if inappropriate (note reasons below)

	No. of steps	Entire line?
Trial 1		YES / NO
Trial 2		YES / NO

Do not administer a second trial if the child completes 15 steps OR completes the whole line in fewer than 15 correctly executed steps

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Sways wildly to try to maintain balance ☐
- Does not look behind to check position on track ☐
- Does not compensate with arms to maintain balance ☐
- Exaggerated arm movements disrupt balance ☐
- Is very wobbly when placing feet on line ☐

Adjustments to task requirements

- Goes too fast for accuracy ☐
- Individual movements lack smoothness and fluency ☐
- Sequencing of steps is not smooth/pauses frequently ☐

Other ____________________

Comments: ____________________

Balance 3: ZIG-ZAG HOPPING

Record: Number of correct consecutive hops (maximum of 5); **R** for refusal; **I** if inappropriate (note reasons below)

		No. of hops			No. of hops
Right Leg	Trial 1		Left Leg	Trial 1	
	Trial 2			Trial 2	

Do not administer a second trial if the child completes 5 perfect hops on the first trial

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Non-supporting leg held up in front of body ☐
- Hops with stiff legs/on flat feet ☐
- Lacks springiness/no push-off from feet ☐
- Arm movements are exaggerated ☐
- Does not use arms to assist hop ☐
- Stumbles on landing ☐
- Does extremely poorly with one leg (asymmetry striking) ☐

Adjustments to task requirements

- Goes too fast for accuracy ☐
- Does not combine upward and forward movements effectively ☐
- Uses too much effort ☐
- Movements are jerky ☐

Other ____________________

Comments: ____________________

NON-MOTOR FACTORS THAT MIGHT AFFECT MOVEMENT

Complete the sections below by noting any features of the child's behaviour during testing that you suspect might have affected his or her motor performance. Headings (with examples) are given as guidelines only. Although negative aspects are given more emphasis, remember to note positive aspects of the child's behaviour.

	Yes	No
1. **Disorganised** (e.g. scattered clothes slows up dressing after PE; puts on shoes before socks).		
2. **Hesitant/forgetful** (e.g. slow to start complex actions; forgets what to do in the middle of an action sequence).		
3. **Passive** (e.g. hard to interest; requires much encouragement to participate).		
4. **Timid** (e.g. fearful of activities such as jumping/climbing; constantly asks for assistance).		
5. **Anxious** (e.g. trembles; becomes flustered in a stressful situation).		
6. **Impulsive** (e.g. starts before instructions are complete; impatient of detail).		
7. **Distractible** (e.g. looks around; responds to irrelevant noises).		
8. **Overactive** (e.g. squirms and fidgets; moves constantly when listening to instructions, fiddles with clothes).		
9. **Overestimates own ability** (e.g. tries to make tasks more difficult; tries to do things too fast).		
10. **Underestimates own ability** (e.g. complains of task difficulty; anticipates failure before starting).		
11. **Lacks persistence** (e.g. gives up quickly; is easily frustrated).		
12. **Upset by failure** (e.g. looks tearful; refuses to try task again).		
13. **Unable to get pleasure from success** (e.g. fails to respond to praise).		
Other (please specify).		
Overall, do you think these problems prevent the child from demonstrating his or her true movement capability (please circle)	**not at all** **a little** **a great deal**	

PHYSICAL FACTORS THAT MIGHT AFFECT MOVEMENT

Anatomical/postural defect: YES/NO Specify, if possible	
Vision defect: YES/NO	**Hearing defect:** YES / NO
Judgement of weight: average/overweight/underweight	
Judgement of height: average/tall/short	
Other	

SUMMARY OF QUALITATIVE OBSERVATIONS

MANUAL DEXTERITY (Body control/posture; functioning of limbs; spatial accuracy, contrd of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

AIMING & CATCHING (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

STATIC AND DYNAMIC BALANCE (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

