THE EFFECTIVENESS OF BRAIN-BREAKS EXERCISE INTERVENTION ON SOCIO-ECOLOGICAL RISKS USING A TRANSTHEORETICAL MODEL AMONG OVERWEIGHT AND OBESE CHILDREN IN SHANGRAO, CHINA

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AVE	Average Variance Extracted
CDC	Center for Disease Control and Prevention
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CR	Composite Reliability
DB	Decision Balance
DB-C	Chinese Version of Decisional Balance Scale
IPAQ-C	Chinese Version of International Physical Activity Questionnaire
KI	Standardised Kurtosis Index
MI	The Model Modification Index
ML	Maximum likelihood
MLR	Robust Maximum Likelihood
MVPA	Moderate Vigorous Physical Activity
PA	Physical activity
PE	Physical environment PE: Physical environment
PE-C	Chinese Version of Physical Environment Scale for Exercise
POC	Process of Change
RCTs	Randomised Controlled Trial
RM ANOVA	Repeated Measures Analysis of Variance
RM MANOVA	Repeated Measures Analysis
RMSEA	Root Mean Square Error of Approximation

SD	Standard Deviation
SE	Social Environment
SE-C	Chinese Version of Social Support Scale for Exercise
SEE	Self-Efficacy
SEE-C	Chinese Version of Self-Efficacy for Exercise Scale
SEM	Structural Equation Modelling
SI	Skew Index
SOC	Stages of Change
SOC-C	Chinese Version of Stage of change scale
SRMR	Standardised Root Mean Square
TLI	Tucker-Lewis index
TTM	The Transtheoretical Model
WHO	World Health Organisation

KEBERKESANAN INTERVENSI SENAMAN *BRAIN-BREAKS* TERHADAP RISIKO SOSIAL-EKOLOGI MENGGUNAKAN MODEL TRANSTEORETIKAL DALAM KALANGAN KANAK-KANAK BERAT BADAN DAN OBES DI SHANGRAO, CHINA

ABSTRAK

Obesiti dalam kalangan kanak-kanak telah menjadi kerisauan kesihatan umum yang signifikan di seluruh dunia dengan pelbagai faktor penyumbang. Untuk mendapatkan pemahaman yang lebih menyeluruh tentang isu ini, kajian ini menggunakan kombinasi Model Sosial-Ekologi dan Model Trans-Teoretikal (TTM) untuk menganalisis faktor risiko sosial-ekologi dalam kalangan kanak-kanak berlebihan berat badan dan obes di China. Senaman video *Brain-breaks*, yang direka khusus untuk tetapan bilik darjah, telah diperkenalkan sebagai alat intervensi untuk meningkatkan aktiviti fizikal (PA) kanak-kanak. Kajian ini bertujuan untuk mengkaji hubungan antara pembolehubah TTM, faktor sosial-ekologi, dan PA dalam kumpulan indeks jisim badan (IJB) yang berbeza dan kesan latihan video *Brain-breaks* terhadap pembolehubah kajian dalam kalangan kanak-kanak obes dan berat badan berlebihan di Bandar Shangrao, Wilayah Jiangxi, China. Kajian ini dijalankan dalam dua fasa: kajian keratan rentas untuk Fasa 1 dan percubaan terkawal rawak untuk Fasa 2. Persampelan rawak kluster telah digunakan untuk mengambil peserta dalam Fasa 1. 1573 kanak-kanak dan remaja berumur 9-15 tahun telah diambil. 100 peserta dari Fasa 1 telah

menyertai Fasa 2. Semasa Fasa 1, peserta yang memenuhi kriteria kelayakan menerima pakej soal selidik untuk diisi di dalam bilik darjah. Pemodelan persamaan struktur digunakan untuk mengkaji hubungan antara pembolehubah kajian. Fasa 2 telah dijalankan untuk mengkaji keberkesanan intervensi senaman video *Brain-breaks* pada pembolehubah yang diukur. Fasa 2 terdiri daripada empat minggu, dan peserta dibahagi secara rawak kepada kumpulan intervensi dan kawalan. Hanya kumpulan intervensi diberikan latihan video 10 minit *Brain-Breaks* setiap hari. Analisis varians pelbagai pengukuran berulang (ANOVA) digunakan untuk mengkaji kesan intervensi terhadap dua kumpulan kajian. Analisis data dilakukan oleh SPSS 27.0 dan Mplus 8. Dalam fasa 1, kebanyakan peserta adalah lelaki (56.8%) dengan umur purata 12 tahun (sisihan piawai 1.68). Model struktur akhir sesuai dengan data dengan baik [indeks Bandingan Kesesuaian (IBK) = .920, indeks Tucker Lewis = .916, Baki Punca Kuasa Piawai (BPKP) = .049, Penghampiran Punca Kuasa Ralat Min (PPKRM) (90% Selang Keyakinan) = .039 (.038, .040)]. Ia juga menjana hubungan antara yang signifikan antara pembolehubah TTM, faktor sosial-ekologi dan jumlah PA. Peserta dalam Fasa 2 mempunyai purata umur 13.4 (sisihan piawai = 2.53) dan purata IBK 22.8 (sisihan piawai = 2.22). Pada akhir kajian, kumpulan intervensi menunjukkan skor yang jauh lebih tinggi daripada kumpulan kawalan pada tiga konstruk psikologi [manfaat yang dirasakan, keberkesanan kendiri, dan SOC dengan nilai-*p* <.001, <.001, <.001, masing-masing]. Kumpulan intervensi juga mendapat markah yang lebih tinggi dalam jumlah PA berbanding kumpulan kawalan (nilai-*p* = .001). Kesimpulannya, sokongan sosial

