

Interventions to Treat Obesity in Mexican Children and Adolescents: Systematic Review and Meta-Analysis

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Context: Prevalence of overweight and obesity has been rising in the past 3 decades among Mexican children and adolescents. **Objective:** To systematically review experimental studies evaluating interventions to treat obesity in Mexican children and adolescents (≤ 18 years old). **Data Sources:** For this study, 13 databases and 1 search engine were searched. **Data Analysis:** A total of 29 studies met the inclusion criteria. Overall, 2302 participants (age range, 8–16 years) from 11 states in Mexico were included. Most of the studies ($n = 17$ of 29) were provided in a clinical setting. A random-effect meta-analysis of 4 randomized controlled trials was conducted and a significant effect was found on body mass index reduction that favored the intervention group (-1.52 ; 95%CI, -2.15 to -0.89) for short-term (≤ 6 mo) interventions. **Conclusions:** A multicomponent, multidisciplinary, and individualized intervention that includes dietary modifications, physical activity practice, behavioral strategies, and active parental involvement might help treat childhood obesity in Mexico. However, long-term results need to be produced to identify effectiveness pointers that might help establish an integrated, long-lasting care model to treat obesity.

INTRODUCTION

Mexico is an upper-middle-income Latin American country, and it has been experiencing the double burden of malnutrition in recent decades.¹ Specifically, childhood overweight and obesity rates have been increasing in the population younger than 19 years. According to the latest results from the National Health and Nutrition Survey 2018, it is estimated that in

Mexico, 8.2% of infants (0–4 years old), 35.6% of children (5–11 years old), and almost 40% of the adolescents (12–19 years old) present overweight or obesity.² These increasing levels position Mexico among the countries with higher levels of overweight worldwide.³ According to the Organization for Economic Cooperation and Development's estimations, such rates will continue to increase if no effective strategies are implemented.⁴ Currently, no national intervention

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Table 1 PICOS framework

Population	Children and adolescents from zero to 18 years old (mean age at the start of the study or evaluation) from any ethnicity or sex living in Mexico, with overweight or obesity, were included.
Interventions	Studies testing obesity treatment through lifestyle, environmental, behavioral, pharmacologic, or surgical interventions, delivered in any setting, were considered.
Comparator	Studies with or without a control group were considered.
Outcomes	Weight-related outcomes (eg, body mass index, body mass index z-score)
Study design	Experimental studies

or guideline exists targeting obesity treatment among children and adolescents.

Excess body fat in children and adolescents can lead to a variety of clinical conditions and psychosocial disorders. Children with obesity might have significant reductions in quality of life and a greater risk of early discrimination, low self-esteem, and depression. Children and adolescents with overweight and obesity are likely to maintain their weight status into adulthood and are at higher risk of development of chronic diseases, contributing to increased morbidity or premature death.⁵

Lifestyle interventions can lead to improvements in weight and cardiometabolic outcomes in children or adolescents.⁶ However, effectiveness can be smaller compared with pharmacologic or surgical interventions.⁷ Still, most of the evidence shows short-term effects, with limited evidence about long-term efficacy. In addition, the safety of such pediatric obesity treatments remains unclear.⁷

Because of the severity of the consequences childhood obesity has on the child's health and well-being, it is essential to identify interventions that can treat obesity in the short and long term.⁸ The "Childhood and Adolescent Obesity in Mexico: Evidence, Challenges, and Opportunities" (COMO) Project aims to synthesize and use data to comprehend the extent, nature, effects, and costs of childhood or adolescent obesity in Mexico.⁹ This article is part of the COMO project. In this study, we aimed to systematically review experimental studies assessing lifestyle, environmental, behavioral, pharmacologic, or surgical interventions to treat obesity in Mexican children and adolescents (<18 years old).

METHODS

This systematic review has been registered with the International Prospective Register of Systematic Reviews (PROSPERO registration no. CRD42019154132).¹⁰ Also, it has been reported according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.¹¹ The systematic review strategy was based on the Population, Intervention, Comparator, Outcomes, Study (PICOS)

design framework (Table 1). For more details on the methods we used, see Appendix 1.

Electronic searches

Terms such as "overweight," "obesity," "child," "adolescent," "intervention," "program," "Mexico" in the search strategy. The databases searched included Medline, Embase, the Cochrane Library, Global Health Library, LILACS, CINAHL, CAB abstracts, ERIC, PsycINFO, ScienceDirect, Scopus, AGRICOLA, and SciELO Citation Index. Also, relevant material was searched in the search engine Google Scholar. When possible, searches were also conducted in Spanish to capture relevant references. No inclusion study design restrictions were applied. Full reports and conference abstracts were included if these met the inclusion criteria. Reference lists of included studies also were scrutinized for additional publications. Searches were performed in January 2020 and updated in January 2021.

