BIOSCIENCE JOURNAL

PREVENTION AND INTERVENTIONAL STRATEGIES OF ADOLESCENT OBESITY / OVERWEIGHT - SYSTEMATIC REVIEW AND META-ANALYSIS OF 10 YEARS RESEARCH

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How to cite: MUNUSAMY, G. and SHANMUGAM, R. Prevention and Interventional Strategies of Adolescent Obesity / Overweight - Systematic Review and Meta-analysis of 10 Years Research. *Bioscience Journal*. 2023, **39**, e39078. https://doi.org/10.14393/BJ-v39n0a2023-65745

Abstract

The purpose of this review was to reach a consensus on the evidence of the literature investigating multiple school-based interventions (physical activity, diet, and sedentary behavior) to prevent or reduce high body mass index z-score and waist circumference among adolescents. A systematic search of five electronic databases: Pubmed, MEDLINE, Science Direct Index, HINARI, and Google Scholar were conducted to identify published studies between January 2010 and December 2020. Only studies that used randomized controlled trials to assess the effects of physical activity and/or physical education, nutritional education and/or dietary behavior, and sedentary behavior on adolescents' body mass index z-score and waist circumference were included. The risk of bias in credible studies was evaluated using the Standard Cochrane tool. A random effects model was used to assess the impact of the interventions included on the waist circumference and body mass index z-score. Of the 2,090 citations reviewed, n = 1,954 (789 interventions, 1,165 controls) from five studies were included. Overall, a minimally significant reduction was found in BMI z-score MD -0.05 [95% CI: -0.20, 0.11, p-value < 0.0001, I^2 = 87%] and waist circumference MD -0.97 [95% CI: -1.53, -0.42, p-value = 0.26, I^2 = 25%] between 3 to 12 months than 12 to 24 months. Multiple school-based interventions for adolescents that last between three and twelve months are more successful. Further study should focus on the effect of coupled components on the efficacy of multicomponent therapies integrated with theoretical/conceptual aspects.

Keywords: Adolescent. Body mass index. Obesity. Overweight. Schools. Waist circumference.

1. Introduction

Overweight (OW) and obesity is a serious health concern that has become a pandemic all over the globe (Lobstein et al. 2015; Janakiraman et al. 2020), and its risk starts among adolescents (Munusamy and Shanmugam 2022a). OW and obesity are due to an imbalance between energy consumption and intake that leads to premature demise and disability by enhancing the risk of cardio metabolic disease, dementia, depression, osteoarthritis, and some kinds of cancer (Bluher 2019). Globally, the estimated prevalence of obesity and OW in adolescents is about 340 million (World Health Organization 2021).

Cultural tradition, sedentary life, availability of food, consumption of junk foods, socio-economic status, urbanization, area of residency, infections, and support of caregivers/parents are the main factors that affect obesity/OW and high body mass index (BMI) in adolescents through epigenetic modulation throughout life (Huang and Qi 2015; Lee and Yoon 2018; Linner and Almgren 2019; Reilly et al. 2019; Munusamy and Shanmugam 2022b). OW and obesity in childhood and adolescence lead to greater increases in BMI (Munusamy and Shanmugam 2022c) and are associated with higher chances of premature death and disability in adulthood (Roth et al. 2018).

Physical inactivity is one of the top four risk factors for mortality and is associated with 3.2 million annual deaths, according to a global review. In India, the frequency of insufficient physical activity (PA) among adolescents aged 11 to 17 was 71.6% for girls and 69.6% for boys (World Health Organization 2014). Adolescents must engage in at least 60 minutes of moderate -to- vigorous PA daily, yet 81% of those between the ages of 11 and 17 do not meet these standards (World Health Organization 2018). The Global Burden of Disease Study found that physical idleness and food risk factors contributed to increases of 23.7% and 20.7%, respectively, between 2010 and 2017 (Stanaway et al. 2018).

To reduce sedentary behavior (SB) among adolescents, they should increase active transportation and decrease time on screens. There is proof that high SB is linked to aberrant adiposity changes, poor cardio-metabolic fitness, behavioral issues, disordered eating, and impaired sleep (World Health Organization 2016). Teens require initiatives to increase PA, lower SB, and promote healthy eating habits because PA even decreases during adolescence, they spend a lot of time inactive (Martinez-Gomez et al. 2010), and they have poor food habits (Kumar et al. 2017; Rathi et al. 2017). Teenagers who live healthy lifestyles are less likely to suffer from physical and mental health problems like obesity, cardiovascular disease, diabetes, and depression (Taylor et al. 2016).

Prevention of obesity/OW should begin in childhood rather than as an adult because it is harder to treat. This can be achieved by regular PA, dietary changes, and targeting behavioral change to reduce SB is critical for intervention (Kelly et al. 2017; Munusamy and Shanmugam 2022d). Health-promoting strategies intended for adolescents must make every effort to understand and address their perspectives to aid in preventing them.

Schools are the ideal location to commence early prevention programs to enhance the health of teenagers (Patton et al. 2016) and future adults (Centers for Disease Control and Prevention 2011; WHO 2017). Numerous school-based interventions have a significant impact on BMI, according to prior research reviews (Al-Khudairy et al. 2017; Liu et al. 2019). However, the effects were minimal, fleeting, and inconsistent between interventions (Hynynen et al. 2016; Kelly et al. 2017). Moreover, the combined effects of PA, SB, and diet are hardly reported. As far as we are aware, no recent review has concentrated solely on PA, SA, and nutrition intervention and follow-up at two levels—3 months to 1 year and 12 months to 24 months—and their effect on BMI z-score and waist circumference (WC).

By better understanding, if the aforementioned characteristics are connected with intervention success, decisions about the development of an intervention can be made based on data. This study presents a comprehensive review of the effectiveness of multiple school-based treatments targeting PA, diet, and SB among adolescents aged 11 to 18 years, analysing intervention components by BMI z-score and WC.

2. Material and Methods

The systematic review was performed as per PRISMA guidelines (Liberati et al. 2009).

Review questions

(1) In lowering the high BMI z-score and WC among adolescents aged 11-18, how efficacious are PA, diet, and SB interventions?

(2) Do interventions that span from three months to one year or from one year to two years have a different level of effectiveness?

Systematic Search

This systematic search was carried out on online data records of Pubmed, MEDLINE, Science Direct index, HINARI, and Google Scholar to identify studies published in the English language, open access journals from January 2010 and December 2020 by using the search term "overweight OR obese", "adolescent OR teenage OR teens OR youth", "PA OR exercise AND physical education", "nutrition OR diet", "sedentary behavior OR screen time", "BMI OR body mass index", "waist circumference", "schools OR school-based" and "randomized controlled trial OR RCT".

Eligibility criteria

Participants

Studies included healthy adolescents aged 11 to 18 years, BMI <85th percentile, BMI ≥85th percentile, boys or girls, or both sexes. Studies of adolescents with medical conditions such as diabetes, dyslipidemia, eating disorders, cognitive impairment, or physical or mental disabilities were excluded.