adalah penting untuk perubahan tingkah laku kanak-kanak yang berlebihan berat badan dan obes. Latihan video *Brain-breaks* mempunyai faedah praktikal dalam kanak-kanak Cina yang berlebihan berat badan dan obes kerana ia mengubah tingkah laku dan motivasi kanak-kanak untuk lebih banyak PA.

THE EFFECTIVENESS OF BRAIN-BREAKS EXERCISE INTERVENTION ON SOCIO-ECOLOGICAL RISKS USING A TRANSTHEORETICAL MODEL AMONG OVERWEIGHT AND OBESE CHILDREN IN SHANGRAO, CHINA

ABSTRACT

Childhood obesity has become a significant public health concern globally with multiple contributing factors. To gain a more comprehensive understanding of this issue, this study utilised a combination of the Social-ecological Model and the Transtheoretical Model (TTM) to analyze the social-ecological risk factors among overweight and obese children in China. The Brain-breaks exercise video, specifically designed for classroom settings, was introduced as an intervention tool to enhance children's physical activity. This study aimed to examine the inter-relationship between TTM variables, social-ecological factors, and physical activity (PA) in different body mass index (BMI) groups and the effect of Brain-breaks exercise videos on the study variables among obese and overweight children in Shangrao City, Jiangxi Province, China. This study was conducted in two phases: a cross-sectional study for Phase 1 and a randomised controlled trial for Phase 2. Cluster random sampling was used to select participants for Phase 1, resulting in the recruitment of 1573 children and adolescents between the ages of 9 and 15. From this group, 100 participants were selected to participate in Phase 2. In Phase 1, eligible participants received a questionnaire package

to complete in class, and structural equation modeling was used to examine relationships between study variables. Phase 2 evaluated the effectiveness of Brain-breaks exercise videos, with participants randomised into intervention and control groups for four weeks. Only the intervention group received a daily 10-minute video exercise. Data analysis was performed by SPSS 27.0 and Mplus 8, and the mixed factorial analysis of variance (ANOVA) was used to examine the intervention effects on both groups. In phase 1, most participants were boys (56.8%) with a mean age of 12 years old (SD = 1.68). The final structural model fits the data well [comparative fit index (CFI) = .920, Tucker Lewis index (TLI) = .916, Standardised Root Mean Square Residual (SRMR) = .049, Root Mean Square Error of Approximation (RMSEA) (90% CI) = .039 (.038, .040)]. It also generates significant inter-relationships between TTM variables, social-ecological factors, and the amount of PA. Participants in Phase 2 had a mean age of 13.4 (SD = 2.53) and a mean BMI of 22.8 (SD = 2.22). The intervention group had significantly higher mean scores than the control group on three psychological constructs, including perceived benefits, self-efficacy, and stage of change (p = .006, = .001, < .001, respectively), while the control group had higher scores on perceived barriers (p < .001). The intervention group also had significantly more PA (p = .003). The study concludes that social support is critical for behaviour change in overweight and obese children, and Brain-breaks exercise videos have practical benefits for Chinese overweight and obese children, altering behaviour and motivation towards increased PA.

CHAPTER 1

INTRODUCTION

1.1 Background

Obesity in children is one of the most serious public health problems of the twenty-first century (World Health Organisation, 2020). It garners considerable public attention because childhood overweight and obesity are likely to result in chronic conditions such as type II diabetes that may persist into adulthood when more severe adverse health consequences emerge (Colditz, 1992). The rapid pace of urbanization has resulted in the prevalence of overweight and obesity among children and adolescents in developing countries (Varadharajan et al., 2013). In China, the detection rate of obesity in 2010 was between 8.90% and 15.35% for boys and between 2.81% and 8.08% for girls in all age groups from 7 to 18 years old. As of July 2021, the prevalence of overweight and obesity among Chinese children and adolescents aged 6-17 was already approaching 20% (China CDC, 2021). Therefore, the issue of overweight and obesity among children and adolescents in China's cities has been elevated to a priority.

