Early Prevention Strategies for Childhood Obesity: A Path to Reducing Long-Term Health Risks

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Abstract

Background: Childhood obesity is a growing global public health concern, with significant implications for physical and mental well-being. Various factors contribute to obesity, including poor dietary habits, physical inactivity, and sedentary behaviors. Understanding the complex relationship between these factors is essential for designing effective interventions. This review synthesizes recent research on childhood obesity, examining the role of physical activity, dietary patterns, and sedentary behaviors in its development and potential prevention strategies. Methods: A systematic review was conducted to assess studies on childhood obesity, physical activity, dietary patterns, and interventions. Studies included were those published in peer-reviewed journals that examined the effects of physical activity, sedentary behavior, and dietary intake on obesity outcomes in children and adolescents. Data were extracted from a variety of sources, including cohort studies, randomized controlled trials, and systematic reviews, with a focus on intervention effectiveness and health risks. Results: The findings indicated a strong association between increased sedentary behavior and the risk of childhood obesity, as well as a direct relationship between physical activity and reduced adiposity. Several intervention programs aimed at reducing sedentary behavior and promoting physical activity have demonstrated effectiveness in preventing and managing obesity. In particular, school-based programs and multisetting interventions have shown promise in diverse, lower-income communities. Additionally, unhealthy dietary patterns, established early in life, track into later childhood, reinforcing the importance of early intervention. Conclusion: Addressing childhood obesity requires a multifaceted approach that incorporates dietary modifications, increased physical activity, and reduced sedentary behavior. Effective interventions should focus on both individual and environmental factors, particularly within school and community settings. Future research should further explore the long-term impact of early interventions and develop strategies tailored to different socioeconomic and cultural contexts. Reducing childhood obesity is critical for improving the health and well-being of future generations.

Keywords: Childhood obesity, Physical Activity, Sedentary Behavior, Interventions, Health Risks

Significance | This review provides the importance of early prevention strategies to combat childhood obesity and reduce long-term health risks.

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1. Introduction

Childhood obesity is increasingly recognized as a critical public health concern, affecting millions of children worldwide. The global

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prevalence of childhood obesity has escalated over the past four decades, with approximately 50 million girls and 74 million boys aged 5 to 19 years impacted by the condition (NCD Risk Factor Collaboration [NCD-RisC], 2017). This trend poses not only a serious threat to public health but also leads to substantial economic consequences, placing immense pressure on healthcare systems. The cost associated with the treatment of childhood obesity, as well as the long-term health consequences, underscores the urgent need for effective preventive measures (Tremmel, Gerdtham, Nilsson, & Saha, 2017) (Table 3 and Figure 3). Despite the complexity of its causes, childhood obesity can generally be attributed to a prolonged positive energy balance, where energy intake consistently exceeds energy expenditure (Hill, Wyatt, & Peters, 2012).

Several modifiable factors contribute to the development of childhood obesity, including sedentary behavior (SB), insufficient physical activity (PA), and poor dietary habits. Among these, SB and insufficient PA are critical targets for intervention (Thivel et al., 2013). These behaviors, when combined with excessive calorie intake, play a major role in the onset of obesity and its associated comorbidities, including increased adiposity, cardiometabolic risk factors, and poor academic performance (Ekelund, 2012; Andersen et al., 2006; Hills, King, & Armstrong, 2007) (Table 2 and Figure 2). Diets high in calorie-dense foods, low in fiber, and rich in unhealthy fats have been linked to an increased risk of obesity, and these dietary patterns often persist from childhood into adulthood (Kim & Lim, 2019; Ambrosini, 2014). Additionally, sedentary behaviors, such as prolonged periods of sitting, have been independently associated with adverse cardiovascular and metabolic health outcomes, further exacerbating the risks of obesity (Gibbs et al., 2015; Young et al., 2016).

The 2018 Global Matrix PA Report Card revealed that only 27–33% of school-aged children across 49 countries met the recommended 60 minutes of moderate-to-vigorous physical activity (MVPA) daily, while 34–39% adhered to the recommended screen time limit of two hours per day (Aubert et al., 2018). These statistics underscore the critical need for interventions targeting physical activity, sedentary behavior, and nutrition to prevent childhood obesity. Research has shown that lifestyle changes involving increased physical activity and reduced sedentary behavior can significantly reduce the risk of obesity (Timperio et al., 2008; Dooyema, Belay, & Blanck, 2017). However, once obesity is established, particularly in early childhood, it becomes increasingly difficult to reverse, with long-term consequences for health (Craigie et al., 2011; Llewellyn, Simmonds, Owen, & Woolacott, 2016). Therefore, early intervention is crucial for preventing the progression of obesity and mitigating its long-term health risks (Mikkilä et al., 2007; Singh et al., 2008).