ASSESSMENT SUMMARY AND INTERVENTION PLAN

Name:		Gender: M / F
Home address:		
School:	Class/Year/Grade:	Referral Source:
Movement Coach:	Date of meeting:	

A. Movement Competence

1. Results on standardised tests (enter total scores and mark percentiles)

Movement ABC-2 Test	Total Test Score				
Movement ABC-2 Checklist	Total Motor Score				

2. Profile of competence on Test and Checklist

Movement ABC-2 Test	Manual Dexterity				
	Aiming & Catching				
	Balance				
Movement ABC-2 Checklist	Section A Score		Comment		
	Section B Score				

3. Summary of motor observations common to Test and Checklist (use qualitative data from Test, along with individual item data from Checklist)

4. Other test data (summarise and describe outcome)

5. Child interview (summarise and list three main movement concerns)

6. Parent interview (summarise and list three main movement concerns)

7. School concerns in relation to movement

Continued on reverse

B. Non-motor factors that might affect the child's ability to perform/learn movement skills

The Movement ABC-2 Test and Checklist provide information on factors that might affect the child's ability to learn or perform movement skills. Examine the appropriate sections in the Test and Checklist, combine with any other data available, and summarise these here.

C. Overall profile of child's strengths and weaknesses

For some children the results of formal assessments of various kinds will be available. For others, school reports and interviews will provide enough information. Describe here any information you consider relevant to planning a movement programme for the child.

D. Environmental context

Varying amounts of support will be available for the child. Summarise here the potential – give names and degree of commitment where possible and specify the contribution to be made.

At home:

At school:

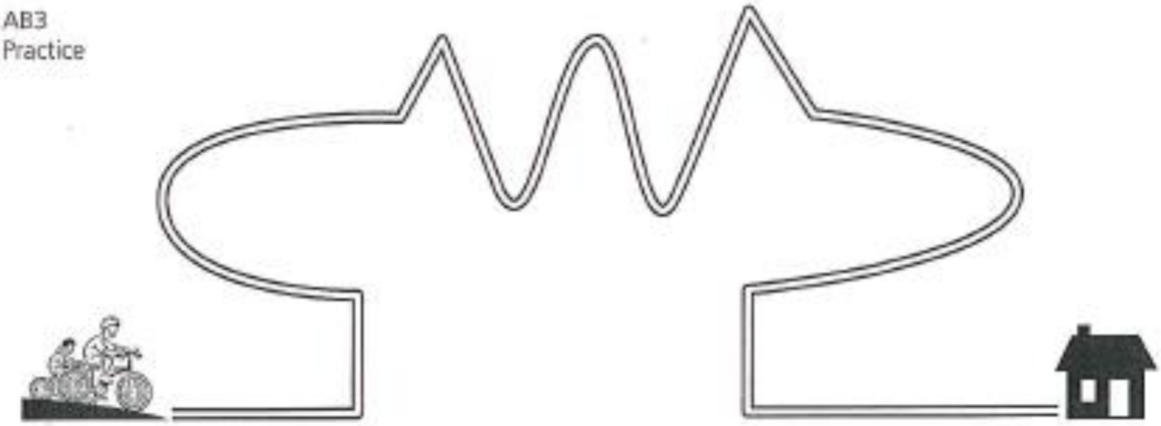
From the health services:

In the community:

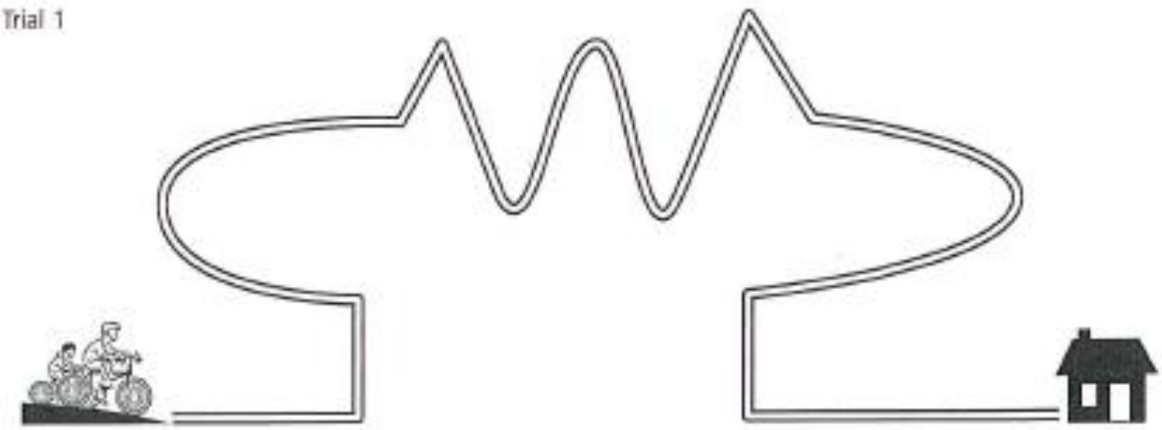
E. Objectives and main priorities

Summarise here the agreed short-term movement objectives for the child (and non-motor if any). Specify the target time for achievement and date of first review. On a separate sheet(s) outline in more detail how and where each target skill will be taught, and sketch the longer-term objectives.