Interventions

The studies reported on PA measured by subjective or objective assessment (e.g., accelerometer) or physical education and nutritional education and diet and SB or screen time represented with three interventions at baseline and a post-intervention measurement on BMI z-score and WC. The duration of interventions should be no less than 3 months and no more than 24 months. Studies excluded purely electronic-based interventions except for text messages.

Comparators

The control group received no intervention, standard training or education or any other kind of intervention.

Outcome measures

The study reported on BMI z-score and WC as a primary or secondary outcome or as another outcome.

Study design

Randomized controlled trials (randomization at the school grade or class or partakers level) were included. Observational and non-randomized controlled trials, non-controlled trials, case reports, case series, opinion papers, letters to the editor, commentary, conference abstracts, reviews and meta-analyses, and study protocols were excluded.

Timeframe and setting

The duration of the intervention and follow-up does not exceed 24 months. The intervention is mainly based on the school environment.

Language

Studies in English and full-text open access available are eligible for inclusion.

Study selection

After assessing titles and briefly searching abstracts, 2,052 studies were found to have been taken out of context. Therefore, 60 abstracts were retained for further digitization. Of these abstracts, 17 were found to be duplicates and were therefore also excluded based on eligibility criteria. Of the 21 relevant full-text articles that were screened, 16 were eliminated by the authors based on inclusion criteria. Finally, five articles were left, which were reviewed by two independent authors for the extraction of data.

Data extraction

Two distinct scholars independently extracted the data using an elaborate form that the researchers had created. All articles identified in this review were assessed for applicability inter-reviewer reliability (78%), checked for abstracts, and re-tread for inclusion criteria. The authors' disagreement was resolved by discussion and an agreement was reached regarding eligibility.

Risk of bias assessment

Using the International Cochrane Collaboration's recommended (Higgins et al. 2011) criteria for quantitative RCTs, two independent authors assessed the risk of bias in the included studies. The following areas have been considered: sequence generation, allocation concealment, blinding of study personnel and participants, incomplete outcome data, selective outcome reporting, and other possible sources of bias. Each paper was thoroughly reviewed for each topic, and assessments of potential bias were made in one of three categories: low risk, high risk, or uncertain risk.

Statistical analysis

The meta-analysis was carried out using the RevMan 5.3 version of the Cochrane Review Manager software. Since each outcome variable was a continuous variable, we recorded its means and standard deviations. Each follow-up evaluation's unique results are presented. The mean difference (MD) at a 95% confidence interval (CI) was used to compare treatment and control outcomes. In the current review, a p-value of 0.05 was shown to be statistically significant. The I^2 statistic allowed an estimation of the heterogeneity (I^2) of the test. I^2 was graded as low in this analysis for 25%, moderate for 50%, and high for 75%. A random effect model (Crowther and Lim 2010) was used for percentages of I^2 >50%. The possibility of publication bias was visually evaluated by analyzing the funnel plots for all comparisons using Egger's regression test. There is no conclusive proof of publishing bias, and our analysis found no signs of systemic heterogeneity.

3. Results

Literature search

A total of 2,090 records were identified. Five documents from three separate intervention studies were selected based on screening and eligibility assessments (Figure 1).

Study characteristics

Study characteristics and participant

Table 1 outlines the overall study and participant characteristics. Three studies were cluster RCTs (Leme et al. 2018; Lubans et al. 2016; Grydeland et al. 2014) and two were matched-pair cluster RCTs (Pbert et al. 2013; Pbert et al. 2016). Overall, study participants ranged in age from 11 to 18 years; however, in those studies, only girls (aged 12-18 years) and boys (aged 12-14 years) participated. Four studies showed participant numbers <5,00 with the minimal sample size being 82 (Pbert et al. 2013), one study contained n=1,324 adolescents, with the highest sample size (Grydeland et al. 2014).

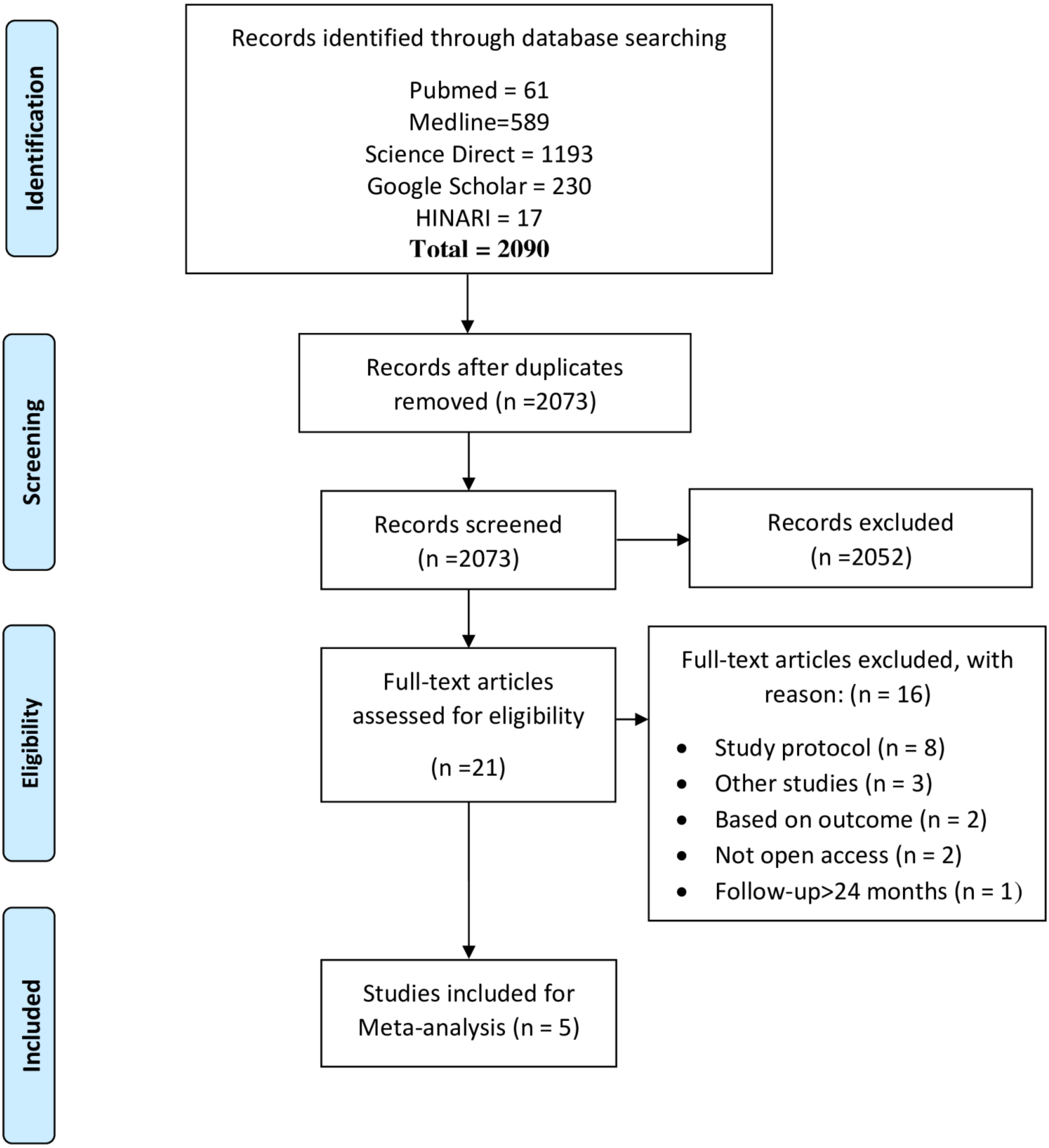

Figure 1. PRISMA flow diagram for the selection of studies.