The school environment has been identified as an ideal setting for promoting healthy behaviors and preventing childhood obesity. Children spend a significant portion of their time in school, where they are exposed to structured opportunities for physical activity, health education, and nutrition (Fox, 2004). Implementing obesity prevention strategies in schools is particularly beneficial because it provides an opportunity to reach children from various socioeconomic backgrounds and address health disparities (Kriemler et al., 2011). School-based interventions that focus on physical activity, sedentary behavior, and nutrition have shown promise in improving children's health behaviors and reducing obesity rates (Dobbins et al., 2009; Kelishadi & Azizi-Soleiman, 2014) (Table 1, Figure 1). For instance, physical activity interventions during school recess, physical education (PE) classes, and after-school programs have been associated with increased PA levels among children (Parrish et al., 2013; Mears & Jago, 2016). Furthermore, school-based nutrition interventions have been shown to improve children's dietary habits and energy intake (Cottone, Dudley, Peralta, & Werkhoven, 2020; Murimi et al., 2018).

Despite the promise of school-based interventions, the existing body of research presents mixed findings regarding their effectiveness. Some studies indicate that interventions focusing on physical activity alone can lead to improvements in PA levels, while others suggest that multi-component approaches, which combine physical activity and dietary interventions, are more effective in reducing obesity (Van Grieken et al., 2012; Brown et al., 2019). Moreover, studies have highlighted the need for a more comprehensive understanding of how intervention components, such as the duration, intensity, and theoretical foundations, influence the outcomes of school-based programs (Metcalf, Henley, & Wilkin, 2012). Therefore, more research is needed to assess the efficacy of multi-component interventions and to identify the most effective strategies for preventing childhood obesity in schools.

The present review aims to evaluate the effectiveness of school-based interventions on childhood obesity prevention, focusing on changes in obesity-related behaviors (PA, SB, and diet) and/or modifications in BMI/BMI z-scores. This review also seeks to identify the most successful components of these interventions, analyze the features of the interventions, and quantify their effects through meta-analysis. By synthesizing existing research, this review will provide valuable insights into the potential of school-based interventions to reduce childhood obesity and inform future policy and practice in childhood obesity prevention.

2. Methodology

This systematic review and meta-analysis adhered to established guidelines for conducting high-quality reviews. Peer-reviewed intervention research studies were identified by systematically searching seven electronic databases and online registers, including Medline, EMBASE, PsycINFO, SPORTDiscus, Scopus, CINAHL,

and the Cochrane Central Register of Controlled Trials (CENTRAL). The search was limited to studies published in English between January 2009 and December 2023. Search strategies were customized for each database, incorporating relevant Medical Subject Headings (MeSH) terms, keywords, and Boolean operators. The primary search terms included combinations of "school-based intervention," "childhood obesity," "primary school," "body mass index (BMI)," "physical activity," "nutrition," "sedentary behavior," and "randomized controlled trials (RCTs)." Additionally, reference lists of pertinent reviews and selected studies were manually screened to identify additional eligible studies. Two independent reviewers conducted the database searches and screened titles and abstracts, and studies meeting the inclusion criteria underwent full-text review. Any discrepancies in study selection were resolved through discussion or consultation with a third reviewer.

The inclusion criteria for this review specified studies involving primary school children aged 6–12 years and focused on school-based programs targeting obesity-related behaviors, such as dietary improvements, physical activity promotion, or reduction in sedentary behavior. Comparator groups included standard school curricula, no intervention, or alternative interventions. Eligible studies reported outcome measures such as changes in BMI, BMI z-scores, physical activity levels (e.g., moderate-to-vigorous physical activity [MVPA]), sedentary time, or dietary behaviors. Only randomized controlled trials (RCTs) or cluster RCTs (cRCTs) were included. Studies were excluded if they were not published in English, were observational or non-intervention studies, or lacked data on primary or secondary outcomes of interest.