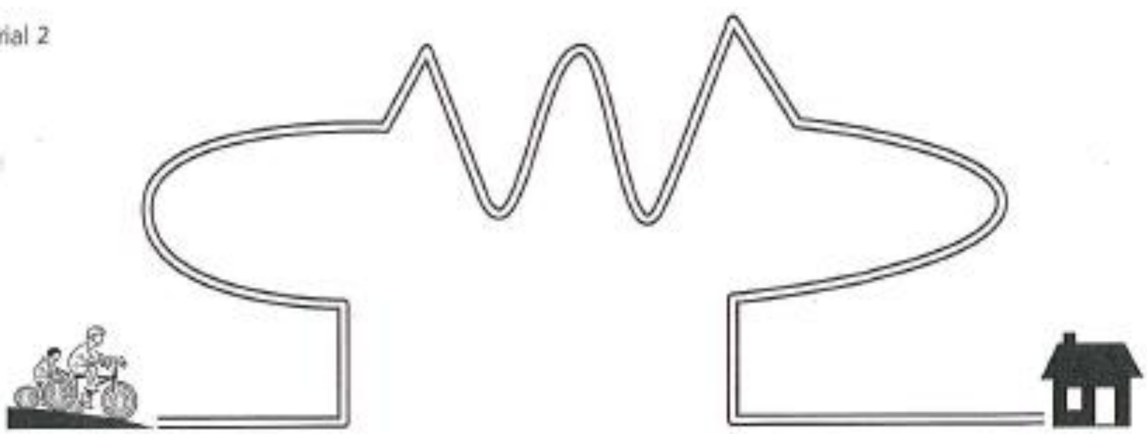
AB3
Practice



Trial 1



Trial 2



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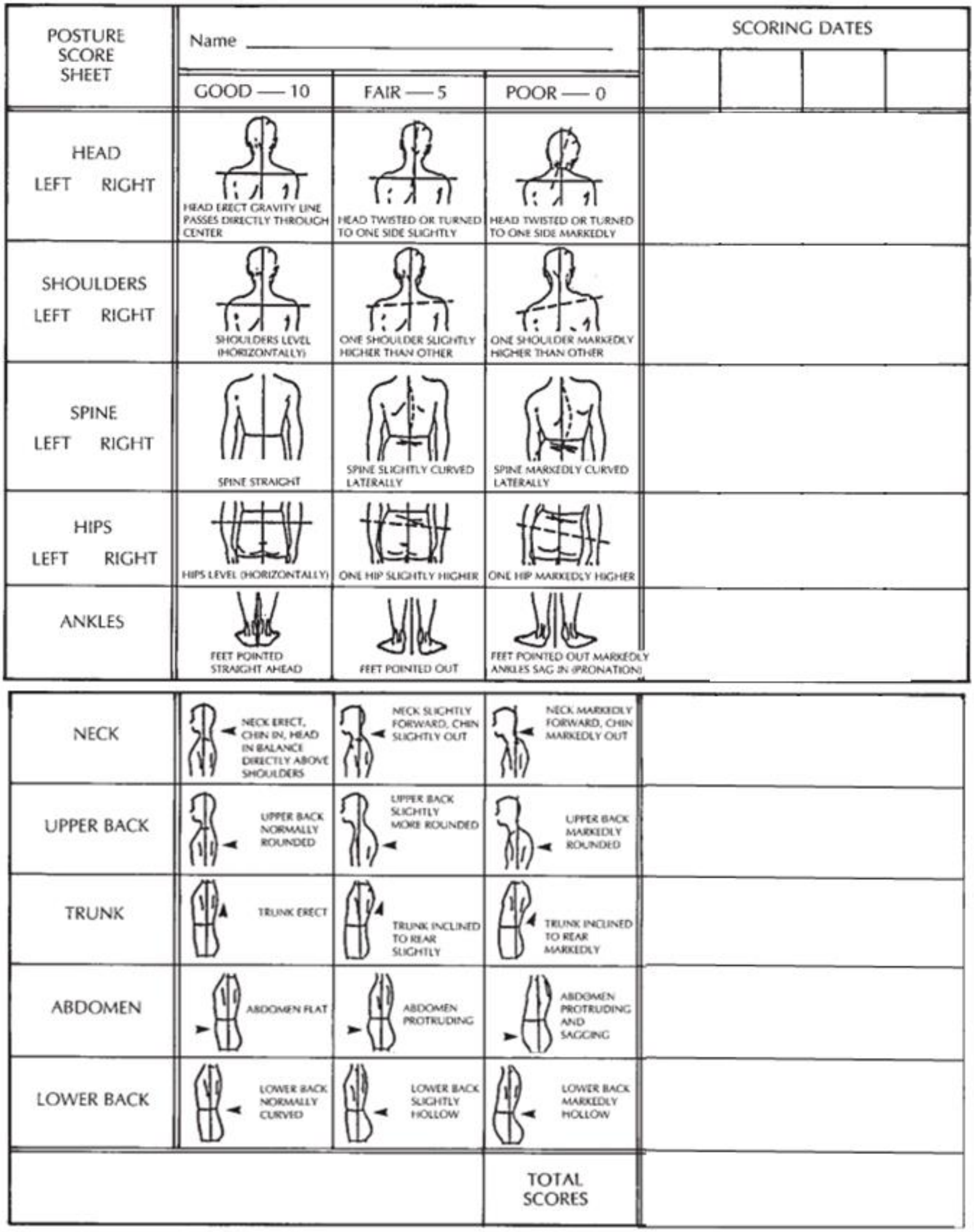
Appendix M: Posture scoring chart