Selection criteria

Reports from 1995 onward in English, Spanish, or Portuguese were considered in this review. Following the PICOS framework (Table 1), the inclusion criteria were as described in the following paragraphs.

Population Children and adolescents from zero to 18 years old (mean age at the start of the study or evaluation) from any ethnicity or sex living in Mexico were considered in this review. Studies including children and adolescents with overweight or obesity (defined as body mass index [BMI] above a healthy weight range; BMI z-score > 1; clinical diagnosis; or study population reported as having overweight or obesity) were included. Mexican children living in a different country were excluded from this review to conceptualize the obesity problem within the country sociodemographic characteristics and avoid confounding information inherent to migration phenomena. Studies in which children were analyzed under severe conditions (eg, HIV, cancer, fibrosis, Down syndrome), premature babies, and pregnant adolescents were excluded.

Studies Studies in which obesity treatment was tested through lifestyle, environmental, behavioral, pharmacologic, or surgical interventions were considered. Studies delivered in any setting (eg, home, school, clinic, community) or digital domains (eg, mobile-phone-network interventions) were considered.

Comparator Studies with or without a control group were considered.

Outcomes Effectiveness measurements included anthropometric changes (eg, weight, BMI, BMI z-score). Because of the type of interventions considered in this review, any lifestyle changes (eg, dietary, physical activity, behavioral outcomes) were also recorded.

Study design Experimental studies were considered in this review.

Data extraction

Titles and abstract screening and full-text review was performed by 2 reviewers (L.L.-C., M.G.-B.) and 100% checked by a third reviewer (M.A.-M.). Two reviewers (M.A.-M. and L.L.-C.) extracted data independently from included papers. In case of any disagreement, a third author was contacted (Y.Y.G.-G.). A data extraction form was created based on the Effective Public Health Practice Project Quality Assessment Tool¹² and the Template for Intervention Description and Replication.¹³ Data on the main components of the studies were extracted and categorized according to the components included: nutritional (eg, diet prescriptions, nutritional advice); physical activity (PA; eg, PA practices, PA advice); behavioral or psychological (eg, psychological, family, or behavioral therapy); environmental (ie, changes in children's settings to promote a weight change); pharmacologic (eg, sibutramine); or bariatric surgery. Any theory or framework used in the design or delivery of the intervention was recorded.

Risk of bias

Following the Cochrane Handbook's recommendation for Systematic Reviews of Interventions for health promotion interventions,¹⁴ the Effective Public Health Practice Project Quality Assessment Tool¹² tool was used. Evidence was rated as strong, moderate, or weak on the basis of their selection bias; study design; confounders; blinding; data collection methods; withdrawals and drop-outs; intervention integrity; and analysis. Also, funding sources and reported conflicts of interests were extracted and considered in this review. For more details, see [Appendix 1](#).

Data synthesis and analysis

A narrative synthesis was conducted across all the included studies. From those randomized controlled trials (RCTs) in which the mean difference and its standard deviation of BMI were reported or could be calculated, a meta-analysis was conducted. Whenever provided, intention-to-treat data were used. WebplotDigitizer software was used to extract data when data were provided in graphs. The formulas from the Cochrane Guidelines were used to estimate the effect size.^{15,16} Lifestyle interventions in obesity are quite heterogeneous; hence, we chose a random effect model for this analysis.^{17,18} Because of the small sample sizes, the Hedges estimator¹⁹ was used to fit the random-effect model. The analysis was done using R statistical software, using the library "metafor".

RESULTS

Through the searches, 7363 references were identified, from which 1432 were retrieved for full-text review. Overall, 886 references were identified by reporting obesity-related data in Mexican children and are included in the COMO database. From these, 29 studies (presented in 31 publications)^{20–50} met the inclusion criteria ([Figure 1](#)). Most of the publications were full-text papers, except for 3 abstracts,^{24,32,45} 1 doctoral thesis,⁴⁶ and 1 letter to the editor.⁵⁰ Ten studies were RCTs,^{20,21,25,26,34,40–43,48} 3 were controlled clinical trials,^{27,29,35} 3 were cohort analytic studies with >1 group (2 or 3 groups, before and after),^{32,39,46} and 13 were cohort analytic studies with a single group (before and after).^{22–24,28,33,36–38,44,45,47,49,50}

Overall, the 29 identified studies included 2302 participants (age range, 8–16 years) recruited from 11 states of 32 states in Mexico ([Figure 2](#)). Most of the studies were conducted in a clinical setting (n = 17); some (n = 7) in a school setting. One included both settings (ie, school and clinic).⁴⁰ In 1 study, participants were recruited in a school, but activities were delivered outside school hours.⁴¹ Two studies were conducted in summer camps^{39,46}; the setting was unclear in 1 of the studies²⁴ ([Table 2](#)).^{20–50}