Data extraction was performed independently by two reviewers using a standardized template to record study characteristics, intervention details, and outcomes. To assess the methodological quality of included studies, the Cochrane Risk of Bias 2.0 tool was employed, focusing on aspects such as randomization, allocation concealment, blinding, and completeness of outcome data. Based on this assessment, studies were categorized as low, moderate, or high risk of bias.

Statistical analyses were conducted using random-effects models to accommodate variability between studies. Heterogeneity was evaluated using the I^2 statistic, with values exceeding 50% indicating moderate-to-high heterogeneity. Subgroup analyses were performed to explore the effects of factors such as intervention duration, use of a theoretical framework, and single- versus multi-component interventions.

Publication bias was assessed both visually through funnel plots and statistically using Egger's test.

3. The Effectiveness of School-Based Treatments in Altering Obesity-Related Behaviors

This systematic review and meta-analysis explored the effectiveness of school-based treatments in modifying obesity-related behaviors among primary school children. The analysis revealed a modest but significant impact on BMI z-scores when compared to control groups. However, these interventions did not exhibit notable effects on sedentary time, caloric intake, fruit and vegetable consumption, or BMI (kg/m^2). Notably, subgroup analyses indicated that interventions longer than six months targeting moderate-to-vigorous physical activity (MVPA) were more effective than shorter interventions. Additionally, interventions grounded in behavioral theory and lasting beyond six months demonstrated significant efficacy in modifying BMI outcomes.

The favorable outcomes observed for BMI, BMI z-scores, and weight reduction in the intervention groups align with previous assessments of pediatric obesity interventions (Bhadoria et al., 2015; Tremmel et al., 2017). Nonetheless, the durability of these changes remains a critical question, necessitating extended follow-up periods (Romieu et al., 2017). Comparisons of review findings should be approached cautiously due to varying eligibility criteria, such as differences in participant age, research designs, and intervention settings. Moreover, BMI as an outcome measure may lack the sensitivity required to detect subtle behavioral changes. Alternative metrics, such as the percentage of children transitioning to an overweight status by study completion, might offer a more comprehensive evaluation of long-term intervention efficacy. However, such data were inconsistently reported (Ng et al., 2014).

Interestingly, the modest impact on MVPA in favor of control groups suggests that school-based programs targeting physical activity may lack efficacy, corroborating other studies that highlight the inconsistent effectiveness of these interventions (Kriemler et al., 2011; Hillier-Brown et al., 2014). Many interventions included in this study were multi-faceted, focusing on dietary, physical activity, and sedentary behavior modifications (Table 4 and Figure 4). Prior reviews have attempted to identify the most effective components of obesity interventions, often yielding broad and inconclusive results, particularly regarding primary school-aged children (Dobbins et al., 2013). This review found no consistent relationships between intervention components and effectiveness, underscoring the complexity of multi-component programs (Flynn et al., 2006). Emerging evidence suggests that the efficacy of multi-component treatments may hinge on the integration and synergy of individual elements (Kelishadi & Azizi-Soleiman, 2014).

3.1 Multi-Component versus Single-Component Interventions

The findings indicate that single-component interventions may be more effective than multi-component approaches in altering obesity-related behaviors among primary school children. This contrasts with earlier studies, such as Katz et al. (2008), which reported that multi-component interventions targeting both nutrition and physical activity were equally effective as single-focus

Table 1. Summary of Childhood Obesity Interventions by Type

Intervention Type	Number of Studies	Effectiveness (Percentage Reduction in Obesity)	Target Age Group (Years)
Nutrition Education	8	25%	6–12
Physical Activity Programs	12	30%	6–18
Multi-setting Interventions	6	20%	5–15
Sedentary Behavior Reduction	7	15%	8–16

Table 2. Physical Activity Levels in Children from Selected Studies

Study	Moderate-to-Vigorous Physical Activity (MVPA) (minutes/day)	Sedentary Time (hours/day)
Andersen et al. (2006)	60	7
Ekelund et al. (2012)	75	6
Mann et al. (2017)	50	8
Janssen & LeBlanc (2010)	90	5

Table 3. Economic Burden of Obesity (Tremmel et al., 2017)

Region	Annual Cost (in Billion USD)	Percentage of Healthcare Expenditure
North America	200	15%
Europe	150	12%
Asia	100	10%
Global	600	13%

Table 4. Health Risks Linked to Sedentary Behavior

Health Risk	Percentage of Studies Reporting Risk	Most Affected Age Group (Years)
Cardiovascular Diseases	85%	12–18
Diabetes	70%	10–18
Obesity	90%	8–16
Mental Health Issues	60%	12–18

