REVIEW ARTICLE

The Effectiveness of Obesity Intervention Programs: A Systematic Review of Experimental Studies

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ABSTRACT

Objective: **This systematic review sought to identify effective interventions and intervention elements in the management of obesity and to identify priorities for further intervention development and research.**

Design: **We searched the scientific database of PubMed for potentially eligible articles.**

Materials and methods: **Our initial search using selected keywords resulted in 727 articles. After the selection process, we included 12 articles that reported either body weight or body mass index (BMI) changes as an outcome of obesity intervention programmes.**

Results: **All included studies showed decrease in body weight and/ or BMI among intervention groups and post-intervention for non-control group studies. The intervention elements include nutritional advice and modification, physical activities, health volunteers among the community members, online platform such as web-based approach or smartphone apps, behavioural skills, and psychosocial support.**

Discussions: **All studies included in this review found positive obesity intervention effects. Majority of the studies included in this systematic review had multi-component obesity intervention such as nutrition, physical activity, educational, environmental, and behavioural aspects.**

Conclusions: **The current evidence from included studies is insufficient to draw firm conclusions about intervention elements that are more effective than others. More research is needed to extend the body of evidence.**

KEY WORDS

obesity, intervention, programs, health services, experimental studies

INTRODUCTION

Obesity is a current important worldwide public health problem[1]. The global prevalence of obesity in adults has been alarmingly high[2]. In 2016, more than 1.9 billion (39%) adults, 18 years and older, were overweight and 650 million of them (13%) were obese. Most of the world's population live in countries where overweight and obesity kills more people than underweight. As for childhood obesity globally, the prevalence of overweight and obesity among children and adolescents aged 5-19 years old has risen dramatically from just 4% in 1975 to over 18% in 2016[3]. The World Health Organization (WHO) highlights prevention of obesity as an important priority to reduce the impact of non-communicable diseases[4]. Obesity is a major risk factor for several non-communicable diseases such as diabetes mellitus, cardiovascular disease, hypertension, cerebrovascular accident, and certain forms of cancer leading to increased risk of premature death to serious chronic conditions that reduce the overall quality of life[5].

Obesity interventions are often evaluated as a whole, as opposed to the specific elements that comprised the interventions, which hinders effective implementation and dissemination of evidence-based approaches to reduce obesity[6]. Therefore, the aim of this systematic review is to identify effective interventions and intervention elements in the management of obesity and to identify priorities for further intervention development and research.

MATERIALS & METHODS

Search Strategy

The systematic review search was performed throughout August 2021 for all the relevant titles, abstracts, and keywords in the journal database of PubMed for articles from September 2020 until August 2021. This search was conducted in accordance with the Preferred Reporting Items for a Systematic Review and Meta-analysis (PRISMA) checklist. The keywords used are experiment* OR intervention* AND obese* AND adult*.

Selection Criteria

The inclusion criteria for the database searches were (a) Experimental or interventional studies that fulfil the keywords and terms searched, (b) Availability of full text articles, (c) Original articles, (d) English-language articles, and (e) Study outcome of body weight and/or BMI changes. The exclusion criteria in this search were (a) Case study articles, (b) Review articles, and (c) Study protocols. The articles were first identified through the title screening process. Next, the articles' abstracts were screened using the eligibility criteria. Full text articles obtained were subsequently included in qualitative analysis. The flow of the article search is described in Figure 1.