Three studies aimed at only girls (Pbert et al. 2013; Pbert et al. 2016; Leme et al. 2018), and one study only on boys (Lubans et al. 2016), and one study aimed at both gender (Grydeland et al. 2014). Four studies were follow-up assessments between 6 to 12 months (Pbert et al. 2013; Pbert et al. 2016; Lubans et al. 2016; Leme et al. 2018) and two studies were follow-ups at 12 to 24 months (Grydeland et al. 2014; Lubans et al. 2016). Two studies were 2 to 3 years in duration (Pbert et al. 2013; Grydeland et al. 2014), two studies were 1-year in duration (Pbert et al. 2016; Leme et al. 2018), and one study was not reported in terms of duration (Lubans et al. 2016). Three studies utilized (Pbert et al. 2013; Pbert et al. 2016; Leme et al. 2018) Bandura's Social Cognitive Theory (SCT), one applied with Self-Determination Theory (SDT) and SCT (Lubans et al. 2016) and one study not constructs theory (Grydeland et al. 2014).

Table 1. General description of included studies.

First author (yr), country	Design, study name, theory/ model	Participants, age in years/mean age (SD) years	Study period, intervention duration	Sample size (n) BA = IG:CG	Follow up months IG:CG	
					3 to 12	12 to 24
Lori Pbert et al., (2013), USA	Pair-matched cluster RCT, Lookin' Good Feelin' Good, SCT	Girls, 15.8 (1.02)	2008 - 2009 16 wks	n = 82 BA = 42:40	6th 42:40	Nil
Grydeland et al., (2014), Norway	Cluster RCT, HEIA, NR	Boys & girls, 11 – 12 / 11.2 (0.3)	2007 - 2009, 20 months	n = 1,324 BA = 465:859	Nil	20th 465:859
Pbert et al., (2016), USA	Pair-matched cluster RCT, Lookin' Good Feelin' Good, SCT	Girls, 16.4 (1.21)	Sep 2012 – Jun 2013, 6 months	n = 126 BA = 58:68	8th 54:57	Nil
Lubans et al., (2016), Australia	Cluster RCT, ATLAS, SDT and SCT	Boys, 12 - 14 / 12.7 (± 0.5)	NR, 20 wks	n = 361 BA = 181:180	8th 139:154	18th 121:143
Leme et al., (2018), Brazil	Cluster RCT, H3G-Brazil, SCT	Girls, 14 - 18 / 15.6 (0.87)	Feb to Aug 2014, 6 months	n = 253 BA =142:111	6th 89:55	Nil

Note. ATLAS = Active Teen Leaders Avoiding Screen-time, BA = baseline assessment, CG=control group, HEIA = HEalth In Adolescents, H3G = Healthy Habits, Healthy Girls, IG = intervention group, NR = not reported, RCT = randomized controlled trial, SCT = Social Cognitive Theory, SDT = Self-Determination Theory.

Intervention characteristics

Table 2 shows the characteristics of the PA, DB, and SB interventions, as well as their impact on the BMI z-score and WC. Duration of intervention was > one year in one study (Grydeland et al. 2014) and in four studies intervention duration was less than one year (Pbert et al. 2013; Pbert et al. 2016; Lubans et al. 2016; Leme et al. 2018). Three studies proved PA thru physical education class (Grydeland et al. 2014; Lubans et al. 2016; Leme et al. 2018), and two interacted with PA during a counseling session (Pbert et al. 2013; Pbert et al. 2016). In five trials using the DB intervention, one of which focused on energy assessment (Leme et al. 2018), four studies suggested reducing SSB and increasing the intake of fruits and vegetables (Pbert et al. 2013; Grydeland et al. 2014; Pbert et al. 2016; Lubans et al. 2016). Each of the five research explored ways to lower SB among partakers (Pbert et al. 2013; Grydeland et al. 2014; Lubans et al. 2016; Pbert et al. 2016; Leme et al. 2018).

Table 2. Intervention Characteristics and Effects of Physical Activity, Dietary, Sedentary Behaviour findings on BMI z-score and Waist Circumference.

Study	PA session/ Physical education session	DB content / education session	SB or Screen time	Outcome measures	Findings
Lori Pbert et al. (2013)	1 hour or more PA a day/6 x one to one counselling session x 18 to 29 min x 2 months	3 structured meals a day, including breakfast, 5 or more servings of fruits and vegetables a day, zero limits of soda and SSB	2 hours or less viewing of TV, computer, and video games a day	BMI, BMI z-score, WC, accelerometer, 24-hour dietary recall youth risk behavior survey	No significant differences in BMI z-score (p < 0.74). Small, more favourable changes in WC (p < 0.5)
Grydeland et al. (2014)	PA break in regular classes 10 min of PA/week, awareness on leisure time activity, step counts/day, sports recess activities/PE class	Fruit and vegetable intake, limit SSB, lesson with booklet and posters	Active community campaigns 5 x 3 weeks, hours of screen time use advice	BMI, BMI z-score adapted syntaxes SPSS by World Health Organization, WC, pedometer, self-reported screen time	No Significant effect on BMI z-score (p =0.23) and WC (p =0 .5). But beneficial effects were found for BMI z-score (p=0.003) in girls, but not in boys.

Table 2. Continued.

Pbert et al. (2016)	After-school exercise program includes games, walking, and dance 3 sessions/week, step counts/day 1 hour for the last 7-day period, 6 x 1 to 1 counselling session x 18 to 29 min x 2 months	Counselling on nutrition 30 min × 6 weeks, booklet, food and tracking log (Increase fruit and vegetable, limit consumption of soda, SSB, fast food, and unhealthy snacks)	TV/computer/game use for the average school day in the past 7 days	BMI, BMI z-score, WC, accelerometer, 24-hour dietary recall, youth risk behavior survey	Not found improvement on BMI z-score (p = 0.601) and WC (p = 0.693)
Lubans et al. (2016)	Sport session includes aerobic exercises and resistance training 6 × 20 min, sport recess 1 pack/school, LTPA, step counts ≥ 480 min/day for at least 3 days × 17 weeks/PE class/20 × ~90 min, researcher-led seminars (3 × 20 min)	SSB consumption	Recreational screen time min/day	BMI, BMI z-score determined by LMS method, WC, muscular fitness, pedometer, resistance training skills battery, ASAQ, NSW schools PA, and nutrition survey	No significant changes in BMI z-score (P = 0.163) and WC (P = 0.549). But there is a within group effect from baseline to 18 months (P < 0.001)
Leme et al. (2018)	Lifetime PA ≤ 30 min/week to ≥90 min/week /PE lesson	Healthy food choices, dietary intake, estimate energy intake	TV / computer use, SB for weekdays, weekends (hours/day)	BMI, BMI z-score, WC, Godin - Shephard LTPA Questionnaire, BFFQ, self-report for SB	No significant effect on BMI z-score (p = 0.055) and WC (p = 0.038).