Overall, 20 of the 29 studies included a nutritional component, 19 included a PA component, 8 included a psychological or behavioral component, and 3 studies included pharmacologic treatment. The effects of 2 different bariatric surgeries among participants were reported in 1 study³²; however, this was 1 of the included abstracts, and it was poorly reported. None of the included studies reported an environmental change to aid the weight-loss process. In 16 studies, parents or siblings were included. The duration of the 29 studies

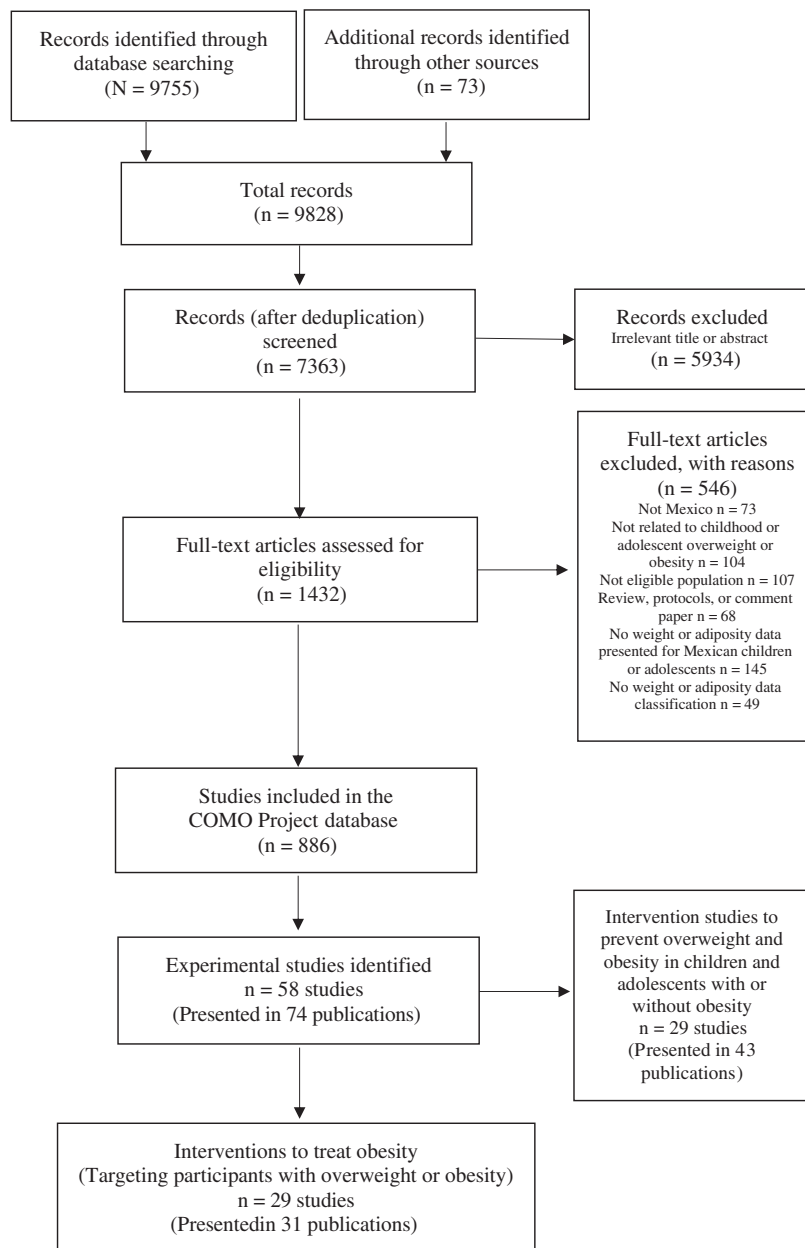


Figure 1 PRISMA flowchart. COMO, Childhood and Adolescent Obesity in Mexico: Evidence, Challenges, and Opportunities.

ranged from 1 week to 12 months. There was no long-term (>12 mo) study identified in this review. An approximate number of sessions was calculated from reported information in the publications, and this number varied from 4 to 106 sessions. See Table 2 or Table S1 in Appendix 2 in the Supporting Information online.

Significant reductions in anthropometric outcomes were reported in 10 of the 29 studies,^{21–23,25,33,36,38,47–49} 9 reported no significant changes,^{20,26,27,34,35,40,41,43,44} and the effect of the intervention was unclear in 5 studies.^{24,32,37,39,45} In 2 studies,^{28,50} significant changes were reported in some, but not all, of the anthropometric

outcomes considered (eg, changes in skin folds, but not in BMI). Two studies^{29,46} reported effectiveness only in those participants who finished the intervention. For more details on the outcomes see Table S2 in Appendix 2 in the Supporting Information online.

