THE EFFECTIVENESS OF ACTIVITY BASED INTERVENTIONS IN THE MANAGEMENT OF OVERWEIGHT AND OBESITY IN CHILDREN – A SYSTEMATIC REVIEW

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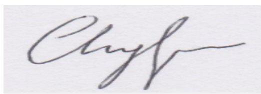
DECLARATION

I Chibuzo Ngozi Ezenwugo declare that this Dissertation is my own, unaided work. It is being submitted for the degree of MSc (Physiotherapy) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

__________________________

1st day of July 2020 in Tzaneen, Limpopo, South Africa

DEDICATION

To my greatest fan, my dearest husband, Emeka Ezenwugo (Snr),

To my amazing and considerate children, Emeka (Jnr), Tochi and Dera

To Mum and Dad, for giving me the opportunity to be who I am today

To every kind word and caring hand

that helped me attain this milestone

May you all be thoroughly blessed by the true giver of blessings.

Thank you, Jesus, for growing me through this challenging but rewarding process.

I owe all I am to you.

ABSTRACT

BACKGROUND: Childhood overweight and obesity is a disease that constitutes a current global pandemic. It leads to a series of morbid medical conditions which progress into adulthood. Sedentary living, unhealthy diets and the over-reliance on technology are implicated as reasons for the current pandemic. Concurrent aerobic and resistance exercises are an effective combination of physical activity interventions relevant for altering the body's energy expenditure. Physical activity interventions should be administered in conjunction with dietary control to ensure success. Furthermore, literature suggests that behavioural interventions, family involvement and prolonged monitoring will increase the likelihood of sustained weight loss.

AIM: To determine whether physical activity based interventions are effective in the management of overweight and obesity in children

METHODS: A comprehensive internet search identified randomised controlled trials published between January 2002 and February 2018 that used the BMI z-score to assess the efficacy of sole physical activity interventions in dealing with overweight/obesity in children aged 6-12-year-old.

RESULTS: Four studies were included in this systematic review. The risk of bias for each study was low. Physical activity interventions all resulted in a reduction of the BMI z-score, however, the degree of BMI z-score reduction varied between studies. The review results also showed that during the follow-up period, when direct supervision was removed, many participants regained some of the weight lost.

CONCLUSION: Sole physical activity based interventions are effective in reducing BMI z-score of overweight and obese children. Activity interventions should be conducted thrice weekly for about an hour and should include both aerobic and resistance exercises. However, multimodal interventions inclusive of diet, exercise and behaviour modification supersedes sole activity interventions in efficacy. A family supported dietary intervention with behavioural modification should be the first line of action followed subsequently by a long-term activity lifestyle change. Sustained weight loss often poses a challenge in most overweight and obesity management programmes. Family involvement and prolonged monitoring increase the likelihood of sustaining weight loss.

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DEFINITION OF TERMS

Terms	Definitions
Body Mass Index	Body mass index (BMI) is a value derived from the mass and height of a person. The BMI is defined as the body mass divided by the square of the body height and is universally expressed in units of kg/m^2, resulting from mass in kilograms and height in metres.
overweight	Overweight is a weight considered abnormal or undesirable. It is quantified as a BMI value at or greater than 85th to less than 95th percentile for age and sex.
obesity	Obesity is the state of being grossly fat. It is quantified as a BMI value that is at or greater than 95th percentile for age and sex.
physical activity	Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure. Physical activity encompasses all activities, at any intensity, performed during any time of day or night. It includes exercise and incidental activity integrated into daily activity.
z-score	z-scores are used to compare results to a “normal” population. The value of the z-score tells us how many standard deviations you are away from the mean. If a z-score is equal to 0, it is on the mean. If a z-score is equal to +1, it is 1 standard deviation above the mean. If a z-score is equal to -2, it is 2 standard deviations below the mean.

ABBREVIATIONS

Abbreviation	Description
% BF	Percentage body fat
BMI	Body Mass Index
BMI z-score	Body Mass Index standard deviation score
CDC	Centres for Disease Control
CG	Control group
CI	Confidence interval
CNS	Central nervous system
GRADE	Grading of Recommendations Assessment, Development and Evaluation tool
HICs	High-Income countries
IG	Intervention group
IOTF	International Obesity Task Force
LMICs	Low- and middle-income countries
METs	Metabolic equivalents
MD	Mean difference
MVPA	Moderate-to-vigorous physical activity
NHANES	National Health & Nutrition Examination Survey
PICO	Population, Intervention, Comparator, Outcome
RCT	Randomised Control Trial
RMR	Resting metabolic rate
SDT	Self-determination theory
SES	Socioeconomic status
TEF	Thermic effects of food
VAT	Visceral adipose tissue
VPA	Vigorous Physical Activity
WHO	World Health Organisation

“I reduced a huge fat fellow to a moderate size in a short time by making him run every morning until he fell into a profuse sweat……some hours later I permitted him to eat freely of food, which afforded but little nourishment; and lastly, set him to some work which he was accustomed to for the remaining part of the day”. – Galen (AD 160)

1. CHAPTER ONE: INTRODUCTION

"*When more food than is proper has been taken, it occasions disease" – Hippocrates, 400BC*

1.1. Introduction to chapter

This chapter gives a global overview of the cause, consequence, prevalence and demographics of overweight and obesity. It describes the important pillars of overweight and obesity management. The chapter goes further to outline the aim, objectives and rationale of the systematic review.

1.2. Overweight and Obesity – the elusive disease

Overweight and obesity are major health concern of the 21st century (Sabin et al., 2015, Morris et al., 2015, Eknoyan, 2006). They constitute an elusive (Callahan, 2013) worldwide pandemic that ravages global communities (Swinburn et al., 2011). The World Health Organisation (WHO) defines overweight and obesity as the abnormal buildup of excess fatty cells around the body, increasing the risk of impaired healthy functioning. The terms overweight and obesity are often used interchangeably, but they have distinctly different meanings. Overweight is simply an above-normal weight (Ogden and Flegal, 2010) and is a precursor to obesity (World Health Organization, 1998). Obesity, however, is gross fatness (Ogden and Flegal, 2010). Obesity is now labelled as a disease because its presence can directly initiate a train of morbid events that lead to death (Jung, 1997). Obesity, sadly, is a preventable disease (Ofei, 2005, Pool, 2001).

The body mass index (BMI) is a popular measure used to quantify body weight (Schwartz et al., 2017, Ogden and Flegal, 2010). The degree of overweight and obesity specifically in children is assessed using a measure called the BMI z-score (Pietrobelli et al., 1998) because the BMI z-score is able to account for the constantly changing body composition of children (Kelley et al., 2017).

In 2016, there was an estimated 1.9 billion overweight and obese adults globally (World Health Organisation, 2018). Growing worldwide overweight and obesity trends are seen not only in adults but also in children (Kyriazis et al., 2012). Global obesity statistics in child and adolescents have increased 10-fold since 1975, with the prevalence rising from 11 million in

1975 to 124 million in 2016 (World Health Organisation, 2018). Currently, the number of children and adolescents overweight globally stands at 213 million (World Health Organisation, 2018). The combined worldwide prevalence of overweight and obesity in children and adolescents is approximately 340 million (World Health Organisation, 2018). The Global Burden of Disease collaborative foresees a bleak future for overweight and obesity trends in children if effective strategies are not implemented to curb the growing problem (Lobstein and Jackson-Leach, 2016).

In Africa, the prevalence of overweight and obesity has doubled in the past 30 years – the fastest overweight and obesity growth rates recorded worldwide (De Onis and Blössner, 2000). The prevalence of obesity has increased rapidly in low- and middle-income countries (LMICs), particularly in Northern and Southern Africa, the Middle East and the Pacific Islands (World Health Organisation, 2018). Overweight and obesity prevalence in South Africa is amongst the highest in Africa (Reddy et al., 2009) and these trends are also explicitly noted in its child population (Armstrong et al., 2011). Nonetheless, the effects of undernutrition in some South African child populations have not fully abated, and this has led to communities being plagued with the coexistence of undernutrition and overnutrition (Popkin et al., 1996) suggesting that there is much more to the obesity disease that the just an absence or presence of food (Walker and Segal, 1980). Also, certain South African cultures may not be favourably disposed to weight loss because some still perceive thinness and weight loss as a sign of domestic struggles and even disease (Mvo, 1999).

Obesity, once established in childhood becomes difficult to reverse (Dehghan et al., 2005), often progresses into adulthood (McLennan, 2004) and ultimately results in numerous co-morbidities (De Onis et al., 2010a). Stroke, type II diabetes, hypertension, metabolic syndrome, sleep disorders and cancers are but a few health risks associated with obesity (Kopelman, 2007, Bitsori and Kafatos, 2005, McLennan, 2004). Type II diabetes and hypertension, previously known as diseases of adulthood, are now being detected in children (Pandita et al., 2016, Boutayeb and Boutayeb, 2005, Hannon et al., 2005) and have been linked to current obesity trends (Higgins and Adeli, 2017, Fowler-Brown and Kahwati, 2004). Only a drastic change in overweight and obesity trends will avert the imminent consequences of a large population of obese children growing up to become obese adults (Sabin et al., 2015).

Overweight and obesity in children also results in social consequences such as stigmatisation and discrimination (Gortmaker et al., 1993, Wardle et al., 2005) resulting in diminished self-esteem and other psychological fallouts (Wang et al., 2009). Health-related quality of life (HRQOL) is also negatively affected in obese children (Ravens-Sieberer et al., 2001). A study conducted by Schwimmer et al. (2003) stated that obese children have a lower HRQOL than even children undergoing chemotherapy for cancer. The complexity of obesity is further compounded by the fact that there is a significant genetic component to its aetiology (Jung, 1997) and pathogenesis (Pijl, 2011).

The economic consequence of obesity is notable. Obesity, as well as obesogenic diseases, place a significant financial burden on a country's health system and ultimately result in limited productivity of the economically active population (Some et al., 2016). Obese children are often absent from school for more days than those of normal weight (Geier et al., 2007). Data collected from the United States Medical Expenditure Panel Surveys (MEPS) found that obese patients had relatively higher annual medical expenses than their normal weight counterparts. Obesity also accounts for a significant portion of annual increments in healthcare spending (Apovian, 2016).

Overweight and obesity in children can be attributed to a combination of factors. Dietary patterns, activity, lifestyle habits and urbanisation (Armstrong et al., 2006, Mvo, 1999, Cameron et al., 1992) all feed into the condition. The relationship between cultural, socioeconomic and genetic predisposition also play significant roles (Apovian, 2016, Boutayeb and Boutayeb, 2005). Technological advancement and fast-paced living have resulted in changes in global dietary habits and has impacted on activity and fitness levels in children (Hummel et al., 2013). Paediatric aerobic fitness levels have declined steadily since the 1970s (Tomkinson and Olds, 2007) and the increasing sedentary behaviour seen in children has been shown to have a direct correlation with adverse health outcomes (Nelson et al., 2006).

Childhood overweight and obesity is partly a consequence of insufficient and irregular physical activity (Ildikó et al., 2007). Physical activity is considered a major pillar in paediatric obesity prevention and management because of its influence on body composition and metabolism (Epstein et al., 1998). Promoting physical activity in children is a strategic way of encouraging energy expenditure and thereby controlling weight (Must and Tybor, 2005). An imbalance in the consumption of energy through feeding versus physical activity leads to weight gain (Spear et al., 2007). Beyond improving a child's body composition, physical activity presents other benefits to the individual such as physical fitness (Rowland and Boyajian, 1995), bone health (Janssen and LeBlanc, 2010) and general well-being (Yu et al., 2008). Yackobovitch-Gavan et al. (2009) reported that even moderate amounts of physical activity have the potential to improve the psychological state in adolescents. A review conducted by Strong et al. (2005) on physical activity recommends a daily dosage of at least 60 minutes of moderate- to- vigorous physical activity (MVPA), 5-8 METS (metabolic equivalents for specific activities based on the ratio of activity to resting energy expenditure) in school-age children. The WHO supports this recommendation (World Health Organisation, 2010a). Activities as basic as bicycling, brisk walking and active outdoor play are enough to meet daily activity targets that help to control overweight and obesity (Strong et al., 2005). The walking school bus is an innovative intervention, aimed at promoting physical activity in children. The walking school bus practices the concept of active transport (Sabin et al., 2015) and involves group walking to- and-from school under the safe supervision of an adult. This community-based child transport programme promotes MVPA in children and encourages both parental and community involvement (Mendoza et al., 2011). Walking is a form of activity that expends energy (Morris and Hardman, 1997) and therefore the walking school bus is an innovative and exciting strategy to sustain activity in school children. Moreover, physical activity habits formed in childhood are often carried over into adult life (Huang et al., 2009, Taylor et al., 1999).

Dietary modification forms another integral pillar of overweight and obesity management (Crino et al., 2003). Teaching families to eat healthy foods is a way of combatting childhood obesity (Brown, 2011). The Traffic Light Diet, developed by Dr LH Epstein, codes each food type according to the colours of a traffic light. Each food is labelled as an unhealthy choice - RED, an "okay" choice - AMBER or a healthier choice – GREEN (Epstein et al., 1984). This family-based approach to paediatric obesity management was developed to encourage the consumption of nutrient-dense foods while discouraging high-calorie intake (Brown, 2011). The Food Guide Pyramid is another popular child and adult dietary guide that has been adopted by various countries to suit their individual population needs (Painter et al., 2002).

Behavioural therapy is additionally an important pillar of child weight management. For activity and dietary interventions to be successful, there needs to be appropriate behavioural therapy to stimulate positive decision-making (Dietz and Robinson, 2005). Goal setting, problem-solving, healthy thinking-about-food, relapse prevention, parental modelling and monitoring are essential constituents of behavioural therapy (Spear et al., 2007).

Multiple studies have found that implementing overweight, and obesity prevention and management strategies in a family setting produces favourable results (Golan, 2006, Ling et al., 2016, Ranucci et al., 2017). Even interventions that have been targeted only at the child's parents are successful and also economically viable (Mead et al., 2017). The success of these interventions could be due to the parent's integral role in shaping the lifestyle behaviour of their children (Golan, 2006, Ling et al., 2016). When parents embrace the responsibility for weight loss, positive activity and dietary habits are reinforced at home, making weight maintenance an attainable goal. Weight maintenance success may be achieved in the home when the main objective is to slow down weight gain as the child grows rather than to achieve a time-structured weight loss (Israel et al., 1987). This slow but steady progress ultimately results in a reduction of body mass index (BMI) as their height increases (Barlow and Dietz, 1998).

González-Gross et al. (2008) designed a comprehensive pyramid called the Healthy Lifestyle Pyramid that integrates both feeding, activity and behavioural guides into a self-explanatory educational tool. It offers child-specific and evidence-based guidelines on how to achieve both dietary and exercise benefits resulting in a healthy lifestyle. The WHO supports the creative integration of various weight management protocols when dealing with overweight and obesity pandemic. The organisation advocates for evidence-based policies that make multifaceted weight management strategies available to all (World Health Organisation, 2018).

A reduction in the dependence and usage of technology and screen-devices has also produced minimal but favourable results (Spear et al., 2007). Weight loss medication (Spear et al., 2007), surgical intervention (Luttikhuis et al., 2009) and a sugar-tax system (Escobar et al., 2013) are other strategies being used to tackle this growing problem.

Unfortunately, there is minimal consensus, limited understanding and unremarkable success in the use of activity interventions to manage overweight and obesity in children (Alberga et al., 2013b, Trost et al., 2014). There is limited evidence-based data on the topic (Shalitin et al., 2009) because many randomised control trials assess the impact of multimodal interventions whereas only a few focus solely on physical activity interventions (Farpour-Lambert et al., 2009). Limited management success can be attributed partly to the ineffective execution of weight management designs that sustain physical activity participation (Alberga et al., 2013b, Trost et al., 2014).

Jiménez-Pavón et al. (2010) concluded that weaknesses in study methodologies had played a significant role in the lack of conclusive evidence on the topic. Methodological flaws include subjective measures of physical activity; inaccurate measurement of study outcomes and imprecise definition of the target population (Jiménez-Pavón et al., 2010). For this review, studies with a well-defined population of interest, a prescribed dosage of physical activity as well as BMI z-score measures have been selected to address the methodological challenges noted by Jiménez-Pavón et al. (2010).

1.3. Problem statement

Overweight and obesity in children constitute a growing global challenge, spanning through both high-income countries (HICs) and low- and middle-income countries (LMICs) (Ng et al., 2014). The epidemic feeds into an array of lifestyle disease patterns, some of which arise even in childhood (Ogden et al., 2006). Although various literature support the integration of physical activity into effective overweight and obesity management, its implementation remains unclear (Ling et al., 2016).

There is a dearth of reviews that focus solely on the effective implementation and sustainability of activity interventions (Mead et al., 2017). Moreover, there is little conclusive evidence on the type and dosage of activity interventions that will result in long-term weight control in 6-12-year-old children. Children in this age group are at a time when they begin to develop self-confidence, personal identity, peer awareness, body consciousness and an understanding of the future (Centres for Disease Control and Prevention, 2019). Therefore, interventions need to be customised to meet their specific needs.

1.4. Review question

Are activity based interventions effective in the management of overweight and obesity in children?

1.5. Review aim

To determine whether physical activity based interventions are effective in the management of overweight and obesity in children

1.6. Review objectives

- To determine what type of activity based interventions are used in the management of overweight and obesity in children (the type of activity and dosage of activity)
- To determine whether these interventions have been effective
- To suggest how sustainability of interventions can be ensured based on the literature available

1.7. Significance of the study

In the past 30 years, the global prevalence of overweight and obesity has risen more rapidly in children than in adults (Ng et al., 2014). It is, therefore, imperative that appropriate and prompt action is taken to manage the spike in the prevalence of paediatric obesity that has become a threat to public health (Booth et al., 2003).

Children who perform regular physical activity are more likely to carry this healthy practice into adolescence and adult life (Alberga et al., 2013b, Huang et al., 2009, Alberga et al., 2013a). It is preferable to tackle weight problems at an earlier stage in life because overweight and obesity intervention programmes are more effective in younger children (Knop et al., 2015) and obese children are better able to lose and maintain weight loss than adults (Epstein et al., 1995). If interventions are not instituted early, the degree of overweight and obesity often increases (Gupta et al., 2012) and becomes more challenging to treat. Baker et al. (2007) discussed the adverse effects of overweight and obesity in childhood and highlighted that the age bracket between 7-to-13 years as a critical period for intervention and prevention of the disease.

This review seeks to enhance the body of literature on the appropriate management of overweight and obesity during this critical period in a child's life. The review intends to determine how to effectively institute physical activity interventions in overweight and obesity management, a topic that has been poorly documented on and experienced only minimal success (Trost et al., 2014).

1.8. Conclusion of chapter

This chapter has provided a clear overview of the overweight and obesity complex and the motivation for this systematic review. The following section will provide a detailed definition and classification of overweight and obesity. The literature appraisal will describe the pathogenesis and consequences of overweight and obesity as well as current ways of managing the disease.

2. CHAPTER TWO: LITERATURE REVIEW

*"It is easier to preserve **Health** than to recover it, and to prevent **Diseases** than to cure them…. without due **Labour** and **Exercise**, the **Juices** will thicken, the **Joint** will stiffen, the **Nerves** will relax and, on these **Disorders**, **Chronical Distempers**, and a crazy old Age must ensue". – Cheyne G, 1724*

2.1. Introduction to chapter

This chapter aims to provide an in-depth description and classification of overweight and obesity. This chapter will delve into the origin, aetiology and progression of the disease while offering solutions based on current evidence obtained from scholarly literature.

2.2. Anthropometric measures used for quantification of overweight/obesity

The precise measurement of body-fat mass requires the use of costly and complex high-tech equipment (Kumar and Kelly, 2017) such as dual-energy X-ray absorptiometry (DXA) (Vanderwall et al., 2018, Pintauro et al., 1996), magnetic resonance imaging (MRI) and computed tomography (CT) (Yu et al., 2010). However, these tools are uncommon in most domestic and clinical settings, difficult to understand in lay terms and with regards to the use of CT scans, require exposure to radiation (Pietrobelli et al., 1998). Various anthropometric tools are useful in quantifying body weight and are described below.

2.2.1. Body mass index (BMI)

The body mass index (BMI) is the most basic (De Onis et al., 2010b) and reliable (Sebo et al., 2008) marker of childhood and adolescent overweight and obesity, appropriate for use in clinical assessments (Krebs et al., 2007, Barlow and Dietz, 1998) and able to isolate the weightiest children with some measure of accuracy (Pietrobelli et al., 1998). It has therefore been chosen for use in this systematic review. It is a surrogate anthropometric measure (Javed et al., 2015) for quantifying overweight and obesity, is currently the most common and widely accepted gauge (Schwartz et al., 2017, Ogden and Flegal, 2010). Hence, it can be used as a screening tool to identify children who are at risk of developing obesogenic diseases in adulthood (US Preventive Services Task Force, 2010). The higher a child's BMI, the higher their probability of becoming an obese adult (Krebs et al., 2007).

The BMI is calculated by determining the weight and height relationship (Keys et al., 1972, Ogden and Flegal, 2010, Prentice and Jebb, 2001). It is widely utilised because it is derived from these two basic anthropometric measures, recorded routinely in clinics visits (Himes, 2009). It is a useful tool for goal setting and progress monitoring because it is easily appreciable by lay people (Himes, 2009). The precise measurement of weight and height require attention to detail to ensure measurement accuracy (Lampl et al., 2001, Lipman et al., 2004). Measurement reliability for measures like height and weight are often sufficient for BMI calculations (Himes, 2009).

Although relatively user-friendly (Pietrobelli et al., 1998), this measure poses its own specific set of challenges. The BMI is unable to differentiate between muscle mass and fat mass (Vanderwall et al., 2018, Llewellyn et al., 2016, World Health Organisation, 2000) hence there has been a longstanding debate on whether other bodyweight measures should be favoured over the BMI (Kragelund and Omland, 2005). Children are in a constant state of growth and development and therefore their body fat, height and weight are very fluid values that vary according to age and sex (Caroli et al., 2007, Ogden and Flegal, 2010, Kumar and Kelly, 2017). The BMI is also deficient when measuring children with atypical body structures (Kumar and Kelly, 2017) and it is unable to account for height/weight ratio changes noticed at certain growth spurts phases of childhood and adolescence (Franklin, 1999). This has resulted in the use of the BMI z-score for quantification of overweight and obesity specifically in children.

2.2.1.1. BMI z-score

Age and gender-specific BMI is known as the BMI z-score or BMI standard deviation score (SDS). The z-score is derived from the child's age, gender and BMI value (Pietrobelli et al., 1998) and is based on a reference scale that quantifies the variability of a child's BMI from the mean value of a reference child population of the same age and sex (Himes, 2009, Pietrobelli et al., 1998). BMI in children is measured this way to accounts for their ever-changing body composition (Kelley et al., 2017). High BMI-for-age is the standard criteria used to define overweight and obesity in children (Barlow and Dietz, 1998, Hedley et al., 2004). The Centres for Disease Control defines overweight as BMI z-score > 1.04 and obesity as BMI z-score > 1.64 (Vanderwall et al., 2018). It is a useful and appropriate measure for assessing BMI changes over time (Himes, 2009) and determining annual changes in adiposity in children (Inokuchi et al., 2011, Berkey and Colditz, 2007).