Note. ASAQ = adolescent sedentary activity questionnaire, BMI = body mass index, BFFQ = Brazilian food frequency questionnaire, DB = dietary behavior, min = minutes, LTPA = leisure time physical activity, NSW = New South Wales, PA = physical activity, PE = physical education, SB = sedentary behaviour, SCB = sugar containing beverages, SSB = sugar sweetened beverages, WC = waist circumference.

Study quality

Whilst essential, disagreements had been rectified through discussion. The risk of bias summary is represented in Figure 2. Amongst the included studies, three trials were assessed as having at low-risk bias (Lubans et al. 2016; Leme et al. 2018; Grydeland et al. 2014) and two as having high-risk bias (Pbert et al. 2013; Pbert et al. 2016) throughout all quality standards.

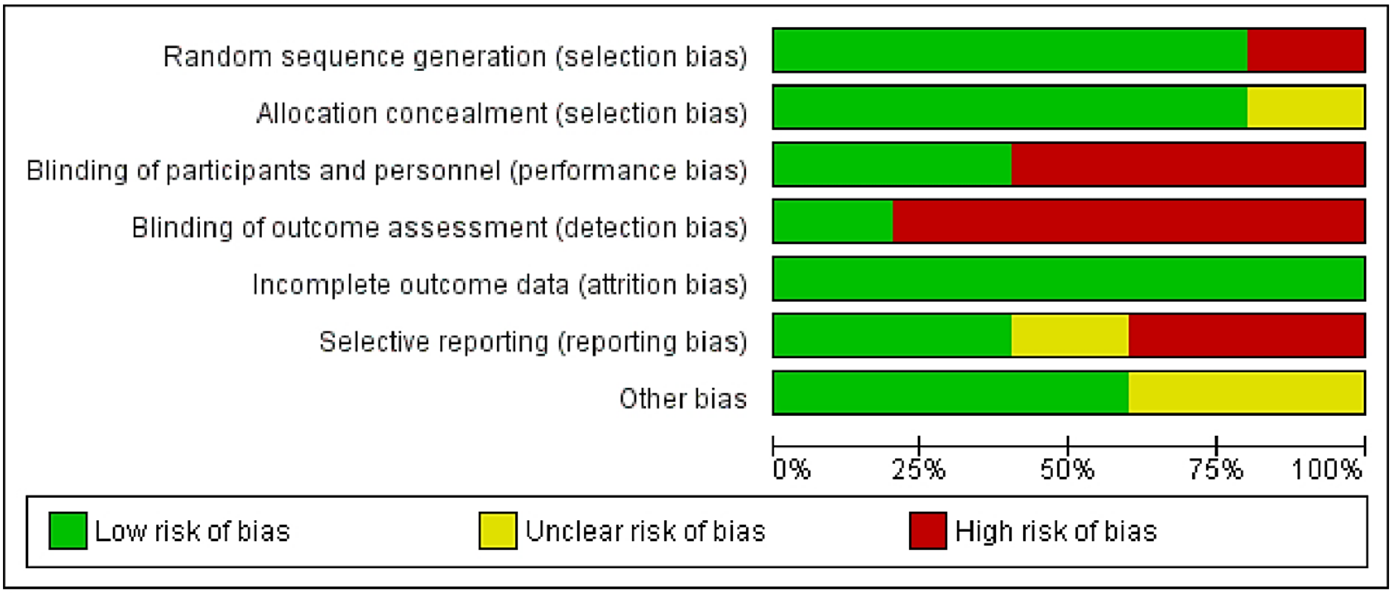

Figure 2. Risk of bias summary: using Cochrane Risk of Bias Assessment.

Effects on BMI z-score

The multiple interventions pooled analysis mean difference (MD) -0.05 [95% CI: -0.20, 0.11], p-value < 0.0001, with evidence of significant study between heterogeneity (I^2 = 87%), was supported by four trials as having provided efficacy (Figure 3A). It demonstrates that teenagers have a considerable shift in BMI z-score with a smaller impact. With no indication of between-study heterogeneity (I^2 = 0%), the efficacy of the intervention that was provided between 12 and 24 months was determined (Figure 3B) of the collective intervention pooled analysis MD -0.03 [95% CI: -0.08, 0.02], p-value = 0.48. In two pooled quantitative analyses, we evaluated the efficacy of the intervention duration. It reveals that there is a marginal difference in BMI z-score reductions for interventions lasting less than and greater than one year.