Of the 29 included studies, 10 were RCTs; however, only 4 were included in the meta-analysis.^{20,21,40,48} One was excluded because it comprised a pharmacologic therapy (ie, sibutramine, banned since 2010 in Mexico).²⁵ Three provided nutritional supplementation (with some generic dietary advice, but not a lifestyle intervention).^{26,34,43} One did not provide sufficient information to calculate the effect size.⁴¹ The study of



Figure 2 Map of the Mexican 11 states from which evidence was reported.

Rosado et al⁴² was excluded from the meta-analysis because in that study, the aim was to increase ready-to-eat cereals as a strategy to reduce excess body weight, and no individualized nutritional advice was provided to participants.

The population included in the 4 RCTs included in the meta-analysis was 237 participants (age range, 11–13 years old). The duration of these 4 RCTs varied from 3 months to 12 months. The intensity and frequency of sessions also varied, from 5 to 100 sessions. In the Díaz et al²¹ study, children with obesity participated in the intervention frequently during the first 12 weeks, and then the intensity decreased to monthly visits. The Díaz et al²¹ study was the only 1 presenting 6 and 12 months of data. Because the remaining studies included in the meta-analysis lasted 3.5 or 4 months, 2 analyses were done: 1 including data from Díaz et al²¹ recorded at 6 months (Figure 3)^{20,21,40,48} and another with data at 12 months (Figure 4).^{20,21,40,48} Overall, there was a significant effect (-1.52 ; 95%CI, -2.15 to -0.89 ; $I^2 = 66\%$) (Figure 3) on BMI in the short term (≤ 6 mo) favoring the intervention groups. The effect was diminished but remained significant when including the 12 months of data from Díaz et al²¹ (-1.31 ; 95%CI, -1.73 to -0.89 ; $I^2 = 50\%$) (Figure 4).

Overall, 6 of the 29 studies were considered of strong quality,^{25,29,34,40,42,47} 5 of moderate quality,^{20,35,36,38,44} and the rest ($n = 18$) were considered of low quality. In 11 studies,^{20,21,25,26,34,40–43,48} participants were randomly assigned into different study groups; in 7 of these, the randomization methods were reported, and in 6,^{21,25,34,40,42,47} blinding of participants and personnel was reported. In most of the included studies ($n = 20$),^{20–23,25–29,33–36,38,40–42,47,48,50} individuals were somewhat likely to represent the target population. In 12 of the 29 studies, some relevant confounders were

identified and controlled for.^{21,25,26,29,34,35,40,42,44,46,49} In most of the included studies, the data collection tools were valid and reliable. Data collection for anthropometric measurements did not raise any quality uncertainties, because all the studies collected data according to international protocols. However, lifestyle outcome measurements were very heterogeneous across studies, and the validity of tools was not reported in most cases. Withdrawals and drop-outs reported in 17 of the studies. When analyzing data, intention-to-treat analysis was used in only 3 studies.^{21,25,49} (Table 3).^{20–50}

Thirteen of the 29 studies did not report any funding source, and 3 reported not receiving funding for the intervention.^{22,33,41} For 1 study, authors reported receiving funding from the food industry,⁴² and in another, authors reported receiving funding from a pharmaceutical company.²⁵ National funding was reported in 2 studies,^{26,43} and for 1 study, authors reported receiving support from international organizations.²¹ Six of the 29 studies reported^{28,29,34,35,40,48} receiving funding from public institutions (eg, public hospitals, public universities), and 1²³ reported receiving funding from private institutions (eg, private universities, insurance companies). The authors' conflicts of interest were not reported in 17 studies. In those studies that reported it, no conflict of interest was declared.

DISCUSSION

In this systematic review and meta-analysis of evidence from studies of obesity in Mexican children and adolescents, we found a significant short-term (≤ 12 mo) effectiveness on BMI reduction. However, these results need to be cautiously interpreted in the light of the analysis' limitations. Only 4 RCTs,^{20,21,40,48} with an overall