Physical activity (PA) was widely recognized as a critical factor constantly associated with childhood overweight and obesity (Gamble et al., 2009). It was also seen as the most critical component of promoting a healthy lifestyle (Sabo et al., 2019). Regular PA has proven effective in preventing and treating many chronic diseases, such

as diabetes, cardiovascular disease, and cancer, and is also an essential intervention for overweight and obesity (Kueh et al., 2018). However, PA participation is a complex behaviour driven by the interaction between multiple variables in different domains (Rovniak et al., 2002). These domains are generally characterized as psychological, social, and environmental (Ishii et al., 2013). Due to the complexity of the influences of these variables on PA, an integrated framework is needed to explain them adequately (Martinez et al., 2013).

The Social-ecological Model developed by Bronfenbrenner (1994) was a conceptual model designed to further the understanding of the dynamic interactions between diverse personal and environmental factors. A considerable number of studies have used this model to explore the relationship of PA with the social environment (SE), the physical environment (PE), and psychological factors (Sallis et al., 2015). Specifically, with this model, scholars have found that the network of interactions between social environmental factors (e.g., cultural background, social networks, family and friend support, and social norms) and physical environmental factors (e.g., the availability and quality of perceived sports facilities), and psychological factors (e.g., self-efficacy, perceived benefits and barriers, and stage of change) were significantly associated with PA participation (Brownson et al., 2009; Carlson et al., 2012; Lee & Kim, 2017). Thus, a broader understanding of the variables related to PA participation among overweight and obese children from different ethnic groups and

regions will help develop efficient intervention programs to address the multiple barriers that contribute to childhood obesity.

One suggested strategy for promoting and retaining youth participation in PA was to structure the intervention by applying the Transtheoretical Model (TTM) or Stages of Change Model, which was commonly applied in traditional mental health counseling to describe the behavioural change (Kim, 2007). According to Prochaska (1997), TTM was a theoretical model that utilised behavioural and cognitive strategies to coordinate the initiation and maintenance of PA, focusing on exercise persistence and how it interacts with psychological variables (Prochaska & DiClemente, 1983; Prochaska et al., 1992, 2002). When studying health behaviour change, TTM was one of the most widely cited and adopted models to demonstrate a thorough understanding of a particular behaviour and how it changes over time (Buckworth et al., 2013; Bull, 2001).

Although TTM is often referred to simply as the Stages of Change Model, its most commonly used version actually includes several different constructs: Stages of Change (SOC), Decision Balance (DB), Self-Efficacy (SEE), and Process of Change (POC) (Prochaska & Velicer, 1997). The core construct of TTM was the SOC which included five main stages (pre-contemplation, contemplation, preparation, action, and maintenance) for adopting healthy behaviours (Dishman et al., 2010). DB was the second psychological construct of TTM, which consisted of the perceived benefits (pros) and barriers (cons) of maintaining existing behaviours or starting new ones (Plotnikoff et al., 2001). It is essential for people to change their behaviour, and it has a significant

impact on them from the early stages (pre-contemplation to preparation) to the action stage (Janis & Mann, 1977; Velicer et al., 1998). SEE reflects the level of confidence individuals have in maintaining their intended behavioural change in situations that frequently trigger relapse (Bandura, 2006). People with greater self-efficacy were likelier to begin and maintain healthy behaviours and participate in regular PA (Bandura, 1994). POC was defined as people's covert and overt actions to progress through the stages (Prochaska & DiClemente, 1983). It can be classified into cognitive and behavioural progress (Bernard et al., 2014; Kim, 2007).

This study aims to gain a thorough understanding of the social-ecological risk factors for childhood overweight and obesity among children and adolescents in China, as well as to identify the most influential risk factors through assessment. Understanding the factors contributing to children's overweight and obesity from an ecological perspective enables us to develop more comprehensive and effective strategies for addressing the issue and avoiding public health crises.

1.2 Problem Statement

Childhood and adolescent obesity are serious medical condition that has a negative impact on their health (Kansra et al., 2021). It's particularly troubling because excess weight typically puts children at risk for implicit health hazards that were previously thought to occur only in adults, such as diabetes, high blood pressure, and high cholesterol. With the dramatic growth of the national economy, the nutritional status of Chinese children and adolescents has continued to improve. but the prevalence

of overweight and obesity among this population has also attracted increasing concerns. Previous studies have shown that obesity among children and adolescents is a highly complex condition with numerous contributing variables originating from the genetic, environmental, psychological, socioeconomic, and cultural background of an individual child. However, the majority of prior studies examined single influential factors, omitting a comprehensive examination of the factors influencing overweight and obesity.