POSTURE SCORE SHEET	Name ______			SCORING DATES
	GOOD — 10	FAIR — 5	POOR — 0	
HEAD LEFT RIGHT	HEAD ERECT GRAVITY LINE PASSES DIRECTLY THROUGH CENTER	HEAD TWISTED OR TURNED TO ONE SIDE SLIGHTLY	HEAD TWISTED OR TURNED TO ONE SIDE MARKEDLY	
SHOULDERS LEFT RIGHT	SHOULDERS LEVEL (HORIZONTALLY)	ONE SHOULDER SLIGHTLY HIGHER THAN OTHER	ONE SHOULDER MARKEDLY HIGHER THAN OTHER	
SPINE LEFT RIGHT	SPINE STRAIGHT	SPINE SLIGHTLY CURVED LATERALLY	SPINE MARKEDLY CURVED LATERALLY	
HIPS LEFT RIGHT	HIPS LEVEL (HORIZONTALLY)	ONE HIP SLIGHTLY HIGHER	ONE HIP MARKEDLY HIGHER	
ANKLES	FEET POINTED STRAIGHT AHEAD	FEET POINTED OUT	FEET POINTED OUT MARKEDLY ANKLES SAG IN (PRONATION)	
NECK	NECK ERECT, CHIN IN, HEAD IN BALANCE DIRECTLY ABOVE SHOULDERS	NECK SLIGHTLY FORWARD, CHIN SLIGHTLY OUT	NECK MARKEDLY FORWARD, CHIN MARKEDLY OUT	
UPPER BACK	UPPER BACK NORMALLY ROUNDED	UPPER BACK SLIGHTLY MORE ROUNDED	UPPER BACK MARKEDLY ROUNDED	
TRUNK	TRUNK ERECT	TRUNK INCLINED TO REAR SLIGHTLY	TRUNK INCLINED TO REAR MARKEDLY	
ABDOMEN	ABDOMEN FLAT	ABDOMEN PROTRUDING	ABDOMEN PROTRUDING AND SAGGING	
LOWER BACK	LOWER BACK NORMALLY CURVED	LOWER BACK SLIGHTLY HOLLOW	LOWER BACK MARKEDLY HOLLOW	
			TOTAL SCORES	

Appendix N: Online exercise intervention validation form

Sample and CD with entire form

Exercise Intervention Analysis

As an expert in your respective field I would like to ask for your assistance in completing the following form to get feedback and guidance on whether my proposed exercise intervention is suitable for adolescents with autism between the ages of 11-15.

*Required

Please view the programme overview below. Would you make any changes to the programme overview? If so please comment under the option "other" with proposed changes and reasons for the changes. *

- ○ The overview looks good, I would not make any changes
- ○ Other: ____

Overview of the 12 week intervention programme

Component	Intervention phase		
	Weeks 1-4	Weeks 4-8	Weeks 8 -12
Aerobic function	As part of the warm up and cool down One additional aerobic exercise to be included		
Strength	2 upper body 1 core 1 lower body	3 upper body 2 core 1 lower body	3 upper body 2 core 2 lower body
Endurance	2 exercises	Progress reps and sets	Progress reps and sets
Manual dexterity	2 exercises	2 exercises & progress	3 exercises
Ball skills	3 exercises	Increase speed and distance	Increase speed and distance
Balance	2 exercises	2 exercises (eyes open to closed)	3 exercises (eyes open to closed)
Agility	1 exercise	1 exercise	1 exercise
Gait	2 exercises	Progress exercises	Progress exercises
Posture	Postural corrections for each exercise done and emphasis on correct posture for ADLS		
Flexibility	*Stretching to be done at the end of each session		

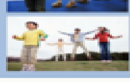
IN-DEPTH ANALYSIS OF WEEKS 1-4

The following questions pertain to weeks 1-4 of the exercise intervention

Please see the image below. Do you believe these 2 warm up exercises are appropriate for weeks 1-4 for the exercise intervention ? If no, please give a reason for your answer under the option "other". *

- ○ Yes
- ○ Other: ____

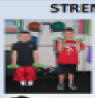
Warm-up exercises for weeks 1-4

TYPE OF EXERCISE	No.	EXERCISE	SETS	REPS	TIME
WARM UP  	2	A walk in available space "Jumping Jacks" dance – this dance will be done to music and the children will give ideas for moves that will slowly build their own dance	1 walk 1 dance	-	5 min

Please see the image below. Do you believe the following strength exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other" *

- ○ Yes
- ○ Other: ____

Strength exercises for weeks 1-4

TYPE OF EXERCISE	No.	EXERCISE	SETS	REPS	TIME
STRENGTH  	2 upper body	Bicep & tricep curls (with a 2kg weight) Squeezing balls/play dough or hand grip dynamometer	1 1	15 15	

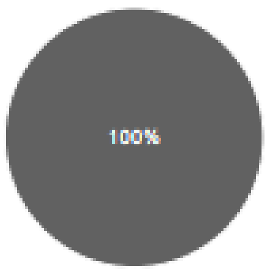
Appendix O: Summary of responses of online exercise intervention validation form

6 responses

View all responses

Summary

Please view the programme overview below. Would you make any changes to the programme overview? If so please comment under the option "other" with proposed changes and reasons for the changes.