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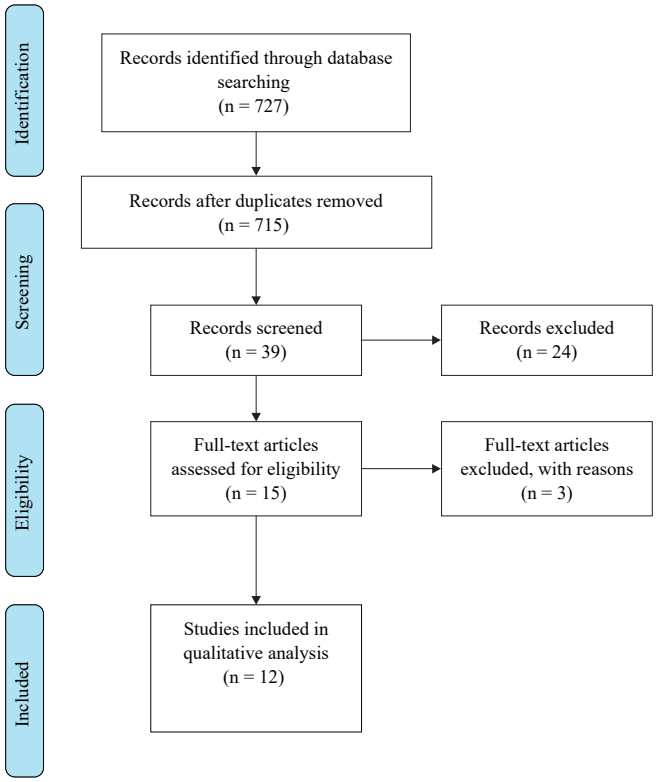

Figure 1: PRISMA flowchart

Operational Definition

Obesity intervention programmes in this context refers to any programme or activities either conducted at health centres or community, that aimed to intervene the obesity problem

Data extraction tool

All researchers independently extracted the information for each article into an excel sheet. The data was customized into (a) Author (year), country (b) Study objective(s) (c) Study characteristics (design, duration, intervention) (d) Characteristics of participants, and (e) Desired outcome measure (Table 1).

Quality Assessment Tool

By using the mixed method assessment tool (MMAT version 2018), the articles were critically appraised for its quality by the researchers. This tool has been shown to be useful in systematic review encompassing different study designs[7].

RESULTS

Study Selection

The selection process is illustrated in the PRISMA flow chart in Figure 1. A total of 727 studies were identified in the initial searches in PubMed database. After screening of duplicates, titles and abstracts were screened, a total of 15 articles were short-listed. Subsequent full-text assessment excluded 3 articles, leaving 12 articles for qualitative analysis.

Irrelevant studies were excluded based on screened titles and abstracts (n = 49); while the reason for excluding studies via full-text reading were inappropriate study objectives (n = 2) and supplementary research (n = 1).

Study and Sample Characteristics

A total of twelve experimental studies were included in this systematic review. Four of the studies were done in the United States of America (USA), two in Spain, and one each in South Africa, Australia, China, Korea, Japan and Singapore. The number of participants ranged from 13 to 1,298 adolescents (2 studies), adults (9 studies), and elderly (1 study) with the mean age ranging between 12.88 to 72.9 years old. Eleven out of twelve studies selected the participants based on BMI, while only one study used waist circumference to select the participants. The minimum pre-intervention BMI for adults and elderly was 23 kg/m^2, while for adolescents, the BMI should be $\geq 85_{th}$ percentile. As for the waist circumference measurement, $\geq$ 90 cm for men and $\geq$ 85 cm for women were considered as truncal obesity.

Regarding the study design, there were three-armed randomized controlled trial (RCT) study (n = 1), two-armed RCT study (n = 4), two-armed pilot RCT study (n = 1), quasi-experimental study with control group (n = 2) and pre-test — post-test without control group (n = 4). The study duration was between 4 weeks and 12 months. The outcome measured in the selected studies were (a) mean or median percentage of body weight and BMI reduction, (b) mean body weight and BMI reduction, and (c) mean BMI (pre- and post-intervention).

Summary of Interventions

Two of the selected studies were having nutritional intervention only[8,9], while the other ten studies were having combination of intervention elements such as nutrition, physical activities, behavioural and psychosocial. Five of the studies were using the online platform to convey the intervention[10-14].

Intervention Effects

All the studies that were having intervention and control group showed that there were significantly higher body weight reduction and/or BMI reduction among the intervention groups. There was one study among the expert-led group versus community volunteer-led group showed that those in volunteer-led group were having slightly higher body weight reduction and BMI reduction as compared to the expert-led group[15].

DISCUSSION

In this review, all studies showed that those in the intervention group were having significant weight and BMI reduction as compared to the control group. This finding is in line with the previous study of intensive lifestyle intervention programme[16]. There were four studies in this review using pre-test — post-test without control group as the design of the study, all of the studies showed significant weight and BMI reduction at post intervention. On the other hand, an experimental study demonstrated that in the intervention group, the mean scores of knowledge, perceived benefits, physical activity and nutrition behavior were significantly higher after the intervention than those before the intervention[17].