Childhood overweight and obesity are a result of a variety of factors in a child's life. Creating supportive environments and communities to enhance children and adolescents' regular physical activity (PA) is considered one of the most fundamental ways to prevent overweight and obesity (World Health Organisation, 2020). In this study, the researcher uses the Social-ecological Model to analyze the common levels of exposure that a Chinese urban child faces on a daily basis, including intrapersonal, interpersonal, school, and community, in order to understand better which risk factors are significantly associated with child weight status and their PA participation. The Social-ecological Model is an intuitive theoretical framework for addressing multiple spheres of influence. It can aid in the understanding of the factors that influence behaviour and also provide direction for developing successful programs through the establishment of a supportive social environment for PA. As described in the model, the perceived social environment, such as cultural background, social norms, family support, and friend support, as well as the perceived physical environment, such as the

availability and quality of perceived exercise facilities, play a crucial role in influencing and sustaining PA participation (Kueh et al., 2018). These environmental factors interrelate with personal characteristics, such as demographic and psychological factors, thus influencing people's behaviour (Bronfenbrenner, 1994). PA has been shown to attenuate the damage associated with childhood obesity, including reducing fat storage, increasing caloric expenditure, and improving blood lipid profiles. Among the cognitive behavioural factors related to physical activity, attitudes and perceptions of physical activity, lack of motivation, and perceived barriers were identified as significant factors in reducing physical activity.

Meanwhile, the Transtheoretical Model (TTM) has been used to explain the changes in PA and diet behaviour in obesity. TTM is a theoretical model widely used to describe the process of behaviour change, including progression through a series of stages (Prochaska & DiClemente, 1983). Studies have reported that physical activity interventions based on TTM effectively reduce BMI in obese school-aged children (Woods et al., 2002) and promote physical activity in young adults (Ham et al., 2016). However, the available studies of TTM-based exercise interventions have mainly been conducted in community or clinical settings with adults or patients (Woods et al., 2002; Hutchison et al., 2009), and only a few studies have been conducted in school settings targeting overweight and obese children, especially in China.

The researcher believes that applying these constructs among overweight and obese children and adolescents in China could significantly enhance their health

awareness and weight control. One key intervention tool in this study is the Brain-breaks exercise video, initially proposed by HopSports in 2014. This video is a promising resource designed to promote individual health and learning. However, it's important to highlight that this intervention tool is relatively unfamiliar not only to overweight and obese children and adolescents in China but also within various Chinese populations where research on its application is scarce. By incorporating the TTM and PA intervention in this study, the researcher hopes to establish the TTM and Brain-breaks intervention as valuable assets in combatting the growing prevalence of overweight and obesity among Chinese children and adolescents in the future.

Therefore, in the present study, the researcher applied a combination of the SEM framework and TTM-based exercise intervention in Chinese overweight and obese children. The Brain-breaks video is the instrument to provide TTM-based exercise intervention to the participants. Participants' base levels of SOC, DB, SEE, and PA amount could help determine the PA intervention's effectiveness (Brain-breaks video) in improving these measured variables. Researchers anticipate that positive effects could help overweight and obese children become more physically active and derive health benefits from it.

1.3 Rationale and Significance

Poor health habits developed in childhood can have a long-term negative effect on a child's health. Childhood obesity has risen to become one of the world's most serious public health problems in recent years. The issue affects people with low and

middle incomes in a wide variety of countries, most notably in urban areas. Obesity among children is increasing at an alarming rate. In 2016, it is estimated that the global population of overweight children under the age of five will exceed 41 million. Almost half of the overweight children under the age of five live in Asia, and a quarter in Africa (WHO, 2016). In China, the number of overweight and obese children and adolescents has reached 120 million, with over 70% living in cities (Guo et al., 2019). Additionally, studies have revealed that the prevalence of overweight and obesity among children and adolescents continues to increase in both urban and rural areas (Zhang et al., 2016). In July 2021, the China CDC announced that the obesity rate among children and adolescents aged 6-17 is approaching 20%. This figure shows a modest increase from the past. Since overweight obesity not only has a long-term negative impact on children and adolescents in terms of physical health but also has a significant negative effect on children's mental health development, overweight and obesity among children and adolescents in China has become a serious public health problem that requires research to inform public policy.

Children, particularly those of younger ages, are primarily influenced by the components of their immediate environment, specifically their family, peers, school, and community. Their exposure to the environment enables them to influence health behaviours. The purpose of this study is to examine the social-ecological factors that contribute to overweight and obesity in Chinese children and adolescents and the effect of the Brain-breaks exercise videos on the stages of change among overweight and

obese children in China. Although numerous academic projects and studies have been conducted to combat childhood obesity, very few have examined social-ecological risk factors with a particular emphasis on children in China and explored the effects of the Brain-breaks exercise videos as an intervention for obese children in China. Due to the abundance of variables associated with a child's common social-ecological influences, childhood overweight and obesity can be assessed at multiple levels. Identifying the interactions and effects of multiple exposure levels on childhood overweight and obesity will shed light on the significant influences in each environment to which a child is exposed. Additionally, it is beneficial to establish a strong theoretical foundation for the early prevention and intervention of overweight and obesity in children and adolescents, as well as to control the prevalence of overweight and obesity in children and adolescents.

1.4 Research Questions

The research questions are derived from a review of the available literature.

1. What are the validity and reliability of the Chinese version of the TTM and social-ecological questionnaires?

2. Are there any relationships between TTM, social-ecological variables, and PA in Chinese children who are underweight, normal, overweight and obese in Shangrao City, Jiangxi Province, China?