Various scholars have refuted this argument by querying the accuracy of the BMI z-score as a measure of adiposity in children (Freedman et al., 2017, Vanderwall et al., 2018). Vanderwall et al. (2018) conducted a study on a large cohort of obese children to determine whether the BMI z-score is an appropriate tool for detecting medium to long-term changes in body fat. Body fat changes were monitored using dual-energy x-ray absorptiometry to confirm whether the results of the BMI z-score were accurate. After the intervention was administered, the study found that although the BMI z-score displayed 70% sensitivity to changes in body fat, it fell short on specificity (42%). This low specificity implied that there was only a 42% likelihood of the BMI z-score to recognise changes in body fat. The study concluded that BMI z-score should be used as a screening tool and not as a measure of the change in obese children. Prior to this, Vanderwall et al. also carried out another observational study in 2017 to establish whether the BMI was a suitable prognostic tool for adiposity in young overweight and obese children. The findings of this study concurred with those of the later 2018 study and cautioned the use of the BMI z-score as a prognostic indicator of percentage fat mass and total fat mass in children less than 9years (Vanderwall et al., 2018). The study, however, also stated that in children older than nine years, the BMI z-score was a good prognostic indicator of total fat mass (Vanderwall et al., 2017). Must and Anderson (2006) agreed with these findings stating that because BMI is unable to differentiate between fat and muscle tissue, therefore BMI and BMI z-score run the risk of wrongly classifying children into overweight and obesity categories and are only effective in public health research. Similarly, in a cross-sectional study of 1196 children and adolescents, Freedman et al. (2009) also identified the handicap of the BMI z-score to categorise overweight children accurately. Most recently, a study by Woo and Cole (2017), again, questioned the use of BMI z-score in assessing weight status and change especially in extremely obese children.

Various other scholars have also stated that the BMI z-score does not provide an accurate prediction of body fat content (Ellis et al., 1999, Wells, 2000). However, Reilly (2006) argued in favour of the BMI and in effect, the z-score. Reilly (2006) stated that even though BMI is not able to accurately predict body fat content, it can still benefit the diagnosis of overweight and obesity in children because it is not necessary to accurately determine body fat mass for a diagnosis of overweight and obesity to be made.

BMI z-score is a relevant measure for assessing overweight and obesity management interventions. A retrospective chart values and percent body fat as well as an increase in lean body mass post-intervention. The improvement in BMI z-score was also significantly related to improvements in biochemical outcomes (Kirk et al., 2005). This study supports the relevance of the BMI z-score as a tool for assessing obesity intervention programmes and also shows that the BMI z-score is directly related to changes in percent body fat and biochemical outcomes, even if not accurately. Another study which aimed to assess the effect of exercise-only interventions on BMI z-score also displayed changes in percent body fat. The study was conducted as a systematic review and meta-analysis by Kelley et al. (2014) on a sample of 835 overweight and obese children and adolescents. In favour of the BMI z-score, the study recorded statistically significant reductions in BMI z-score and percent body fat. This result suggests that exercise improves BMI z-score and percent body fat in children and adolescent. However, Kelley et al. (2014) also added that the BMI z-score is not necessarily the most sensitive indicator of body composition and changes observed in body fatness may not always reflect on the BMI z-score value. Another systematic review and network meta-analysis review examined a clinical behavioural weight management programme using BMI z-score and other biochemical measures. The weight management programme included dietary and physical activity advice as well as prescribed weekly group exercise sessions. The results showed a significant reduction in BMI z-score by (Kelley et al., 2017) has come out in support of the BMI z-score for use in assessing exercise effectiveness over time. The study included 34 randomised control trials representing a sample of 2,239 participants from a wide range of racial groups. The review recorded a significant direct linkage between reductions in BMI z-score and exercise training but advised that additional well-designed randomised trials were necessary. This was because when the Grading Recommendations Assessment, Development and Evaluation (GRADE) was conducted to determine the strength of the body of evidence, confidence in the results were considered low to very low and downgraded based on study limitations and inconsistency. However, (Kelley et al., 2017) still expressed confidence in the results because of consistency among study findings and apparent intransitivity.

Other body composition assessment tools exist but tend to fall short when compared to the BMI because of their high level of technicality and impracticality or frankly, their inability to offer any benefit beyond what the BMI already provides. However, the relevance of these other body composition assessment tools become appreciable when determining a child's obesity risk profile (Gower et al., 1999, Katzmarzyk et al., 2004). Some of these other measures are described below.

2.2.2. Skinfolds

Body skinfolds measures body fat by determining fat thickness in areas such as the triceps, biceps, abdomen, subscapular etc. (Caroli et al., 2007). It is a useful, non-invasive tool because it specifically assesses subcutaneous fat (Krebs et al., 2007). Inconsistencies in the subcutaneous and total body fat ratio have been recorded in people of varying sex, age and ethnic profile (Wells, 2001). There is limited reference literature on the use of skinfold thickness measurements in children (Bedogni et al., 2003) and the measure seems to hold no real value over the BMI (Krebs et al., 2007). Additionally, it relies heavily on accurate inter-rater consistency and therefore requires a certain level of expertise (Wells, 2001).

2.2.3. Body circumference

Body circumference gives an indication of fat distribution and especially of abdominal adipose tissue. Waist circumference has attracted significant attention as a viable measure of adiposity in children (Krebs et al., 2007) because paediatric abdominal obesity often trails into adulthood (Goran et al., 1998) and has been linked to metabolic disorders (Barreira et al., 2012, Tanaka et al., 2004) and cardiac disease (Tchernof and Despres, 2013, Carr et al., 2004, Despres, 2006). The waist circumference provides a good indication of blood pressure, cholesterol levels and Type 2 diabetes status (Lee et al., 2006, Maffeis et al., 2001). However, its application in clinical settings is often challenging, and the measure has shown no ability that exceeds that of the BMI (Sarria et al., 2001). It is, therefore, more often used only as a risk assessment tool (Krebs et al., 2007). The hip circumference can also be used to determine waist-hip-ratio when assessing general health, although this measure shows a weaker relationship with body fatness than the waist circumference (Seidell et al., 2001).

2.2.4. Bioelectrical impedance analysis (BIA)

The BIA is a well-known, inexpensive and user-friendly assessment tool used both in healthy and ailing subjects (Kyle et al., 2015, Wang and Shen). It distinguishes between lean muscle mass and body fat tissue (Kyle et al., 2004) and then uses a scientific equation to determine total body fat (Williams et al., 2007). It measures the resistance (impedance) of body tissue to a minimal dose of electrical current that is undetectable by the human body (Kyle et al., 2004). Body composition values derived from the BIA can be used to assess the dietary status and monitor development in the growing child especially under controlled settings like healthcare institution. However, the measure has poorly standardised implementation procedures for different ages, gender and ethnic groups (Khalil et al., 2016). The BIA is also limited in relevance to individual measurements and various studies have labelled the BIA as a poor estimator of individual body composition (Jaffrin et al., 2011, Pichler et al., 2013).

Other measurement tools not described here are air displacement plethysmography (ADP) and hydrodensitometry. Further research ingenuity is needed to identify the most appropriate diagnostic tools necessary for determining the degree of overweight and obesity in children so that population-specific measures can be taken for dealing with the current global pandemic (Reilly, 2006).

2.3. Classification of children into overweight or obese categories

There is a lack of consensus on a singular universal cut-off for defining overweight and obesity (Caroli et al., 2007, Gupta et al., 2012, Schwartz et al., 2017). There are three major classification definitions of overweight and obesity. The International Obesity Taskforce (IOTF) (Cole and Lobstein, 2012), the World Health Organization (WHO) (De Onis et al., 2004) and the Centres for Disease Control and Prevention (CDC) (Kuczmarski, 2002) all have different reference ranges for defining overweight and obesity in children (Cole et al., 2000, De Onis and Blössner, 2000).

The IOTF growth charts are an acceptable growth reference dataset compiled based on data retrieved from six countries (Brazil, Great Britain, Netherlands, United States, Singapore and Hong Kong) (Cole et al., 2000). The reference provides BMI growth charts with age and gender-specific cut-offs from 2-18 years expressed as percentiles or standard deviation scores (Cole et al., 2000). The IOTF cut-off for overweight is close to the 90th percentile while that of obesity lies above the 98th percentile (Cole and Lobstein, 2012). The original intention of the IOTF cut-offs was to provide a singular worldwide definition for paediatric overweight and obesity thereby replacing the different reference definitions that were based on country-specific data. Although the IOTF cut-offs are comparable to the WHO growth standard and growth reference curves (De Onis and Lobstein, 2010), the different reference definitions have proved to be incompatible, hence creating a challenge when seeking a comprehensive perspective of the state of worldwide overweight and obesity prevalence (Cole and Lobstein, 2012).

In 2007, the WHO published for children 5-19 years, growth reference curves using data from Brazil, Ghana, India, Norway, Oman and the United States (De Onis et al., 2004). The curves outline the ideal growth pattern for normal healthy children (De Onis et al., 2004). A homogenous sample of children were used in determining these growth curves and therefore the dataset tends to exclude outlying children with very high or very low BMI percentiles and z-score values (De Onis et al., 2004). The WHO growth charts do not include BMI values beyond standard deviations of two because these values are not defined as 'healthy' BMI. The WHO growth charts also face a similar challenge on the other end of the growth chart spectrum, where children with low BMI percentiles lie. The WHO overweight and obesity reference range falls short when identifying children with extreme weights as compared to the CDC growth charts (Mei et al., 2008).

The 2000 National Centre for Health Statistics and the Centres for Disease Control and Prevention (CDC) growth charts originate for use in the US child population aged 2-18 years (Kuczmarski, 2000). The growth charts outline percentiles for various ages and can be used to determine z-scores based on height, weight, gender and BMI-for-age values (Kuczmarski, 2000). The 2000 CDC growth charts use the following BMI ranges for defining overweight and obesity in 2-18-year olds:

<u>*Overweight:*</u> *BMI at or greater than 85th to less than 95th percentile for age and sex*
<u>*Obesity:*</u> *BMI at or greater than 95th percentile for age and sex*
<u>*Severe obesity:*</u> *BMI at or greater than 120% of the 95th percentile for age and sex, or BMI at or above 35 kg/m^2*

Yet still, Skinner and Skelton (2014) described further grading of obesity into the following categories:

<u>Class I obesity:</u> BMI at or above 95th percentile to less than 120% of the 95th percentile

<u>Class II obesity:</u> BMI at or above 120% to less than 140% of the 95th percentile, or BMI at or above 35 kg/m^2

<u>Class III obesity:</u> BMI at or above 140% of the 95th percentile, or BMI at or above 40 kg/m^2

This review favours the use of the 2000 CDC definition and growth charts (Kuczmarski, 2002) because they outline a range of percentiles and allow for the calculation of BMI Z-score whereas the IOTF charts are not favourable in this regard (Himes, 2009). The WHO growth charts are homogenous and not inclusive of the weightiest children, limiting its ability to assess children with higher BMI percentiles and z-scores (De Onis et al., 2007) - the category of children that are relevant to this review. The 2000 CDC growth charts provide an effective tool for monitoring BMI and have been widely adopted by many experts (Krebs et al., 2007). However, the weakness of the CDC definitions and growth charts and other cut-off definitions lies in the fact that they were not compiled according to descriptive standards relevant specifically for African and Asian populations (Rossouw et al., 2012).

2.4. Epidemiology

Global overweight and obesity prevalence in children have been well documented. Over the past 20 years there been a spike in the prevalence of overweight and obesity among children (García-Hermoso et al., 2018) affecting both HICs and LMICs (Ellulu et al., 2014). There are discrepancies in reported estimated prevalence because of the varying classification cut-offs used in different countries. However, there is still universal consensus is that the worldwide prevalence is high and still rising (De Onis et al., 2010b, Lobstein et al., 2015, Ng et al., 2014, Rossouw et al., 2012, World Health Organisation, 2018). Nonetheless, some other studies have reported that over the past 10-15 years, the steep increase in prevalence has abated and somewhat plateaued out (Olds et al., 2010, Howel, 2011, Wabitsch et al., 2014, Thomas et al., 2014, Chung et al., 2016, Merema et al., 2019, Ng et al., 2014). The levelling off of overweight and obesity trends is limited to HICs (Olds et al., 2010, Wabitsch et al., 2014, Gregg and Shaw, 2017, Ng et al., 2014), varying among racial groups (Madsen et al., 2010, Gregg and Shaw, 2017) and widening between people of different socioeconomic groups (Chung et al., 2016).

Some studies have ventured as far as suggesting that overweight and obesity prevalence rates among children are now on a decline (Morgen et al., 2013, Rodd and Sharma, 2016).

In 2016 the WHO estimated that globally, there are four million children under five years-of-age and 340 million children and adolescents between 5-19 years who are either overweight or obese. Adults above 18 years-of-age recorded a prevalence of 1.9 billion (World Health Organisation, 2018). Two relatively recent United Kingdom (UK) articles (King, 2011, Agha and Agha, 2017), predicted that the UK obesity prevalence would range from 60-65% in adult men and 25-50% in adult women by 2050. According to Agha and Agha (2017) this rising trend also applies to children with the number of obese boys aged six to 10 years estimated at 50% by 2050. Although these articles were not conducted as systematic reviews and the methodology used to calculate such estimates were undocumented, their results are still of some significance and are of great concern. The extent of the overweight/obesity pandemic can be appreciated when a crude comparison is made between prevalence figures from earlier years and these 2050 estimates. The prevalence of obesity among adult in the UK was only 15% in 1993 (Mokdad et al., 2003) and even lower at 13.4% in 1960 for the United States of America (Flegal et al., 2010).

The latest Global Burden of Disease Study on overweight and obesity in adults and children, conducted in 2013 (Ng et al., 2014), analysed systematically identified literature while employing the use of a mixed-effects linear regression to adjust for study biases. It reported estimates for both HICs and LMICs using the BMI. The document provides a comprehensive breakdown of the current state of worldwide overweight and obesity trends. Even though bodyweight categories were based on the IOTF definitions of BMI (Cole and Lobstein, 2012) as opposed to CDC definitions (Kuczmarski, 2000) used in this review, these figures are still relevant. The document gives specific percentages in gender and age categories for a ≈30-year comparison. Adult overweight and obesity had significantly increased between 1980 and 2013 [male: 28.8% (95% UI 28.4-29.3) to 36.9% (36.3-37.4)], female: [29.8% (29.3-30.2) to 38.0% (37.5-38.5)]. For children and adolescents in HICs the prevalence increased from 16.9% (16.1-17.7) to 23.8% (22.9-24.7) in boys and 16.2% (15.5-17.1) to 22.6% (21.7-23.6) in girls between 1980 and 2013. Amongst children and adolescents in LMICs an increase from 8.1% (7.7-8.6) to 12.9% (12.3-13.5) in 2013 for boys and from 8.4% (8.1-8.8) to 13.4% (13.0-13.9) in girls was recorded.

Both the WHO and the Global Burden of Disease studies recorded a higher prevalence of overweight and obesity amongst adult females than males (females - 40% and 38%, males – 39% and 36.9% respectively) (World Health Organisation, 2018, Ng et al., 2014). Other published studies have provided varying data on the breakdown of the worldwide prevalence of overweight and obesity according to demographics profiles. Kelly et al. (2008) recorded a higher prevalence of overweight in males (24%), but higher prevalence of obesity in females (11.9%) in 2005 while Agha and Agha (2017) recorded the prevalence of obesity amongst adult women to be 22% and that of males to be 28%. Among children and adolescents, the WHO reported that the prevalence of overweight and obesity was higher in boys than in girls in 2016 (19% and 18% respectively) (World Health Organisation, 2018). A recent National Health and Nutrition Examination Surveys (NHANES) conducted in the USA, between 2015 - 2016 using the CDC overweight/obesity classification, documented different results. The study noted no significant difference in the prevalence of obesity amongst boys and girls aged 6-11 years, stating that the prevalence amongst girls and boys has averaged out (Hales et al., 2017).

The Global Burden of Disease stratified the information according to HICs and LMICs (Ng et al., 2014). For HICs the prevalence of overweight and obesity was higher in boys than in girls in 2013 (23.8% and 22.6% respectively) while in LMICs the reverse was the case (12.9% in boys and 13.4% in girls). Other scholars have recorded varying figures for overweight and obesity prevalence in boys and girls. For 2010, Agha and Agha (2017) recorded a higher overweight and obesity prevalence in girls (24%) than in boys (19%) for the UK population, a HIC.

In South Africa, the 2010 North West Child-Health-Integrated-Learning and Development (NW-CHILD) longitudinal study concurred with the findings of (Ng et al., 2014) but added that the prevalence of obesity amongst boys was on an upsurge when compared to girls even though girls still showed a higher overall prevalence of obesity (Pienaar, 2015). Study discrepancies may be attributed to the use of differing definitions for overweight and obesity, as well as variations in study population groups. However, the overall consensus is that we have not yet mastered a way of effectively dealing with the disease.

Childhood overweight and obesity growth trends in LMICs have overtaken those seen in HICs (World Health Organisation, 2018). The two major culprits implicated for the rising prevalence of overweight and obesity in LMICs are a reduction in physical activity levels and the consumption of energy-rich and fatty diets (Boutayeb and Boutayeb, 2005, Prentice, 2005). Until recently, health programmes in LMICs have emphasised the eradication of poverty and malnutrition as well as reducing child and maternal mortality rates (Boutayeb and Boutayeb, 2005, Kelishadi, 2007, Lobstein et al., 2004). However, the current overriding threats to public health in developing countries are obesogenic diseases (Adogu et al., 2015). Kelishadi (2007) has emphasised the need for a shift in focus to evidence-based prevention and treatment protocols that target overweight and obesity in children while still paying attention to nutritional deficiencies in such populations.

A review conducted by Gupta et al. (2012) compiled cross-sectional data from children in 21 different LMICs, of which South Africa was one of these. Study findings of this review ought to be interpreted with caution because the review included studies published between 1974-2010 that utilised various diagnostic criteria for defining overweight and obesity. The review concluded that in 1995, an average of 3.3% of preschool children (under 5years) in all LMICs were overweight with Africa having the second-highest global figures (3.9%) (De Onis et al., 2010b, De Onis and Blössner, 2000). The WHO concurs with this finding and has placed Africa's overweight and obesity epidemic growth rates at the highest globally stating that numbers have doubled between 1990 and 2010 (World Health Organisation, 2018). Furthermore, in the (Gupta et al., 2012) study, children in the older age bracket of 5-19 years recorded an even higher prevalence of overweight and obesity (10%), implying that overweight and obesity figures increase as children get older. Armstrong et al. (2006) conducted a South African study between 2001 - 2004 to determine the prevalence of overweight and obesity in boys and girls aged 6-13 years old based on a sample of 10,195 primary school children. The study sample was selected from five of the nine South African provinces and was representative of children from different socioeconomic backgrounds. The study reported overweight and obesity figures based on the IOTF standard cut-offs, with adjustments made for representation of the different South African ethnic groups. The study concluded that the prevalence of overweight and obesity amongst South African boys was 10.9 and 2.4 % respectively. Amongst girls overweight and obesity prevalence stood at 17.5% and 4.8% respectively. These figures show similar trends to those recorded by the Global Burden of Disease Study (Ng et al., 2014) which also recorded that girls in LMICs were weightier than boys. Despite the high prevalence of overweight and obesity in LMICs, policy development driven by national government is lacking in many LMICs (Lachat et al., 2013).

Overweight and obesity trends in South Africa seem to be following the trends seen in HICs (Armstrong et al., 2006, Truter et al., 2010). A South African cross-sectional descriptive report compiled by Rossouw et al. (2012) summarised results from 19 different studies conducted between 1999 and 2004 on children and adolescents. Most studies assessed weight status using the IOTF cut-offs. The results showed that earlier studies recorded a much lower prevalence of overweight and obesity and that later studies reported a prevalence of approximately 15% for overweight and obesity in children and adolescents. Ng et al. (2014) also recorded a 15% prevalence for overweight and obesity in HICs in the early 1980's. Additionally, the Rossouw et al. (2012) study recorded a marked difference in prevalence among various geographical areas, ethnic groups, age groups and between boys and girls. The rise in the prevalence of overweight and obesity in early childhood and at the beginning of adolescence tended to be gender and ethnicity dependent. There was a higher prevalence of overweight and obesity in girls especially towards menarche which was attributed to physical activity levels around puberty which are shaped by socio-cultural values. (Agha and Agha, 2017) also agrees that ethnicity is a major determinant of obesity and also noted differences in the prevalence of overweight/obesity along ethnic lines. Overweight/obesity figures in African girls increased during puberty while the opposite occurred in Caucasian girls. Armstrong et al. (2006) attributed this variation partly to social conditioning. Another explanation for this finding could be the tendency for some African communities to perceive overweight as a sign of affluence, positive well-being (Mvo, 1999) and the absence of HIV/AIDS (Clark et al., 1999).

It is obvious that variables such as social conditioning, racial profile and socioeconomic status are not to be overlooked when dealing with the overweight/obesity pandemic but rather require adequate consideration by the multidisciplinary team. Studies on multidisciplinary cost-effective approaches including activity based interventions have been conducted mainly in HICs (Atay and Bereket, 2016) although Lobstein et al. (2015) still believes there is great need for further studies.

2.5. The genesis and history of obesity

The physical features of overweight and obesity were first described by Mohr in 1840 (Brobeck, 1946). However, its origin dates back 30,000 years ago when the concept of "survival of the fittest" fuelled the thinking that those who stored the most energy would survive times of food scarcity (Haslam, 2007). The origin of obesity was initially attributed solely to excessive food intake and not necessarily to reduced physical activity. A theory labelled the "thrifty gene hypothesis" links obesity to a genetic predisposition (Serlie et al., 2011) that causes the body to have an excessive insulin response to feeding thereby limiting the deficiency of glucose in times of food shortage (Eknoyan, 2006, Haslam, 2007, Pijl, 2011).

This theory supports the belief that what we term as obesity today, was originally a side effect of natural human evolution (Eknoyan, 2006). King (2011) also suggests that the current overweight and obesity pandemic goes beyond sedentariness and overindulgence, but that instead, our bodies are not metamorphosing at the same pace as our society.

The notion that having excessive "flesh" was desirable was well evident in the Middle Ages, as is depicted in the artwork of the time (Eknoyan, 2006) but by the early 1900s, a shift in thinking was fuelled by the recognition of obesity as a health problem with the medical consequence (Guerrini, 2000). In 1905, William Osler ascribed obesity to "overeating - a vice more prevalent than and only a little behind over drinking in its disastrous effects" (Eknoyan, 2006). However, during the early 20th century, there was still some belief that fatness was a symbol of wealth and prosperity with obesity occurring mostly in aristocrats who had unlimited access to food and who carried out intellectual duties that did not require much physical activity (Haslam, 2007). A heavy child was seen and a healthy child and the concept of "bigger is better" was well accepted (Dietz, 1998).