Majority of the studies included in this systematic review had multi-component obesity intervention such as nutrition, physical activity, educational, environmental and behavioural aspects. There is strong evidence that multi-component obesity interventions increased physical activity[18], and weight loss for adolescents[19,20]. Multi-component interventions also modestly improved weight status among adults[21], including overweight or obese adults[22]. The shortest duration of intervention among the included studies was four weeks, which showed lower mean body weight reduction as compared to most other studies with longer duration of intervention. Two studies in this review that were using nutritional intervention only also showed lower mean body weight reduction as compared to multi-component intervention studies. In general, multi-component interventions are more effective than single component efforts, especially over longer durations[18,19,21,22]. Longer-term studies showed greater weight loss among participants in multi-component interventions that address nutrition and physical activity than among participants in nutrition-only interventions; however, in the short-term, both interventions appeared to have similar benefits[22].

One of the studies in this review was among the expert-led group versus community volunteer-led group that showed that those in volunteer-led group were having slightly higher body weight and BMI reduction as compared to the expert-led group. In a previous study, the students were encouraged to take a leading role and discuss proposals with their school principals and teachers, thereby taking ownership of the strategies to promote healthy eating and physical activity[23]. There is

Table 1: Articles included in the systematic review

Author (year), country	Study objective(s)	Study characteristics (design, duration, intervention)	Characteristics of participants	Desired outcome measure(s)
1. Lopez-Hernandez *et al*. (2020), Spain[8]	To assess the relationship between nutritional knowledge and nutritional parameters such as dietary intake, anthropometric parameters, and biomarkers	Before—after non-randomized interventional study between October 2014 and May 2015 (8 months). Obesity intervention: 15 fortnightly nutritional education workshops conducted by a nurse and nutritionist with more than 10 years of teaching and research experience in the field of nutrition. The sessions were organized with a theoretical-practical character and lasted for 60 minutes each.	N = 66 adults with mean age of 50.23 years old, BMI > 25 kg/m^2, and lack of regular physical exercise.	Mean body weight and BMI reduction. Statistically significant changes were observed ($p < 0.001$) with a weight loss of 3% (mean pre: 87.24 kg vs mean post: 84.51 kg) and a significant decrease in BMI (mean pre: 32.87 kg/m^2 vs mean post: 31.79 kg/m^2).