3. Does the Brain-breaks exercise videos has a significant effect on the TTM variables, social-ecological variables, and PA in overweight and obese children in Shangrao City, Jiangxi Province, China?

1.5 Research Hypotheses

1. The Chinese version of TTM questionnaires (SEE, DB, SOC) and social-ecological questionnaires (SE and PE) are valid and reliable among the Chinese children population.

2. There are significant relationships between TTM variables, social-ecological variables, and PA in Chinese children who are underweight, normal, overweight and obese in Shangrao City, Jiangxi Province, China.

3. Brain-breaks exercise videos has a significant effect on the stages of change, TTM variables, social-ecological variables, and PA in overweight and obese children in Shangrao City, Jiangxi Province, China.

1.6 Research Objective

The general objective of this study is to examine the relationship between TTM variables, social-ecological variables, and PA in Chinese children with different BMI groups, as well as the effect of Brain-breaks exercise videos on the study variables among overweight and obese children in Shangrao City, Jiangxi Province, China.

1.6.1 Specific Objectives

1. To validate the Chinese version of TTM questionnaires and social-ecological questionnaires.

2. To determine the inter-relationships between TTM variables, socio-ecological variables, and PA in Chinese children in Shangrao City, Jiangxi Province, China.

3. To determine the time effect of the Brain-breaks exercise videos on the TTM variables, social-ecological variables, and PA among overweight and obese children in Shangrao City, Jiangxi Province, China.

4. To determine the group effect of the Brain-breaks exercise videos on the TTM variables, social-ecological variables, and PA among overweight and obese children in Shangrao City, Jiangxi Province, China.

5. To determine the interaction effect of the Brain-breaks exercise videos on the TTM variables, social-ecological variables, and PA among overweight and obese children in Shangrao City, Jiangxi Province, China.

1.7 Summary

This chapter presented a summary of the study. It began with an introduction to the research, which was accompanied by illustrations outlining the statement of problems and the significance of the research. Additionally, the rationale for the research and operational definitions was illustrated.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To fully understand the relevant progress of the current research, the researcher conducted a comprehensive literature review, including published and unpublished previous studies related to the research topic. The researcher has summarized all the information gathered in this chapter to enable readers to understand the study. This chapter were divided into chapters to describe all relevant variables and concepts of this study.

All previous research articles were obtained from online databases that contain authentic journals that publish all relevant articles. Online databases such as Google Scholar, PubMed, Web of Science, ResearchGate, Scopus, and CNKI were the primary databases used by the researchers to collect all relevant prior research. The literature search was conducted using the following keywords: childhood overweight and obesity, social-ecological risks, obesity intervention, physical activity, health concern, transtheoretical model, Chinese children, stages of change, processes of change, decision balance, prevalence, exercise self-efficacy, motivation, social-ecological model, Brain-breaks video, intervention, CFA, Multi-group SEM, Mixed-factorial

ANOVA. When conducting literature searches, "AND" or "OR" were used as Boolean operators to combine keywords.

2.2 Literature Search Strategies

E-databases were explored extensively, including CNKI, Google Scholar, Researchgate, PubMed, and Scopus, for related journals, papers, books, and articles. Associated search terms utilised independently or in combination included obesity, childhood obesity, Social-Ecological Model, social-ecological risk of obesity, obesity interventions, social support for exercise, Transtheoretical Model, International Physical Activity Scale, structural equation modeling, and the Brain-breaks exercise video.

2.3 Health Concerns Related to Childhood Overweight and Obesity

Childhood obesity has far-reaching effects across multiple organ systems and contributes to a spectrum of health issues, encompassing sleep disturbances, respiratory disorders, gastrointestinal complications, endocrine disruptions, cardiovascular ailments, and psychiatric disorders (Styne et al., 2017). Specifically, obese children exhibit an increased susceptibility to chronic conditions such as asthma (Ford, 2005), obstructive sleep apnoea (Fragkou, 2022), and type 2 diabetes (Elkhatib Smidt, 2021). Moreover, childhood obesity emerges as a risk factor for cardiovascular diseases, manifesting as hypertension and elevated blood cholesterol and triglyceride levels (Faienza et al., 2022). These factors contribute to the development of enduring, life-threatening illnesses, including stroke, coronary heart disease, and hypertension. Additionally, childhood obesity is associated with elevated mental health risks, leading

to diminished self-esteem and a lower quality of life (Çoban et al., 2019), often exacerbated by the increased likelihood of encountering bullying (Shaw et al., 2019). It is worth noting that mental health risks have predominantly been explored within developed countries, with limited research conducted in developing nations (Cianconi et al., 2020).