Gradually, doctors noticed a rise in the number of bigger bodied patients presenting with medical conditions and found that bigger bodied patients did not live for as long as their normal-weight counterparts. They initially took this evidence lightly, thinking it was because the affected individuals failed to understand the connection between calorie intake, body weight and the medical consequences (Pool, 2001). The quest for a solution to obesity led to the use of diet prescription as the first standard management for obesity (Cahnman, 1968). Regrettably, this offered only limited and short-lived success. Scientists continued conducting extensive research, attempting to answers questions on eating, metabolism, genetics and their relationship with obesity (Pool, 2001).

In the mid-1900s, John R. Brobeck conducted laboratory experiments on rats and found that the hypothalamus, a small part of the human brain, was responsible for satiety and hunger (Brobeck, 1946). Dr GC Kennedy went further to propose that body fat is controlled by an "adiposity negative feedback" system in the hypothalamus (Kennedy, 1966) which regulates the amount fat the body stores, a mechanism that is "fiercely defended" by the body (Richard and Picard, 2011). It was during this period that obesity was first recognised as a cause of illness (Eknoyan, 2006).

Alongside this discovery, psychoanalysts of the Freudian era in the 1930s proposed psychotherapy as an alternative. The aim was to deal with the subconscious drives in people that were causing them to overeat. They championed behavioural therapy as the appropriate intervention and hypothesised that the removal of environmental cues that triggered overeating would solve the problem (Cahnman, 1968). The hypotheses proved to be a futile intervention – as the prevalence of obesity continued to rise.

In the early 1980s, scholars warned that obesity was slowing progressing into a global epidemic and not just a problem of Western industrialised countries (Gilman, 2008). In a 1981 issue of the UK's The Times newspaper, an article that mentions "a war against obesity, sloth and addiction", pointed towards this growing realisation (Haslam and Haslam, 2009). Scholars cautioned that the battle against overweight and obesity would be a major scourge of the 21st century (van Asseldonk, 2016, Gilman, 2008) over tobacco smoking which at that time was labelled as "the war of the 20th century" (Cole and Fiore, 2014). The problem became even more apparent and somewhat comical when the USA struggled to enlist some recruits into military service and also had to deal with combat readiness of those on active duty because of their weight status (Tanofsky-Kraff et al., 2013, Gilman, 2008). Unfortunately, today, the global overweight and obesity pandemic has become established.

2.6. The pathogenesis of overweight and obesity

Hippocrates, the father of traditional medicine, taught that all effective medical treatment must be founded on a clear understanding of the fundamentals surrounding the development of the disease (Serlie et al., 2011). Hence, an in-depth knowledge into the manner of the pathogenesis of overweight and obesity will shed light on better treatment protocols, inform policy-making and disease awareness, thereby, improving health and economic outcomes (Schwartz et al., 2017). Although much work has been done on obesity research, studies have been conducted mainly on adult subjects or mature animal models (Campbell et al., 2011). Our understanding of the pathogenesis of overweight and obesity remains somewhat of a mystery to scientists (Schwartz et al., 2017, Schwartz et al., 2000) and the physiology surrounding weight regulation specifically in childhood an even greater enigma (Campbell et al., 2011). Hill et al. (2012) are convinced that the pathogenic mechanisms that influence weight loss and weight gain in adults are the same as that in children.

A simplistic explanation of the disease is that overweight and obesity are the consequence when calorie consumption exceeds energy expenditure for a sustained period of time (Serlie et al., 2011, Velloso et al., 2008, De Souza et al., 2005, Levine et al., 2005, Marques-Lopes et al., 2004) and that high levels of energy influx or outflow will result in either weight gain or weight loss (Hill et al., 2012). However, the pathogenesis of overweight and obesity is more complex than this (Schwartz et al., 2017) which is the very reason why it has been so challenging to treat.

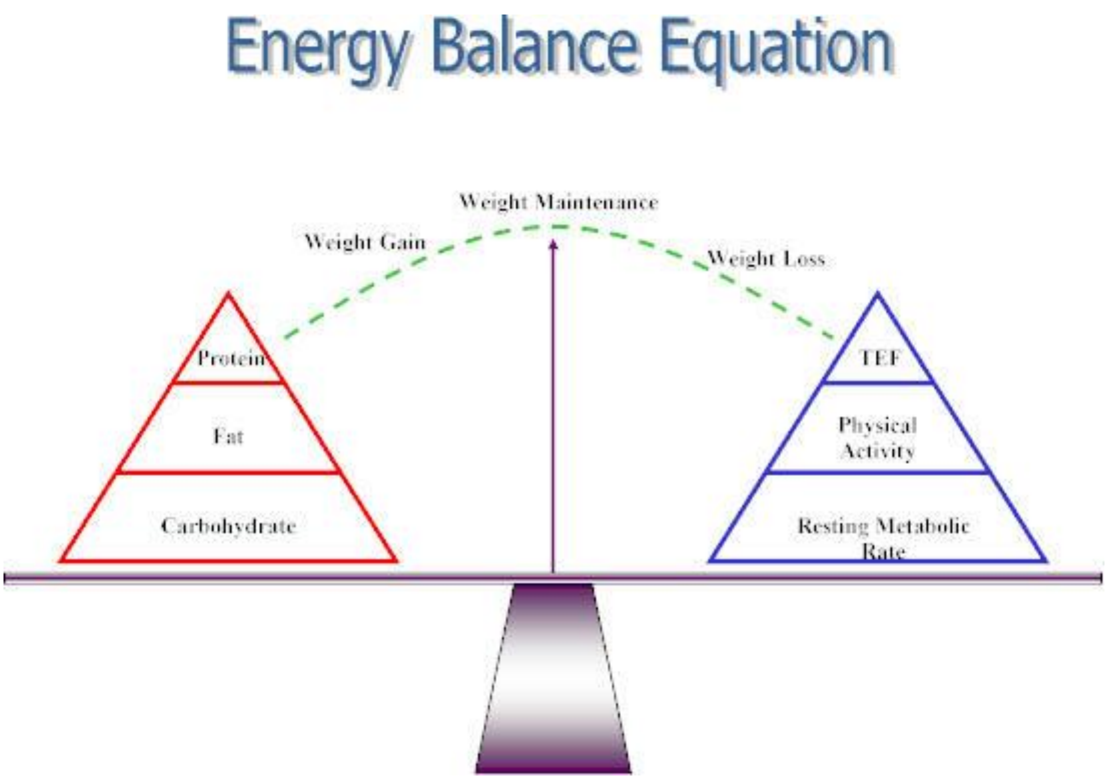

Figure 2:1: Energy balance equation (Seebohar, 2002)

A good understanding of the energy balance equation is critical for effective obesity management (Hill et al., 2012). Bodyweight hinges on the energy balance equation (also referred to as the energy homeostasis system) and all genetic and environmental factors influence weight loss/weight gain via this equation (Hill et al., 2012). Energy balance has three components: energy intake, energy expenditure and energy storage. Energy intake occurs through food intake while energy expenditure is achieved through physical activity, resting metabolic rate (RMR) and thermic effects of food (TEF) (Seebohar, 2002). The RMR is defined as energy combustion when we are at rest while the TEF refers to the energy expended during food metabolism (Poehlman and Horton, 1989). Weight loss can only occur if energy output exceeds energy intake. Conversely, weight gain occurs when there is a resultant positive energy balance (Hill et al., 2012).

The physiological regulation of body weight occurs through the central nervous system (CNS). Afferent nerve fibres carry information about the state of body's energy stores to the brain while efferent fibres respond with information from the CNS to effect energy intake and expenditure (Sandoval et al., 2008). Energy balance is necessary for normal energy homeostasis. The energy homeostasis system enables stability in the body's energy stores by regulating energy intake and expenditure (Blundell et al., 2015).

Leptin and insulin are hormones that are necessary for the regulation of the body's adiposity levels (Schwartz et al., 1997). Leptin and insulin levels in the blood indicate the body's fat content and energy balance (Considine et al., 1996, Bagdade et al., 1967). Low leptin and insulin blood levels as a result of fasting, acts on the hypothalamus (Sabin et al., 2015) to stimulate appetite and inhibit energy expenditure (Hill et al., 2012). The opposite is the case when there is food intake - satiety signals are stimulated to regulate portion size and modulate food intake and energy balance (Schwartz et al., 2000). The two pathways have opposite effects on energy homeostasis and in effect determine how much fat is stored.

Saturated fatty acids in unhealthy diets form a major part of the cascade of homeostatic changes that lead to diet-induced obesity (Moraes et al., 2009, Milanski et al., 2009). Research has shown that the frequent consumption of energy-rich fatty foods results in some sort of micro assault to the hypothalamus that triggers an inflammatory response (Cintra et al., 2012, Thaler and Schwartz, 2010, Milanski et al., 2009). This alters the anorexigenic and thermogenic signals generated by leptin and insulin, disrupting the body's natural energy homeostasis system and thereby causing the base body mass value to be adjusted upwards and set at a higher level (Velloso et al., 2008) leading to overweight. A chronic imbalance between energy intake and energy expenditure may look small when assessed daily but on the long run, it amounts to a constant positive energy balance (Sabin et al., 2015) and the recalibration of the body's base weight to an increased value (Thaler and Schwartz, 2010) ultimately resulting in obesity. This adipose tissue dysfunction ultimately leads to high body-mass levels (Klöting et al., 2014) that become "fiercely defended" by the body and challenging to recalibrate (Schwartz et al., 2017) resulting in weight loss difficulty.

A randomised control trial conducted by Cintra et al. (2012) on mouse models, aimed to confirm the effects of calorie-dense saturated fatty acid diets on overweight and obesity while contrasting the impact of unsaturated fatty acid diets on hypothalamic activity. The study confirmed the significance of saturated fatty acid diets on the installation and progression of the disease. Conversely, unsaturated fatty acid diets had a significant beneficial impact on the control of food intake and body mass. Another randomised study on mice subjects determined that moderate and consistent physical activity (treadmill running) significantly reduced hypothalamic inflammation and normalised energy homeostasis (Yi et al., 2012).

2.7. The overweight and obesity cause-effect complex

Genetic, hormonal, environmental, familial, physical, dietary and socioeconomic components are all etiological variables that affect the childhood overweight and obesity complex (Gupta et al., 2012, Incledon et al., 2011) which further compound the elusiveness of the disease. Management interventions have generally been tunnel-visioned, focusing mainly on the two major culprits of childhood overweight and obesity - diet and physical activity. However, even though some etiological variables may not directly influence energy balance, they are sometimes the precursors and intermediaries that connect unhealthy eating and activity with overweight and obesity in children (Hemmingsson, 2014). The figure below was developed based on scientific literature from over 460 references and the Nutrition Ecological Model (NutriMod). It provides a clear picture of the multiplicity of cause-effect determinants of overweight and obesity. Diet, activity and biological factors affect overweight and obesity directly while all other factors play an indirect role in the development of overweight/obesity (Hummel et al., 2013).

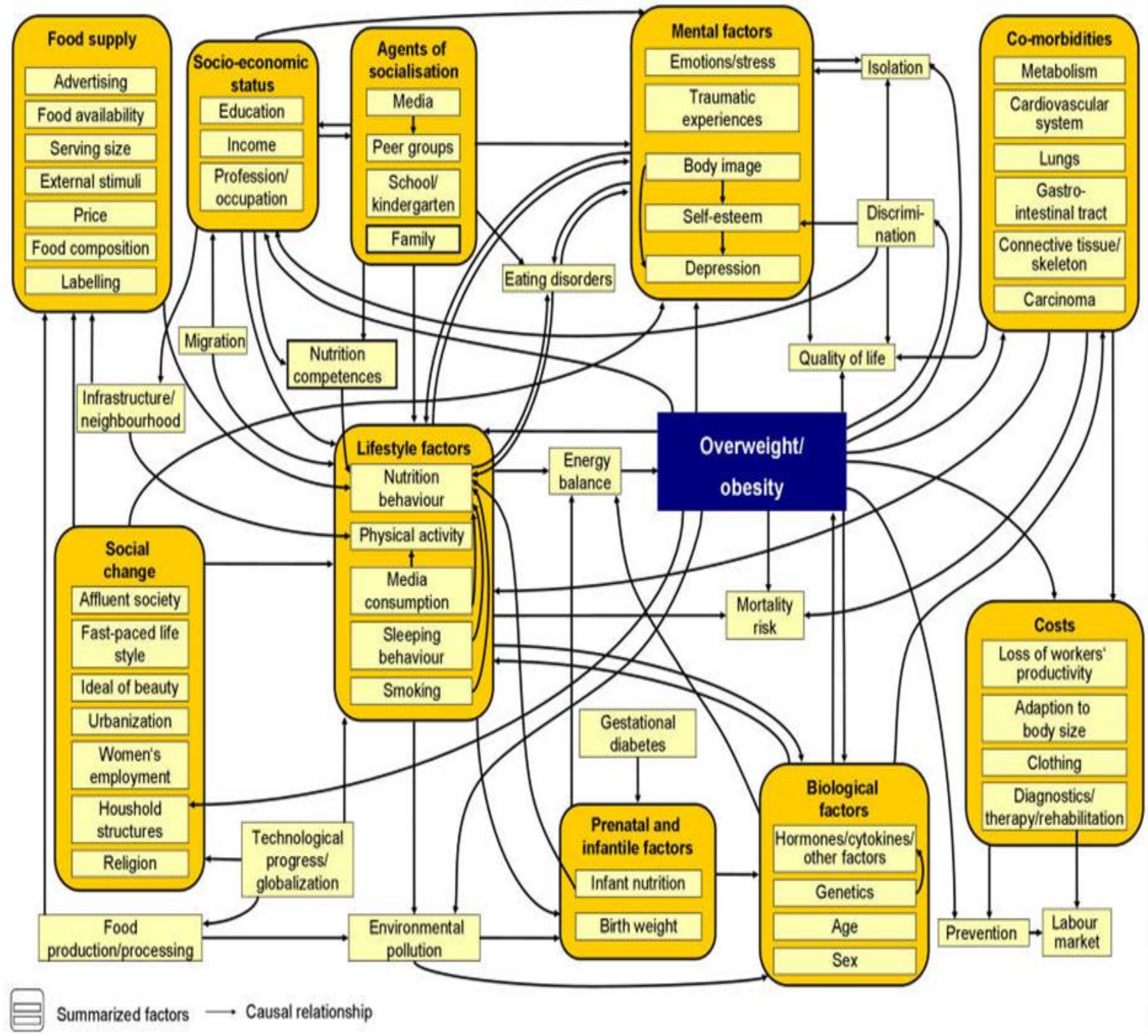

Figure 2:2: The overweight and obesity cause-effect complex (Hummel et al., 2013)

The following section uses Figure 2.2 as a guide to expound on the cause-effect overweight/obesity complex as it relates to children. Their complex relationship will be discussed under the following subheadings:

- Biological factors
- Perinatal and infantile factors
- Social change
- Co-morbidities
- Lifestyle factors
  - Food supply and nutritional behaviour
  - Physical activity
- Agents of socialisation
  - Family and peers
  - Myths, beliefs, culture and religion
- Socio-economic status
- Economic cost
- Mental factors

2.7.1. Co-morbidities and the childhood overweight/obesity complex

Paediatric overweight and obesity can be directly linked to a cascade of noncommunicable diseases as described below.

The life bracket between early life and adolescence is a critical period that shapes the future risk of developing lifestyle diseases (Newton et al., 2017). However, we are yet to fully understand the nature of the association and in-depth studies by way of various meta-analyses are still lacking (Llewellyn et al., 2016). Childhood overweight and obesity impedes quality of life (Friedlander et al., 2003, Ravens-Sieberer et al., 2001) and significantly compounds the risk of developing multiple lifestyle diseases many of which only become apparent in adulthood (Brisbois et al., 2012, Simmonds et al., 2015). Diabetes mellitus (Chan et al., 1994, Colditz et al., 1995) and hypertension (Rimm et al., 1995, Willett et al., 1995) in adulthood are two major obesogenic diseases that have been linked to high body mass index (BMI) in childhood (Reilly et al., 2011). Nowadays, these diseases are being detected even in childhood as a result of current overweight and obesity trends (Pandita et al., 2016, Boutayeb and Boutayeb, 2005, Hannon et al., 2005, Higgins and Adeli, 2017, Fowler-Brown and Kahwati, 2004). Obesity-induced musculoskeletal disorders such as arthritic joint changes lead to painful joints and further limit the mobility of obese children (Jung, 1997, Wearing et al., 2006, Must and Strauss, 1999). Respiratory challenges such as asthma (Gennuso et al., 1998, Papoutsakis et al., 2013) and various forms of sleep apnoea (Bhattacharjee et al., 2011, Chay et al., 2000, Verhulst et al., 2007) have also been linked to childhood obesity. Sleep quality indicators such as sleep onset, duration, depth and sleep respiration quality may be hampered (Beebe et al., 2006) resulting in daytime drowsiness which has a significant impact on a child's scholastic performance and emotional balance (Beebe et al., 2006). Sleep disorders can also be associated with satiety and hormonal changes that alter metabolic and endocrinal balance (serotonin secretion and glucose combustion) leading to overeating, further entrenching the disease (Rosmond and Björntorp, 2000). A recent systematic review and meta-analysis by Llewellyn et al. (2016) confirmed that most adult diseases of lifestyle have a significant correlation with paediatric obesity. Childhood overweight and obesity significantly increases premature mortality in adulthood (Reilly and Kelly, 2011). Ultimately, we may see a reversal in modern day's steady increase in life expectancy as a result of overweight and obesity trends (Daniels, 2006).

2.7.2. Biological factors affecting the childhood overweight/obesity complex

Paediatric obesity is a complex phenotype with self-evident characteristics. Its complexity can be seen in the fact that it is determined by intricate interactions between genetic composition and environment influences which ultimately control the probability of development of the disease (Manco and Dallapiccola, 2012). Various studies (Allison et al., 1994, Tambs et al., 1991, Bodurtha et al., 1990) conducted on blood relatives and adopted relatives have confirmed that familial predisposition plays a 40%-70% role in obesity predisposition. Agha and Agha (2017) noted that the prevalence of obesity is higher in children who live in households where both parents are overweight or obese. Levine et al. (2005) even suggest that obese children are biologically programmed to becoming that way. Hochberg et al. (2010) proved a significant maternal genetic influence on obesity predisposition during the intrauterine and early postnatal periods of a child's development.

The fat mass and obesity-associated protein (FTO), a gene with multiple variants have been implicated as the link between genetics and obesity. The FTO has been strongly linked to the onset of obesity in childhood even extending till adult life (Bollepalli et al., 2010, Frayling et al., 2007, Hinney et al., 2007, Stunkard et al., 1990) and displays its influence on variables such as body weight, BMI and waist circumference (Scuteri et al., 2007). Although the FTO is not the only genetic marker that has association with obesity, it was the first to be described and is the most well-known to have association with BMI values (Leonska-Duniec et al., 2016, Loos and Bouchard, 2008, Frayling et al., 2007, Scuteri et al., 2007). Obesity comes in different forms and its development can be attributed to the presence of certain forms of the FTO in one's genetic make-up (Duicu et al., 2016). The complex interaction between FTO and other individual traits like BMI, adiposity, leptin levels, calorie intake, energy balance control, satiety sensitivity all have a cumulative effect on the weight status of a child (Cecil et al., 2008, Kring et al., 2008, Frayling et al., 2007).

Variants of the FTO gene have shown a differing association with each specific ethnic populations (Hennig et al., 2009). Specific FTO variants are heavily associated with BMI and obesity in Caucasian populations (Grant et al., 2008, Scuteri et al., 2007) while other variants have shown a negligible effect on other ethnic populations (Bollepalli et al., 2010). A cohort study, the first of its kind in Africa, was conducted in 2009 on 2208 lean Gambians. The study found that none of the 16 FTO gene variants assessed, showed association with body mass in Gambians, a generally lean population that survives mainly on a traditional diet (Hennig et al., 2009). A genetic-association study by Scuteri et al. (2007) did not find a significant association between African-Americans and a specific FTO gene variant but noted that this variant was associated with weight, BMI and hip circumference in both European and Hispanic Americans. A later trial on 578 obese African-Americans and 1424 controls then disagreed with this finding and noted a correlation between the FTO gene and BMI in African-Americans (Grant et al., 2008). Adeyemo et al. (2010) detected similar FTO gene relationship between African-American and West African populations. A cross-sectional study by Bollepalli et al. (2010), conducted on non-Hispanic whites and African-Americans children and adolescents, showed that distinct variants of the FTO gene were associated with BMI z-score in non-Hispanic whites while other variant showed more significant association in African-Americans.

A South African study conducted by Lombard et al. (2012), aimed to replicate studies conducted in western countries to determine which genes, present in the South African black population, predispose to obesity and elevated BMI. The cohort included adults and adolescents. FTO gene variants found in the black South African population were significantly linked to elevated BMI values and subjects who possessed seven FTO genes in their genetic makeup had an 11% higher BMI score than those who only possessed three FTO genes in their genetic make-up. Moreover, a more recent case-control study conducted by Duicu et al. (2016) on a cohort of obese and normal-weight Romanian children assessed two variants of the FTO gene and their relationship with obesity outcome measures. The study confirmed that children that carry a particular variant of the FTO gene are more predisposed to higher body fat mass, BMI, adiponectin (a hormone associated with obesity) and body circumference than those who carry other variants of the gene. The study also showed that there is a significant relationship between FTO variants and BMI z-score.

The robust body of literature confirms the association of the FTO gene with obesity and the BMI z-core in children and that certain populations possess specific variants of the FTO gene. Literature has explained why some children are more prone to weight gain than others who consume the same foods and engage in similar levels of physical activity. Various study results also show that there is limited consistency on the topic which further buttressing the point on the complexity of the obesity disease. Based on this, Loos (2011) proposed a treatment rationale called "personalised medicine". The reasoning suggests that future obesity management needs to consider custom-made, genetics-based, disease risk profiling of children so that prevention programmes can target individual prognostic indicators. This treatment rationale promises early preventative management to safeguard against obesity (Matuchansky, 2015). Studies that investigate genetic constitution and familial predisposition have provided hope that genetics in the future will shed light on the successful management of this complex disease and even possibly prevent it before it begins (Hochberg et al., 2010, Maes et al., 1997).

2.7.3. Perinatal/infantile factors affecting the childhood overweight/obesity complex

Causal factors associated with childhood overweight and obesity extend far back into intrauterine life and forward into early life. Perinatal birth weight has proven to be somewhat genetically dependant (Wang et al., 1995). Other perinatal variances such as undernourishment of the foetus intrauterine followed by plentiful food supply postnatally predispose an individual to obesity (Ravelli et al., 1976). A retrospective study was conducted on a cohort of Nigerian adults that were exposed to famine during the very early stages of their lives as a result of the Biafran war. The study confirmed a direct association between foetal-infant undernutrition and adult obesity, hypertension and glucose intolerance (Hult et al., 2010). Yet another systematic review conducted by Hochberg et al. (2010) confirmed that low infant birth weight has an indirect but significant effect on obesity, diabetes and cardiovascular risk. Pijl (2011) further explained that foetal malnutrition results in the adaptation of genetic profiles that predispose to obesity.