2. Phelan *et al*. (2021), USA[10]	To test the feasibility integrating virtual reality (VR) into standard behavioural weight loss treatment.	Pilot randomized trial study, 4 weeks. Participants were randomly assigned to (1) Standard Behavioural Weight Loss plus Non Weight-Related Virtual Reality (i.e., Control Group) or (2) Standard Behavioural Weight Loss plus Weight- Related Virtual Reality (i.e., Intervention Group). Obesity intervention: The Intervention Group's VR scenarios complemented three weight control lessons: assertiveness in restaurants (session 2), modifying home eating cues (session 3), and modifying home exercise cues (session 4).	N = 13 adults with mean age of 43.3 years old, BMI ≥ 25 kg/m^2.	Mean percentage of body weight reduction. The intervention and control groups both lost weight and unadjusted means (SD) averaged 3.4% (2.7) and 2.3% (3.6), respectively, over the 4 weeks.
2. Phelan *et al*. (2021), USA[10]	To test the feasibility integrating virtual reality (VR) into standard behavioural weight loss treatment.	Obesity intervention: In the Control Group, they were given non-weight diet, and activity related scenarios using the New York Times VR app (i.e., programs on marine life, nature, and sounds from around the world).		
3. Grace *et al*. (2021), South Africa[37]	To determine the effect of a combined physical activity and nutrition education intervention program on body mass index (BMI), blood pressure and selected biochemical variables in overweight and obese South African adolescents from the KwaZulu-Natal area.	Quasi-experimental pre-test—post-test 10-week intervention study. Obesity intervention: Intervention Group received combination of (1) Supervised physical activity program (20 exercise sessions, 2 days/ week), (2) Unsupervised physical activity program (30 exercise sessions, 3 days/ week), and (3) Nutrition education program (a registered dietitian individually discussed information surrounding food consumption habits).	N = 41 adolescents with mean age of 14.5 years old in the Intervention Group and 13.6 years old in the Control Group, BMI ≥ 85th percentile.	Mean BMI reduction. The Intervention Group showed a significant reduction ($p < 0.01$) in mean BMI from 30.8 kg/m^2 (pre) to 29.8 kg/m^2 (post), over 10 weeks.
4. Huang *et al*. (2020), China[38]	To assess the effects of a 6-week program of combined endurance and strength training exercise and dietary restriction on central hemodynamic parameters and gut microbiome composition.	Pre-post intervention study, 6 weeks. Obesity intervention: Combined endurance (including bicycling, walking, running, dancing, and ball games) and strength training exercise; with dietary restriction (dietitians prepared and supervised all meals).	N = 24 obese adolescents with mean age of 12.88 years old.	Mean body weight and BMI reduction. Statistically significant ($p < 0.001$). Mean weight (pre) 82.64 kg vs (post) 74kg. Mean BMI (pre) 31.02 vs (post) 27.78 kg/m^2.
5. Batsis *et al*. (2021), USA[11]	To evaluate the feasibility, acceptability, and preliminary outcomes of a technology-based weight management intervention for rural older adults with obesity.	Single-armed, weight management intervention study, 6 months. Obesity intervention: Program consisting of nutrition and exercise sessions delivered using a blend of synchronous, video conferencing sessions with real-time communications and the use of remote monitoring using Fitbit and enhanced by periodic face-to-face interactions.	N = 44 elderly with mean age of 72.9 years, BMI ≥ 30 kg/m^2.	Mean percentage of body weight and BMI reduction. Statistically significant ($p < 0.001$). Weight reduction 4.7%, BMI reduction 5.1%.