Furthermore, childhood overweight and obesity frequently set the stage for unfavorable adult weight status, escalating the potential for morbidity and premature mortality over a lifetime. A systematic review of 11 studies revealed a robust association between childhood obesity or overweight and significantly elevated risks of premature mortality and cardiometabolic morbidity in adulthood, including conditions such as diabetes, hypertension, stroke, and ischemic heart disease (Reilly & Kelly, 2011). Notably, ischemic heart disease and stroke are the foremost causes of accidental death worldwide, accounting for 25% of all fatalities and contributing to 12.9 million deaths in 2010 alone. Given the global prevalence of cardiometabolic diseases, the link between childhood obesity and cardiometabolic disorders is particularly alarming (Weihrauch-Blüher et al., 2019). Additionally, hypertension stands out as a leading risk factor for the global disease burden, and it has been observed that obese children are more prone to experiencing increased weight gain in adulthood (Lei et al., 2021). Overweight and obesity are not only risk factors for chronic metabolic ailments such as hypertension, atherosclerosis, and diabetes but also pose a threat to the mental well-being of children and adolescents (Byrne et al., 2019).

While the causes of obesity are multifaceted, it is believed that decreased physical activity, increased sedentary time, and excessive consumption of energy-dense foods are the primary individual behaviours and dispositions believed to contribute to weight gain and the likelihood of obesity in children and adolescents (Sibson, 2019).

These individual behaviors are inherently embedded within their organizational, environmental, and political contexts, which form the basis for their initial development. Lastly, the epidemiology of childhood obesity displays variations dependent on factors such as age, gender, race, ethnic background, and the daily external environment to which children are exposed (Knebusch et al., 2021). Furthermore, childhood overweight or obesity has been associated with early puberty, a risk factor for adult conditions like depression, type 2 diabetes, and cardiovascular disease (Brix et al., 2020), particularly pronounced among females, with higher BMI associated with reaching puberty milestones earlier, as evidenced in the cohort and sibling-matched analyses.

To attain a comprehensive comprehension of childhood overweight and obesity and to begin addressing this public health crisis, concerted and collaborative efforts across multiple sectors and settings, including government, healthcare, schools, and communities, are imperative (Lazarus et al., 2022).

2.4 The Social-Ecological Model

The Ecological Theory of Health posits that an individual's health is intricately linked to their daily interactions with the environment (Institute of Medicine, 2003). To comprehensively grasp the phenomenon of childhood obesity, it is imperative to delve into the intricate web of social and ecological factors that contribute to the risk of excess body fat.

The Social-Ecological Model serves as a conceptual framework, illuminating the dynamic interplay between various individual and environmental elements (Sallis

et al., 2008). It provides a visual representation of the ecological system that underlies specific health behaviors or outcomes, illustrating how multiple influences and their interactions impact the health and well-being of individuals (Institute of Medicine, 2003). This model proves invaluable in dissecting the multitude of factors that influence health behaviors and outcomes, with a particular focus on childhood overweight and obesity (Timmins et al., 2018).

The Social-Ecological Model offers a broader perspective by directing attention towards the wider political and environmental contexts that shape an individual's personal and interpersonal characteristics (Langille & Rodgers, 2010). Recognizing the diversity of daily experiences faced by children and their unique responses to these experiences underscores the need for a comprehensive framework. The Social-Ecological Model aids in visualizing these experiences, fostering a deeper understanding of the intricate interplay between the myriad daily exposures faced by children and their impact on health behaviors (Institute of Medicine, 2003). It is a valuable tool to illuminate the perplexing questions surrounding the prevention of childhood overweight and obesity and the strategic placement of interventions (Aberman et al., 2022). By identifying and addressing the most influential environmental factors in a child's living environment, preventive and interventional efforts may be more enduring and impactful.

Many studies on childhood obesity have aimed to pinpoint the single most influential factor among various contributing elements, often using the Social-

Ecological Model. However, they may overlook the substantial combined influence of several factors across different levels (Sheinbein et al., 2019). For instance, a study involving 4898 American cases identified factors such as a child's ethnicity, physical activity, maternal age, and family structure as key influencers of childhood obesity (Noh & Min, 2020). Furthermore, the Social-Ecological Model has been instrumental in elucidating the contributing factors to pediatric obesity and in constructing a framework for prevention and intervention. In a study involving telephone surveys of 560 children, various layers of the Social-Ecological Model were employed to analyze data collected at different levels, revealing the individual contributions of each level to a child's weight status (Khawaja et al., 2020). The layers of the model representing parental demographics and neighborhood characteristics emerged as the most influential in childhood obesity. In contrast, layers pertaining to diet and physical activity displayed a significant yet comparatively smaller connection to pediatric weight.

2.5 Childhood Obesity Interventions

2.5.1 Childhood Obesity and Physical Activity

PA represents a critical modifiable component of human energy expenditure, with a particular focus on Moderate and Vigorous Physical Activity (MVPA) due to its relevance. Extensive research has demonstrated the potential of PA in preventing weight gain and addressing obesity (Atlantis et al., 2006). PA not only directly increases energy expenditure, leading to weight reduction, but it also plays a vital role in preserving and enhancing lean body mass, thereby bolstering the body's capacity to burn energy (Nordisk, 2005). In the context of childhood obesity, PA exerts its influence on metabolism by reducing fat stores, elevating caloric expenditure,

enhancing glucose tolerance, and optimizing lipid profiles, mitigating the adverse effects associated with childhood obesity. Conversely, insufficient PA and the rise in sedentary behaviors, such as screen-based activities, have been consistently linked to a heightened risk of chronic conditions, including obesity (Lanigan et al., 2019).