There has been a century-long belief that breastfed babies are less likely to become obese (Casazza et al., 2013) and that practising exclusive breastfeeding for the first six months of life assists in controlling paediatric weight gain (Gillman et al., 2001, Harder et al., 2005). Despite this general knowledge, Mvo (1999) documented that breastfeeding has been underutilised as a means of protein-energy nutrition in infants and toddlers in South Africa. Many mothers opt for the use of bisphenol A (BPA) feeding bottles for infant feeding which have been shown to stimulate the production of fatty cells in children (Johnson et al., 2014).

Furthermore, the genetics of paediatric obesity displays some distinct differences to that of adult obesity (Haberstick et al., 2010) with the proportional effects of genetic composition, environmental influences and gender constantly changing as a child progresses to adulthood (Haberstick et al., 2010, Schousboe et al., 2003). Again, these variances, highlight the complex cause-effect relationship between early life and overweight/obesity in children.

2.7.4. Social change and the childhood overweight/obesity complex

From the rise of the First Industrial Revolution until now, there has been a consistent and rapid change in society that has resulted in the rise in childhood overweight and obesity. In the past centuries, the world was plagued with malnutrition and food shortage (Benyshek and Watson, 2006). Great strides made in technological research led to the industrialisation of the 20th century (Pijl, 2011). There was a massive progressive shift from manual work to mechanised labour and transportation resulting in heightened food security in most affluent societies. The availability of food led to a disruption in the food ingestion versus manual labour work output balance meaning that individuals ate more but performed less physically strenuous activities (Eknoyan, 2006, Pijl, 2011). Many modern-day jobs are sedentary in nature and demand much less physical exertion and energy consumption than they did 50 years age (Church et al., 2011). There is a massive upswing in the use of automobiles for school transportation (Tremblay et al., 2014). People in LMICs have also shifted from labour-intensive work and traditional diets to less physical exertion and the consumption of energy-rich high-calorie diets (Popkin et al., 1996). Currently, the prevalence of diseases of lifestyle in LMICs is growing at an even faster rate than in HICs (Kelishadi, 2007). This shift in dietary consumption and energy expenditure is known as 'nutritional transition' (Rossouw et al., 2012). The resultant situation is that obesity has crept into many communities and has become a widespread global problem (Armstrong et al., 2006) with consequent lifestyle diseases.

Previously, overweight and obesity were mainly problems of urban affluent societies in HICs (Gluckman et al., 2011). With the advent of social and economic globalisation, LMICs have also began to face similar problems (Popkin, 2007, Rossouw et al., 2012, Sabin et al., 2015) as people in these countries migrate from rural communities into the urban built environment (Rossouw et al., 2012) and up the economic ladder. Urbanisation is now a common occurrence in many Sub-Saharan African countries, and sadly, it has resulted in lower levels of consistent physical activity that are vital for maintaining healthy body weight (Onywera, 2010, World Health Organization, 2004). The built environment includes the man-made buildings and structures that form part of the urbanised macro-living spaces where people reside and work (Committee on Environmental Health, 2009). Physical activity patterns in children are heavily dependent on the community environment in which they reside (Kohl and Hobbs, 1998, McClelland et al., 2001). Overweight and obesity are on the rise, especially in urban areas (Rossouw et al., 2012) and the built environment has been directly linked with physical activity (Heath et al., 2006). In this era of urbanised living, access to vast outdoor spaces for recreational activity may be limited. Innovative planning of urban outdoor spaces requires the maximisation of available space while considering walking and cycling routes to ensure active living (Handy et al., 2002). Children can only engage in reasonable physical activity if they live in a community environment that is conducive for such. Activity-friendly neighbourhoods comprising mainly of schools, shops, community and recreational facilities near residential homes and with designated side-walks, have been linked to increased physical activity (Heath et al., 2006, Saelens et al., 2008). The appropriate design and layout of outdoor spaces encourages exercise and leisure activities in children and their adult supervisors (Committee on Environmental Health, 2009). Unfortunately, nowadays, outside play is not as appealing to children. Children have somewhat lost the capacity for active and creative play when compared to children from 20 years ago (McQuade et al., 2019). Instead, active and creative play has been substituted by sedentary play in the form of cell phones, tablets, computer games and television (Nelson et al., 2006). Epstein et al. (2006) found that children are more favourably disposed to substituting sedentary activities for physical activity if they reside close to a recreational park.

Urbanised living in the built environment, crime and criminality, heavy traffic and working parents has forced children to spend more time indoors for fear of danger during unsupervised outdoor play (Li and Seymour, 2019, Zhou, 2015). A study conducted in Nigeria found that people were more disposed to walking if they perceived their neighbourhoods as safe (Oyeyemi et al., 2012). Some studies (Committee on Environmental Health, 2009, Gordon-Larsen et al., 2006) also found fewer child recreation areas in underprivileged neighbourhoods, neighbourhoods which often have higher levels of crime (Foster and Giles-Corti, 2008). It is therefore not surprising that a high prevalence of overweight and obesity is also associated with low-income neighbourhoods that have limited play areas (Giles-Corti et al., 2003).

A careful assessment of activity enablers and hindrances will assist in improving activity patterns in children. Town planning policies that insist on recreational parks, bicycle lanes, spacious sidewalks and round-the-clock community policing ensure that space challenges and security concerns are addressed even in low-income neighbourhoods (Lachat et al., 2013, Hidding et al., 2018).

2.7.5. Lifestyle factors and the childhood overweight/obesity complex

Lifestyle factors affecting the childhood overweight and obesity complex have been discussed here under two subheadings - nutritional behaviour/ food supply and physical activity.

2.7.5.1. Nutritional behaviour and Food supply

A child's relationship with food is influenced by multiplicity of factors. Gustatory and visual stimuli will determine their food preferences. Food marketing, food availability, serving size and satiety also affect feeding behaviour and will ultimately influence overweight and obesity (Hummel et al., 2013).

Four components of dietary intake influence weight status: meal frequency, the quantity of food ingested per meal, energy and nutrient content of each meal, systemic utilisation of food (Mvo, 1999). Food energy density holds important significance in dietary composition and refers to the total energy content comprising of fats, starch, protein and even water (Krebs et al., 2007). The consumption of high-density foods increases the total intake of energy into the body (Bell et al., 1998, Rolls et al., 1999). Energy-dense diets play a major role in disrupting the energy input/outflow equalisation in the body (Hill et al., 2012) resulting in overweight/obesity and many non-communicable diseases. Growing children are exposed to cheap meals and snack packed with sugar, fats, salt, colourants and flavourants but highly deficient in nutritional content (Pandita et al., 2016, Banfield et al., 2016, Malik et al., 2013, Mancino et al., 2014). Consuming significant amounts of sugary drinks tilt the energy equilibrium equation towards weight gain. Various studies have observed a direct connection between excess glucose consumption in the form of sweetened beverages and total energy intake (Ludwig et al., 2001, Tordoff and Alleva, 1990). A South African study by Feeley et al. (2013) recorded a significant association between the consumption of sugar-sweetened soft drinks and BMI z-score in men. Similar results were also recorded for adolescents in a study Jamaican study Francis et al. (2009) and a global review by Schneider et al. (2017).

Furthermore, there is an association between excessive television watching and unhealthy eating. Children who spend a significant amount of time in sedentary activity, nibble on more junk food and are less interested in eating fruits and vegetables (Snoek et al., 2006). Consuming larger portion sizes also shows linkage to increased energy intake and results in overweight/obesity risk, as seen in a review conducted by Kral et al. (2004).

Some scholars have proposed limiting starchy food intake. A study by Hall et al. (2015) proposed that limited starch intake stimulates significant energy expenditure (even at rest) if complemented by a high-protein diet. However, it is commonly known that a balanced diet is an absolute essential for healthy growth in children and some scholars advocate for only moderate dietary restriction in the growing child (Zwiauer, 2000, Abrignani et al., 2019) complimented by increased physical activity with the hope that the effects of increased physical activity will counteract the increased body weight over time. Tilting the focus to weight gain prevention rather than weight loss, allows the child to become thinner over time as they grow in height (Cole et al., 2005).

Policy makers in many LMICs have not been proactive in ensuring that food advertising, labelling and pricing steer families towards healthy food choices. These challenges were noted in a systematic policy review that assessed for the availability of policies to reduce salt and fat consumption and encourage fruit and vegetable intake as well as physical activity in LMICs. The study found that only a minority of LMICs had policy guidelines in place to tackle poor diet-and-exercise induced lifestyle diseases (Lachat et al., 2013).

Assessment of dietary habits using 24-hour recall and food frequency questionnaires (Nicklas et al., 2001) is a necessary first step in determining the dietary lifestyle of a child. However, the significance of dietary intake in overweight and obesity management is only relevant if the energy expenditure part of the energy balance equation (physical activity) can be accurately quantified.

2.7.5.2. Physical activity

The significant relationship between childhood overweight/obesity and physical activity has been highlighted here. Furthermore, recommendations for physical activity have been discussed.

Physical activity is defined as structured and non-structured bodily movements produced by muscular activities that result in energy combustion in the body (Caspersen et al., 1985, Westerterp, 1999). Physical activity encompasses exercise. Exercise refers to structured body activity intended to achieve cardiovascular fitness (Caspersen et al., 1985). There is documented evidence to confirm that an inactivate lifestyle presents a risk for both morbid disease and emotional disorders (Ranucci et al., 2017). Conversely, there are numerous benefits of engaging in physical activity such as weight control, healthy bone ossification, improved cardiovascular fitness, psycho-emotional well-being (Janssen et al., 2010), improved academic performance (Singh et al., 2012, Biddle, 2001) and reduced risk of cardiac and metabolic disease (Leonska-Duniec et al., 2016, Fulton et al., 2004).

Moderate to vigorous physical activity (MVPA) specifically, is of immense benefit to children and adolescents (Lonsdale et al., 2013). Furthermore, a healthy physical activity lifestyle in childhood spirals into adult life resulting in long-term health benefits (Kelder et al., 1994, Malina and sport, 1996) while limiting heart disease, diabetes, high blood pressure, osteoporotic bony changes, various cancers, low self-esteem and depression (Park et al., 2012). Consistent high levels of physical activity have also been linked with sustained long-term weight loss (Wing and Hill, 2001). A study conducted by Muthuri et al. (2014b) in Kenya found that a low percentage of children (12.6%) aged 9-11 years met up with recommend daily MVPA requirements and rather opted for low intensity physical activity that do not meet up with prescribed energy expenditure requirements. A similar study also noted that South African children aged 7-15years documented high levels of low intensity physical activity. Higher parental level of education and high household income as well as attending a private school were strong determinants of overweight and obesity status and were negatively associated with sufficient physical activity (Muthuri et al., 2014a).

Determining levels of physical activity in children is a complex calculation because energy expenditure is made of various components. Physical activity, RMR and TEF all form part of energy expenditure (Seebohar, 2002). Therefore, quantified physical activity is not synonymous with total energy expenditure but rather only a component of it (Krebs et al., 2007). In addition, children and adolescents require a mandatory residual positive energy balance to account for their developmental needs (Hill et al., 2012).

Physical activity components include planned/structured activity and non-exercise activity thermogenesis (NEAT) (Schwartz et al., 2017). Planned/structured activity is physical exercise, the component of physical activity that is most relevant to this review. Non-exercise activity thermogenesis (NEAT) refers to the passive physical activities we engage in during our normal daily routine even without consideration, e.g. domestic chores, driving, walking, eating etc. (Levine et al., 2005). Engaging is NEAT has been shown to induce weight loss (Levine et al., 2005, Levine et al., 1999) and can account for 15% - 50% of total daily energy expenditure depending on how active an individual is (Levine et al., 2002). NEAT values are reduced in overweight and obese individuals and are a contributing factor to the progression of obesity (Levine et al., 2005). Hence, encouraging overweight and obese children to engage in usual domestic chores may have a small but cumulative effect on controlling the disease. Ravussin et al. (1986) also noted the beneficial effects of normal activities of daily living on NEAT but added that NEAT values were variable in subjects regardless of their weight status – an addition that further compounds the complexity of obesity and its management.

Physical activity in children can be subjectively assessed by visual monitoring or by retrospective questioning, although children often struggle with an accurate recollection of physical activity behaviour (Troiano et al., 2012). Objective quantification can be achieved using a pedometer, accelerometer (Cardon and De Bourdeaudhuij, 2007) or heart rate monitor (Janz et al., 1992). Pedometers are the easiest to use and most readily available (Krebs et al., 2007).

The recommended dosage of physical activity in normal-weight healthy children is 60min/day (World Health Organisation, 2011) but a good percentage of children worldwide do not meet this daily recommended level of physical activity (Beets et al., 2010, Hallal et al., 2012, Micklesfield et al., 2014). A 13-country study reviewed pedometer-assessed levels of physical activity in HICs. The results were variable among countries and found that children from countries with less automobile-centred lifestyles where walking and cycling were commonplace had higher levels of physical activity than those that relied on the use of automobiles (Beets et al., 2010). In 2012 the Lancet Physical Activity Series conducted a more widespread survey that included LMICs. The study documented activity levels in adults and children aged 13-15years and reported that 80% of children perform less than the prescribed 60min/day of moderate to vigorous physical activity and that boys were more active than girls (Hallal et al., 2012). Another study conducted in Cameroon to evaluate physical activity patterns in urban and rural communities found that both communities were equally plagued with physical inactivity but that rural dwellers were still more active than urban dwellers (Sobngwi et al., 2002). In South Africa, Micklesfield et al. (2014) also noted the challenge of inactivity in urban children, as well as in rural dwellers, even though rural children reported walking as a means of transport. Also, of note was that moderate-to-vigorous physical activity (MVPA) was significantly higher in boys than in girls, informal activity was more prevalent in girls than boys and sedentary activity increased as children grew older. Reddy et al. (2003) also agreed with the finding that South African girls engaged in less physical activities than their male counterparts.

Exercise, a major component of daily energy expenditure, has proved to be a weaker stimulant of initial weight loss when compared to interventions incorporating diet or diet and exercise concurrently (Ross et al., 2001, Shalitin et al., 2009). This difficulty in weight loss, using activity solely, can be attributed to the pathogenesis of obesity. The energy homeostasis system can counteract the effects of increased physical activity by involuntarily stimulating hunger in the hypothalamus, thereby encouraging eating and in effect avoiding weight loss. In contrast, the energy homeostasis system is less able to counteract for high-calorie ingestion to prevent weight gain because physical exercise is a voluntary activity (Hill et al., 2012).

2.7.6. Agents of socialisation and the childhood overweight/obesity complex

Agents of socialization perform the duty of instilling values and social norms in the life of a child. They thereby exert significant influence on a child.

2.7.6.1. Family members and peer groups

Parental involvement plays a major role in encouraging child participation and discouraging obesogenic behaviour (Campbell and Hesketh, 2007, Golan, 2006, Epstein et al., 1994). Parents are well suited to ensure the effectiveness of diet, physical activity and behavioural interventions. They can influence child weight status, so it is not surprising that children whose parents are obese are highly likely to become obese adults themselves (Whitaker et al., 1997). Family-centred weight management programmes provide parents with the opportunity to institute lifestyle changes in their children (Skelton et al., 2012) with the support of other health professionals. This approach has been termed the "gold standard" in paediatric obesity management (Whitlock et al., 2010). Parental leadership, interest, availability, monitoring and emotional support are all essential arms of a family-centred approach (Golan, 2006, Sallis et al., 2000). A study by Israel et al. (1987) found that parents who monitored activity and diet at the start of intervention were more likely to sustain obesity interventions in their children than those who show less monitoring compliance. A review conducted by Biddle et al. (2005) in girls 10-18 years on physical activity participation resolved that structured sporting activities with supportive family involvement were a major determinant of the participation in girls of this age group. Loveman et al. (2015) also highlighted this important fact in a review conducted on 3057 overweight or obese children aged 5 to 11 years. The study found that even parent-only interventions produce similar effects to interventions that include both parent and child. The vital role of parents in early identification and referral to primary healthcare providers for evidence-based management cannot be overemphasised (Coppock et al., 2014).

Peer groups also exert a strong influence on a child's body weight perception (Gwozdz et al., 2015, Nie et al., 2015). Peer interaction may provide motivation for routine physical activity and organised sports (Stock et al., 2007). Peer effects can be steered positively to encourage fun, consistent physical activity in overweight and obese children.

2.7.6.2. Myths, beliefs, culture and religion

Sociocultural beliefs form part of the complex matrix of factors influencing the onset and progression of overweight and obesity in children as well as their physical activity behaviour. The different cultural perceptions of body weight and their relevance to health and wellbeing cannot be ignored (Clark et al., 1999, Mvo, 1999). Racial and ethnic affiliations are directly related to one's body image perception (Rosen et al., 1991, Altabe, 1998, Clark et al., 1999). Two American studies recorded that African-American girls were less concerned about their body weight than their counterparts of other racial groups and did not view weight loss as an incentive to motivate lifestyle change (Altabe, 1998, Rucker III and Cash, 1992). Kemper et al. (1994) also documented interesting differences in body image perceptions between American black and white adolescent. The black adolescents selected a larger body structure as ideal body weight and perceived that their parents considered them thin. On the other hand, the white adolescents felt that their parents considered them to be "heavy" and wished to be much thinner. Clark et al. (1999) also documented similar results in African-Americans women. These women were comfortable with higher ideal body size than their non-African-American counterparts. It is of note that body weight perceptions of specific racial groups trickle down to children proving that parents and society play a significant role in a child's body image perception (Kemper et al., 1994). A qualitative study conducted in a low SES community in the Western Cape Province of South African on a group of overweight Xhosa speaking women found that these women did not view exercise as a tool for maintaining body weight. They instead relied on ‘yo-yo’ dieting and home remedies such as ‘black tea’ to help control weight gain – most often without success. These women regarded weightiness as a sign of financial security, health and marital harmony and felt no overwhelming need to change their weight status or that of their children. They also did not associate overweight and obesity with potential health challenges (Mvo, 1999).

Many cultures encourage physical activity in boys but view physical activity as socially undesirable for girls (Kaluski et al., 2009), and this may be one of the reasons why many studies report higher levels of activity in boys than in girls (Pate et al., 1996, Deheeger et al., 1997). Kaluski et al. (2009) reported that social conditioning among Israeli children affects the level of physical activity in girls. A systematic review found physical activity levels in Arab children to be very low compared to that of children from other countries and even that of Arab adults (Sharara et al., 2018). The extremely warm temperature experienced in Arab countries was a major reason for inactivity and minimal outdoor play. However, other causes of inactivity in children were attributed to socio-cultural values that encourage academic and religious participation over sport. Religious beliefs also dictate a conservative dress code for females that is unsuitable for exercise.

Intrinsic barriers to physical activity were assessed in a study by Bani-Issa et al. (2019) conducted in the United Arab Emirates (UAE). The study reported a low perceived self-efficacy in sustaining a wholesome dietary and exercise lifestyle amongst Arab children, lower than that of children from other cultures. Cultural practices also bear weight on the success of dietary control. Arab cultures are largely communal family-orientated cultures that socialise around food. Mealtimes are viewed as a shared experience which involves families and invited friends eating out of a communal dish (Dagmar, 2018), a practice that may challenge selective dietary choices.

The multidisciplinary weight management team needs to give these factors serious consideration when designing and implementing weight management interventions if success is to be achieved (Mvo, 1999).

2.7.7. Socio-economic status and the childhood overweight/obesity complex

Socioeconomic status (SES) is a risk factor for developing overweight and obesity (Newton et al., 2017). However, this relationship differs in HICs and LMICs (Kimm et al., 2005, Stalsberg and Pedersen, 2010). Obesity is more prevalent in underprivileged children living in HICs (Drewnowski, 2009) and more evident in affluent children in LMICs (Dinsa et al., 2012). Although advances in clinical medicine, nutritional transition and changes in the way of life have all resulted in a longer lifespan for people living in LMICs, it has also resulted in various setbacks. Dietary changes from traditional diets to processed calorie-dense foods, the over-reliance on technology and sedentary living are features mostly noted in families of higher SES living in LMICs that have resulted in an increase in non-communicable diseases. These trends are following after disease trends seen in HICs a few decades ago (Steyn and Mchiza, 2014). A good understanding of the relationship between SES and overweight/obesity trends will allow LMICs to steer clear of the mistakes made by HICs over the past years that has led to the overweight and obesity epidemic seen in these countries today (Gluckman et al., 2011, Steyn and Mchiza, 2014).

There are only a few published studies conducted on the relationship between SES and overweight/obesity in LMICs, and even fewer studies have been conducted on child subjects. One study that focuses on physical activity noted an inverse relationship between SES and physical activity in children living in Sub-Saharan African countries (Muthuri et al., 2014b). The dearth of published studies has limiting the development of customised policies and programmes to target the current obesity problem in these countries (Ash et al., 2017). One recent systematic review conducted by Newton et al. (2017) found 15 relevant studies and reported on the relationship between SES and obesity based on studies from seven HICs and just one LMICs. This review reported that women of lower SES residing in HICs had a higher BMI than those of higher SES; however, results amongst males were variable. It was hypothesized that women are generally more weight conscious than males (Lee et al., 2009) and that affluent women may be better resourced to maintain an ideal weight (Jeffery and French, 1996). Also, men of lower SES may engage in more labour-intensive jobs that assist in controlling body weight (Chang and Lauderdale, 2005). Other studies have reported an overall inverse association between both adults and child overweight/obesity and socioeconomic status (Dinsa et al., 2012, Ball and Mishra, 2005, McLaren, 2007). A South African study conducted by Feeley et al. (2013) also recorded similar results with children from affluent homes showing a higher predisposition to overweight and obesity than those from economically challenged homes. Socioeconomic status has also been directly linked with levels of physical activity (Schwartz et al., 2017). In HICs, children of higher SES tend to be more active (Stalsberg and Pedersen, 2010) whereas in LMICs, children of lower SES are the ones who are generally more active (Reddy et al., 2012). A similar inverse association is noted between overweight/obesity and level of education (Cohen et al., 2013).

Another study by Gallo et al. (2012) assessed the relationship between obesity, SES and cardiovascular risk in Mexican-American women. Cardiovascular risk was quantified using inflammatory markers. The study reported an inverse association between inflammatory markers and socioeconomic status in this group and implicated obesity and unhealthy eating as a reason for this finding.

Frequent consumption of processed fast foods is positively linked with BMI and adiposity in children (Thompson et al., 2004) and adults (French et al., 2000). In Soweto, a developing community of South Africa, fast foods are a luxury for the affluent. The direct correlation between SES and purchasing power implies that people of higher SES that can afford these convenient but expensive fast foods, tend to be the ones who are more likely to be overweight and obese in this population (Feeley et al., 2013). Nonetheless, people with lower economic capacity may also settle for a different range of calorie-dense foods through street vendors that sell cheap snacks and meals thereby also affecting their risk of developing overweight and obesity. Monteiro et al. (2004) suggested that the socioeconomic patterning of overweight and obesity in LMICs will gradually follow the patterns seen in HICs where overweight and obesity progressively becomes a disease of the less affluent as those of higher-income become more health-conscious.