6. Kim *et al*. (2020), Korea[39]	To evaluate the effectiveness of an intervention focusing on dietary self-efficacy and behaviours on the improvement of abdominal obesity.	Single-blind, parallel-group randomized controlled trial study, 6 months intervention, 12 months follow up. Obesity intervention: Intervention Group: "Healthy Life Plan" that combined individual counselling with education and monitoring. Control Group: provided with brief information on their health examination results and the necessity of lifestyle change.	N = 583 abdominally obese adult (waist circumference of ≥ 90 cm for men and ≥ 85 cm for women) with mean age of 53 years old.	Mean BMI reduction. Statistically significant ($p < 0.001$). Intervention Group 0.41 kg/m^2 vs Control Group 0.35 kg/m^2.
7. Lim *et al*. (2021), Singapore[12]	To compare the effects of a culturally contextualized smartphone-based intervention with usual care on weight and metabolic outcomes.	Parallel multicentre 2-group randomized controlled trial study, 6 months. Obesity intervention: At baseline, all participants received a single 45- to 60-minute advisory session from a registered	N = 204 adults with type 2 diabetes, mean age of 51.2 years old, BMI ≥ 23 kg/m^2.	Mean weight and BMI reduction. Statistically significant ($p < 0.001$). Mean weight reduction (intervention) 3.6kg vs (control) 1.2kg.
7. Lim *et al*. (2021), Singapore [12]		research dietitian concerning diet and physical activity. Intervention Group additionally used a smartphone app to track weight, diet, physical activity, and blood glucose and then communicated with dietitians for 6 months.		Mean BMI reduction (intervention) 1.3 kg/m^2 vs (control) 0.4 kg/m^2.
8. Mallorquí-Bagué *et al*. (2021), Spain [40]	To longitudinally explore through a randomized clinical trial if overweight and obesity could be modified after 1 year of a multimodal psychosocial intervention.	Multicentre, randomized, parallel-group, primary prevention clinical trial study, 12 months. Obesity intervention: Intervention Group: energy restricted traditional Mediterranean diet, physical activity promotion and psychosocial (behavioural-motivational) support. Control Group: usual healthy lifestyle recommendations, without specific motivational advice for increasing physical activity or losing weight.	N = 342 adults with mean age of 65.24 years old, BMI of 27-40 kg/m^2.	Mean BMI (pre and post). Statistically significant ($p < 0.001$). Intervention Group (pre) 32.59 kg/m^2 vs (post) 30.03 kg/m2. Control Group (pre) 32.51 kg/m^2 vs (post) 31.85 kg/m^2.
9. Mizushima *et al*. (2021), Japan[15]	To directly compare the outcomes between expert- and volunteer-led versions of a weight-loss intervention in Japan.	Non-randomized comparative trial study, 3 months. Obesity intervention: Both groups received the same program content and intervention period. Community volunteers were trained in four of five 3-hour training sessions while experts were highly trained and experienced professionals in the fields of exercise and nutrition prescription.	N = 145 adults with mean age of 54 years old (expert-led group) and 57.2 years old (volunteer-led group), BMI of 25-40 kg/m^2.	Mean weight and BMI reduction. Statistically insignificant. Expert-led group (mean weight reduction): 6.3 kg, (BMI reduction): 2.3 kg/m^2.
9. Mizushima *et al*. (2021), Japan[15]				Volunteer-led group (mean weight reduction): 6.4 kg, (BMI reduction): 2.5 kg/m^2.
10. Thomas *et al*. (2020), USA[13]	To evaluate the effects of a Web-based virtual reality (VR) programme for enhancing behavioural skills training and weight loss when offered as an adjunct to a commercial online weight management programme.	Randomized controlled trial study, 6 months. Obesity intervention: All participants received 6 months of no-cost access to the online weight management programme offered by WW (formerly Weight Watchers). Intervention group was enhanced with the Experience Success (WW + ES) programme, consisting of four Web-based VR sessions for training in behavioural weight-loss skills related to the home environment, the workplace, physical activity, and social situations.	N = 146 adults with mean age of 58.3 years old, BMI of 27-40 kg/m^2.	Mean weight reduction. Statistically significant ($p < 0.05$). Intervention Group: 4.7kg vs Control Group: 2.6 kg.
11. Prasad *et al*. (2021), USA[9]	To test the feasibility of time restricted eating (TRE) in adults with overweight and obesity.	2 phase open label, non-randomized, prospective intervention study, 3 months. Obesity intervention: Phase 1: 2-week baseline observation run-in phase to identify individuals with eating window of 14 hours or more. Phase 2: 90-day TRE intervention phase aiming to reduce the eating window to 10 hours/day, while consuming their usual diet.	N = 14 adults with mean age of 51 years old, BMI of 25-50 kg/m^2.	Median percentage of weight and BMI reduction. Statistically significant ($p = 0.017$). Median weight reduction: 2.2kg, median BMI reduction: 2.3 kg/m^2.