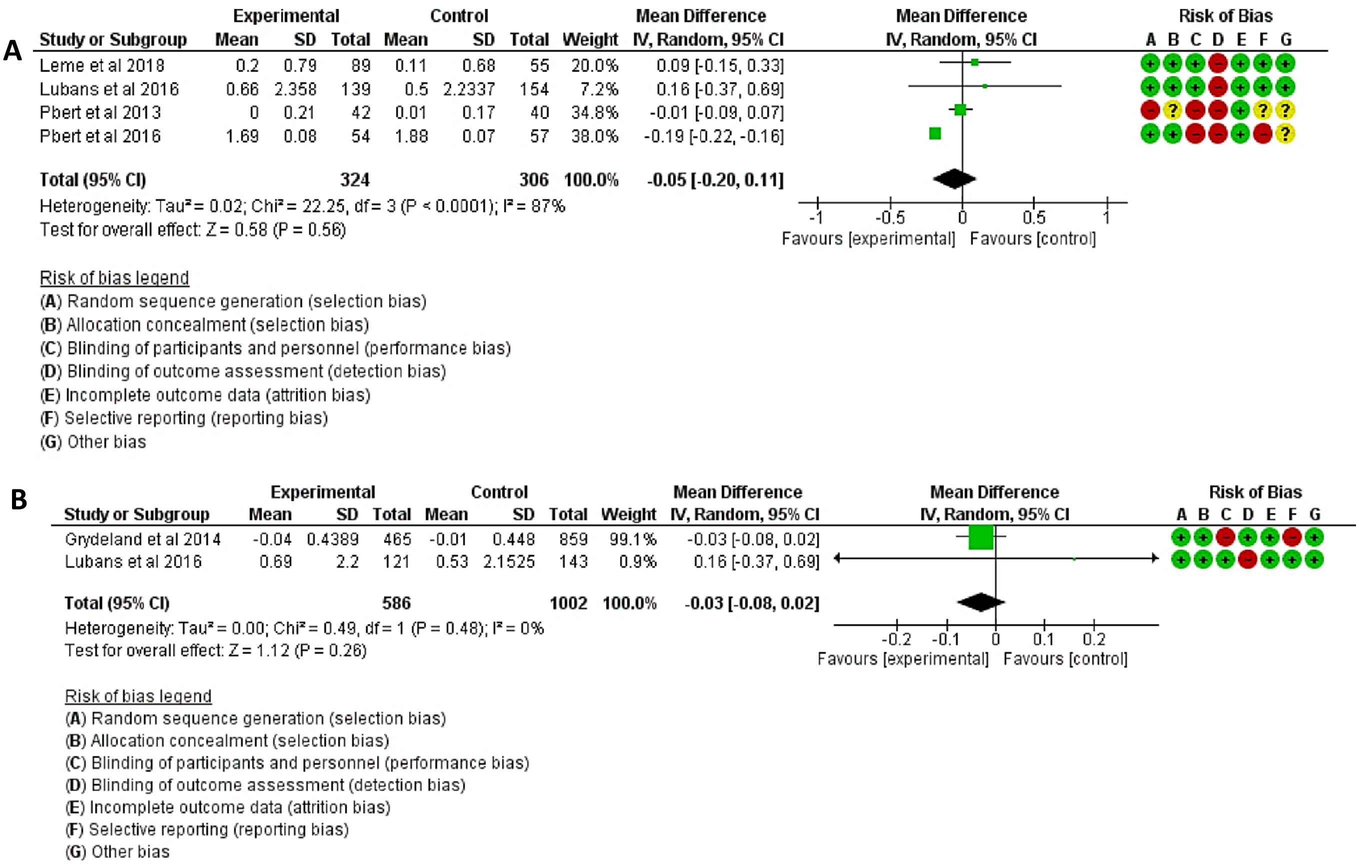

Figure 3. A - Forest plot changes in physical activity, dietary behavior, sedentary behavior intervention (3 to 12 months) effects on BMI z-score; B - Forest plot changes in physical activity, dietary behavior, sedentary behavior intervention (12 to 24 months) effects on BMI z-score.

Effects on WC

Random effects pooled analysis showed a borderline effect of PA, DB, and SB on WC at 3 to 12 months intervention duration MD -0.97cm [95% CI: -1.53, -0.42], p-value = 0.26, with evidence of significant study between heterogeneity (I^2 = 25%), was supported by four trials (Figure 4A). It shows that teens have a significant change in WC with a lesser influence. The efficacy of the intervention that was provided between 12 and 24 months was determined by the multiple interventions (Figure 4B) MD 0.20cm [95% CI: -0.22, 0.62], p-value = 0.94, pooled analyses showed no indication of between-study heterogeneity (I^2 = 0%). We assessed the effectiveness of the intervention period in two pooled studies. When WC is reduced for treatments lasting between three and twelve months as opposed to between twelve and twenty-four, there is evidently a substantial difference.

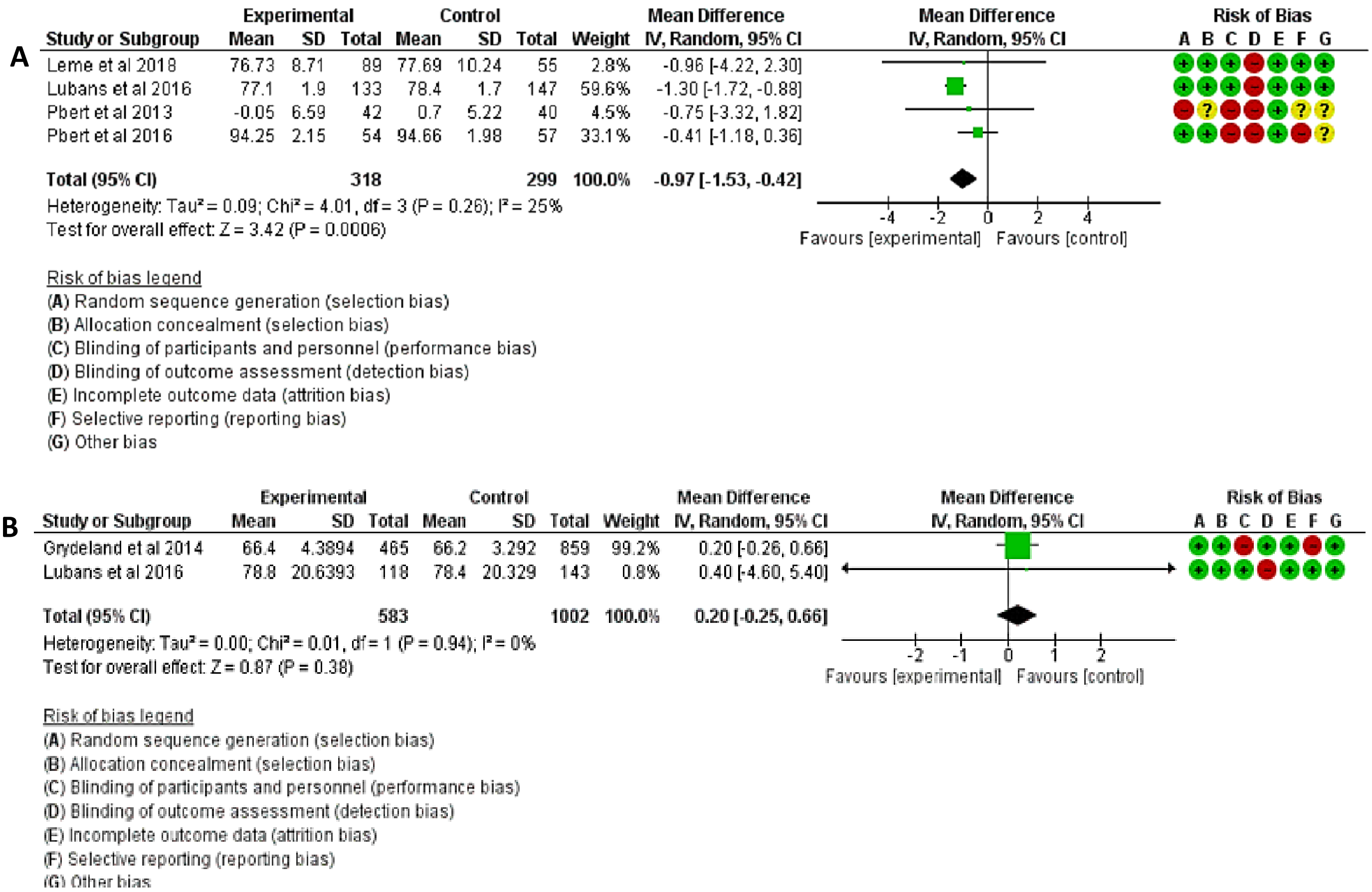

Figure 4. A - Forest plot changes in physical activity, dietary behavior, sedentary behavior intervention (3 to 12 months) effects on waist circumference; B - Forest plot changes in physical activity, dietary behavior, sedentary behavior intervention (12 to 24 months) on effects waist circumference.

Publication bias

The Egger's regression test and the Begg and Mazumdar rank correlation did not reveal any funnel plot asymmetry for interventions lasting 3 to 12 of months, indicating no publication bias for the BMI z-score (p = 1.0000 and p = 0.0873, respectively) (Figure 5A) and WC (p = 1.0000 and p = 0.7624, respectively) (Figure 5B). Neither the rank correlation nor the regression test showed any funnel plot asymmetry for BMI z-score (Figure 6A) and WC for the 12- to 24-month intervention period (Figure 6B).