2.7.8. Economic costs and the childhood overweight/obesity complex

The presence of childhood obesity (especially in severe forms) places an additional financial burden on the family (Some et al., 2016). The cost of medication, diagnostics, therapy and rehabilitation to manage the disease are noteworthy. In a cross-sectional study by Schwimmer et al. (2003), overweight/obese children and adolescents recorded a significantly higher number of days of absenteeism from school than those of normal weight. Clinical obesity management programmes set up to deal with the disease are resource-intensive and costly to maintain. As a result, these programmes are often only accessible to a limited number of children in more affluent communities (Dietz and Robinson, 2005, Summerbell et al., 2003).

The economic cost of the disease increases as the child progresses into adulthood. The adverse effects of overweight and obesity filter through and affect the economy on an individual (micro-) and national (macro-) level. The overweight/obese individual is plagued with an increased risk of premature mortality, morbidity and decreased work output resulting in a lower probability of sustaining employment (McCormick et al., 2007). Other micro-level economic consequences of overweight and obesity include discrimination, reduced level of education, less probability of getting married, lower household income and a higher rate of household poverty (Gortmaker et al., 1993). A household survey administered by the South African Labour and Development Research Unit (SALDRU) found that employment status is adversely affected by overweight and obesity in South Africa (Some et al., 2016). Overweight and obesity also have a macro-level impact on national economies. The disease results in lost time in man-hours due to sickness, under-productivity and absenteeism from work leading to heightened costs of running a business and a reduction of tax revenue. These all culminate into an increment in government expenditure to cater for the treatment of obesity, obesogenic diseases, disability and unemployment benefits (McCormick et al., 2007, Rissanen et al., 1990).

2.7.9. Mental factors and the childhood overweight/obesity complex

Again, the cause-effect relationship between childhood overweight/obesity and mental factors are quite complex. Socio-economic stressors lead to emotional and psychological consequence (McLaren, 2007). Hemmingsson (2014) argued that socioeconomic and psychological factors may have a stronger correlation with overweight and obesity than diet or activity. Unemployment results in heightened financial pressure on a family and elicits negative emotions in parents (Roelfs et al., 2011) including feelings of depression and helplessness (Ferrie et al., 2005). Stress-related negative emotions (Gallo and Matthews, 1999) often trickle down from parents to children (Rodgers and Chabrol, 2009) and present as abnormal eating habits, dependency on addictive substances, suboptimal academic performance, insomnia and unhealthy perception-of-self (Christensen et al., 1983, Yap et al., 2014). Many energy-dense foods are cheaply available (Drewnowski and Specter, 2004, Drewnowski, 2009) and are therefore more appealing to an already strained budget. Disordered eating attracts stigmatisation (Latner et al., 2008) which weighs heavy on children and can seriously affect their emotional health (Erickson et al., 2000, Strauss, 2000) resulting in a vicious cycle of overeating and further psychological assault.

2.8. The progression of overweight and obesity into adulthood

The FTO gene confirms that obesity has a hereditary component (Duicu et al., 2016). The probability of developing childhood obesity is heavily dependent on parental weight status (Schwartz et al., 2017, Krebs et al., 2007). Whitaker et al. (1997) conducted a retrospective study in America on 854 subjects looking at individuals born between 1965 and 1971 to determine the relationship between paediatric obesity, obesity in young adulthood and parental obesity. The study found that obese and non-obese children were twice as likely to develop adult obesity if their parents were obese. Also, obesity in children above three years was a strong indicator of possible adult obesity, irrespective of parental weight status. Pregestational maternal BMI is another strong indicator of paediatric obesity (Catalano et al., 2009, Sharp et al., 2015).

Genetic coding influences the BMI of ≈70% of population groups (Maes et al., 1997). A 2-year study conducted on elementary school children in Italy found that parental BMI significantly influenced childhood BMI (Giampietro et al., 2002). Childhood BMI is also directly influenced by parental history of myocardial infarct and cerebrovascular disease (Glowinska et al., 2002, Muratova et al., 2001).

Serdula et al. (1993) reviewed public health data issued from two HICs between 1970 and 1992. Although the author noted that various included studies used different study designs and definitions of obesity, the review still concluded on the following: the higher the age and greater the degree of childhood obesity, the stronger the probability of developing adult obesity.

2.9. Dealing with the scourge of overweight and obesity

2.9.1. Prevention of overweight and obesity

The old saying: “Prevention is better than cure” also holds for overweight and obesity management. Prevention is an integral component of halting the scourge of the overweight and obesity pandemic (Lobstein et al., 2004). It is more feasible to avoid excessive weight gain than it is to treat overweight and obesity (Hill et al., 2012) because the body has a natural pathophysiologic defence mechanism that is strongly resistant to weight loss once body weight has been established. On the other hand, the body is minimally resistant to putting on weight (Dulloo and Jacquet, 1998, Jebb et al., 1996). Therefore, the management of overweight and obesity in children must firstly involve the prevention of weight gain before it occurs and becomes fully established (Hill et al., 2012).

The UNICEF's mission statement is grounded on offering children 'the best start to life'. In the past, 'the best start to life' partly referred to providing children with adequate nutrition. Ironically today, 'the best start to life' is now about preventing over-nutrition of children (Sabin et al., 2015). Research has shown that overweight/obesity is a heterogeneous disease - diverse in character and content (Sabin et al., 2015). Although multiple studies have been conducted on childhood overweight and obesity, the complexity of the disease has created confusion amongst scholars on how best to manage the condition (Jebb et al., 2007). Evidence-based prevention strategies have proved difficult to construct for various reasons (Caroli et al., 2007). Most of the work on obesity research has been carried out on adult subjects or mature animals and little is known about the physiology of body weight or how hormones affect the development of overweight and obesity specifically in children (Sabin et al., 2015, Schwartz et al., 2017). The lack of a standardised measure for determining the degree of overweight and obesity in children calls for further detailed clinical investigation into overweight and obesity diagnostics (Reilly, 2006, Must and Anderson, 2006). Also, the feasibility of conducting randomised controlled trial studies for the general population is fraught with challenges resulting in most studies being conducted in schools and healthcare establishments (Lobstein et al., 2015) under controlled settings hence introducing selection bias (Lobstein and Swinburn, 2007, Caroli et al., 2007). There is limited knowledge of how genetics affects the individual response to exercise. Leonska-Duniec et al. (2016) discovered that FTO and other genetic markers show varying association with the effectiveness of exercise on obesity management regimens. The focus of research needs to be on identifying the specific genes in children that play a role in overweight and obesity (Manco and Dallapiccola, 2012).

Till date, common sense and quick-fix strategies have failed to contain the global pandemic (Schonfeld-Warden and Warden, 1997). There is a lack of effective, long-term strategies for dealing with overweight and obesity and people enrolled in dietary and lifestyle management programmes tend to regain the weight lost (Schwartz et al., 2017). Sophisticated strategies must go beyond providing the common-sense approach and focus more on carefully crafted controlled studies effective in providing evidence for dealing with the disease (Sabin et al., 2015). Scholars must consider diversifying the range of treatment approaches offered (Wang et al., 2013). Ash et al. (2017) argued that dietary control and physical activity are not the only components of overweight and obesity management that need to be addressed. Broad evidence bases founded on intervention implementation in developing countries and amongst ethnic minorities with emphasis on media, sleep behaviour, funding and family-involvement are imperative. Various systematic reviews have found that greater efficacy and sustainability of weight management interventions are seen when protocols include a wide range of strategies. Several scholars have recognised the importance of substituting mono-component interventions with a multifaceted lifestyle approach ranging from dietary intake, recreational play, physical education at school and after-school sports involving parental and community participation (Avery et al., 2012, Khambalia et al., 2012, Larson et al., 2011, Wang et al., 2013, Ling et al., 2016, Rajmil et al., 2017).

2.9.2. Exercise prescription for overweight and obesity management

Exercise prescription refers to an outlined physical activity regimen designed for a specific purpose (Suleman, 2016). Exercise prescription should offer significant levels of exercise intensity that will result in energy expenditure enough to induce weight loss and alter biochemical outcomes (Shalitin et al., 2009). The WHO recommends the use of a combination of cardiovascular exercise and weight-training for optimal health and cardiovascular benefit (World Health Organisation, 2010b). Lonsdale et al. (2013) added that spontaneous bursts of high-intensity activity during sessions of physical exercise were effective in improving MVPA in children.

A systematic review conducted by García-Hermoso et al. (2015) recommended that weight management programmes should be conducted for three days a week and comprise of aerobic and resistance exercises performed simultaneously at moderate to vigorous intensity. The study showed that this exercise prescription is effective in improving body composition variables such as body mass and waist circumference in overweight and obese children. Benefits were also most noticeable in long term exercise programmes lasting beyond 24 weeks. In a randomised control study conducted by Monteiro et al. (2015), thirty-two obese adolescents were randomised into two parallel exercise groups – cardiovascular exercise and concurrent cardiovascular and weight training exercise for 20 weeks (50 mins x 3 per week, supervised). They were compared to a control group of 16 participants who maintained their usual lifestyle. Percentage body fat (%BF) was the primary outcome measure. After a 20-week intervention period, both intervention groups displayed a significant reduction in %BF with no noticeable difference between the two intervention groups. Both forms of exercise were found to be equally beneficial. A review by Kelley et al. (2017) representing thirty-four studies and 2,239 children and adolescents also found that both cardiovascular workout and concurrent cardiovascular and weight-training resulted in statistically significant reductions in BMI z-score in children. Physical activity sessions averaged 3 times per week for 50 minutes per session over a 12-week period. Strength training alone did not display favourable reductions and concurrent training ranked higher is efficacy than cardiovascular training alone. However, it is important to note that confidence in effect estimates was ranked as low for cardiovascular exercise and very low for concurrent cardiovascular and weight training. Another recent systematic review by García-Hermoso et al. (2018) was conducted on 12 RCTs with 555 youths to determine whether a combination of the weight-training and cardiovascular workout was more effective than just cardiovascular workout in treating obesity. The anthropometric outcomes included body mass, BMI and waist circumference. The study found that a combination of the two exercise forms was more effective than the use of only one form of exercise in reducing anthropometric outcomes, especially when interventions lasted beyond 24 weeks. Exercise intervention in all 12 RCTs lasted between 10-48 weeks. Exercise sessions averaged 47 minutes with a frequency of 2.8 times a week. The study went further to highlight the importance of empowering parents with information on effective exercise prescription for their children.

Child studies on the role of sole activity interventions agree that exercise improves BMI z-score in children and adolescents (Kelley et al., 2014, Maffeis et al., 2007, Reilly and McDowell, 2003). Two previous systematic reviews assessing the efficacy of physical activity as a sole intervention in managing overweight/obesity in children and adolescents were identified (Atlantis et al., 2006, Stoner et al., 2016) however these reviews focused on a different age brackets other than 6-12-years and did not assess BMI z-score. Stoner et al. (2016) reported only a small reduction in BMI and even more modest changes in the other outcome measures assessed. Subgroup analysis of this review revealed that incorporating diet into the exercise plan resulted in more significant improvements in BMI and other outcome measures. Atlantis et al. (2006) compared exercise dosage and found that lower doses of exercise (120–150 min/weeks) were less effective in altering body fat than a higher dose (155–180 min/weeks at moderate-to-high intensity). Khawandanah and Tewfik (2016) added that slow and progressive dietary and exercise lifestyle changes are more sustainable than sudden and rapid weight loss.

Various adult studies on the topic were included in a review by (Verheggen et al., 2016) and also concluded that diet-only interventions were more effective than activity-only interventions in reducing body weight. A study by Thompson et al. (1997) documented sustained weight loss for periods longer than one year when dietary restrictions were incorporated into exercise interventions programmes. Sum et al. (1994) on the other hand, recorded conflicting evidence and noted weight loss in military personnel when sole-activity interventions were administered. The energy homeostasis system could be implicated for the relatively limited effectiveness of sole-activity based programmes, and this is because the energy homeostasis system compensates for increased physical activity by increasing appetite and ultimately limiting weight loss (Hill et al., 2012). Effective management programmes benefit from a measure of dietary control to counteract the energy homeostasis system and ensure sustainability.

Schwartz et al. (2017) went further to say that vigorous physical activity is less effective in activating initial weight loss but most successful in maintaining weight loss over long periods. Klem et al. (1997) conducted a qualitative retrospective study in the USA aimed at determining the components that lead to long-term weight loss in individuals enrolled in the National Weight Control Register (NWCR). The subjects were successful in maintaining weight loss over 5.5 years and the study reported that sustained moderate- or heavy-intensity activities were an integral component of long-term weight loss. Klem et al. (1997) also noted that those who were successful in maintaining a normal body weight over time were those who sustained healthy feeding and dietary habits. Successful “resetting” of the energy homeostasis system described by Schwartz et al. (2017) could be responsible this outcome.

Interventions that include screen-time and active gaming to manage overweight and obesity have been considered as additives that encourage physical activity in children by taking advantage of their existing interests (Daley, 2009). This initiative has resulted in varying results. Although (Maddison et al., 2014) and (Christison et al., 2016) reported no improvement in weight status as a result of such interventions, (Trost et al., 2014) recorded an improvement in BMI z-score values after a 16-week active gaming and family-based paediatric weight management programme. (Peng et al., 2013) noted that such interventions are enjoyable and stimulate a desire for future play while (Daley, 2009) concluded that active gaming is efficacious in motivating physical activity.

Other forms of modern technology such as Short Message Services (SMS) have been used to communicate with children beyond the initial intervention periods when weight rebound and dropout mostly occur. This modality requires that the children send weekly communication about their exercise and dietary behaviour and they, in turn, receive feedback messages from the weight management programme co-ordinator (De Niet et al., 2012).

A wide range of activities should be on offer to cater to the individual abilities and preferences of each child. Exercise activities ought to be exciting and entertaining to ensure sustained participation of obese children (Deforche et al., 2011) who often find cardiovascular exercise more challenging than their normal-weight counterparts (Deforche et al., 2006). Parents and children should be empowered with basic age-appropriate theoretical information and practical skills that support physical activity so that they can take ownership of their progress (Deforche et al., 2011). Setting SMART short-term goals (Specific, Measurable, Attainable, Realistic and Timed) gives quantifiable meaning to their effort and are essential in ensuring success (Bovend'Eerdt et al., 2009). Constant refinement of activity interventions in response to the individual goals guarantees success (Jones et al., 2011). Necessary additions such as background music serve as both a motivator for physical activity and distractor from physical discomfort (De Bourdeaudhuij et al., 2002).

The physical activity sociocultural environment is important to note. Children socialise more actively in a comfortable social environment (Franzini et al., 2009). They sustain physical activity for more extended periods when they participate alongside their peers. Conversely, social exclusion and undesirable peer pressure negatively affect activity patterns in children (Salvy et al., 2012).

Exercise instructors and teachers are role models that play a crucial role in ensuring positive learning experiences and optimal participation (Alberga et al., 2013b). A young, friendly and personable instructor will more likely develop mentorship relationships with the children and influence positive outcomes. Instructors should have a pre-planned lesson schedule and should also be able to pass on exercise skills safely and efficiently to the children (Alberga et al., 2013b). A review conducted by Lonsdale et al. (2013) found that the exercise instructor's teaching strategies significantly affects the effectiveness of exercise interventions. Stock et al. (2007) suggested the use of peer trainers for administering activity interventions during obesity management programmes. The study recorded positive fitness attitudes and improved general well-being in children who were coached by peers. Parents also demonstrated positivity towards the success of a physical activity programme if they felt confident about the exercise instructor (Pescud et al., 2010, Robinson et al., 2003).

Robinson et al. (2003) reported that the lack of transport is a major barrier to participation in weight-loss programmes. Parents usually have to straddle with work and domestic timetables. A physical activity venue that is within reasonable proximity to the home is of value to parents and children and improves attendance (Pescud et al., 2010). Yackobovitch-Gavan et al. (2009) also cited transportation as a major reason for the drop-out of study participants.

Outcome measures such as body weight, waist circumference should be monitored long beyond intervention. Without prolonged follow-up of subjects and the assessment of their progress data, it will be difficult to confirm if indeed prescribed interventions have been truly effective (Jones et al., 2011).

2.9.3. Ensuring 'effectiveness' in the management of childhood overweight and obesity

The Oxford dictionary defines effectiveness as "the degree to which something is successful in producing the desired result".

The magnitude of BMI z-score reduction can be termed to be effective if it is sufficient in improving obesity-related health outcomes (Kirk et al., 2005). Some studies have specified that effective childhood obesity interventions for children should achieve a minimum reduction in BMI z-score of -0.25 because such reductions result in improved adiposity and metabolic health (Ford et al., 2010, Reinehr and Andler, 2004). However, various studies that have documented only modest BMI z-score reductions ranging from -0.13 to -0.16 in 12-month family-based multi-modal obesity intervention programmes have found that even such minimal improvements were associated with reduced cardiovascular risk (Croker et al., 2012, Kolsgaard et al., 2011, Kirk et al., 2005). Again, a 6-month supervised sole exercise programme which had significant effect on cardiovascular risk documented a reduction of 0.19 in BMI z-score (Salem et al., 2010). A Cochrane review by Oude Luttikhuis et al. (2009) recorded an even smaller BMI z-score change of −0.06 points as a significant pooled treatment effect of behavioural interventions when compared to usual care. Yet Cole et al. (2005) cautioned against comparing BMI z-score reductions amongst different studies and reiterated that BMI z-score is not sufficiently sensitive to changes in severely obese children. Nevertheless, for well-constructed studies where BMI z-score has been used as the outcome of interest, these ranges of BMI z-score reductions could still give some indication of whether interventions have been effective.

A review by Fogelholm et al. (2008) concluded that all planned, structured and purposeful physical activity is effective in increasing energy expenditure, obesity prevention and management. Several studies have utilised structured physical activity programmes in an attempt to achieve effective weight management in children. Structured physical activity intervention programmes generally offer the following value: A select group of participants meet a skilled trainer at a particular venue to perform the prescribed activity for a predetermined duration to achieve their defined weight management goals. Structured programmes are a viable option that can be adapted to various health care settings at minimal extra cost (Whitlock et al., 2010). Children show great enthusiasm when they play sports, identify with a team, receive coaching from a young adult mentor and can show off their skills in front of their family and peers (Robinson et al., 2003) during structured programmes. Although many child overweight and obesity intervention programmes have employed a structured format (Ranucci et al., 2017), other scholars still advocate for less rigidity in intervention programmes. Pandita et al. (2016) commented that primary school children and adolescents benefited more from a combination of structured and unstructured play and recommended that of the 60 minutes of daily physical activity, only 30 minutes of it should include structured sports and supervised exercise.

School, community and clinic settings all offer varied benefits when administering a structured weight management programme. Structured school-based interventions have documented some success in decreasing the prevalence of obesity and BMI (Gortmaker et al., 1993, Robinson, 1999). A study conducted by Weintraub et al. (2008) found that some of the children who participated in a structured soccer programme pilot study went on to join soccer teams at their schools after the study was completed. Lombardo et al. (2019) labelled schools as “laboratories” for obesity prevention since children spend a significant portion of their days at school. Also, MVPA administered in the school setting is both of physical and cognitive benefit to children (Dudley et al., 2011). Physical education is usually a part of the curriculum in most schools and is an ingenious way of sustaining activity levels in children (Lonsdale et al., 2013, Dobbins et al., 2013) as part of effective activity interventions.

“Effectiveness” can further be gauged on the implementation of overweight and obesity management that ensures long term weight control (Shalitin et al., 2009). De Niet et al. (2012) outlined several challenges that limit the long-term success of physical activity programmes. High drop-out rates, a relapse of unhealthy lifestyle behaviours and regaining of lost weight are the major culprits. Average drop-out rates as high as 30-40% have been recorded in many studies (Oude Luttikhuis et al., 2009). There is a need for long term maintenance strategies that ensure a sustained reduction of both BMI and BMI z-score values in children (Mead et al., 2017) because short term interventions (less than 3 months) have not proved to be effective in this regard (Summerbell et al., 2005). Golan and Crow (2004) suggested that school-based structured interventions that are inclusive of the family may be beneficial in this regard because obesity management programmes, even those that focus solely on parents, have produced significant, sustained weight loss in obese children even after a 7-year period.

Self- motivation is another integral component of effective physical activity participation and behavioural intervention (Ng et al., 2012). This has been underpinned by the self-determination theory (SDT), which refers to the autonomous motivation without the need for external stimulation or incentive (Deci and Ryan, 1985). The SDT makes a differentiation between self-inspired physical activity that is seen as exciting and activity that is dependent on external motivation, engaged in only to obtain a reward or to avoid negative consequence (Owen et al., 2014). Autonomous motivation ensures a sustained healthy lifestyle inclusive of physical activity as noted in a review by Teixeira et al. (2012). Owen et al. (2014) tested the relevance of the SDT principle in children and found it to be somewhat relevant. The review noted a significant positive correlation between autonomous motivation and physical activity in children (even though the correlation was only weak to moderate in size). Martin et al. (2012) added that several other factors affect physical activity behaviour in children. Some of these other factors, notable mostly in school settings, include size of play areas (Ridgers et al., 2010, Cradock et al., 2007), level of supervision (Sallis et al., 2001), the availability of balls (Zask et al., 2001) and other sporting equipment (Taylor et al., 2011). Appropriate design and implementation of effective activity programmes requires a shift in health behaviour and relies on the support of healthcare professionals to institute change (De Niet et al., 2012) using cost- effective strategies (Summerbell et al., 2003).

2.10. Research gaps identified

During this literature review process, it was discovered that many studies on childhood overweight and obesity utilised both physical exercise and diet as the study intervention. Very few studies focused solely on physical activity interventions and even fewer studies have assessed physical activity interventions for overweight and obese children throughout their whole primary school career (age 6-12 years). The role of this study is to determine whether focusing solely on physical activity interventions is effective during this age bracket when children are still interested in informal play.

2.11. Conclusion

An in-depth knowledge into the literature surrounding the paediatric overweight and obesity pandemic lays a necessary foundation for successful management. This literature review has highlighted various facts.

Overweight and obesity form a disease complex that has a significant impact on the wellbeing of individuals in all age groups. Certain variables influence its onset and progression while overweight and obesity, in turn, lead to several health consequences. Although many scholars agree that the prevalence of overweight and obesity is high, there is no globally acceptable standard for quantifying the disease. Many overweight and obesity management protocols have utilised the trial and error method of problem-solving to deal with the pandemic. Some obesity management interventions have been unsuccessful while many others have been successful but only for a limited time. Many intervention programmes struggle with non-compliance, weight gain relapse and high dropout rates leading to limited efficacy. Effective paediatric management can only be realised if the multiplicity of overweight and obesity determinants are considered when setting up weight management programmes, and this is a mammoth task to achieve. The next section will outline the methods used for this systematic review.

3. CHAPTER THREE: METHODS

3.1. Introduction to chapter

This chapter describes the methodology implemented in this quantitative systematic review. It gives a detailed outline of the study design, population of interest, criteria for study selection, data collection and synthesis. The study guidelines were based on the Joanna Briggs Institute (JBI) Reviewer's Manual (Joanna Briggs Institute, 2019).