A cross-sectional study examining the intensity of PA involving 425 children in Southwest England revealed that both moderate and high-intensity PA were associated with a reduction in BMI z-scores, while light-intensity PA correlated with reduced screen time (An et al., 2020).

A review of cross-sectional investigations provides further evidence of the inverse relationship between PA and child weight status (Prentice-Dunn, 2012). Studies on Spanish children and adolescents, for instance, have shown that MVPA is linked to lower adiposity indicators, including Fat Mass Index (FMI), Total Fat Mass (TFM), and Body Fat Mass (BFM) (Marques et al., 2016). However, it's important to note that causality may be bidirectional, as increased PA measures have not consistently demonstrated significant effectiveness in intervention studies (Koletzko et al., 2020).

A meta-analysis, focusing on children aged 5 to 12 years and including 47 studies, identified 19 studies displaying a small yet statistically significant effect favoring the experimental group (Brown et al., 2016). In contrast, a systematic review and meta-analysis of adolescents aged 10 and older in school settings, based on 12 randomized controlled trials, revealed minimal and statistically insignificant effects of PA and MVPA on obesity, possibly attributed to the age of the sample and compliance with accelerometer measurements (Borde et al., 2017).

2.5.2 Interventions to Enhance PA

Children worldwide are gradually becoming more physically inactive with decreased recreational activities and active transport during the COVID epidemic.

Concurrently, the proliferation of sedentary screen-based activities, both at home and in school, has further curtailed PA engagement. Addressing this issue necessitates a collaborative effort involving governments, school administrators, and parents to tackle the diverse geographical challenges related to declining physical activity and increased screen time (Whiting et al., 2021).

Scholars worldwide have undertaken a range of interventions to combat childhood obesity, given the significant impact of physical activity on body composition and metabolism (Campbell et al., 2002). These interventions fall into several categories: School-based, Community-based, Family-based, and Environment-oriented. Most interventions have traditionally focused on behavioral changes at the individual level, such as increasing daily physical activity or improving dietary habits. For instance, a study proposed ten recommendations for the treatment of obese children and adolescents at a tertiary referral center in southern Sweden (Nowicka & Flodmark, 2007). Regrettably, current interventions have struggled to make a global impact and have not halted the rising prevalence of obesity (Susann et al., 2018).

Existing literature suggests that educational interventions in schools, emphasizing healthy eating habits and PA, may hold promise for obesity prevention. In China, a cluster-randomized controlled intervention study involving 9858 participants demonstrated that a comprehensive PA program, encompassing classroom curricula, school environment support, family involvement, and engaging programs/events, had a positive impact on promoting PA and subsequently reducing BMI z-scores (Wang et al., 2018). A systematic review of 17 studies on childhood obesity prevention in Africa found that school-based interventions, while somewhat effective in increasing PA among children, indicated that parental involvement might be more effective. However,

the quality of evidence was often poor, and intervention implementation was susceptible to external disruptions such as strikes (de Villiers et al., 2015).

Another meta-analysis of 25 trials focused on school-based interventions for childhood obesity suggested that these interventions did not significantly increase moderate-to-vigorous physical activity throughout the day, with no notable differences observed across gender and socioeconomic status (Love et al., 2019). Recent technological advancements, particularly web-based interventions, have been used to provide tailored content on healthy lifestyles encompassing diet and exercise. These findings highlight the potential of online interactive programs as innovative tools to promote healthy behaviors (Verrotti et al., 2014).

However, the limited number of interventions addressing diverse populations and obesity-risk behaviors beyond diet and physical activity has impeded the development of comprehensive, tailored approaches. For instance, community-based interventions aimed at childhood obesity, involving 2250 children, did not provide conclusive evidence of a significant increase in physical activity (Gómez et al., 2018). Active video games have also been proposed as an approach to promote physical activity, but the current evidence base is insufficient to recommend their widespread use on school campuses, warranting higher-quality research (Norris et al., 2016).

Few studies targeting school-based PA and obesity prevention have been conducted in developing countries (Dobbins et al., 2013). In a cluster-randomized trial involving 374 Lebanese elementary students, a school-based intervention successfully increased PA, resulting in a significant decrease in BMI (-0.73 kg/m^2) and waist circumference (-4.77 cm) (Kranjac & Kranjac, 2021). Nevertheless, challenges remain regarding the adaptability and universality of such interventions. Furthermore, studies conducted in developing countries tend to underrepresent ethnic minorities and non-

traditional families. It has been noted that female students may benefit less from such interventions, emphasizing the need for more engaging activities tailored to girls (Jago et al., 2014). To build a comprehensive evidence base, there is a pressing need to implement a broader range of child interventions in developing countries (Ash et al., 2017).