12. Beleigoli *et al*. (2020), Australia[14]	To compare the effectiveness of a web-based behaviour change intervention personalized through either computerized or human-delivered feedback with a non-personalized intervention in promoting weight loss in community-based adults with overweight or obesity.	3-arm (1:1:1), parallel, randomized controlled trial study, 6 months. Obesity intervention: (1) Platform only (24-week behaviour change program delivered using a web platform with personalized computer-delivered feedback), (2) Platform plus coaching (same 24-week web-based behaviour change program plus 12 weeks of personalized feedback delivered online by a dietitian), (3) Waiting list (non-personalized dietary and physical activity recommendations delivered through an e-booklet and videos).	N = 1,298 adults with mean age of 33.6 years old, BMI ≥ 25 kg/m^2.	Mean weight and BMI reduction. Statistically significant (p = 0.001). Highest reduction in Group 2 (Platform plus coaching), mean weight reduction: 1.57 kg, mean BMI reduction: 0.56 kg/m^2.

also some evidence that layperson- or peer-led approaches support positive behavioural change and improved health outcomes among adults living with obesity[24,25], or obesity-related comorbidities[26]. Layperson- or community-led interventions have proven to be associated with low-resource areas or settings in which culturally tailored approaches are preferred by community members[27,28].

There were also studies in this review using behavioural elements as the obesity intervention such as behavioural weight loss skills related to the home environment, the workplace, physical activity, and social situations, and psychosocial (behavioural-motivational) support. A previous review paper found that physical activity, nutrition education, behavioural modification and family involvement are common treatment components and have improved weight loss and health-related outcomes in adolescents with morbid obesity[29]. While behavioural element for intervention of obesity have demonstrated efficacy, several factors such as target population, format used, intensity of intervention, duration, and setting can influence the outcomes. These contexts may be particularly crucial when considering implementation and integration of intervention into healthcare systems and clinical practice, as these should be maximally effective while at the same time, designed to minimize costs and burden[30].

Five studies in this review were using online platform for obesity intervention programme and showed better body weight and/or BMI reduction as compared to the control group that either used printed manuals or unrelated online resources. A previous review paper found that web-based interventions for both weight loss and weight loss maintenance were more effective than minimal or control conditions. However, when contrasted with comparable non web-based interventions, results were less consistent across reviews[31]. There was one study in this review using smartphone apps to track body weight twice weekly, diet and physical activity daily, and to communicate regularly with the research dietitians. The participants could choose the weight loss goal between 3% to 10%, having individualized calorie and carbohydrate goals; and physical activity goal of 10 000 steps daily set by the app[12]. Previous studies have reported that the use of mHealth applications is effective in many contexts and across several populations. A pilot RCT by Ross and Wing[32], showed that self-monitoring technologies such as Fitbit activity monitor, scale and mobile app combined with brief phone-based interventions resulted in greater adherence and weight loss compared with standard self-monitoring tools alone such as reference book, pedometer, paper-based booklet and body weight scale.

There was one study in this review using time-restricted eating (TRE) as an intervention element. They chose the participants with eating duration of 14 hours or more. At the end of 3 months intervention, the TRE was reduced to about 11 hours. The body weight and BMI were significantly reduced by 2.2 kg and 2.3 kg/m^2. They were consuming their usual diet while aiming to reduce the eating window to 10 hours per day. TRE is a specific intermittent fasting (IF) protocol involving consistent fasting and eating periods within a 24-hour cycle. Prior small studies in humans with overweight or obesity demonstrate that TRE can result in reduced calorie intake and is associated with a decrease in body weight and/or fat mass[33,34]. The TRE is attractive as a weight-loss option in which it does not require tedious and time-consuming methods such as calorie-counting or adherence to complicated diets[35].

Ten out of twelve studies in this review were combining at least two elements; nutrition and physical activity. Evidence continues to grow suggesting that physical activity should be combined with dietary energy restriction for optimal outcome in the setting of weight loss. These elements should complement each other as the dose of exercise necessary to elicit significant weight loss is relatively large. In addition, caloric restriction is more efficacious for rapid weight loss than physical activity alone. Importantly, combining physical activity with energy restriction helps to counter the common harmful effects of caloric restriction alone, including loss of lean tissue and lowered resting metabolic rate[36].

Strength and Limitation

The major strengths of this systematic literature review include the application of a systematic search strategy and adherence to PRISMA guidelines. However, as we only included peer-reviewed articles from a database, we cannot fully exclude the occurrence of a publication bias. In addition, a language bias may have affected our results as we only took English language articles into account. Nevertheless, this systematic literature review provides valuable insights into significant obesity intervention programmes worldwide.

CONCLUSION

All studies included in this review found positive obesity intervention effects. Among the effective intervention elements include nutritional advice and modification, physical activities, health volunteers among the community members, online platform such as web-based approach or smartphone apps, behavioural skills, and psychosocial support. However, the current evidence is inadequate to draw firm conclusions about the intervention types or approaches that are more effective than others. Therefore, more research is urgently needed to extend the body of evidence.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest in this study.

REFERENCES

1. Sönmez MO, Nazik F. Changing Nutrition Habits: Snack Consumption, Meal Skipping and Anthropometric Parameters of University Students in Turkey. Southeast Asian J Trop Med Public Health. 2019; 50(1): 180-90.
2. Blackstone RP. Epidemiology, Measurement, and Cost of Obesity. In: Obesity: The Medical Practitioner's Essential Guide: Switzerland: Springer International Publishing; 2016.
3. WHO. Obesity and Overweight 2020 [
4. Pearce C, Rychetnik L, Wutzke S, Wilson A. Obesity prevention and the role of hospital and community-based health services: a scoping review. BMC Health Services Research. 2019; 19.
5. WHO. Controlling the global obesity epidemic. 2017.