Table 2 General characteristics of included studies

Reference; study design	Setting characteristics: location, setting, year intervention was implemented	Participants' characteristics: total initial sample, female sex (%), mean (SD) age	Main intervention	Main characteristics of intervention: duration, follow-up period, intensity and frequency	Nutritional component	PA component	Psychological or behavioral component	Pharmacologic or surgery component	Other relevant component
Ceballos-Gurrola 2020 ²⁰ Randomized controlled trial	NR (Nuevo Leon) Public secondary school in a municipality in the urban area. 2014	62 46.7% Mean (SD) age: 13.3 (1.01) y	The CENLO (not an abbreviation) health program considered 3 simultaneously: nutritional orientation, PA practice, and phototherapy (ie, light therapy or heliotherapy post-PA)	3.5 mo NR 14 nutritional sessions (60 min/wk) + 56 PA sessions (60 min × 4 times/wk) + 28 phototherapy sessions (40 min × 2 times/wk) Delivered by: NR	✓	✓	NR	NR	Phototherapy was implemented in 1 of the interventions groups.
Díaz 2010 ²¹ Randomized controlled trial	Hermosillo (Sonora) Public primary care unit within a secondary care hospital 2006–2007	43 51.1% 11.6 (2.1) y	Behavioral modification intervention based on a program, culturally appropriate topics focused mainly on the health belief model and a simple food guide	12 mo NR 12 sessions (2 h group sessions/12 wk) + 21 sessions with a nutritionist (weekly during the first 12 consecutive weeks, months after that) + 12 sessions with physician (10–15 min monthly consultations) Delivered by: trained general practitioners, a pediatrician, and a nutritionist	✓	✓	✓	NR	Parents received 6 education sessions and were encouraged to lose weight if they were overweight.
Elizondo-Montemayor ^{22a} Cohort (1 group before and after)	Monterrey (Nuevo Leon) 8 Public schools of low SES 2010–2011	96 45.8% 9.1 (1.4) y	Dietetic and lifestyle intervention, including individualized diets and PA, advice Information was given to parents about healthy food and eating.	1 school year NR 13 session (30 min each) Delivered by: nutritionist	✓	✓	NR	NR	Parents were involved in the intervention.
Elizondo-Montemayor 2014 b ^{23a} Cohort (one group before and after)	Monterrey (Nuevo Leon) 8 Public schools of low SES NR	125 45.5% NR	Dietetic and lifestyle intervention, including individualized diets Information given to parents about healthy food and eating	1 school year NR 13 sessions (45 min each) Delivered by: nutritionist	✓	NR	NR	NR	Parents were involved in the intervention.
Escalante-Izeta 2013 (abstract) ²⁴ Cohort (1 group before and after)	Mexico City (Mexico City) No data on setting NR	10 NR NR	Lifestyle intervention based on the Spanish program "Kids in Motion," which aims to produce changes in the child and their family, lifestyle, eating habits, and emotional factors contributing to weight gain	3 mo NR 11 sessions (no additional detail provided) Delivered by: NR	✓	✓	✓	NR	NR

(continued)

Table 2 Continued

Reference; study design	Setting characteristics: location, setting, year intervention was implemented	Participants' characteristics: total initial sample, female sex (%), mean (SD) age	Main intervention	Main characteristics of intervention: duration, follow-up period, intensity and frequency	Nutritional component	PA component	Psychological or behavioral component	Pharmacologic or surgery component	Other relevant component
García-Morales 2006 ²⁵ Randomized controlled trial	Mexico City (Mexico City) Outpatients attending the Endocrinology Department of a public children's hospital 2001–2003	51 56.5% 14.9 (1.2) y	Pharmacologic intervention (ie, sibutramine) plus lifestyle changes intervention Participants received individually tailored diet and exercise advice.	6 mo NR 18 sessions (no additional detail provided) Delivered by: practitioner, pediatric nutritionist, and registered nutritionist (for anthropometry)	✓	✓	NR	✓	NR
Garibay-Nieto 2017 ²⁶ Randomized controlled trial	Mexico City (Mexico City) Pediatric obesity clinic at a public hospital 2012–2014	83 NR 12.6 (2.7) y	Patients received a lifestyle intervention program and were randomly assigned to receive either metformin (1 g/d) and conjugated linoleic acid (3 g/d) or a placebo (1 g/d). Lifestyle intervention included a structured PA session, followed by a psychoeducational group session and educational material about healthy lifestyles.	4 mo NR 4 sessions (each included 1 h PA + psychoeducational group session + medical consultation) Delivered by: nutritionists, psychologists, pediatricians, pediatric endocrinologists, and a physical trainer	✓	✓	✓	✓	Parents were involved in the intervention.
González-Heredia 2014 ²⁷ Controlled trial	Ciudad Obregon (Sonora) Family medicine unit of a public hospital NR	60 51.6% 9.2 (2) y	Lifestyle intervention focused on eating habits modification through individualized diets.	6 mo NR Delivered by: unclear	✓	NR	NR	NR	The intervention included personalized diet for the parents and children.
Hall-López 2017 ²⁸ Cohort (1 group before and after)	Mexicali (Baja California) Public elementary school NR	26 42.3% 9.4 (0.3) y	PA practice intervention based on the CATCH model (US program), including moderate to vigorous exercise	10 mo NR; 80 sessions (50 min × 2 times/wk) Delivered by: unclear	NR	✓	NR	NR	Pedagogical elements of teaching support for the teacher to instruct PA with moderate to vigorous intensity for ≥50% of class time.
Huang 2010 ^{29–31} Controlled trial	Mexico City (Mexico City) Public children's hospital NR	97 41.2% 11.9 (1.4) y	Lifestyle intervention included dietary advice, PA practices, behavioral counselling, and active involvement of the family.	6 mo NR 24 sessions + 4 parents intensive lifestyle support sessions + 6 telephone sessions (15 min monthly) Delivered by: nutritionist, physician, clinical psychologist	✓	✓	✓	NR	Family (parents and siblings) was involved in the intervention.