3.2. Background of systematic review methodology

Systematic reviews form an integral part of evidence-based research (Tranfield et al., 2003, Khan et al., 2003), in fact they rank highest on the hierarchy of clinical evidence (Clarke and Chalmers, 2018). Systematic reviews are preceded by the compilation of a research protocol including a well formulated research question (Shamseer et al., 2015). The term 'systematic' denotes a form of research characterised by a rigorous and standardised study methodology (Khan et al., 2003). Systematic review methodology requires a clearly defined study selection criteria, quality assessment using a standardised study appraisal tool, data collection and synthesis of study evidence (Khan et al., 2003, Yassin, 2017). Such rigorous methodology serves to assemble similar research literature under a single umbrella for evaluation and synthesis (Smith et al., 2011, Gopalakrishnan et al., 2013) and ultimately to steer healthcare decision making as directed by the systematic review results (Gopalakrishnan et al., 2013, Clarke and Chalmers, 2018, Sackett et al., 1996).

3.3. Eligibility criteria

3.3.1. Studies

This study reviewed literature that focused on activity interventions used in the management of overweight and obese children aged 6-12-years. The age range was chosen specifically to include all primary school pre-adolescent children. A computerised database search was conducted to isolate all relevant randomised control trials (RCTs) published in English from January 2002 till February 2018 (a 15-year data search). Non-randomised control trials, case reports and case-control studies were excluded. Each included study had a length of the intervention of 12 weeks and above. Studies on children that possessed confounding medical conditions, that could affect the results of the review, were excluded.

3.3.2. Interventions

Studies on children age 6-12-years that administered only physical activity in the intervention group were considered for inclusion. All study participants had to either be overweight or obese with a body mass index above the 85th percentile. Physical activity could be achieved either by structured or non-structured physical activity programmes. Participants in the control group could receive any other form of overweight and obesity management intervention or "no intervention".

3.3.3. Outcome measures

The primary outcome measure of this review is the Body Mass Index z-score (BMI z-score). Secondary outcome measures of interest include physical activity count before intervention, daily moderate-to-vigorous physical activity, 7-day physical activity, waist circumference, percentage overweight, total body fat mass, abdominal fat mass, percentage fat mass, fat-free mass, body composition, cardiorespiratory fitness, blood pressure, Arterial intima-media thickness (IMT), screen time, Rosenberg Self-Esteem Scale, 10-item Children's Depression Inventory, The Overconcerns With Weight and Shape Subscale of the McKnight Risk Factor Survey, Paediatric Quality of Life Inventory (PedQL4.0), past-year physical activity (week^{-1}) using Modifiable Physical Activity Questionnaire for Adolescents, total cholesterol (TC), plasma insulin, insulin resistance, C-reactive protein (CRP) and nutrition.

3.4. Data Collection

3.4.1. Search Strategy

According to the JBI systematic review protocol (Joanna Briggs Institute, 2019), a three-step search was used to identify all studies relevant to the review. An initial search of Pubmed and CINAHL databases was conducted. Secondly, search terms were identified from the initial database search and used to perform a comprehensive search of all other databases. These databases included PubMed, CINAHL, Physiotherapy Evidence Database (PEDro), Cochrane Central Register of Controlled Trials, SPORTDiscus and SCOPUS. Thirdly, a reference list search was conducted for all the included studies to identify additional literature. An additional study was identified at this stage.

The search terms identified were combined to isolate studies suitable for the review. Search terms include activity, exercise, management, treatment, obesity, overweight, adolescence, and children. Search terms combinations are outlined in Table 3:1.

Table 3:1: Search terms

Search Term	Boolean Operator	Search Term	Boolean Operator	Search Term	Boolean Operator	Search Term	Boolean Operator	Search Term
Activity	AND	Management	AND	Overweight	AND	Adolescence	OR	Children
Activity	AND	Management	AND	Obesity	AND	Adolescence	OR	Children
Exercise	AND	Management	AND	Overweight	AND	Adolescence	OR	Children
Exercise	AND	Management	AND	Obesity	AND	Adolescence	OR	Children
Activity	AND	Treatment	AND	Overweight	AND	Adolescence	OR	Children
Activity	AND	Treatment	AND	Obesity	AND	Adolescence	OR	Children
Exercise	AND	Treatment	AND	Overweight	AND	Adolescence	OR	Children
Exercise	AND	Treatment	AND	Obesity	AND	Adolescence	OR	Children

Search filters were:

- 6 -12- years old
- Randomised Control Trial,
- January 2002 – February 2018

3.5. Methodological Quality

The JBI Critical Appraisal Checklist for Randomised Control Trials (Appendix three) (Tufanaru C, 2017) is a tool that assesses the methodological quality and possible study design bias of each included study. This JBI appraisal tool was developed by research experts and serves to critically appraise the methodological quality of individual studies as well as to assist in data synthesis and interpretation (Tufanaru et al., 2017).

The initial search process was conducted in all databases using the search term combinations (Table 3:1). Two independent primary reviewers (C.N.E and A.T.A) considered all retrieved titles and abstracts for relevance to the review. C.N.E is a WITS Masters student and the author of this review. A.T.A is a WITS Post-Doctoral Physiotherapist. Both reviewers conducted this process independently and then compared their findings. Each reviewer read through the full-text of the isolated articles and further sorted them based on the study inclusion criteria. Again, the final selection was conducted independently by the two reviewers to eliminate selection bias as guided by the JBI appraisal tool. A third reviewer (Prof. J Potterton) was consulted in cases where the first two reviewers were unable to reach a consensus (Joanna Briggs Institute, 2019). All reviewers have experience in research methodology and systematic review. The primary reviewers decided that a minimum score of seven 'yeses' was required for a study to be included in the review. Subsequently, the findings of the appraisal tool were used in understanding study results and formulating a firm opinion. The quality of methodological rigor was graded based on two previous reviews on effectiveness as follows: Poor < 50%, Moderate 50–80%, Good > 80% (Mbuzi et al., 2018, Reilly et al., 2016). This grading was not intended to exclude any articles but rather to highlight the methodological quality of each study. Risk of bias assessment was conducted to determine the overall quality of each study (Porritt et al., 2014). The risk of bias was classified into low (-), moderate (?) or high (+) risk of bias (Higgins and Green, 2011).

3.6. Data Extraction

Data were extracted using the JBI Data Extraction Tool for Experimental Studies (Appendix four) to isolate quantitative data from included studies. Documented data included demographics, type of activity intervention, length of activity intervention, the outcome of the intervention and follow-up period.

3.7. Data Synthesis

All comparable data were pooled together for statistical analysis using the JBI-SUMARI software (System for the Unified Management, Assessment and Review of Information) (https://app.jbisumari.org/). The changes in BMI z-score (continuous data) at various points in each study were calculated. These values were summarised as mean differences (MD) with 95% confidence intervals (CI). Across-study statistical heterogeneity was assessed using the quantification of statistical heterogeneity (I^2) and standard chi-squared (Cochran's test) statistics. The random-effects model was applied based on the result of the I^2 statistic (Tufanaru C, 2017). Statistical heterogeneity was graded as low, moderate or high heterogeneity for I^2 values of 25%, 50%, and 75% respectively (Higgins et al., 2003). For the chi-squared test, a statistically significant p-value ($p<0.05$) indicates statistical heterogeneity (Tufanaru C, 2017). The decision of whether to report on the results of the data analysis in the form of a forest plot was determined by the degree of study heterogeneity. Study results were reported in the form of a narrative in the event of high statistical heterogeneity.

3.8. Conclusion

A quality systematic review requires a sequential compilation and execution of all the methodological components. Chapter three has given an outlay of the steps followed when conducting the systematic review. The next section will outline the process of study selection and the results of the systematic review.

4. CHAPTER FOUR: RESULTS

4.1. Introduction to chapter

This systematic review aimed to determine whether physical activity interventions are an effective way of managing overweight and obesity in children aged 6-12-years. Randomised control trials published between January 2002 and February 2018 were considered for the review. Study eligibility was pre-determined using specific inclusion and exclusion criteria.

This chapter first illustrates the study selection process to show how the final four research papers were chosen. The excluded articles and the conditions that rendered them irrelevant to the review have been outlined. Secondly, an assessment of methodological quality, as well as inter-rater reliability, have been documented using the JBI critical appraisal checklist. Risk of bias assessment has been done to rate the quality of the evidence. Thirdly, narratives and tables have been used to expound on relevant data retrieved from the eligible studies. The study results have been broken down into various components to allow for easy comparison and to answer the review objectives. Results of the data extraction are presented using the PICO model (**P**opulation, **I**ntervention, **C**omparison and **O**utcome) for quantitative research.

4.2. Method of study selection

4.2.1. Primary Search- Database Search

The flowchart illustrates the sequential process of study identification, screening, assessment and final selection of the included studies for data synthesis and meta-analysis. An outline of excluded studies and the reasons for exclusion have also been provided (Figure 4.1). A total of 6641 potential articles were found through database and reference list searching. After abstract and title screening, full text review for inclusion and exclusion, and quality appraisal, four studies remained for inclusion into this review. Figure 4.1 illustrates the sequential process.

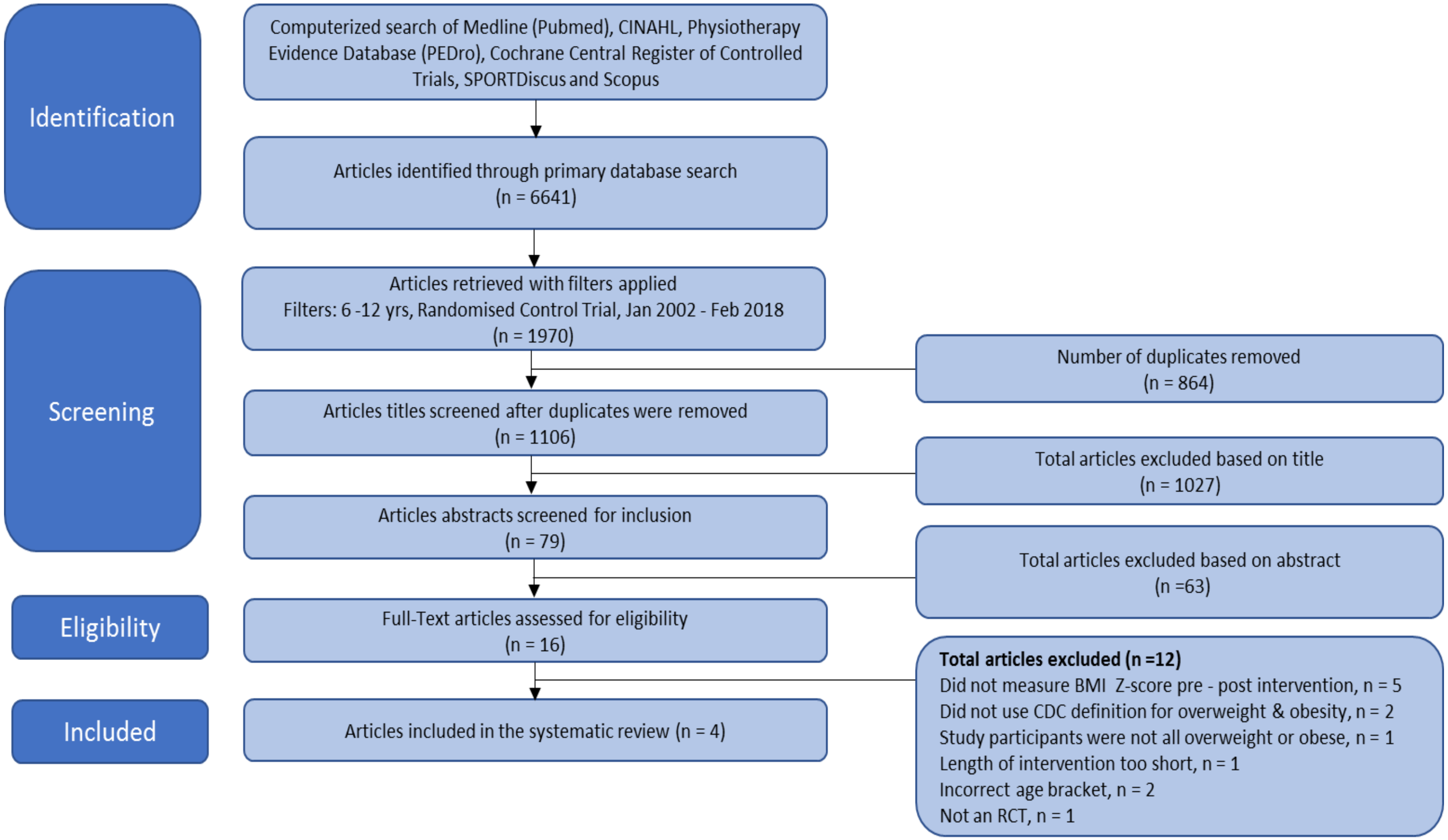

Figure 4:1: Flowchart illustrating the included study selection process

4.2.2. Secondary Search - Reference List Search

A secondary search of the reference list of the 16 articles extracted for full eligibility (n=16) was conducted. Only one additional article was extracted, as shown in Figure 4.2 below:

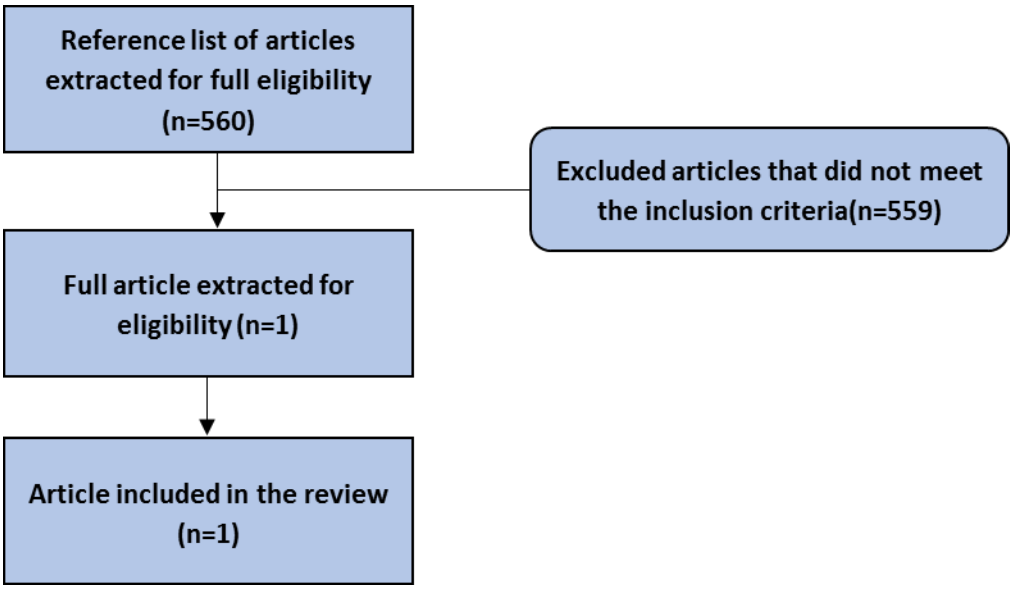

Figure 4:2: Secondary search from the reference list of eligible articles

Five eligible study papers complied with the inclusion criteria and were included in the systematic review. On further examination, two of these papers (Shalitin et al., 2009, Yackobovitch-Gavan et al., 2009) were found to have utilised the same study population. We chose to include Shalitin et al. (2009) over Yackobovitch-Gavan et al. (2009) because the write-up in Shalitin et al. (2009) provides more comprehensive information on the study that was conducted. Therefore, finally, four studies (with a total of 302 study participants) were included in the review.

4.3. Study appraisals

4.3.1. Measure of agreement

The kappa value (k) is a measure of inter-rater agreement (McHugh, 2012). The two independent reviewers met and agreed on final scores where there were discrepancies. The K-value was 0.142, which signified a low level of inter-rater reliability.

4.3.2. Assessment of quality of evidence

Overall, the four included studies scored moderate to good methodological quality (62% to 85%). Most studies were unable to blind those who delivered the treatments because of the design of the studies. The results of the study appraisal are outlined in Table 4.1.

Table 4:1: JBI Critical Appraisal Checklist

	JBI appraisal checklist	Weintraub et al. (2008)	Shalitin et al. (2009)	Farpour-Lambert et al. (2009)	Trost et al. (2014)
1	Was true randomisation used for assignment of participants to treatment groups?	Y	Y	Y	Y
2	Was allocation to treatment groups concealed?	U	Y	Y	N
3	Were treatment groups similar at the baseline?	Y	Y	Y	Y
4	Were participants blind to treatment assignment?	U	U	U	U
5	Were those delivering treatment blind to treatment assignment?	N	N	N	N
6	Were outcomes assessors blind to treatment assignment?	N	N	Y	N
7	Were treatment groups treated identically other than the intervention of interest?	Y	Y	Y	Y
8	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?	Y	Y	Y	Y
9	Were participants analysed in the groups to which they were randomised?	Y	Y	Y	Y
10	Were outcomes measured in the same way for treatment groups?	Y	N	Y	Y
11	Were outcomes measured in a reliable way?	Y	Y	Y	Y
12	Was appropriate statistical analysis used?	Y	N	Y	Y
13	Was the trial design appropriate, and any deviations from the standard RCT design (individual randomisation, parallel groups) accounted for in the conduct and analysis of the trial?	Y	Y	Y	Y
	TOTAL (%) AND QUALITY RATING #	9/13 (69%)	8/13 (62%)	11/13 (85%)	9/13 (69%)
	Classification of quality rating	**Moderate**	**Moderate**	**Good**	**Moderate**

*Abbreviations: N, no; U, unclear; Y, yes

Quality rating: Good: at least 80%, Moderate: 50–80%; Poor: less than 50%

4.3.3. Risk of bias

The JBI protocol was used to guide the risk of bias assessment. The following risk of bias was assessed – selection bias, performance bias, detection bias, attrition bias, and reporting bias. The results are presented in Table 4.2.

Table 4:2: Risk of bias

Risk of bias	Weintraub et al. (2008)	Shalitin et al. (2009)	Farpour-Lambert et al. (2009)	Trost et al. (2014)
1) Selection bias				
• Random sequence generation	+	+	+	+
• Allocation concealment	?	+	+	-
2) Performance bias				
• Blinding of participants and personnel	-	-	-	-
3) Detection bias				
• Blinding of outcome assessment	-	-	+	-
4) Attrition bias				
• Incomplete outcome data	+	-	+	+
5) Reporting bias				
• Selective reporting	-	-	-	-

Risk of bias: low (-), moderate (?), high (+)

4.4. Study description using the PICO format

Table 4.3 gives a comprehensive outline of each study's aim, design, setting and population demographics. A further breakdown of the study group allocation and gender profiles of participants have been described in Tables 4.4 and 4.5, respectively. Table 4.6a-4.6d describes the intervention, control and outcomes of each study.

Table 4:3: Study aim, design and population demographic characteristics

Author	Aim	Study design	Country/settings	Participants
Weintraub et al. (2008)	To evaluate the feasibility, acceptability, and efficacy of an after-school team sports programme for reducing weight gain, increasing physical activity, and improving psychological health in low-income overweight children	2-arm, parallel-group, pilot randomised control trial	Low income, racial/ethnic minority community, implemented at schools, Northern California, USA	**Sample group:** Overweight/obese children, Grade 4-5 **Sample size:** n = 21 **Gender:** Not stated **BMI:** ≥85th percentile for age and sex
Shalitin et al. (2009)	To compare the short- and long-term effects of a 12-week intervention programmes of exercise alone, diet alone, or diet + exercise on BMI, body fat percentage and cardiometabolic risk factors	Randomised Control Trial	Paediatric Obesity Clinic at Schneider Children's Medical Centre of Israel and Paediatric Endocrine Clinic at Soroka Medical Centre, Israel	**Sample group**: Obese children aged 6 – 11 years, Tanner stage 1 **Sample size**: n = 162 **Gender**: Male (81), Females (81) **BMI**: > 95th percentile for age and sex
Farpour-Lambert et al. (2009)	To determine the effects of a physical activity programme on systemic BP and early markers of atherosclerosis (endothelial and smooth muscle cell functions, arterial intima-media thickness (IMT), and arterial stiffness) in pre-pubertal obese children	Randomised Control Trial with a modified crossover design	Obesity Clinic of the Children's Hospital of Geneva, Switzerland	**Sample group**: Obese children 6-11years, Tanner Stage 1 **Sample size:** n = 44 **Gender**: Male (16), Females (28) **BMI:** > 97th percentile for age and sex
Trost et al. (2014)	To evaluate the effects of active video gaming on physical activity and weight loss in children participating in an evidence-based weight management programme delivered in the community	Group- randomised clinical trial	7 YMCAs and 4 schools located in Massachusetts, Rhode Island and Texas, USA	**Sample group:** Overweight/obese children aged 8 – 12 years old **Sample size**: n = 75 **Gender**: Male (34), Females (41) **BMI:** > 85th percentile for age and sex

4.4.1. Population

<u>Country and setting:</u>

All included studies were conducted in HICs (USA, Switzerland and Israel) in schools, clinics, hospitals and community centres (Trost et al., 2014, Farpour-Lambert et al., 2009, Shalitin et al., 2009, Weintraub et al., 2008). Weintraub et al. (2008) specified that all the participants were from low-income and ethnic minority communities while Shalitin et al. (2009) commented that 27% of their sample group were from a part of Israel known to be of a lower socioeconomic status than the other 73%. Trost et al. (2014) were specific about the racial profile of their sample group (34 whites [45%], 20 Hispanics [27%], 17 blacks [23%]) while (Farpour-Lambert et al., 2009) was silent on ethnicity and socioeconomic status. Neither ethnicity nor socioeconomic status was considered during randomisation in any of the studies.

<u>Study group allocation:</u>

The table outlines the breakdown of participants into study groups

Table 4:4: Breakdown of participants into study groups

	Weintraub et al. (2008)	**Shalitin et al. (2009)**	**Farpour-Lambert et al. (2009)**	**Trost et al. (2014)**	**Total**
Intervention group (IG)	9	52	22	34	117
Control group (CG)	12	55 + 55 = 110	22	41	185
Total	21	162	44	75	302

The review included a total of 302 participants. Of this number, 117 participants were randomised into an intervention group (IG), while 185 participants were randomised into a control group (CG).

Gender distribution:

Table 4:5 outlines the gender profile of each included study

Table 4:5: Gender profile of included participants of the studies

	Gender	**Weintraub et al. (2008)**	**Shalitin et al. (2009)**	**Farpour-Lambert et al. (2009)**	**Trost et al. (2014)**	**Total**
Intervention group (IG)	Male	Not stated	23	9	15	47
	Female	Not stated	29	13	19	61
Control group (CG)	Male	Not stated	58	7	19	84
	Female	Not stated	52	15	22	89

Weintraub et al. (2008) did not specify how many male and female participants were included. The total number of male and female participants was 131 and 150, respectively. Farpour-Lambert et al. (2009) and Trost et al. (2014) study groups comprised of a greater number of females than males. The Shalitin et al. (2009) control group consist of a higher number of males than females but overall, there was an equal number of males and females participants in the Shalitin et al. (2009) study.

Age of study participants at baseline:

The total mean age of all the study participants at baseline was 9.18 years.

BMI percentile:

All included studies used the CDC definition for classification of overweight and obesity for children (Kuczmarski, 2000).