Sensitivity analysis

The pooled estimate was calculated for the studies that remained after a sensitivity analysis was performed on each research that was eliminated separately. Sensitivity analysis revealed that a little amount of heterogeneity may be accounted for by the standard of the trials and the number of participants (Pbert et al. 2016) who showed a non-significant MD of 0.00 (95 % CI: -0.07, 0.08) for BMI z-score. For WC changes at follow-up in the removal of one study (Pbert et al. 2016) showed an MD of -1.28 cm (95 % CI: -1.70, -0.87), and the removal of another study (Lubans et al. 2016) showed an MD of -0.46 cm (95 % CI: -1.18, 0.26).

4. Discussion

The systematic review states to find out the efficacy of BMI z-score and WC on school-based multi-component interventions among adolescents (11-18 years) to reduce OW and obesity. Five trials met inclusion criteria, which were based solely on PA, diet, and SB on anthropometric measures such as BMI z-score and WC. According to the findings, school-based interventions PA, diet, and SB have less of an impact on lowering BMI z-score and WC in the duration of 12 to 24 months' time frame than in intervention duration between 3 to 12 months. In general, the results imply that combined interventions lower BMI z-score in teenagers. According to earlier studies, combined strategies on PA, nutrition education, and SB showed small significant results in reducing BMI outcomes (BMI, BMI z-score, and WC) among school-age students than using only one sort of intervention (Friedrich et al, 2012; Kelley et al, 2014; Jacob et al. 2021; Munusamy and Shanmugam 2022d). The overall strength of the evidence is fair.

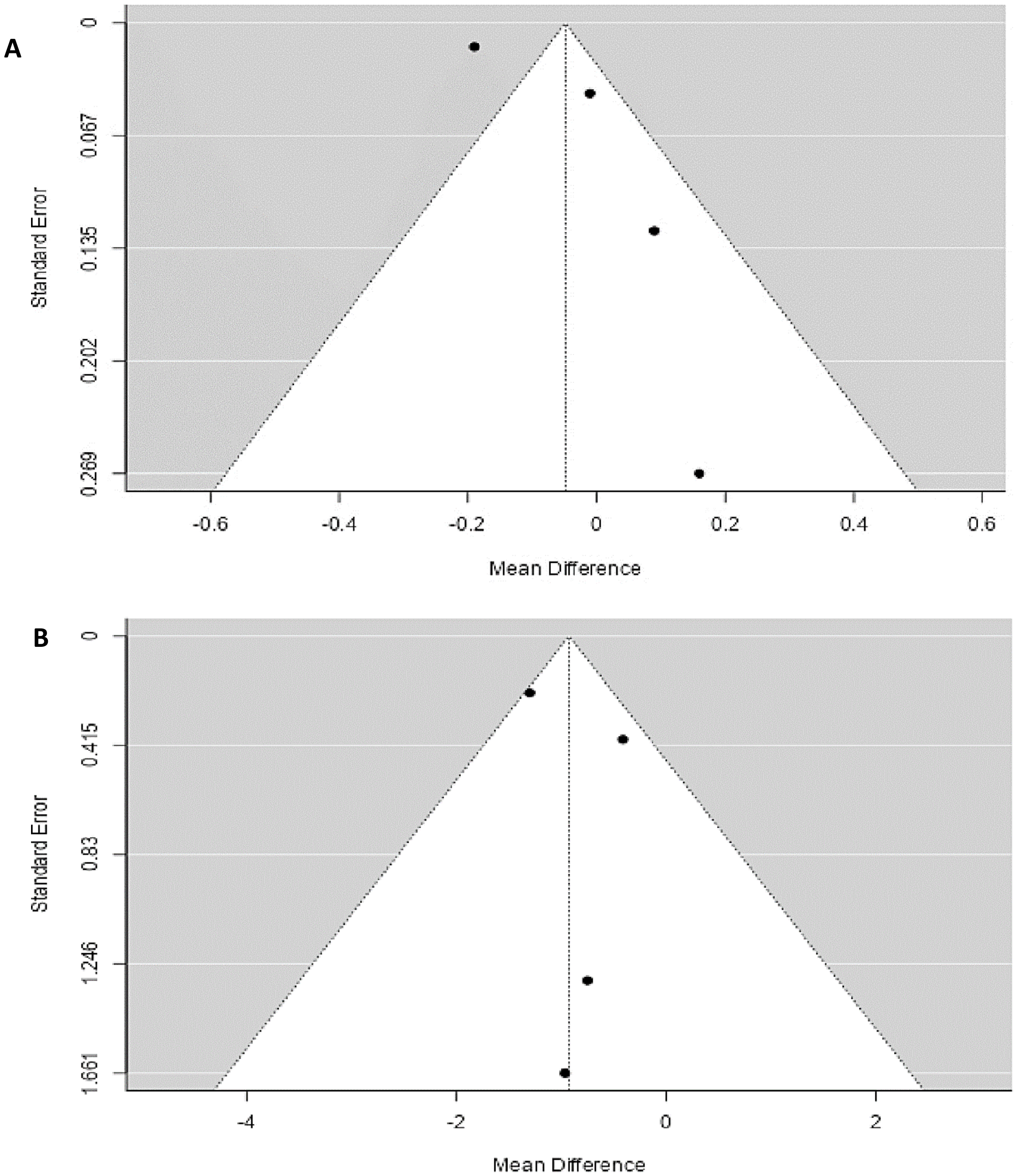

Figure 5. A - Funnel plot changes in BMI z-score on 3 to 12 months (n=4); B - Funnel plot changes in waist circumference on 3 to 12 months (n=4).

Numerous evaluations noted diverse approaches, various study designs, socioeconomic backgrounds, and various outcome measures, all of which produced comparable outcomes (Kornet-van der Aa et al. 2017; Palmer et al. 2018). Prior review, however, demonstrated a correlation between the efficacy of school-based PA and SB programs and shorter intervention times (Hynynen et al. 2016). The review bias score was found very strong on the allocation of concealment, randomization process, and attrition bias. Negative implications were observed due to a lack of participant blinding, outcome data, and reporting bias. A moderate effect on the integrity of the intervention was observed.

In a different study evaluation, it was noted that there was moderate-quality evidence of decreased weight and fair-quality evidence of lowered BMI, primarily in the intervention group as compared to the control group that received no therapy at all. A careful analysis of the evidence is required due to conflicting results, bias risk, or the use of uncountable outcome measures (Al-Khudairy et al. 2017).