(continued)

Table 2 Continued

Reference; study design	Setting characteristics: location, setting, year intervention was implemented	Participants' characteristics: total initial sample, female sex (%), mean (SD) age	Main intervention	Main characteristics of intervention: duration, follow-up period, intensity and frequency	Nutritional component	PA component	Psychological or behavioral component	Pharmacologic or surgery component	Other relevant component
Jimenez 2017 (abstract) ³² Cohort analytic (2 groups before and after)	Guadalajara (Jalisco) No details on setting NR	27 63% 15.7 (NR) y	Surgery intervention. Two different bariatric surgeries: in 1 cohort, the gastric sleeve was performed, and in the other, gastric bypass.	NR 24 mo NR Delivered by: unclear	NR	NR	NR	✓	NR
Laguna-Alcaraz 2017 ³³ Cohort (1 group before and after)	Morelia (Michoacan) Public clinic 2013–2014	13 46.1% 11.5 (1.6) y	Lifestyle intervention included the "PREVENIMSS program" (lifestyle change comprehensive program used in the public health system), nutritional support, and PA performance.	6 mo NR; 10 sessions (with nutritionist) + 24 educational sessions (1 h each) + 72 PA sessions (1 h each) Delivered by: nutritionist, undergraduate physician	✓	✓	NR	NR	NR
López-Alarcon 2019 ³⁴ Randomized controlled trial	Mexico City (Mexico City) Clinical nutrition research unit of a public hospital 2012–2015	245 52.6% 13.6 (1.8) y	Supplementation intervention. Participants were randomly assigned to receive 800 mg EPA + 400 mg DHA or a placebo.	1-mo NR Delivered by: nutritionist did anthropometry; however, the role was unclear	✓	NR	NR	NR	NR
López-Alarcon 2020 ³⁵ Controlled trial	Mexico City (Mexico City) Clinical nutrition research unit of a public hospital 2018	63 35.5% 11.4 (0.3) y	Mindfulness intervention with guided sessions, with interactive activities to teach standard mindfulness skills. A short homework exercise was assigned to help children apply mindfulness skills to daily life.	2 mo 2 mo 8 sessions (2 h each) Delivered by: 2 certified mindfulness consultants	?	NR	✓	NR	Sessions were delivered for parents in parallel with the sessions provided to the children.
Luna-Ruiz 2007 ³⁶ Cohort (1 group before and after)	Leon (Guanajuato) Public family medicine unit 2003–2004	28 46% 9.8 (1.6) y	Educational intervention that included children's mothers. It used a participatory technique following a diabetes mellitus educational program. Also, outdoor PA for mothers and children	6 mo NR; 2 sessions for parents (1.5 h each) + 6 sessions for children (monthly, NR) + 24 PA session for mothers and children (2 h each). Delivered by: nutritionist, physical activity monitor, and "obesity educator"	✓	✓	NR	NR	Parents were involved in the intervention.

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Table 2 Continued

Reference; study design	Setting characteristics: location, setting, year intervention was implemented	Participants' characteristics: total initial sample, female sex (%), mean (SD) age	Main intervention	Main characteristics of intervention: duration, follow-up period, intensity and frequency	Nutritional component	PA component	Psychological or behavioral component	Pharmacologic or surgery component	Other relevant component
Martin-Mosqueda 2012 ³⁷ Cohort (1 group before and after)	Guadalajara (Jalisco) Outpatient nutrition consultation at a medical center NR	7 42.9% 11.5 (0.9) y	"Light mind and weight" was a lifestyle intervention for children and parents. Participants were taught how to put together their menus with no restrictions. They were thought to achieve the right nutritional balance. PA practice sessions were delivered. Cognitive behavioral therapy was conducted in group sessions for children's parents.	3 mo NR 1 nutritional session, 48 PA sessions (30–45 min each) + 12 psychological sessions (90 min each) Delivered by: NR	✓	✓	✓	NR	Parents were involved in the intervention.
Moran 2017 ³⁸ Cohort (1 group before and after)	Mexico City (Mexico City) Pediatric public hospital NR	46 65.2% 11.8 (2.6) y	Educational intervention including both children and parents in small groups (5 children with their parents or guardians) provided material about the importance of adequate nutrition.	4 mo NR 8 group sessions (1 h each) Delivered by: dietitian and medical doctor	✓	✓	NR	NR	Parents were involved in the intervention.
Pompa-Guajardo 2018 ³⁹ Cohort analytic (3 groups before and after)	Unclear (Nuevo Leon) Summer camp. No additional details provided NR	102 38% 10.2 (1.5) NR	Lifestyle intervention delivered at a 5-day summer camp. Activities included group sessions where participants were encouraged to express their feelings about eating behavior and express their thoughts and emotions.	6 mo or 1 y (depending on the allocated intervention group) Group 2 included 12 mo follow-up Group 1: 5 daily sessions during summer camp + 6 group sessions (1/mo after the summer camp) Group 2: 5 daily sessions during summer camp + 12 group sessions (90 min session, 1 every 15 d after the summer camp) + 12 monthly meetings with parents Delivered by: nutritionists, psychologists, pediatricians, and sports doctors	?	?	?	NR	In group 2, parents were involved in the intervention.
Rodríguez-Morán 2014 ⁴⁰	Durango City (Durango)	115 47.8% 13.2 (0.9) y		4 mo NR	✓	✓	✓	NR	Parents were invited to participate in