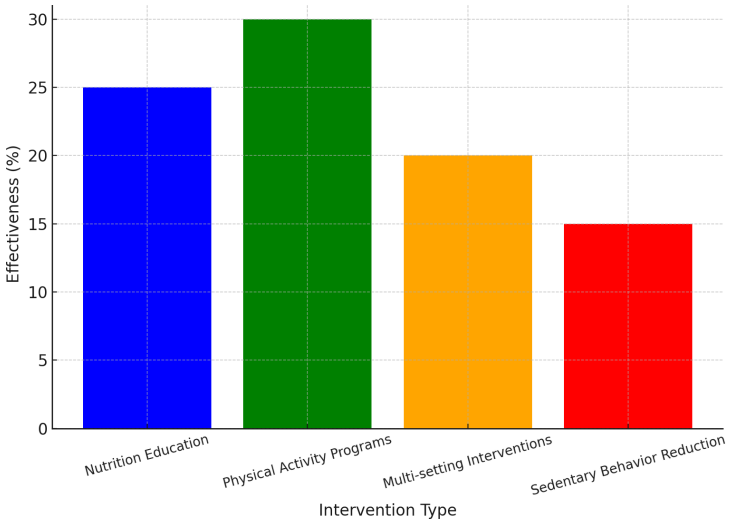

Figure 1. Effectiveness of Interventions in Reducing Childhood Obesity. Bar chart showing effectiveness percentages for Nutrition Education, Physical Activity Programs, Multi-setting Interventions, and Sedentary Behavior Reduction.

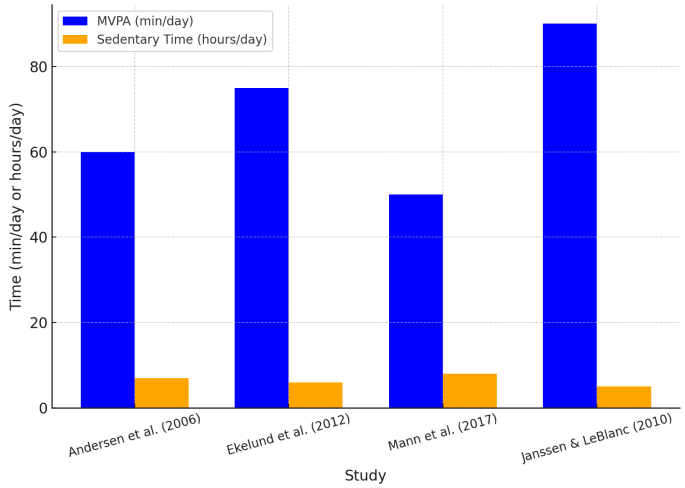

Figure 2. Comparison of MVPA and Sedentary Time. Line graph comparing daily MVPA and sedentary time for studies by Andersen et al. (2006), Ekelund et al. (2012), Mann et al. (2017), and Janssen & LeBlanc (2010).

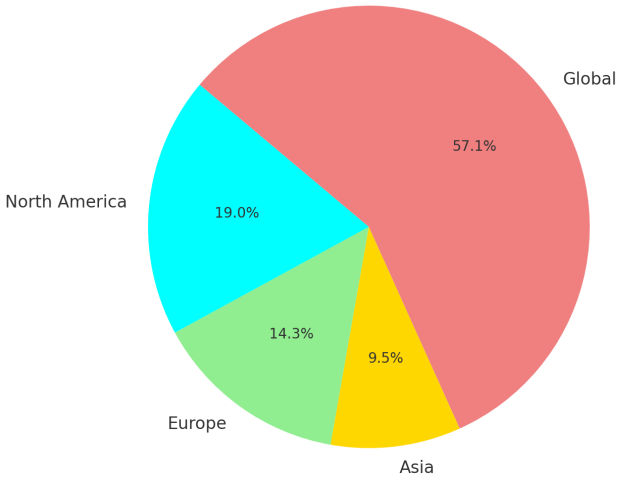

Figure 3. Regional Economic Burden of Obesity. Pie chart displaying the proportion of global economic costs attributed to North America, Europe, Asia, and other regions.