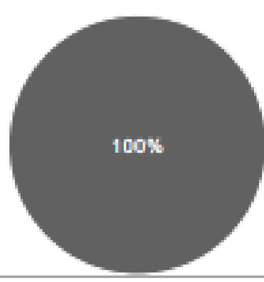
The overview looks good, I would not make any changes	6	100%
Other	0	0%

Overview of the 12 week intervention programme

IN-DEPTH ANALYSIS OF WEEKS 1-4

Please see the image below. Do you believe these 2 warm up exercises are appropriate for weeks 1-4 for the exercise intervention ? If no, please give a reason for your answer under the option "other".

Yes	6	100%
Other	0	0%



Warm-up exercises for weeks 1-4

Please see the image below. Do you believe the following strength exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Strength exercises for weeks 1-4

Please see the image below. Do you believe the following endurance exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Endurance exercises for weeks 1-4

Please see the image below. Do you believe the following manual dexterity exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Manual dexterity exercises for weeks 1-4

Please see the image below. Do you believe the following ball skills exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Ball Skill Exercises for weeks 1-4

Please see the image below. Do you believe the following balance exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

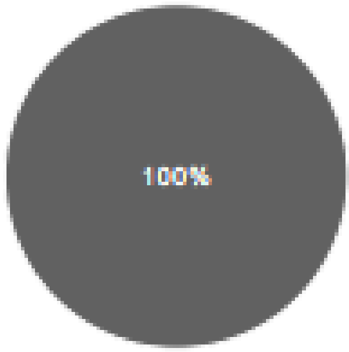
Balance exercises for weeks 1-4

Please see the image below. Do you believe the following agility exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Agility exercises for weeks 1-4

Please see the image below. Do you believe the following gait exercises are appropriate for weeks 1-4 of the exercise intervention? If no, please give a reason for your answer under the option "other"

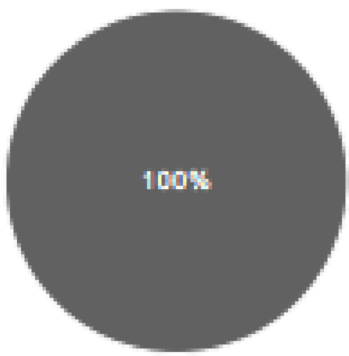
Yes	**6**	100%
Other	**0**	0%



Gait exercise for weeks 1-4

IN-DEPTH ANALYSIS OF WEEKS 4-8

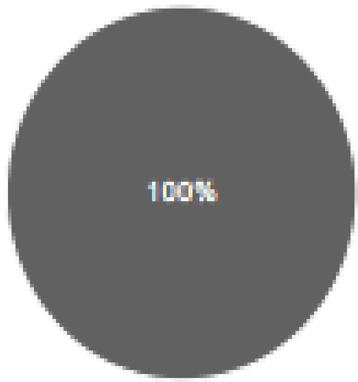
Please see the image below. The warm up exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	**6**	100%
Other	**0**	0%

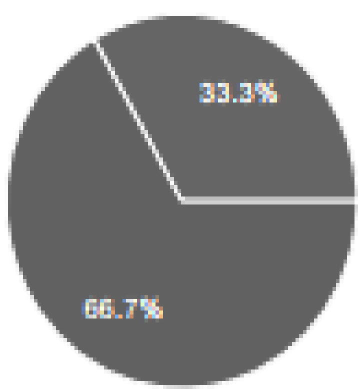
Progression of the warm-up exercises for weeks 4-8

Please see the image below. The strength exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Progression of the strength exercises for weeks 4-8