4.4.2. Intervention

All four included studies administered physical activity in their intervention groups. Three studies gave the participants prescribed physical activity (Shalitin et al., 2009, Weintraub et al., 2008, Farpour-Lambert et al., 2009) while Trost et al. (2014) did not prescribe how much activity was to be done, but instead left that to individual interpretation. A detailed breakdown of the contents of the intervention group physical activity is described in Tables 4.6a-4.6d.

4.4.3. Control / comparators

Trost et al. (2014), Farpour-Lambert et al. (2009) and Weintraub et al. (2008) control participants were given intervention other than physical activity. The (Shalitin et al., 2009) study had two control groups. One group received the dietary intervention, while the second control group received physical activity and dietary intervention simultaneously. A detailed breakdown of the content of each control group is also described in Tables 4:6a-4.6d.

Table 4:6a: Summary of the results and key findings of the included studies

STUDY	INTERVENTION GROUP		CONTROL GROUP		OUTCOME MEASURES
	Demographics	**Intervention programme**	**Demographics**	**Control programme**	
Weintraub et al. (2008)	Mean Age: 9.50 ± 0.58 years Gender: Not stated Sample size: n=9	Content: After-school co-ed soccer programme: - team-building - 15-minute warm-up and stretching - soccer-skills training - practice match Dosage: - 3-days per week (2 practice days and 1 game day) - increased to 4-days per week during month 5 at the request of participating children and parents Duration: - Each session was 2¼ hours long - Started with a homework period - Approximately 75 minutes of activity - 12 weeks FOLLOW-UP PERIOD: Post-intervention assessment at 24 weeks but no active follow-up programme prescribed after the initial programme	Mean Age: 10.34 ± 0.84 years Gender: male and female Sample size: n=12	Content: Traditional after-school nutrition, physical activity and health education programme using active placebo intervention Dosage: 25 sessions Duration: 12 weeks FOLLOW-UP PERIOD: Post-intervention assessment at 24 weeks but no active follow-up programme prescribed after the initial programme	Outcome of interest - BMI Z-score Other outcomes measures - total activity - Moderate Physical Activity (MPA) - Vigorous Physical Activity (VPA) - Television and other screen time - Depressive symptoms - Over concerns with weight - Self-esteem

Table 4:6b: Summary of the results and key findings of the included studies

STUDY	INTERVENTION GROUP		CONTROL GROUP		OUTCOME MEASURES
	Demographics	**Intervention programme**	**Demographics**	**Control programme**	
Shalitin et al. (2009)	Mean Age: 8.21 ± 1.78 years Gender: male and female Sample size: n=52	EXERCISE GROUP Content: - High intensity progressive exercise (defined as 75% max. heart rate) - 45 min aerobics (team sports & running) - 45 resistance training (sit-ups, hand lifting of small weights, ball exercises) Dosage: 90 minutes per session, 3 days/week Duration: 12 weeks FOLLOW-UP PERIOD: Content: Counselling session with dietician. All participants were adviced to maintain a healthy diet of 1500kcal/day and improve activity levels. There was no data collected on compliance to diet and exercise during the follow-up period. Post-intervention assessment at 52 weeks.	DIET GROUP Mean Age: 8.51 ± 1.52 years Gender: male and female Sample size: n=55 DIET + EXERCISE GROUP Mean Age: 8.2 ± 1.56 years Gender: male and female Sample size: n=55	DIET GROUP Content: The child and their parent had weekly meetings with a dietician, balanced hypocaloric diet DIET + EXERCISE GROUP Content: Received both the diet and exercise group programmes FOLLOW-UP PERIOD: Content: Counselling session with dietician. All participants were adviced to maintain a healthy diet of 1500kcal/day and improve activity levels. There was no data collected on compliance to diet and exercise during the follow-up period. Post-intervention assessment at 52 weeks.	Outcome of interest - BMI Z-score Other outcomes measures - body fat - % fat mass - waist circumference - blood pressure - resting energy expenditure - biochemical variables - physical activity - Health related Quality of Life (HRQOL) variables

Table 4:6c: Summary of the results and key findings of the included studies

STUDY	INTERVENTION GROUP		CONTROL GROUP		OUTCOME MEASURES
	Demographics	Intervention programme	**Demographics**	**Control programme**	
Farpour-Lambert et al. (2009)	Mean Age: 9.1 ± 1.4 years Gender: male and female Sample size: n=22	Content: - 30 min aerobic exercises comprising of- fast walking, running, ball games or swimming at heart rate corresponding to 55%-65% of individual max. cardiorespiratory fitness (based on baseline max oxygen consumption [VO_2max] measures by treadmill test) - 20min strengthening exercises comprising of- (a) strengthening of arms, legs, trunk (2-3 series of 10-15 repetitions) using body weight and elastic bands (b) 10 min stretching and cool-down Dosage: - Three 60min sessions/week - 135min/week of physical education Duration: 12 weeks FOLLOW-UP PERIOD: Content: Participants were requested to continue exercising Dosage: 2x per week Duration: 12 weeks	Mean Age: 8.8 ± 1.6 years Gender: male and female Sample size: n=22	Content: No intervention given. Participants were requested to maintain their current level of physical activity Duration: 12 weeks FOLLOW-UP PERIOD: Content: Participants were requested to start the same training programme received by exercise group (modified crossover design) Dosage: 2 days per week Duration: 12 weeks	Outcome of interest - BMI Z-score Other outcomes measures - whole body fat - abdominal fat - fat-free mass - cardiorespiratory fitness - total energy intake - blood pressure - biochemical variables

Table 4:6d: Summary of the results and key findings of the included studies

STUDY	INTERVENTION GROUP		CONTROL GROUP		OUTCOME MEASURES
	Demographics	**Intervention programme**	**Demographics**	**Control programme**	
Trost et al. (2014)	Mean Age: 10.1 ± 1.9 years Gender: male and female Sample size: n=34	Content: - Comprehensive family-based paediatric weight management Programme (JOIN for ME). The Join for ME programme includes: individual weigh-in, introduction of new weekly goals, assessment of progress towards behavioural goals, self -monitoring, calorie range targets, LESS and YES foods and drinks, reduction of screen time, goal setting, increase in physical activity. - Active gaming – computer game that encourage physical activity. Game console, motion capture device and an active sports game were given at the second treatment session. A second active game given at week 9. Dosage: - No specific instructions were given to the concerning the dosage of use of the computer games Duration: 16 weeks FOLLOW-UP PERIOD: No follow-up was done.	Mean Age: 9.9 ± 1.5 years Gender: male and female Sample size: n=41	Content: Received a comprehensive family-based paediatric weight management programme (JOIN for ME) Duration: 16 weeks FOLLOW-UP PERIOD: No follow-up was done.	Outcome of interest - BMI Z-score Other outcomes measures - moderate-to-vigorous Physical Activity (MVPA) - Vigorous Physical Activity (VPA) - Percentage overweight

4.4.4. Outcomes

The primary outcome measured for all included studies was the BMI z-score. BMI Z-score values and changes over time are outlined in Table 4.7a and Table 4.7b while the mean differences in BMI z-score values are outlined in Table 4.8.

Table 4:7a: BMI z-score values and changes over time

Author	Results	Key findings
Weintraub et al. (2008)	**<u>Intervention group</u>** Baseline BMI z-score: 2.15 ± 0.44 12 weeks BMI z-score: 2.08 ± 0.49 24 weeks BMI z-score: 2.06 ± 0.50 **<u>Control group</u>** Baseline BMI z-score: 2.22 ± 0.33 12 weeks BMI z-score: 2.22 ± 0.30 24 weeks BMI z-score: 2.22 ± 0.30	**<u>Within-group analysis</u>** • At 12 weeks (p = 0.03) and 24 weeks (p = 0.04) there was a statistically significant reduction in the BMI z-score in the intervention group. • At 12 weeks there was no significant change in the BMI z-score in the control group • Mean change in BMI z-score at 12 weeks: IG= -0.07 (0.49), CG= 0 (0.30) **<u>Between-group analysis</u>** • At 12 weeks the change difference between the intervention group and the control group in the BMI z-score is significant (-0.07, 95%CI -0.13 to -0.003). • At 24 weeks the change difference between the intervention group and the control group in the BMI z-score is also significant (-0.08, 95%C I-0.16 to -0.003).
Shalitin et al. (2009)	**<u>Intervention group</u>** Baseline BMI z-score: 4.49 ± 0.25 12 weeks BMI z-score: 3.91 ± 0.26 52 weeks BMI z-score: 4.28 ± 0.29 **<u>Control group (diet)</u>** Baseline BMI z-score: 4.89 ± 0.25 12 weeks BMI z-score: 3.70 ± 0.26 52 weeks BMI z-score: 4.10 ± 0.27 **<u>Control group (diet + exercise)</u>** Baseline BMI z-score: 4.76 ± 0.25 12 weeks BMI z-score: 3.55 ± 0.25 52 weeks BMI z-score: 3.87 ± 0.27	**<u>Within-group analysis</u>** • At 12 weeks the reduction in BMI z-score was significantly higher in the diet only group (-1.28 ± 0.66, p ≤ 0.001) followed by the diet and exercise group (-1.2 ± 0.83, p ≤ 0.001) and then the exercise group (-0.61 ± 0.72, p ≤ 0.001) which showed the least change. • At 52 weeks there was no significant difference in the change in BMI z-score in the intervention group. • At 52 weeks the diet only (-0.86 ± 1.08) and diet + exercise (-0.92 ± 1.34) groups showed significant reduction in BMI z-score values when compared to baseline (p ≤ 0.05). • Mean change in BMI z-score at 12 weeks: IG= -0.61 (0.72), CG= -1.28 (0.66) (The diet group was used as the CG during meta-analysis) **<u>Between-group analysis</u>** • At 12 weeks there was a significant difference in the change in BMI z score between the three groups (p ≤ 0.001) • At 52 weeks, between group differences were not significant.

Table 4:7b: BMI z-score values and changes over time

Author	Results	Key findings
Farpour-Lambert et al. (2009)	**<u>Intervention group</u>** Baseline BMI z-score: 2.3 ± 0.6 **<u>Control group</u>** Baseline BMI z-score: 2.3 ± 0.6	**<u>Within-group analysis</u>** • At 12 weeks there was a significant reduction in BMI z-score values of the intervention group (-0.1 ± 0.1, p<0.05) but there was no change in BMI z-score of the control group. • From 12 weeks to 24 weeks there was a significant and even greater reduction in BMI z-score of the intervention group (-0.03 ± 0.05, p = 0.01). At this point the control group was also given the exercise intervention (modified cross-over) which resulted in a significant reduction in BMI z-score (-0.08 ± 0.14, p= 0.009). • Mean change in BMI z-score at 12 weeks: IG= -0.1 (0.1), CG= 0.0 (0.1) **<u>Between-group analysis</u>** • At 12 weeks the change difference between the intervention group and the control group (treatment effect) in BMI z-score was significant (-0.1, p=0.04). • From baseline to 24 weeks the change difference between the intervention group and the control group was not significant.
Trost et al. (2014)	<u>Intervention group</u> Baseline BMI z-score: 2.14 ± 0.08 8 weeks BMI z-score: 2.01 ± 0.08 16 weeks BMI z-score: 1.89 ± 0.08 <u>Control group</u> Baseline BMI z-score: 2.16 ± 0.07 8 weeks BMI z-score: 2.10 ± 0.07 16 weeks BMI z score: 2.05 ± 0.07	**<u>Within-group analysis</u>** • At 16 weeks there was a statistically significant reduction in the BMI z-score of the intervention group (-0.19 ± 0.02, p < 0.05). • At 16 weeks there was also a statistically significant reduction in the BMI z-score of the control group (-0.07 ± 0.02, p <0.05). • Mean change in BMI z-score at 16 weeks: IG= -0.25 (0.03), CG= -0.11 (0.03) **<u>Between-group analysis</u>** • At 16 weeks the change difference between the intervention group and the control group in BMI z-score is significant (0.12 ± 0.03, p < 0.05). • Relative to the control group, the intervention group recorded a significantly higher reduction in BMI z- score (net difference, 0.14 [0.04; 95%CI, 0.07-0.22]; p < 0.001).

Table 4:8: Summary of BMI z-score mean changes over time for all the selected studies

STUDY		MEAN CHANGES BMI Z-SCORE
Weintraub et al. (2008)	Intervention group	Baseline - 12 weeks: -0.07(0.49)
		12 weeks - 24 weeks: -0.02
	Control group	Baseline - 12 weeks: Nil
		12 weeks - 24 weeks: Nil
Shalitin et al. (2009)	Intervention group	Baseline - 12 weeks: -0.61 ± 0.72*
		12 weeks - 24 weeks: 0.42 ± 1.03
	Control group (diet only)	Baseline - 12 weeks: -1.28 ± 0.66*
		12 weeks - 24 weeks: 0.32 ± 0.77
	Control group (diet+exercise)	Baseline - 12 weeks: -1.2 ± 0.83*
		12 weeks - 24 weeks: 0.37 ± 0.83*
Farpour-Lambert et al. (2009)	Intervention group	Baseline - 12 weeks: -0.1 ± 0.1*
		12 weeks - 24 weeks: -0.03 ± 0.05*
	Control group	Baseline - 12 weeks: Nil
		8 weeks - 24 weeks: -0.08 ± 0.14*
Trost et al. (2014)	Intervention group	Baseline - 8 weeks: -0.13±0.08
		8 weeks - 16 weeks: -0.12±0.08
		Baseline - 16 weeks: -0.25±0.03*
	Control group	Baseline - 8 weeks: -0.06±0.07
		8 weeks - 16 weeks: -0.05±0.07
		Baseline - 16 weeks: -0.11±0.03*

***Significant p-value (p<0.05)**

4.4.4.1. BMI z-score values and changes over time

Table 4.7a and 4.7b outline the BMI z-score values at baseline and how they change during and after the intervention. At baseline the mean BMI z-score values of participants in three intervention groups were all similar- (Trost et al., 2014b) (2.14± 008), (Farpour-Lambert et al., 2009b) (2.3 ± 0.6) and (Weintraub et al., 2008) (2.15±0.44). (Shalitin et al., 2009b) recorded the highest mean baseline BMI z-score (4.49±0.25).

4.4.4.2. Mean BMI z-score changes

Table 4.8 outlines the mean changes in BMI z-score over different periods. Mean BMI z-score changes vary significantly within study intervention and control groups. After direct supervision was removed from the intervention groups, the rate of reduction in BMI z-score values significantly declined in (Farpour-Lambert et al., 2009, Trost et al., 2014, Weintraub et al., 2008) and in the Shalitin et al. (2009) study, reverted towards the pre-intervention values. The Shalitin et al. (2009) study results showed that diet and diet+exercise interventions result in marked improvements in BMI z-score of children. The change in BMI z-score at 12 weeks in the diet and diet+exercise groups were not significantly different from each other but both groups displayed significantly greater success than sole exercise interventions in reducing BMI z-score values. Overall, there was a significant difference in changes in BMI z-score between all intervention and control groups.

4.4.4.3. Secondary outcomes

In addition to the BMI z-score, each study measured other variables as described in Table 4:9.

Table 4:9: Secondary outcomes measured

Trost et al. (2014)	Farpour-Lambert et al. (2009)	Shalitin et al. (2009)	Weintraub et al. (2008)
Moderate-to-vigorous Physical Activity (MVPA),	Whole-body fat	Body fat mas	Total activity
Vigorous Physical Activity (VPA)	Abdominal fat	Percentage fat mass	Moderate Physical Activity (MVA)
Percentage overweight	Fat-free mass	Waist circumference	Vigorous Physical Activity (VPA)
	Cardiorespiratory fitness	Blood pressure	Television and other forms of screen time
	Total energy intake	Resting energy expenditure	Psychological outcomes
	Blood pressure	Biochemical variables	
	Biochemical variables	Physical activity	
		Health-Related Quality of Life (HRQOL) variables	

As outlined in Table 4.6, the included studies also measured other anthropometric variables, health-related quality of life, physical activity, cardiorespiratory fitness, biochemical and psychological outcomes.

4.5. Data analysis

4.5.1. Included articles

Data were extracted based on JBI guidelines.

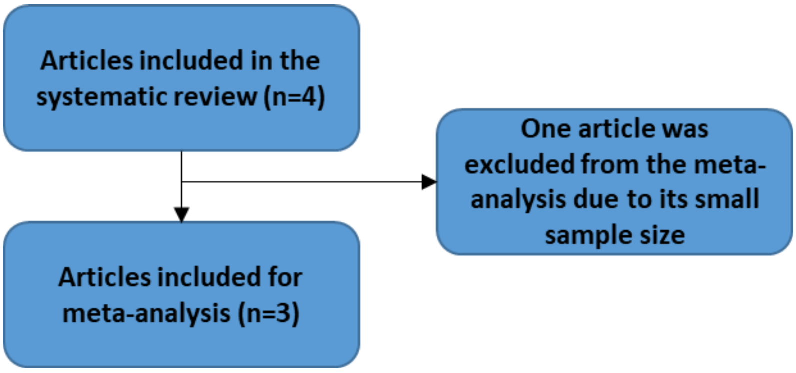

Figure 4:3: Included studies for meta-analysis

4.5.2. Demographics of included studies

Three studies, with a total of 226 participants were included in the data analysis. The Weintraub et al. (2008) study was excluded because it was a pilot study with minimal study participants (Zhang et al., 2013). The Shalitin et al. (2009) study has two control groups but only the result of the diet-only control group was included for data analysis. The pooled mean age of the participants was 8.6±1.46 years. The gender distribution was skewed in favour of the female participants (female: n = 150, male: n = 131).

4.5.3. Results of data synthesis

Statistical heterogeneity was tested using I^2 and standard chi-square statistics. The I^2 value was 99%, and the p-value of the chi-squared test was p=0 which both indicate considerable heterogeneity (Tufanaru C, 2017). Hence, meta-analysis results were not presented in the form of a forest plot.

4.6. Conclusion

This review is constituted of four studies that used sole activity interventions in the management of overweight and obesity in children 6-12-years old. The interventions resulted in a reduction of the BMI z-score with varying degrees between studies. The results also showed that many participants regained some of the weight lost during follow- up after direct supervision was removed. Subsequently, chapter five will discuss the findings of the systematic review. Chapter five will also suggest possible reasons for the study findings and propose suggestions based on knowledge drawn from the literature review.

5. CHAPTER FIVE: DISCUSSION

5.1. Introduction to chapter

This systematic review was conducted to determine whether physical activity is a viable tool for lowering BMI z-score in overweight and obese children aged 6-12 years old. In order to dissect this question, the overall results of the review will be discussed. Important components of effective physical activity interventions utilised in the included studies will be brought to the fore, and practical steps that support sustained physical activity in children will be discussed.

For data synthesis Farpour-Lambert et al. (2009), Shalitin et al. (2009) and Trost et al. (2014) studies were included. Weintraub et al. (2008) conducted a pilot study with a small sample size (n=18) which would have introduced study bias (Zhang et al., 2013) if included in data synthesis. We have chosen not to report on the results of the meta-analysis because studies were not directly comparable (I^2 test of heterogeneity was 99% and chi-squared test p-value=0 indicating considerable heterogeneity). The intervention group in the (Trost et al., 2014) study received a multimodal physical activity and the JOIN for ME programme which was different to that of the intervention groups in the Shalitin et al. (2009) and Farpour-Lambert et al. (2009) studies. Although (Shalitin et al., 2009) and (Farpour-Lambert et al., 2009) are somewhat comparable, the control group participants in the Shalitin et al. (2009) study received dietary intervention while those in Farpour-Lambert et al. (2009) did not receive any intervention. Hence, study results have been reported only as a narrative.

5.2. Findings of included studies

This section will report on the major findings of a relatively small systematic review. The primary outcome of this review is that sole exercise interventions are generally efficacious in improving BMI z-score status in overweight and obese children during the 12-week intervention phase of a weight management programme. Although mean changes in the BMI z-scores of included studies range from low to high, all studies can be termed as somewhat efficacious at 12 weeks. This conclusion is based on information from past literature about the definition of efficacious obesity intervention based on BMI z-score reductions (Croker et al., 2012, Kolsgaard et al., 2011, Salem et al., 2010, Oude Luttikhuis et al., 2009, Kirk et al., 2005).

Secondly, the impact of exercise interventions peaked during the intervention phase when the children received direct supervision. However, after direct supervision was removed, the rate of reduction in BMI z-score values significantly declined. The ability of exercise interventions to result in BMI z-score reduction is not questionable however sustained reduction, which can be termed as long-term efficacy, has been limited mainly by the absence of follow-up monitoring in many weight management programmes. In addition, the concept of “resetting” of the body’s energy homeostasis system may be a function of time. Klem et al. (1997) recorded successful weight maintenance in an adult population when exercise and dietary habits were sustained over 5.5 years. Effective overweight and obesity control with long-term results requires long-term dedication and not just a 6-week to 12-month commitment.

Another probable explanation for this observation could be that ultimately, there was a tapering off of the effect of exercise on BMI z-score values as the participants adapted to the prescribed exercise regimen over time. Participants would have benefitted rather from a diversification of the exercise regimen after a set time to counteract this phenomenon. Better efficacy of exercise interventions in sustaining weight loss over time requires innovative input and additional research to determine how this could be adequately implemented. Various scholars have suggested that overweight and obesity interventions need to shift the focus away from just weight loss and place more emphasis on pleasurable games and activity (Gill et al., 2014, Katz et al., 2012). Continually upscaling the type and intensity of the exercise regimen ensures sustained interest in exercise interventions. Activities such as hiking, group cycling, competitive team sports and active community service programs may prove to be valuable in sustaining interest, ensuring peer interaction and detracting attention away from the negative perceptions associated with overweight and obesity. In this age of technology, the use of cell phone, tablet and computer applications could formulate exciting exercise programs and remind children to engage in active and healthy lifestyles. Parents play a vital role in ensuring paediatric obesity intervention efficacy and will as well benefit from the use of computer technology as a tool for guiding their children. Computer applications could provide suggestions and periodic reminders about healthy eating and exercise ideas. Developing a strong support network between parents allows families to interact, motivate, compare progress and learn from each other’s experiences under the supervision of a trained facilitator.

According to the results from the Shalitin et al. (2009) study, the prescription of sole dietary interventions or a combined regimen of diet plus exercise are of comparable benefit and offer superior benefit than sole exercise interventions in improving BMI z-score status during the initial phase (12 weeks) of a weight management programme. Similar results have been documented previously in a study on adult participants (Giannopoulou et al., 2005). The similarity in intervention results raises the thought that exercise may not be a necessary component at the initial stage of overweight and obesity intervention in children. It also supports the suggestion made by multiple scholars that exercise without dietary restriction is not beneficial in inducing initial weight loss (Schwartz et al., 2017, Stoner et al., 2016, Verheggen et al., 2016, August et al., 2008, Klem et al., 1997). Instead, exercise intervention (along with dietary intervention) is more important for the long-term sustainability of weight control when executed efficaciously. Deforche et al. (2011) agree that combined physical activity and dietary control is beneficial for weight maintenance after the initial weight loss phase in obese children. Reybrouck et al. (1990) offer conflicting advice on the topic, stating that a combination of diet and exercise was more effective than diet-only intervention in a four-month long childhood overweight and obesity management programme. Mono-component interventions need to be substituted for multimodal lifestyle changes ranging from dietary intake, recreational play, physical education at school and after-school sports involving parental and community participation (Khambalia et al., 2012, Larson et al., 2011, Wang et al., 2013).