2.6 The Transtheoretical Model

The Transtheoretical Model (TTM), also known as the Stages of Change (SOC) model, emerged from the collaborative efforts of Prochaska, DiClemente, and their associates during the 1970s and 1980s, evolving further during the 1990s (Glanz, Rimer, & Viswanath, 2008). It garnered the name "Transtheoretical Model" due to its innovative approach of integrating stages of change with key concepts and strategies from various intervention theories (Prochaska, Redding, & Evers, 2008). Kim (2007) aptly describes TTM as a model that recognizes the dynamic nature of health behavior change, including exercise, acknowledging that individuals often undergo multiple attempts at behavior change before achieving success.

As previously outlined, exercise behavior change within the TTM unfolds through five distinct stages (Marcus et al., 1992):

I. **Precontemplation**: Individuals are physically inactive and have no intention of engaging in physical activity within the next six months.

II. **Contemplation**: Individuals are inactive and intend to begin exercising regularly within the next six months.

III. **Preparation:** Individuals engage in the irregular physical activity below a criterion level—three or more times per week for a minimum of 30 minutes each time.

IV. **Action**: Individuals who have been physically active on a consistent basis for less than six months

V. **Maintenance**: Individuals have maintained a regular exercise regimen for at least six months following their initial exercise.

TTM has been successfully applied in numerous studies addressing unhealthy or addictive habits, yielding favorable outcomes in domains such as smoking cessation, alcohol abuse, weight management, and mammography screening (Prochaska & DiClemente, 1992). The effectiveness of interventions rooted in TTM hinges on two fundamental assumptions of the model: 1) the transitions between stages of change are depicted as linear, despite the frequent back-and-forth movement between stages before permanent progression; and 2) an individual's current stage of change can inform the appropriate type of intervention required to facilitate their transition into the maintenance stage (Mason et al., 2008).

2.6.1 Stages of Change

Central to the Transtheoretical Model, the Stages of Change (SOC) framework conceptualizes behavior change as an ongoing process encompassing five distinct stages: pre-contemplation (lacking intent to modify behavior within the next six months), contemplation, preparation, action, and maintenance (sustaining the behavior change for more than six months) (Redding & Evers, 1997). In the setting of health

management, these five stages in the SOC illustrate the process of an individual attempting behavioural modification to achieve better health, consistent with the temporal dimension of change. Compared with other algorithms, stages of change have shown better results and have become the gold standard in TTM studies (Young et al., 2002).

Childhood obesity necessitates a thorough assessment of both the child and their parents to facilitate tailored interventions and case management, a critical component in addressing pediatric obesity.

The stages of change commence with pre-contemplation, serving as the initial stage that characterizes individuals who have either not yet acknowledged the existence of a health issue or do not perceive the need for behavioral health changes. This stage is often associated with individuals who remain unaware or misinformed about their health conditions or who have accumulated past failures in their attempts at behavioral change, resulting in a sense of pessimism regarding their capacity to change (Logue et al., 2005).

The second stage is contemplation, where individuals express a determination to modify their behavior but have not yet taken concrete steps towards implementing the change. Those in this stage have recognized the potential benefits of behavioral alterations for their health but have yet to embark on the journey of change.

Following contemplation is the action stage, during which individuals actively modify their health-related behaviors based on their newfound awareness. This stage represents a decisive transition towards behavioral change.

Finally, the fourth stage of change is maintenance, characterized by the sustained adoption of the altered behavior without regressing to previous stages. In this

stage, individuals establish new behavioral patterns, fostering increased confidence in their ability to maintain the new behavior without reverting to old habits.

2.6.2 Processes of Change

Developed by Nigg et al. (1999), the core premise of the Transtheoretical Model (TTM) is that transitions between stages of change are facilitated by distinct processes and strategies, necessitating interventions tailored to specific stages (Nigg et al., 1999). In general, there exist ten processes of change corresponding to the five stages, which, when activated, promote movement between these stages. These change processes can be categorized into two higher-order domains: cognitive and behavioral. Five of these processes fall within the cognitive (or experiential) domain, encompassing consciousness-raising, dramatic relief, environmental revaluation, self-evaluation, and social liberation. Conversely, the remaining processes fall under the behavioral domain, comprising stimulus control, counterconditioning, reinforcement management, self-liberation, and helping relationships. In the earlier stages—pre-contemplation, contemplation, and preparation—cognitive and experiential processes hold greater efficacy in motivating behavioral change since individuals in these stages have not voluntarily initiated changes in their current health behavior (Kim, 2008).

Conversely, in the later stages, encompassing action and maintenance, behavioral processes take precedence as a crucial approach to bolster and sustain the transition toward healthier behavior, guarding against relapse (Kim, 2008). The processes of change invoked are influenced by the individual's current stage of change, encapsulating the concept of "doing the right thing at the right time" (Prochaska & DiClemente, 1992). Research has indicated that cognitive processes are primarily engaged in the early stages, while behavioral processes come to the forefront in the later stages of change (Velicer et al., 1998). However, another study suggested that many