6. Ma J, Lewis MA, Smyth JM. Translational behavioral medicine for population and individual health: Gaps, opportunities, and vision for practice-based translational behavior change research. Transl Behav Med. 2018; 8: 753-60.
7. Hong QN, Pluyea P, Fabregues S, *et al*. Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552), Canadian Intellectual Property Office, Industry Canada. 2018.
8. López-Hernández L, Martínez-Arnau FM, Pérez-Ros P, Drehmer E, Pablos A. Improved Nutritional Knowledge in the Obese AdultPopulation Modifies Eating Habits and Serum and Anthropometric Markers. Nutrients. 2020; 12(3355): 14.
9. Prasad M, Fine K, Gee A, *et al*. A Smartphone Intervention to Promote Time Restricted Eating Reduces Body Weight and Blood Pressure in Adults with Overweight and Obesity: A Pilot Study. Nutrients. 2021; 13(2148): 11.
10. Phelan S, Peruvemba S, Levinson D, *et al*. Feasibility of a virtual reality-based approach to improve behavioral weight management outcomes. BMC Pilot and Feasibility Studies. 2021; 7(129): 9.
11. Batsis JA, Petersen CL, Clark MM, *et al*. Feasibility and acceptability of a technology-based, rural weight management intervention in older adults with obesity. BMC Geriatrics. 2021; 21(44): 13.
12. Lim SL, Ong K, Johal J, *et al*. Effect of a Smartphone App onWeight Change and Metabolic Outcomes in Asian Adults With Type 2 Diabetes A Randomized Clinical Trial. JAMA Network Open. 2021; 4(6): 14.
13. Thomas JG, Goldstein CM, Bond DS, Hadley W, Tuerk PW. Web-based virtual reality to enhance behavioural skills training and weight loss in a commercial online weight management programme: The Experience Success randomized trial. Obes Sci Pract. 2020; 6: 9.
14. Beleigoli A, Andrade AQ, Diniz MDF, Ribeiro AL. Personalized Web-Based Weight Loss Behavior Change Program With and Without Dietitian Online Coaching for Adults With Overweight and Obesity: Randomized Controlled Trial. J Med Internet Res. 2020; 22(11): 13.
15. Mizushima R, Nakata Y, Sasai H, *et al*. Comparison between volunteer- and expert-led versions of a community-based weight-loss intervention. Preventive Medicine Reports. 2021; 22(101370): 7.
16. Alghamdi RQ. A randomized controlled trial of a 12-week intensive lifestyle intervention program at a primary care obesity clinic for adults in western Saudi Arabia. Saudi Med J. 2017; 38(8): 837-45.
17. Noorbakhsh A, Mostafavi F, Shahnazi H. Effects of the Educational Intervention on some Health Belief Model Constructs regarding the Prevention of Obesity in Students. Int J Pediatr. 2017; 5(8): 5561-70.
18. Kriemler S, Meyer U, Martin E, *et al*. Effect of school-based interventions on physical activity and fi tness in children and adolescents: a review of reviews and systematic update. Br J Sports Med. 2011; 45(11): 923-30.
19. Bourdeaudhuij ID, Cauwenberghe EV, Spittaels H, *et al*. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. Obesity Reviews. 2011; 12(3): 205-16.
20. Murray M, Dordevic AL, Bonham MP. Systematic Review and Meta-Analysis: The Impact of Multicomponent Weight Management Interventions on Self-Esteem in Overweight and Obese Adolescents. Journal of Pediatric Psychology. 2017; 42(4): 379-94.
21. K. Stephens S, J. Cobiac L, Veerman JL. Improving diet and physical activity to reduce population prevalence of overweight and obesity: An overview of current evidence. Preventive Medicine 2014; 62: 167.
22. Johns DJ, Hartmann-Boyce J, Jebb SA, Aveyard P. Diet or Exercise Interventions vs Combined Behavioral Weight Management Programs: A Systematic Review and Meta-Analysis of Direct Comparisons. Journal of the Academy of Nutrition and Dietetics. 2014; 114(10): 1557-68.