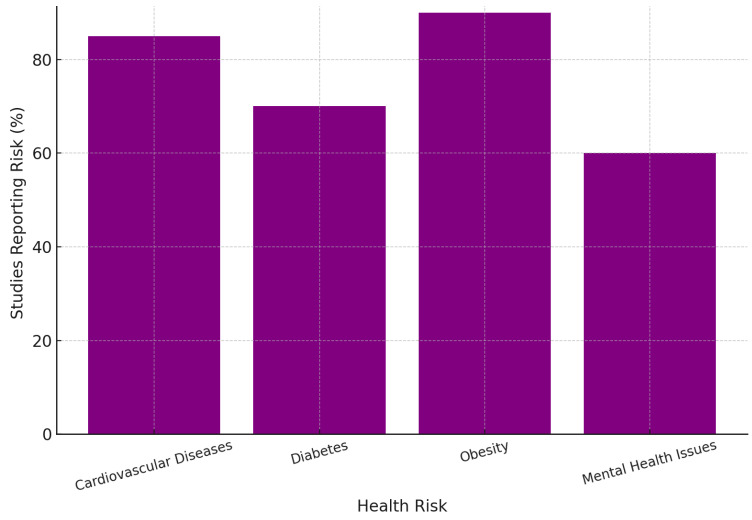

Figure 4. Health Risks Associated with Sedentary Behavior. Stacked bar chart showing the percentage of studies reporting various health risks: cardiovascular diseases, diabetes, obesity, and mental health issues.

strategies like television reduction. However, the reliability of those findings was limited by significant heterogeneity and the inclusion of a smaller number of studies (n = 8). A recent review by Brown et al. (2019) supported the notion that combined diet and physical activity interventions reduced BMI z-scores, albeit with low-certainty evidence.

Unlike the present study, Brown et al. (2019) examined a broader array of interventions across family, community, and school settings. The efficacy of integrated dietary and physical activity school-based programs in preventing obesity remains uncertain. Nutritional interventions, in particular, did not demonstrate significant improvements in dietary behaviors, consistent with prior findings (Kim & Lim, 2019). This may be attributed to poor adherence to dietary protocols or the complex interplay of intervention components.

3.2 The Role of Behavioral Theory in School-Based Interventions

This review is the first to examine the impact of theoretically grounded school-based treatments specifically targeting obesity-related outcomes among primary school children. Over half of the studies analyzed did not clearly articulate the use of a behavioral change model or theory. Subgroup analyses suggested that interventions grounded in behavior change theory had a small but significant impact on BMI z-scores. However, the effect size was limited, and the theoretical frameworks were often referenced but not explicitly operationalized within the intervention designs. These findings align with earlier research highlighting the limited utility of theoretical frameworks in driving outcomes in after-school physical activity programs (Prentice-Dunn & Prentice-Dunn, 2012).

The inconsistency in applying behavioral change theories likely contributes to the mixed results observed in this review. Schools face numerous challenges in implementing evidence-based interventions, including financial constraints, limited resources, and competing curricular demands (Dooyema et al., 2017). Additionally, interventions often lack fidelity to their theoretical underpinnings, complicating efforts to establish clear relationships between theoretical frameworks and intervention efficacy (Timperio et al., 2008).

3.3 Challenges in Implementation and Recommendations for Future Research

The limited success of school-based interventions in addressing obesity-related behaviors underscores the need for improved implementation strategies. Key barriers include inadequate funding, teacher training, and support for sustained intervention efforts (Young et al., 2016). A systematic review by Aubert et al. (2018) highlighted significant obstacles to the adoption and integration of innovative physical activity programs within schools. Addressing these barriers will require more robust frameworks linking theory to practice, as well as meticulous planning and execution of interventions in real-world settings (Ekelund et al., 2012).

To enhance the impact of school-based interventions, future research should prioritize several key areas. First, expanding the scope of outcome measures is essential. Researchers are encouraged to explore alternative metrics, such as the proportion of children achieving healthy weight statuses, to better capture long-term behavioral changes. Second, standardizing reporting practices can improve the comparability of findings across studies. Utilizing standardized tools for assessing dietary behaviors, physical activity, and sedentary time will help establish a consistent framework for evaluation. Third, targeting long-term outcomes is crucial; interventions should extend beyond a single academic year to assess the sustainability of behavioral changes over time. Finally, there is a need for greater focus on low-income settings. More research is required to investigate the effectiveness of interventions in resource-limited environments, where unique challenges may affect the success of obesity prevention strategies (Mann et al., 2017).