5.3. Standardising overweight and obesity definitions

Regarding global overweight and obesity definitions, there are various observations. An initial step to developing globally relevant childhood overweight and obesity prevention and treatment guidelines will be for scholars to reach a consensus on a standardised way of defining overweight and obesity is all populations. The discrepancies and resultant incompatibility (Cole and Lobstein, 2012) seen in the three different childhood overweight and obesity definitions (Cole and Lobstein, 2012, De Onis et al., 2004, Kuczmarski, 2002) has made universality difficult to achieve. Attempting to prescribe one universal definition of overweight and obesity might require an overhaul of all prior statistical data. However, this process is unlikely to be supported by many and is an enormous task to achieve (Callahan, 2013). It is a multi-component disease affected by intrinsic and extrinsic components such as the family, genetics, economic, societal, environmental and psychological factors with the degree of influence of each factor varied at different ages (Hummel et al., 2013). The nature of the disease is wide-ranging in various populations and amongst different ethnic groups. The presence of the disease often results in social stigma and psychological consequence (Wang et al., 2009, Wardle et al., 2005, Gortmaker et al., 1993) further compounding the problem. Because the systemic import of obesity may at first not be obvious, its presence may initially be taken for granted. However, it ultimately becomes a significant health (Kopelman, 2007, Bitsori and Kafatos, 2005, McLennan, 2004) and a quality of life impediment (Schwimmer et al., 2003, Ravens-Sieberer et al., 2001) that trails into adulthood (Dehghan et al., 2005, McLennan, 2004). It is challenging to treat successfully and irreversibly, partly because of the nature of its pathogenesis (Schwartz et al., 2017) and its multifacetedness (Hummel et al., 2013).

5.4. BMI z-score as a measure of overweight and obesity in child populations

Furthermore, there are differing opinions on the use of BMI z-score as a measure of obesity in children. Many scholars (Kelley et al., 2017, Kelley et al., 2014, Reilly et al., 2006, Kirk et al., 2005) recognise the importance of the BMI z-score and argue in its favour despite acknowledging its limitations. The BMI z-score can be calculated using simple and necessary measures of child growth that are often readily available (Pietrobelli et al., 1998). It recognises the fluid and varying nature of development in male and female children (Kumar and Kelly, 2017, Ogden and Flegal, 2010, Caroli et al., 2007) and is still widely accepted as a measure of overweight and obesity child populations. BMI z-score values have been reported on in various paediatric dietary and exercise intervention studies (Larsen et al., 2016, Loveman et al., 2015, Knop et al., 2015, Feeley et al., 2013, Economos et al., 2007, Thompson et al., 2004). However, other scholars caution the use of the BMI z-score to accurately assess changes in body fat (Vanderwall et al., 2018, Freedman et al., 2017, Ellis et al., 1999, Wells, 2000). Woo and Cole (2017) went as far as labelling the BMI z-score as misleading and advocated for the use of a new BMI metric established by Flegal et al. (2009) which better evaluates weight status for children with obesity. However, the metric proposed by Flegal et al. (2009) has not been widely accepted and BMI z-score is still popularly used in clinical practice. Implementing a completely new metric takes time and possesses the challenge of compatibility with current literature. Future studies could assess the popularity of this new metric and its applicability to current research.

5.5. Essential components of physical activity interventions

This section uses information retrieved from various review studies (Alberga et al., 2013b, De Niet et al., 2012, Drewnowski, 2009, Stock et al., 2007, Summerbell et al., 2003) to highlights various elements of physical activity interventions and how they can either facilitate or retard positive intervention outcome while drawing comparisons with prior documented evidence.

Many activity based overweight and obesity management programmes as well as those included in this review, have been conducted in controlled settings such as schools and healthcare establishments. Although controlled environments introduce selection bias into studies, they also offer multiple benefits such as cost control, accessibility and reduced drop-out rates (Daley, 2009, Dietz and Robinson, 2005, Summerbell et al., 2003) which are of extreme importance especially to resource-constrained communities in which such programmes are necessary (Drewnowski, 2009). The use of peer instructors has resulted in positive fitness attitudes and improved general well-being in children (Stock et al., 2007) and may suffice for administering structured activity interventions in lower-income communities where funding of fitness trainers and coaches may be a challenge. Activities such as outdoors team sporting and hiking are creative and all-inclusive activities that are cost-effective.

Similar exercise programmes inclusive of aerobic and strengthening exercises were administered to Shalitin et al. (2009) and Farpour-Lambert et al. (2009) intervention participants, keeping with prescribed exercise forms used in previous activity intervention reviews (Stoner et al., 2016, Atlantis et al., 2006) and in accordance with exercise prescription recommended by the WHO (García-Hermoso et al., 2018, World Health Organisation, 2010b). However, the studies varied in exercise intensity and session duration. Shalitin et al. (2009) administered high-intensity exercise for 90 minutes while Farpour-Lambert et al. (2009) conducted moderate-intensity training for 60 minutes. The lengthy and rigorous exercise prescription offered by Shalitin et al. (2009) may have resulted in the highest reduction in BMI z-score values recorded at 12 weeks when compared to other included studies. Beyond 12 weeks, the rigorous high intensity and lengthy intervention exercises may not have been sustainable for these severely obese children leading to a reversion of BMI z-score towards baseline values once direct supervision had ceased. This result contradicts the school of thought that states that initial weight loss is positively linked to prolonged weight loss success (Ortner Hadžiabdić et al., 2015). Farpour-Lambert et al. (2009) on the other hand utilised only moderate intensity exercise for a shorter duration of 60 minutes. Although this design may have resulted in slower BMI z-score reduction during the initial 12-week period, it may also have ensured better sustainability beyond 12 weeks. In addition, the frequency of exercise sessions in the Farpour-Lambert et al. (2009) study was reduced from three to two times weekly after initial 12-week intervention and this may also have assisted with sustainability. Slow and progressive dietary and exercise lifestyle changes offer the best approach to long term healthy weight and are more sustainable than sudden and rapid weight loss (Khawandanah and Tewfik, 2016).

Weintraub et al. (2008) employed the use of team soccer as the activity intervention and reported significant changes in BMI z-scores at the end of the intervention and during the follow-up period. The study also recorded full retention of study participants until the end of follow-up. The children and their parents so enjoyed the team soccer programme that they requested for the number of weekly sessions to be increased from 3 days to 4 days. Although this was a pilot study and results need to be interpreted cautiously, team sports may be a viable component of activity interventions that sustain interest and ensure sustainable results. The small sample group of 12 participants may have also benefited the study outcome by allowing for individual attention and better bonding between study participants and families.

The Shalitin et al. (2009) study, whose participants were the most obese, was specifically plagued with a high drop-out rate. It is safe to presume that the causal factor behind such a high drop-out rate was extrinsic to the exercise and diet programmes themselves because the high drop-out spanned through all the three different sample groups. Although drop-out has previously been recorded in studies including participants with high levels of obesity (Ortner Hadžiabdić et al., 2015), average drop-out rates usually range between 30%-40% (Oude Luttikhuis et al., 2009). However, the drop-out rate in the Shalitin et al. (2009) study was as high as 53% at the end of follow-up. Social and cultural affiliations may have been the reason for such findings. The Shalitin et al. (2009) study was set in Israel, an Arab population with a distinctly different culture to that of the other included studies. Kaluski et al. (2009) and Sharara et al. (2018) both found high levels of inactivity in Arab child populations, levels even higher than their adult population. Sharara et al. (2018) attributed the relative inactivity in this population to the extreme heat experienced in the Gulf Peninsula that discourages outside play for children, as well as other deeply entrenched social, cultural and religious practices. Restrictive dressing in Arab females affects the ease of movement during exercise (Sharara et al., 2018). Arab cultural practices such as communal eating out of a single dish (Dagmar, 2018), could have impacted in dietary control leading to non-compliance. All the above could have contributed to non-compliance, loss of interest, bodyweight rebound and ultimately, high drop-out rate recorded in this initially successful study. Hence, the importance of considering and adapting exercise interventions to suit the ethnic, social, cultural and religious affiliations of each target group cannot be overemphasised.

The stratification of intervention programmes based on the degree of obesity may benefit the efficacy and appropriateness of intervention programmes because the capabilities and needs of overweight children versus extremely obese children may vary (Suskind et al., 1993). Farpour-Lambert et al. (2009) and Shalitin et al. (2009) focused specifically on obese and severely obese children. One could argue that labelling a child would result in stigmatisation; however, it is important to note that the initial success of these studies may have been because the exercise interventions programmes were specific to obese children and did not include children who were merely overweight. Body size is an indicator of physical activity and participation on children of this age bracket (Alberga et al., 2013a). Children may feel more relaxed and less self-conscious if they are grouped to participate with children of the same weight status as themselves because obese children find physical activity more challenging than their normal weight counterparts (Deforche et al., 2006). Grouping children according to weight status means that the children exercise at a similar pace eliminating the effects of competition and frustration.

Stratification along with gender, ethnic, socio-economic and religious lines may be tricky but should be considered to cater for various sociocultural perceptions that form a common thread amongst people groups and bear weight on the success of weight management interventions. An initial qualitative assessment of the target group before stratification will expose mitigating factors such as social, cultural and familial values that have been shown to have a significant influence on the success of such programmes. Providing basic health education prior to intervention ensures that all participants and family members have the same baseline knowledge of the direct relationship between diet, physical activity, weight gain and health status. Health education also allows them to begin to challenge their preconceived ideas of body weight and lifestyle. Programmes should be offered in a language in which the child is fluent, which would ensure relevance to the target intervention group because the child is then able to identify personally with the group. Various qualitative studies have recognised the importance of language appropriacy in communicating effectively (Mvo, 1999).

The consequent financial implications of personalising overweight and obesity intervention programmes are notable. However, the onus lies on health care providers to sensitise national policymakers and international organisations, based on evidence-based research, to the importance of sufficient budget to fund overweight and obesity interventions. They will circumvent the even more expensive economic and health consequences of obesogenic diseases.

The benefits of prescribed, well-structured and monitored physical activity intervention programmes in children are apparent and have been previously documented (Whitlock et al., 2010, Fogelholm et al., 2008, Robinson, 1999, Gortmaker et al., 1993). Thompson et al. (1997) stated that overweight men are more likely to exercise in structured weight management programmes than in those that are less structured. Such a statement could apply to child weight management programmes. Active computer gaming is an innovative way of utilising a popular sedentary screen-leisure activity to encouraging physical activity in children (Peng et al., 2013, Daley, 2009). Such a modality will presumably be beneficial under controlled conditions. A study conducted by Christison et al. (2016) recorded only minimal improvements in weight status after screen-based activity interventions, although the gains were sustained for six months. Christison et al. (2016) outlined various challenges that may have limited the effectiveness of such interventions. The lack of impact on routine exercise, the stimulation of unhealthy snacking and ultimately, the waning of interest in computer games as the novelty of a new game wears off are some of such challenges. However, such adverse effects did not play out in the Trost et al. (2014) study participants. The active gaming intervention resulted in significant and sustained reductions in BMI z-score over 16 weeks although it neither involved a prescribed dosage of gaming nor any weekly monitoring. Therefore, active gaming may be considered for use in weight management programmes because it may be an effective way of sustaining physical activity beyond periods of direct monitoring when weight gain usually rebounds. Reybrouck et al. (1990) also recognised the need for forms of unsupervised exercise as part of a multimodal intervention for sustained obesity management in children. The inclusion of the family-based programme (JOIN for ME) in conjunction with the active gaming may have also added to the successes recorded in the Trost et al. (2014) study. This highlights the empirically validated importance of family involvement as an integral part of sustained overweight and obesity management in children (Campbell and Hesketh, 2007, Golan, 2006, Epstein et al., 1994). However, it is also important to consider the cost implications of game consoles and the consequent barrier to lower-income families.

The Weintraub et al. (2008) study showed that a traditional after school activity and health education programme is ineffective in improving BMI z-score values in children. However, the JOIN for ME education programme, which was part of the Trost et al. (2014) study produced small but statistically significant reductions even in the control group. In addition to physical activity and calorie control, the JOIN for ME programme also emphasised family involvement and goal setting. The inclusion of a personalised success strategy in conjunction with parental input in the Trost et al. (2014) education programme could have been the reason for its success. Again, this points to family involvement as an important component of successful weight management in children (Campbell and Hesketh, 2007, Golan, 2006, Epstein et al., 1994).

5.6. Ensuring the long-term success of overweight and obesity management in children

Best practice in paediatric overweight and obesity management points towards a multi-pronged solution comprising of exercise, dietary and behavioural intervention. A future goal for medical science will be to the development of 'personalised medicine' (Loos, 2011) as the backbone of all multimodal obesity programmes to ensure evidence-based individualisation that will result in greater intervention efficacy. This is a costly tall order that has not been fully investigated. However, its rewards may be noteworthy, resulting in improved life expectancy and reduced financial loss for national economies (Matuchansky, 2015).

Below is a summarised compilation of practical considerations that support the efficacy of physical activity interventions as a component of long-term overweight and obesity management.

1. The physical activity intervention setting should be a conducive socio-cultural environment that encourages participation of all children regardless of degree of obesity, fitness level, social class, ethnic or religious affiliation (Alberga et al., 2013b, Salvy et al., 2012, Franzini et al., 2009, Weintraub et al., 2008, Suskind et al., 1993).
2. Accessibility and transportation to the physical activity intervention venue will ensure attendance and limit participant drop-out, a challenge experienced in many obesity

management programmes (Pescud et al., 2010, Yackobovitch-Gavan et al., 2009, Robinson et al., 2003).

3. Regular interaction with children enrolled into a weight management programme through short message service (SMS) has proven to be an effective self-monitoring modality that also reduces drop-out rates (De Niet et al., 2012). This modality can also be employed on a long-term basis because it does not necessitate direct supervision but still provides some monitoring.
4. Pleasurable music should be used during physical activity to enhance interest and exercise performance (Schneider et al., 2010, De Bourdeaudhuij et al., 2002).
5. Exercise instructors should be chosen with great intentionality because they play a massive role in ensuring optimal participation and a positive learning experience. They should possess a firm knowledge of exercise theory and obesity management (Alberga et al., 2013b, Lonsdale et al., 2013, Pescud et al., 2010, Robinson et al., 2003). Peer training has also proven to be effective (Stock et al., 2007).
6. Exercise prescription should include approximately 60 minutes of aerobic and resistance exercises performed at moderate-to-vigorous intensity, three times a week (World Health Organisation, 2010b, García-Hermoso et al., 2015). The exercise activities ought to be diverse, exciting and entertaining for it to capture the interest of all children while redirecting their focus from weight loss to pleasurable activity (Gill et al., 2014, Katz et al., 2012).
7. Parents should be encouraged to take ownership of the obesity management programme because their role is of paramount importance in overweight and obesity management programmes (Epstein et al., 1994, Golan, 2006, Campbell and Hesketh, 2007, Whitlock et al., 2010). They should be educated about the contents of the weight management programme and the practical steps they can take to support their children at home.
8. Cultural myths and beliefs should not be overlooked but instead confronted and discussed as part of the child and parent education sessions. Barriers to interventions success need to be considered because the intrinsic benefit to the individual provides a longer-lasting benefit beyond the exercise intervention programme (Robinson et al., 2003).

9. Pediatric obesity treatment teams should include child and adolescent psychologists and psychiatrists (Alberga et al., 2013b, De Niet et al., 2012, Taner et al., 2009) to cater for emotional needs that affect intervention success.
10. SMART (Specific, Measurable, Attainable, Realistic, Timely) short- and the multidisciplinary team should conduct long-term goal setting sessions (Bovend'Eerdt et al., 2009). They provide personalised strategies to ensure optimal success of the weight management programme (Jones et al., 2011).

5.7. Study limitations

The review only considered studies that used the CDC childhood overweight and obesity classification and hence a small number of studies were identified for inclusion. Further research would benefit from widening the scope of included studies by incorporating studies that utilised both IOTF and WHO childhood overweight and obesity cut-offs. In such an instance, studies may then need to be analysed separately to cater to study variability. Following from this, a comparison of the results from each segment of analysed data could shed light on whether the choice of childhood overweight and obesity cut-offs used in the review of studies is of any relevance in reporting on exercise effectiveness. Future studies on the topic could also consider narrowing the age bracket to exclude 12-year-old children. Studies have shown that some children of this age have moved beyond Tanner Stage 1 into puberty when body weight changes seen mostly in girls may be as a result of hormonal changes.

5.8. Conclusion of chapter

The above chapter has summarised the salient points extrapolated from the study results. Physical activity is an effective mode of managing overweight and obesity. However, a multimodal intervention inclusive of diet, exercise and behaviour modification supersedes sole activity interventions in efficacy. The family supported dietary intervention with behavioural modification should be the first line of action followed subsequently by a long-term activity lifestyle change. The following chapter will conclude the systematic review.

6. CHAPTER SIX: CONCLUSION

Physical activity interventions are an integral component of weight loss management programmes in children. Physical activity interventions are most efficacious when used in conjunction with dietary interventions. Dietary control is effective in activating initial weight loss and therefore forms the first line of action for overweight and obesity management in children. A gradual introduction of prescribed exercise activity, the cessation of sedentary habits and the implementation of behavioural therapy all serves as buffers for dietary control. Overweight and obesity management programmes headed by trained multidisciplinary healthcare professionals should be routinely available to children of all age brackets. Past literature has shown that dedicated parental involvement has proven to be a vital key to the success of all overweight and obesity interventions in children. For sustained weight loss, intervention programs need to be designed to include monitoring for lengthy periods of time (beyond 12 months) that will in due course, lead to lifestyle change.

Globally, dietary and activity habits need to be overhauled. A lifestyle overhaul may be quite a feat to accomplish however, various slow and consistent changes make a difference and lead to a societal paradigm shift ultimately resulting in healthy living. Evidence of this shift has already begun in HIC where overweight and obesity prevalence seems to have slowed over the past few years. Health education targeted at the general public ensures an awareness of the dire consequences associated with overweight and obesity in children. International child advocacy organisations should insist on firm government policies that regulate the sugar and nutritional content of consumer diets.

The overweight and obesity pandemic has become a major scourge that threatens human existence. It has seeped into all global communities leaving an indelible impact. Industrialisation, technology and financial gain all share in the blame. On face value, the benefits of technological advancement seemed harmless and vital for stress-free living. However, careful analysis exposes technology's ability to tilt the energy balance equation resulting in higher energy storage in the body. There is an urgent need for further in-depth investigation into specific strategies aimed at the fight against childhood overweight and obesity. The future success of overweight and obesity management may lie in the development of personalised medicine to deal with individual cases seeing that the disease has proved to be quite variable. Although the financial implications of personalised medicine may be significant, they fade in significance when compared to the compounded consequences of a grossly large population. Unless drastic measures are taken in this direction, disastrous consequences will ensue.

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APPENDIX ONE: APPROVAL OF STUDY TITLE

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

09 March 2018
Person No: 1772003
PAG

Mrs CN Ezenwugo
P.o Box 776
0850
South Africa

Dear Mrs Ezenwugo

Master of Science in Physiotherapy: Approval of Title

We have pleasure in advising that your proposal entitled *The effectiveness of activity based interventions in the management of overweight and obesity in children - a systematic review* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

APPENDIX TWO: ETHICAL APPROVAL

Human Research Ethics Committee (Medical) **50 years 1966 – 2016**

Research Office Secretariat: Faculty of Health Sciences, Phillip Tobias Building, 3rd Floor, Office 301,
29 Princess of Wales Terrace, Parktown, 2193 Tel +27 (0)11-717-1252 /1234/2656/2700
Private Bag 3, Wits 2050, email: zanele.ndlovu@wits.ac.za
Office email: hrec-medical.researchoffice@wits.ac.za
Website: www.wits.ac.za/research/about-our-research/ethics-and-research-integrity/

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Ref: W-CJ-171108-1 08/11/2017

TO WHOM IT MAY CONCERN:

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical).

Investigator: **Mrs C Ezenwugo (student no. 1772003).**

Project title: **The effectiveness of activity-based interventions in the management of overweight and obesity in children – a systematic review.**

Reason: This study uses information in the public domain. There are no human participants.

UNIVERSITY OF THE WITWATERSRAND
PROF PE CLEATON-JONES
HREC (MEDICAL)
2017 -11- 08
JOHANNESBURG

Professor Peter Cleaton-Jones

Chair: Human Research Ethics Committee (Medical)

Copy – HREC (Medical) Secretariat: Zanele Ndlovu, Rhulani Mkansi, Lebo Moeng.

APPENDIX THREE: Johanna Briggs Institute (JBI) APPRAISAL TOOL

JBI CRITICAL APPRAISAL CHECKLIST FOR RANDOMIZED CONTROLLED TRIALS

Author: **Reviewer:**

Inclusion criteria	**Y**	**N**	**U**
Age: 6-12yrs	☐	☐	☐
BMI >85th percentile	☐	☐	☐
Study design - RCT	☐	☐	☐
Intervention - Purposeful physical activity	☐	☐	☐
Primary outcome measure - BMI z-score / adjusted for age	☐	☐	☐
Length of intervention: ≥12weeks	☐	☐	☐

SN	Items	Y	N	U	N/A
1	Was true randomization used for assignment of participants to treatment groups?	☐	☐	☐	☐
2	Was allocation to treatment groups concealed?	☐	☐	☐	☐
3	Were treatment groups similar at the baseline?	☐	☐	☐	☐
4	Were participants blind to treatment assignment?	☐	☐	☐	☐
5	Were those delivering treatment blind to treatment assignment?	☐	☐	☐	☐
6	Were outcomes assessors blind to treatment assignment?	☐	☐	☐	☐
7	Were treatment groups treated identically other than the intervention of interest?	☐	☐	☐	☐
8	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?	☐	☐	☐	☐
9	Were participants analysed in the groups to which they were randomized?	☐	☐	☐	☐
10	Were outcomes measured in the same way for treatment groups?	☐	☐	☐	☐
11	Were outcomes measured in a reliable way?	☐	☐	☐	☐
12	Was appropriate statistical analysis used?	☐	☐	☐	☐
13	Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

APPENDIX FOUR: JBI DATA EXTRACTION TOOL

JBI Data Extraction Form for Experimental / Observational Studies

Reviewer ________________________ Date ________________________

Author ________________________ Year ________________________

Journal ________________________ Record Number ________________

Study Method

RCT	☐	Quasi-RCT	☐	Longitudinal	☐
Retrospective	☐	Observational	☐	Other	☐

Participants

Setting ____

Population ____

Sample size

Group A ____________________ Group B ____________________

Interventions

Intervention A ____

____

Intervention B ____

____

Authors Conclusions:

____

____

____

Reviewers Conclusions:

____

____

____

Study results

Dichotomous data

Outcome	Intervention ( ) number / total number	Intervention ( ) number / total number

Continuous data

Outcome	Intervention ( ) number / total number	Intervention ( ) number / total number

APPENDIX FIVE: TURNITIN REPORT

1772003:FINAL_DISSERTAION_JAN2020.docx

ORIGINALITY REPORT

1%	1%	2%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		