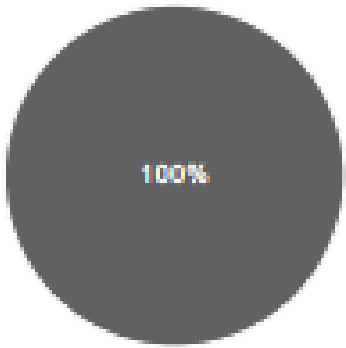
Please see the image below. The endurance exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	4	66.7%
Other	2	33.3%

Progression of the endurance exercises for weeks 4-8

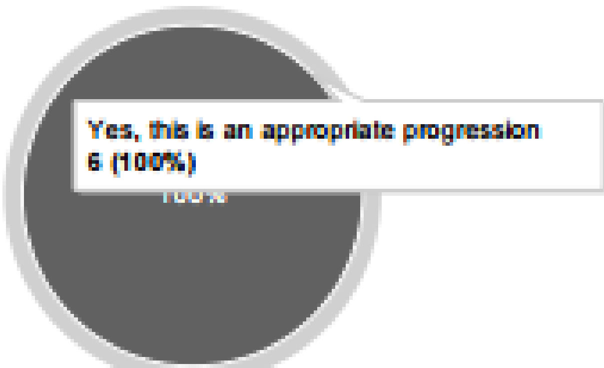
Please see the image below. The manual dexterity exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	6	100%
Other	0	0%

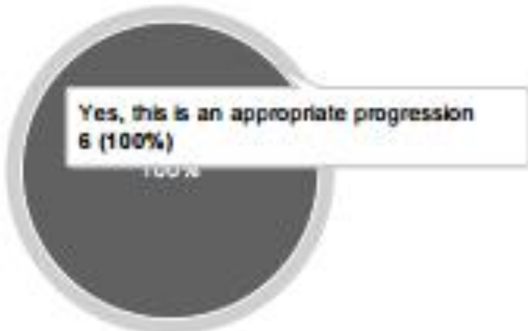
Progression of the manual dexterity exercises for weeks 4-8

Please see the image below. The ball skills exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Progression of the manual dexterity exercises for weeks 4-8

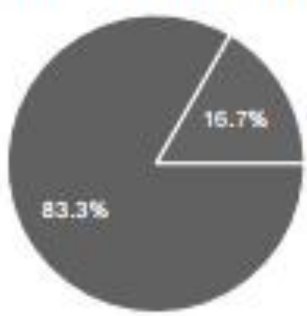
Please see the image below. The ball skills exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the ball skills exercises for weeks 4-8

Please see the image below. The balance exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	5	83.3%
Other	1	16.7%

Progression of the balance exercises for weeks 4-8

Please see the image below. The agility exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the agility exercises for weeks 4-8

The gait exercises have now been progressed from weeks 1-4. Do you believe the following progressions are appropriate for weeks 4-8 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

IN-DEPTH ANALYSIS OF WEEKS 8-12

Please see the image below. The warm-up exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

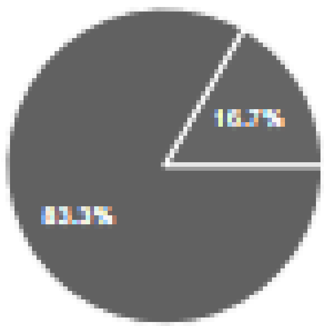
Progression of the warm-up exercises for weeks 8-12

Please see the image below. The strength exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the strength exercises for weeks 8-12

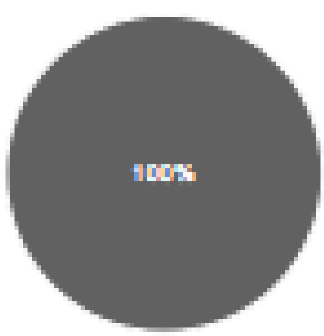
Please see the image below. The endurance exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	5	83.3%
Other	1	16.7%

Progression of the endurance exercises for weeks 8-12

Please see the image below. The manual dexterity exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"



Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the manual dexterity exercises for weeks 8-12

Please see the image below. The ball skills exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the ball skills exercises for weeks 8-12

Please see the image below. The balance exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the balance exercises for weeks 8-12

Please see the image below. The agility exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"

Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the agility exercises for weeks 8-12

Please see the image below. The gait exercises have now been progressed from weeks 4-8. Do you believe the following progressions are appropriate for weeks 8-12 of the exercise intervention? If no, please give a reason for your answer under the option "other"

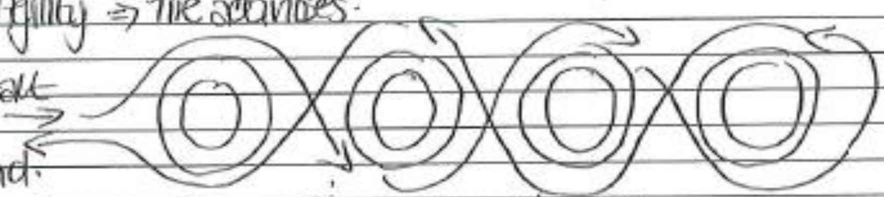
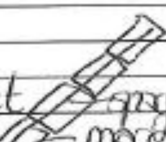
Yes, this is an appropriate progression	6	100%
Other	0	0%

Progression of the gait exercises for weeks 8-12

Thank you for your feedback !

Appendix P: Exercise intervention journal

Sample and CD with scanned copy of journal

Date	Exercise session notes
(5 mins) (5 mins) (3 mins) (5 mins) (5 mins) (5 mins)	⇒ Endurance ⇒ track exercises ⇒ walking marches ⇒ Ball skills ⇒ passing ball in circle ⇒ change direction on cue. ⇒ line passing ⇒ kicking ball ⇒ Balance ⇒ tandem walking on firm surface (10 m). single leg balance *careful with Nadia ⇒ Agility ⇒ The activities. start  End. maybe combine agility with endurance start ... 1 lap around track and start back at beginning?? Gait ⇒ 1 lap heel walking 1 lap toe walking 1 lap walking backwards. Manual dexterity ⇒ pasta guns ⇒ read on internet  spaghetti will be better than cheerios as children — macaroni more likely to eat cheerios instead of uncooked pasta. stretching & education @ end.
#2	Group 1 ⇒ All present warmup ⇒ 2 laps walking – some jogged some ran; walking with high knees (Nadia struggled), heel walks ⇒ changed direction half way through lap strength ⇒ sit to stand, punches & lat raises, bridges (Nadia very uncomfortable ⇒ stretch her hamstrings) whilst others done bridges Agility & Endurance ⇒ ∞ the weaving followed by running around track ⇒ 5 laps each Ball skills ⇒ line passing & circle passing. Balance ⇒ single leg & tandem walking ⇒ Nadia struggling ⇒ needs to hold on to me – William struggling ⇒ needs to hold onto stove Gait ⇒ heel walking ⇒ Michael very good ⇒ tries hard, Nadia struggling. toe walking all managed well – some slow ⇒ Charlotte & Nadia. Manual dexterity ⇒ pasta weaving ⇒ takes long ⇒ each one needs to do 2 spaghettis – Jake always ahead – can give more cheerios to him. stretching ⇒ hamstrings (David extremely tight), Michael tight & Nadia. Need to do stretching effective. Did toe touching, sitting glutes stretch & back stretch (kneeling).

Appendix Q: Human Research Ethics Certificate

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130753

NAME: (Principal Investigator)	Ms Natalia Neophytou
DEPARTMENT:	School for Therapeutic Sciences Faculty of Health Sciences
PROJECT TITLE:	The Efficacy of a 12-Week Exercise Intervention in 11 to 15 Years Old Adolescent with Autism
DATE CONSIDERED:	26/07/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr L Aginsky/Mrs N Benjamin
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 27/09/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.**

Principal Investigator Signature

M130753Date