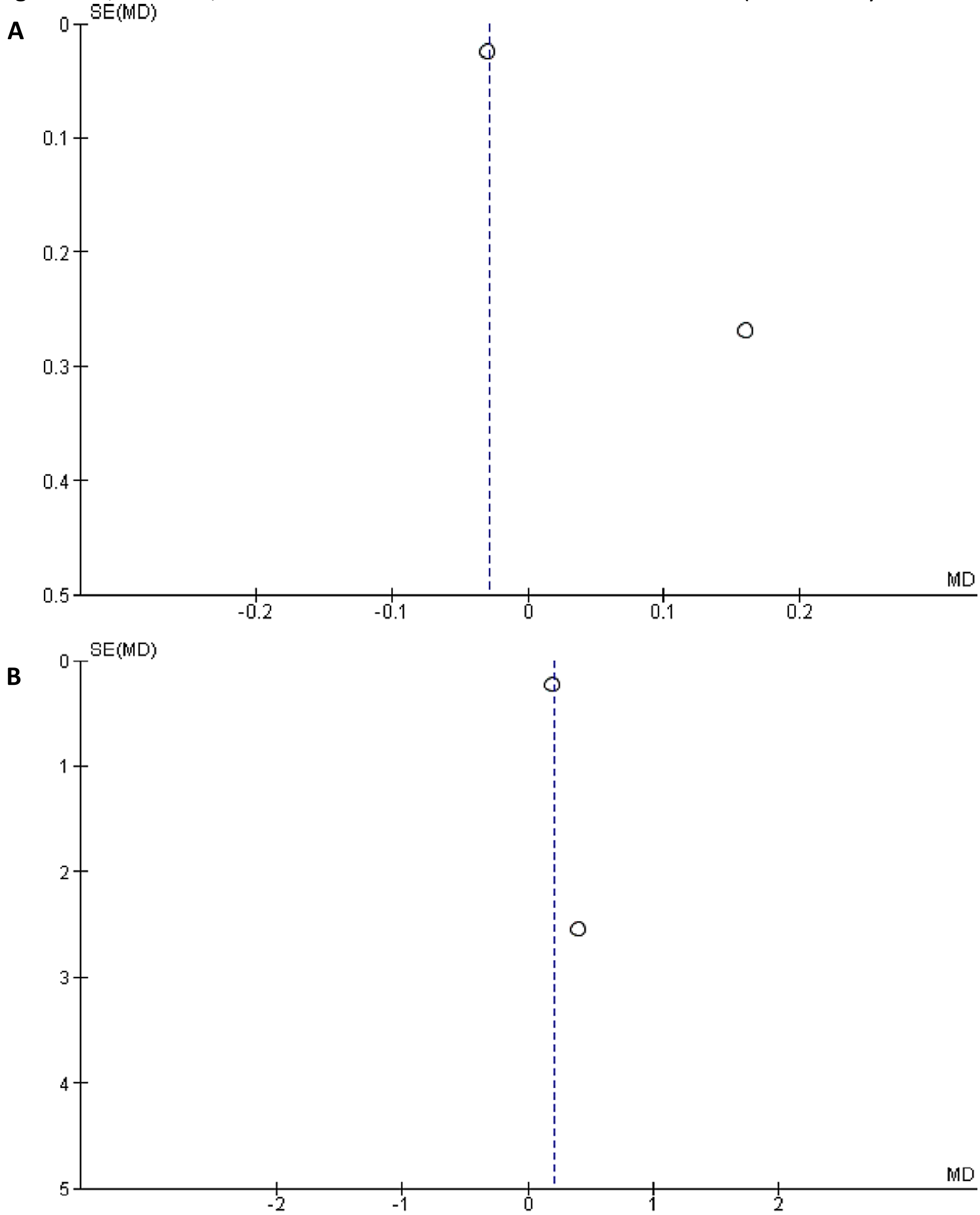

Figure 6. A - Funnel plot changes in BMI z-score on 12 to 24 months (n=2); B - Funnel plot changes in wais circumference on 12 to 24 months months (n=2).

A 25% reduction in the risk of early mortality from cardiovascular disease, cancer, and diabetes, as well as a 10% reduction in the prevalence of insufficient PA are among the Sustainable Development Goals (SDG)-3 of the 2030 Agenda for Global Change's "Leaving no one behind" initiative (United Nations 2019). In order to control BMI, prevent or reduce OW/obesity, risk factors, and comorbidities, as well as lower the likelihood of early mortality, the school setting is a crucial starting point. With well-consented reference standards, standard instruments, and the use of BMI, which gives a measurement for PA, diet, and SB, there is a possibility that participant, observer, and instrumentation bias will be mitigated.

5. Conclusions

The BMI of teenagers is impacted by an intervention, according to the current review. Adolescent behavior needs to be changed most in order to promote a healthy lifestyle, particularly with regard to choosing healthy foods, eating regularly, increasing PA, and reducing leisure screen time. The findings of the current study imply that therapies to treat obese children and adolescents may be accessible and beneficial with the conscious application of theories/models.

Authors' Contributions: MUNUSAMY, G.: conception and design, acquisition of data, analysis and interpretation of data, drafting the article, and critical review of important intellectual content; SHANMUGAM, R.: conception and design, acquisition of data, analysis and interpretation of data, drafting the article, and critical review of important intellectual content. All authors have read and approved the final version of the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Ethics Approval: Not applicable.

Acknowledgments: Not applicable.

References

AL-KHUDAIRY, L., et al. Diet, physical activity and behavioural interventions for the treatment of overweight or obese adolescents aged 12 to 17 years. *Cochrane Database of Systematic Reviews*. 2017, **2017**(6). https://doi.org/10.1002/14651858.CD012691

BLUHER, M. Obesity: global epidemiology and pathogenesis. *Nature Reviews Endocrinology*. 2019, **15**(5), 288–298. https://doi.org/10.1038/s41574-019-0176-8

CENTERS FOR DISEASE CONTROL AND PREVENTION. School health guidelines to promote healthy eating and physical activity. 2011. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21918496

CROWTHER, M.A. and LIM, W. Systematic review and meta-analysis methodology. *Blood*. 2010, **116**(17), 3140–3146. http://dx.doi.org/10.1182/blood-2010-05-280883

FRIEDRICH, R.R., SCHUCH, I. and WAGNER, M.B. Effect of interventions on the body mass index of school-age students. *Revista de Saude Publica*. 2012, **46**(3), 551–560. https://doi.org/10.1590/S0034-89102012005000036

GRYDELAND, M., et al. Effects of a 20-month cluster randomised controlled school-based intervention trial on BMI of school-aged boys and girls: the HEIA study. *British Journal of Sports Medicine*. 2014, **48**(9), 768–773. https://doi.org/10.1136/bjsports-2013-092284

HIGGINS, J.P.T., et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011, **343**(7829), 1–9. https://doi.org/10.1136/bmj.d5928

HUANG, J. Y. and QI, S. J. Childhood obesity and food intake. *World Journal of Pediatrics*. 2015, **11**(2), 101–107. https://doi.org/10.1007/s12519-015-0018-2

HYNYNEN, S-T., et al. A systematic review of school-based interventions targeting physical activity and sedentary behaviour among older adolescents. *International Review of Sport and Exercise Psychology*. 2016, **9**(1), 22–44. http://www.tandfonline.com/doi/full/10.1080/1750984X.2015.1081706

JACOB, C.M., et al. A systematic review and meta-analysis of school-based interventions with health education to reduce body mass index in adolescents aged 10 to 19 years. *International Journal of Behavioral Nutrition and Physical Activity*. 2021, **18**(1), 1–22. https://doi.org/10.1186/s12966-020-01065-9

JANAKIRAMAN, B., et al. Epidemiology of general, central obesity and associated cardio-metabolic risks among university employees, Ethiopia: a cross-sectional study. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*. 2020, **13**, 343–353. https://doi.org/10.2147/DMSO.S235981

KELLEY, G.A., KELLEY, K.S. and PATE, R.R. Effects of exercise on BMI z-score in overweight and obese children and adolescents: a systematic review with meta-analysis. *BMC Pediatrics*. 2014, **14**(1), 1–22. Available from: http://www.biomedcentral.com/1471-2431/14/225