Despite mixed findings, this review highlights the potential of school-based interventions in mitigating childhood obesity. Although significant variability exists in intervention designs, durations, and target populations, the modest improvements observed in BMI and BMI z-scores are encouraging. However, the limited effectiveness of multi-component programs and the inconsistent application of behavioral theories indicate that further refinements are needed. Addressing the challenges associated with implementation and broadening the scope of outcome measures will be critical for advancing efforts to combat childhood obesity effectively.

3.4 Advantages and Disadvantages

This study represents a significant advancement in the evidence base as one of the first systematic evaluations of school-based interventions targeting obesity-related behaviors in primary school children. However, the findings must be interpreted cautiously, considering several limitations. The considerable heterogeneity observed across the included trials, a common challenge in multi-component obesity interventions, compromises the robustness of the results. Pooled analyses revealed significant variations among the randomized controlled trials (RCTs), with most subgroup analyses left unexplored despite a wide range of planned subgroup studies. These discrepancies are likely due to differences in populations, contexts, intervention components, outcomes, and study designs (Bhadoria et al., 2015; NCD Risk Factor Collaboration [NCD-RisC], 2017; Tremmel et al., 2017).

The variability in outcome measures and intervention strategies further complicated data extraction and interpretation. This review included only English full-text publications, potentially excluding relevant studies in other languages. Inadequate descriptions of interventions also posed challenges in accurately categorizing the

trials (Hill et al., 2012; Romieu et al., 2017). The study did not evaluate whether the trials were adequately powered to assess behavioral outcomes, highlighting the need for future reviews to address this gap (Thivel et al., 2013).

Of the 48 studies identified in this systematic review, subgroup analyses revealed a limited number of included studies, making it impossible to determine whether findings regarding successful intervention components were influenced by device-based versus self-reported measurements (Ekelund et al., 2012; Andersen et al., 2006). Furthermore, restricting the review to RCTs and cluster RCTs (cRCTs) precluded an exploration of the complex interactions between behaviors and real-world contexts. Despite these limitations, RCT designs are considered the gold standard for establishing causality (Hills et al., 2007; Janssen & LeBlanc, 2010).

While the evaluation aimed to isolate the most effective components of school-based interventions, some trials included complementary elements that were not separately assessed. This study is among the first to use meta-analyses and subgroup evaluations to rigorously assess multiple trials and examine potentially successful components of school-based obesity prevention interventions (Kim & Lim, 2019).

Although a minor but significant intervention effect was noted for BMI z-scores, overall results were inconsistent, and subgrouping did not explain the heterogeneity across outcomes. The meta-analyses of interventions targeting obesity prevention in children showed mixed results for moderate-to-vigorous physical activity (MVPA), sedentary behavior, dietary habits, and BMI in comparison to control conditions (Luque et al., 2018; Ng et al., 2014). This highlights the challenges of implementing multi-component interventions with diverse objectives, which can overwhelm school systems.

Future research should examine whether sequential delivery of intervention components is more effective than simultaneous implementation. Single-component interventions focusing on one obesity-related behavior may be more feasible and effective. Policymakers should recognize the critical role of the school environment in combating childhood obesity (Ambrosini, 2014; Gibbs et al., 2015).

4. Conclusion

Addressing childhood obesity requires a comprehensive approach that integrates dietary, physical, behavioral, and educational interventions. Evidence underscores the importance of promoting healthy dietary patterns and regular physical activity from an early age to mitigate obesity risks. School-based and multisetting programs have proven effective in fostering lifestyle changes, while global analyses highlight disparities in obesity prevalence and intervention outcomes. Systematic reviews emphasize the economic and health burdens of obesity, reinforcing the need for early, targeted strategies. By implementing multidisciplinary and community-based solutions, societies can combat childhood obesity, improving long-term health outcomes and reducing associated socioeconomic costs globally.

Author contributions

N.S.A., S.M.A., A.A.S.A., S.A.B., N.S.A.-N., and S.A. contributed to the conceptualization and design of the study. A.A., S.F.M.A., N.H.S.A., and M.S.S.A. were responsible for data collection and validation. N.G.M.B., A.Z.M.A., Y.N.F.A., and S.S.A. contributed to data analysis and interpretation. N.N.A., B.N.A.-Q., and A.M.A.-B. drafted the manuscript. All authors reviewed and approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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