(continued)

Table 2 Continued

Reference; study design	Setting characteristics: location, setting, year intervention was implemented	Participants' characteristics: total initial sample, female sex (%), mean (SD) age	Main intervention	Main characteristics of intervention: duration, follow-up period, intensity and frequency	Nutritional component	PA component	Psychological or behavioral component	Pharmacologic or surgery component	Other relevant component
Randomized controlled trial	Low SES secondary schools, located near a public clinic where the study took place NR		Cognitive behavioral therapy plus indications for a low-calorie diet and PA practice	20 nutrition sessions (1 h weekly) + 80 PA sessions (from Monday to Friday) NR Delivered by: medical doctors, psychologists, nutritionists, and physical education and sport graduates					the exercise group sessions.
Romero-Pérez 2020 ⁴¹ Randomized controlled trial	NR (Sonora) Primary schools (unclear if public or private) NR	105 57.1% 10 (0.8) y	PA practice group sessions intervention	5 mo NR 40 sessions (50 min each × 2 times a week) Delivered by: NR	NR	✓	NR	NR	NR
Rosado 2008 ⁴² Randomized controlled trial	Queretaro City (Queretaro) 6 Elementary schools (unclear if public or private) 2002–2003	262 51.1% 9.1 (1.5) y	Intervention looking at the increase in ready-to-eat cereal (from Kellogg's) intake	3 mo NR 12 sessions (1 weekly) NR Delivered by: nutritionist.	✓	NR	NR	NR	Mothers were involved in the intervention.
Rosas-Nexticapa 2017 ⁴³ Randomized controlled trial	Xalapa (Veracruz) 5 Public elementary schools NR	121 53.7% NR	Supplementation intervention. Participants were randomly assigned to (1) 2 gummies 60 mg of DHA and EPA; (2) 3 gummies (90 mg DHA and EPA); (3) 10 g of salmon (211 mg DHA); or (4) 15 g of salmon (316 mg DHA)	3 mo NR 60 doses (Monday to Friday × 3 mo) Delivered by: NR	×	NR	NR	NR	Supplements of DHA
Sáenz-Soto 2004 ⁴⁴ Cohort (1 group before and after)	Monterrey (Nuevo Leon) Pediatric clinic of a third-level hospital NR	25 52% 12 (1) y	Educational intervention targeting adolescents and mothers to modify the level of PA and the consumption of foods rich in fat. PA practice sessions were delivered for both mothers and adolescents.	9 wk 4 wk 4 educational sessions (45–60 min each) + 8 PA sessions (45–60 min each) Delivered by: pediatrician checked, but unclear if delivered	✓	✓	NR	NR	Mothers were involved in the intervention.