KELLY, S., et al. A systematic review of mediators of physical activity, nutrition, and screen time in adolescents: implications for future research and clinical practice. *Nursing Outlook*. 2017, **65**(5), 530–548. https://doi.org/10.1016/j.outlook.2017.07.011

KORNET-VAN DER AA, D. A. et al. The effectiveness and promising strategies of obesity prevention and treatment programmes among adolescents from disadvantaged backgrounds: a systematic review. *Obesity Reviews*. 2017, **18**(5), 581–593. https://doi.org/10.1111/obr.12519

KUMAR, S., et al. Exercise and eating habits among urban adolescents: a cross-sectional study in Kolkata, India. *BMC public health*. 2017, **17**(1), 468. https://doi.org/10.1186/s12889-017-4390-9

LEE, E. Y. and YOON, K-H. Epidemic obesity in children and adolescents: risk factors and prevention. *Frontiers of Medicine*. 2018, **12**(6), 658–666. https://doi.org/10.1007/s11684-018-0640-1

LEME, A. C. B., et al. Sustained impact of the "Healthy Habits, Healthy Girls – Brazil" school-based randomized controlled trial for adolescents living in low-income communities. *Preventive Medicine Reports*. 2018, **10**, 346–352. https://doi.org/10.1016/j.pmedr.2018.04.013

LIBERATI, A., et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of clinical epidemiology*. 2009, **62**(10), e1–e34. https://doi.org/10.1016/j.jclinepi.2009.06.006

LINNER, A. and ALMGREN, M.A.E. Epigenetic programming-the important first 1000 days. *Acta Paediatrica*. 2019, **109**, 443–452. https://doi.org/10.1111/apa.15050

LIU, Z., et al. A systematic review and meta-analysis of the overall effects of school-based obesity prevention interventions and effect differences by intervention components. *International Journal of Behavioral Nutrition and Physical Activity*. 2019, **16**(1), 1–12. https://doi.org/10.1186/s12966-019-0848-8

LOBSTEIN, T., et al. Child and adolescent obesity: part of a bigger picture. *Lancet*. 2015, **385**(9986), 2510–2520. https://doi.org/10.1016/S0140-6736(14)61746-3

LUBANS, D. R., et al. Assessing the sustained impact of a school-based obesity prevention program for adolescent boys: the ATLAS cluster randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity*. 2016, **13**(1), 1–12. http://dx.doi.org/10.1186/s12966-016-0420-8

MARTINEZ-GOMEZ, D., et al. Excessive TV viewing and cardiovascular disease risk factors in adolescents. the AVENA cross-sectional study. BMC Public Health. 2010, **10**, 1–8.

MUNUSAMY, G. and SHANMUGAM, R. Effectiveness of structured interventional strategy for middle-aged adolescence (SISMA-PA) for preventing atherosclerotic risk factors—a study protocol. *PLOS ONE*. 2022a, **17**(7), e0271599. https://doi.org/10.1371/journal.pone.0271599

MUNUSAMY, G. and SHANMUGAM, R. Bacterial Infections and Atherosclerosis - A Mini Review. *Journal of Pure and Applied Microbiology*. 2022b, 16(3), 1595–1607. https://doi.org/10.22207/JPAM.16.3.08

MUNUSAMY, G. and SHANMUGAM, R. A school-based survey among adolescents on dietary pattern , exercise , and knowledge of cardiovascular risk factors (ADEK) study. *Cardiometry*. 2022c, **23**, 123–132. https://doi.org/10.18137/cardiometry.2022.23.123132

MUNUSAMY, G. and SHANMUGAM, R. Effect of school-based interventions on body mass index among adolescents: a systematic review and meta-analysis. *National Journal of Community Medicine*. 2022d, **13**(9), 584–591. https://doi.org/10.55489/njcm.130920222266

PALMER, M., et al. The effectiveness of smoking cessation, physical activity/diet and alcohol reduction interventions delivered by mobile phones for the prevention of non-communicable diseases: a systematic review of randomised controlled trials. *PLOS ONE*. **13**(1), e0189801. https://doi.org/10.1371/journal.pone.0189801

PATTON, G.C., et al. Our future: a Lancet commission on adolescent health and wellbeing. *The Lancet*. 2016, **387**(10036), 2423–2478. https://doi.org/10.1016/S0140-6736(16)00579-1

PBERT, L., et al. A school nurse-delivered intervention for overweight and obese adolescents. *Journal of School Health*. 2013, **83**(3), 182–193. https://doi.org/10.1111/josh.12014

PBERT, L., et al. A school-based program for overweight and obese adolescents: a randomized controlled trial. *Journal of School Health*. 2016, **86**(10), p. 699–708. https://doi.org/10.1111/josh.12428

RATHI, N., RIDDELL, L. and WORSLEY, A. Food consumption patterns of adolescents aged 14-16 years in Kolkata, India. *Nutrition journal*. 2017, **16**(1), 50. Available from: https://sustainabledevelopment.un.org/content/documents/21252030

REILLY, J.J., et al. Physical activity interventions in early life aimed at reducing later risk of obesity and related non-communicable diseases: a rapid review of systematic reviews. *Obesity Reviews*. 2019, **20**(S1), 61–73. https://doi.org/10.1111/obr.12773

ROTH, G. A., et al. Global, regional , and national age-sex-specific mortality for 282 causes of death in 195 countries and territories , 1980 – 2017 : a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*. 2018, **392**(10159), 1736–1788. https://doi.org/10.1016/S0140-6736(18)32203-7

STANAWAY, J.D., et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Stu. The Lancet. 2018, 392(10159), p. 1923–1994. https://linkinghub.elsevier.com/retrieve/pii/S0140673618322256

TAYLOR, S.A., et al. Preventing and treating adolescent obesity: a position paper of the society for adolescent health and medicine. Journal of Adolescent Health. 2016, 59(5), p. 602–606. https://doi.org/10.1016/j.jadohealth.2016.08.020

UNITED NATIONS. Transforming our world: the 2030 agenda for sustainable development. 2019.

WORLD HEALTH ORGANIZATION. Global Accelerated Action for the Health of Adolescents (AA-HA!) Guidance to Support Country Implementation. 2017. Available from: https://apps.who.int/iris/bitstream/handle/10665/255415/9;jsessionid=B309C8C56E5EEFA24FA2F606422AB847?sequence=1

WORLD HEALTH ORGANIZATION. Global status report on noncommunicable diseases. World Health Organization. 2014.

WORLD HEALTH ORGANIZATION. WHO Guidelines on physical activity and sedentary behaviour. 2016. Available from: https://apps.who.int/iris/bitstream/handle/10665/337001/9789240014886-eng.pdf

WORLD HEALTH ORGANIZATION. Physical activity for health: more active people for a healthier world. 2018. Available from: https://apps.who.int/iris/bitstream/handle/10665/272722/9789241514187-eng.pdf1

WORLD HEALTH ORGANIZATION. Obesity and overweight factsheet. 2021. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

Received: 19 May 2022 | **Accepted:** 27 March 2023 | **Published:** 5 May 2023