23. Okely AD, Cotton WG, Lubans DR, *et al*. A school-based intervention to promote physical activity among adolescent girls: Rationale, design, and baseline data from the Girls in Sport group randomised controlled trial. BMC Public Health. 2011; 11(658).
24. Park PH, Wambui CK, Atieno S, *et al*. Improving Diabetes Management and Cardiovascular Risk Factors Through Peer-Led Self-management Support Groups in Western Kenya. Diabetes Care. 2015; 38(8): e110-e1.
25. Bennett D, Owen T, Bradley DT. The £ for lb. Challenge. Evaluation of a novel, workplace-based peer-led weight management programme, 2014-2016. Public Health. 2017; 150: 93-100.
26. Neupane D, McLachlan CS, Mishra SR, *et al*. Effectiveness of a lifestyle intervention led by female community health volunteers versus usual care in blood pressure reduction (COBIN): an open-label, cluster-randomised trial. Lancet Glob Health. 2018; 6(1): e66-e73.
27. Neupane D, Kallestrup P, McLachlan CS, Perry H. Community health workers for non-communicable diseases. Lancet Glob Health. 2014; 2(10): e567.
28. Hill J, Peer N, Oldenburg B, Kengne AP. Roles, responsibilities and characteristics of lay community health workers involved in diabetes prevention programmes: A systematic review. PLoS ONE. 2017; 12(12).
29. Zolotarjova J, Velde Gt, Vreugdenhil ACE. Effects of multidisciplinary interventions on weight loss and health outcomes in children and adolescents with morbid obesity. Obesity Reviews. 2018; 19: 931-46.
30. Brownson RC, Colditz GA, Proctor EK. Dissemination and implementation research in health: Translating science to practice: Oxford University Press; 2012.
31. Sorgente A, Pietrabissa G, Manzoni GM, *et al*. Web-Based Interventions for Weight Loss or Weight Loss Maintenance in Overweight and Obese People: A Systematic Review of Systematic Reviews. J Med Internet Res. 2017; 19(6).
32. Ross KM, Wing RR. Impact of newer self-monitoring technology and brief phonebased intervention on weight loss: a randomized pilot study. Obesity. 2016; 24: 1653-9.
33. Hutchison AT, Regmi P, Manoogian ENC, *et al*. Time-Restricted Feeding Improves Glucose Tolerance in Men at Risk for Type 2 Diabetes: A Randomized Crossover Trial. Obesity. 2019; 27: 724-32.
34. Anton SD, Lee SA, Donahoo WT, *et al*. The Effects of Time Restricted Feeding on Overweight, Older Adults: A Pilot Study. Nutrients. 2019; 11(7): E1500.
35. Lowe DA, Wu N, Rohdin-Bibby L, *et al*. Effects of Time-Restricted Eating on Weight Loss and Other Metabolic Parameters in Women and Men With Overweight and Obesity The TREAT Randomized Clinical Trial. JAMA Internal Medicine. 2020.
36. Laddu D, Dow C, Hingle M, Thomson C, Going S. A Review of Evidence-Based Strategies to Treat Obesity in Adults. Nutrition in Clinical Practice. 2011; 26(5): 512-25.
37. Grace J, Biggs C, Naicker A, Moss S. Effect of Physical Activity and Nutrition Education on Body Mass Index, Blood Pressure and Biochemical Variables in Overweight and Obese Adolescents. Annals of Global Health. 2021; 87(1): 13.
38. Huang J, Liao J, Fang Y, *et al*. Six-Week Exercise Training With Dietary Restriction Improves Central Hemodynamics Associated With Altered Gut Microbiota in Adolescents With Obesity. Front Endocrinol. 2020; 11(569085): 10.
39. Kim SK, Rocha NPR, Kim H. Eating control and eating behavior modification to reduce abdominal obesity: a 12-month randomized controlled trial. Nutr Res Pract. 2021; 15(1): 16.
40. Mallorquí-Bagué N, Lozano-Madrid M, Vintró-Alcaraz C, *et al*. Effects of a psychosocial intervention at one-year follow-up in a PREDIMED-plus sample with obesity and metabolic syndrome. Scientific Reports. 2021; 11(9144): 12.