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Table 2 Continued

Reference; study design	Setting characteristics: location, setting, year intervention was implemented	Participants' characteristics: total initial sample, female sex (%), mean (SD) age	Main intervention	Main characteristics of intervention: duration, follow-up period, intensity and frequency	Nutritional component	PA component	Psychological or behavioral component	Pharmacologic or surgery component	Other relevant component
Santiago-Lagunes 2018 (abstract) ⁴⁵ Cohort (1 group before and after)	Mexico City (Mexico City) Obesity and Adolescents Clinic of the National Institute of Pediatrics (public service) NR	27 NR NR	Individualized lifestyle intervention	8 mo NR 1 consultation (basal consultation, NR) + 8 consultations (weekly up to 8, duration NR) + 6 consultations (monthly consultation up to 6 times to complete 8 mo) Duration: NR Delivered by: multidisciplinary health team (no additional detail provided)	?	?	NR	NR	NR
de Sanchez 2004 ⁴⁶ Cohort analytic (3 groups before and after)	Monterrey (Nuevo Leon) Department of Endocrinology in a public hospital, but children recruited from schools 2002–2005	100 56% 8.8 (1.8) y	Multidisciplinary intervention for weight loss treatment, which consisted of a week-long summer camp and a monthly follow-up for 6 mo (no additional information provided)	1 wk 6 mo 2 sessions + 6 sessions (monthly follow-up) Delivered by: endocrinologist, pediatrician, dietitian, nurse, sports physician, and psychologist	?	?	NR	NR	NR
Velázquez-López 2009 ⁴⁷ Cohort (1 group before and after)	Mexico City (Mexico City) Public family medicine unit NR	40 45% 10.3 (3) y	All patients and their families received personalized nutritional advice once a month.	4 mo NR 4 sessions (1 monthly, duration: NR) Delivered by: nutrition graduates	✓	✓	NR	NR	Family (parents and siblings) was involved in the intervention.
Velázquez-López 2014 ⁴⁸ Randomized controlled trial	Mexico City (Mexico City) Public family medicine unit NR	49 53% 11.3 (2.8) y	Nutritional intervention comparing Mediterranean-style vs a standard diet style.	4 mo NR 5 sessions (consultation every 3 wk) Duration: NR Delivered by: nutritionists	✓	✓	NR	NR	Family (parents and siblings) was involved in the intervention.
Violante-Ortiz 2005 ⁴⁹ Cohort (1 group before and after)	NR, but authors affiliations are within the Mexican context Obesity clinic (unclear if private or public) NR	105 67.1% 15.8 (1.5) y	Pharmacologic intervention (ie, sibutramine 10 mg/d) with behavioral modification intervention, and PA and dietetic advice.	6 mo NR Doses daily Delivered by: nutritionist. No additional health professional reported	✓	✓	✓	✓	NR
Virgen-Ortiz 2007 (letter to the editor) ⁵⁰ Cohort (1 group before and after)	Colima City (Colima) Private school NR	169 NR	PA practice and a diet modification intervention	4 mo NR NR Delivered by: NR	✓	✓	NR	NR	NR

Abbreviations: DHQ, docosahexaenoic acid; EPA, eicosapentaenoic acid; NR, not reported; PA, physical activity; SES, socioeconomic status; CATCH, Coordinated Approach to Child Health, PREVENIMSS program, Spanish abbreviation for "Prevention program from the Mexican Institute of Social Security"; ✓, component included; ?, unclear if the component was included; ×, component not included. Unclear from the publications if the population data of Elizondo-Montemayor et al²² and Elizondo-Montemayor et al²³ overlapped. For this reason, these publications are presented separately.

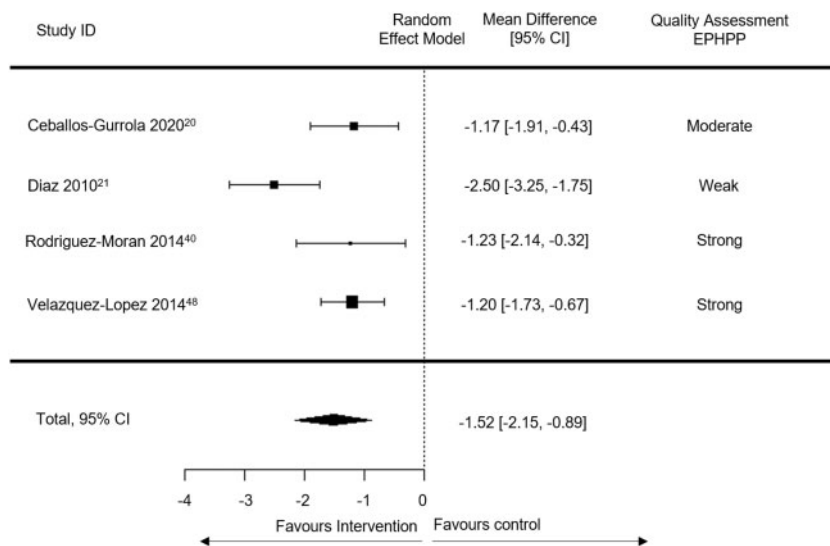


Figure 3 Meta-analysis with 6 months' data ($I^2 = 66\%$). Weight of each study: Ceballos-Gurrola et al,²⁰ 12.7%; Diáz et al,²¹ 27.5%; Rodríguez-Morán et al,⁴⁰ 26.9%; Velázquez-López et al,⁴⁸ 32.8%. Total number of participants in the intervention groups: 116; total number of participants in the control groups: 121. EPHPP, Effective Public Health Practice Project CI, Confidence Interval.

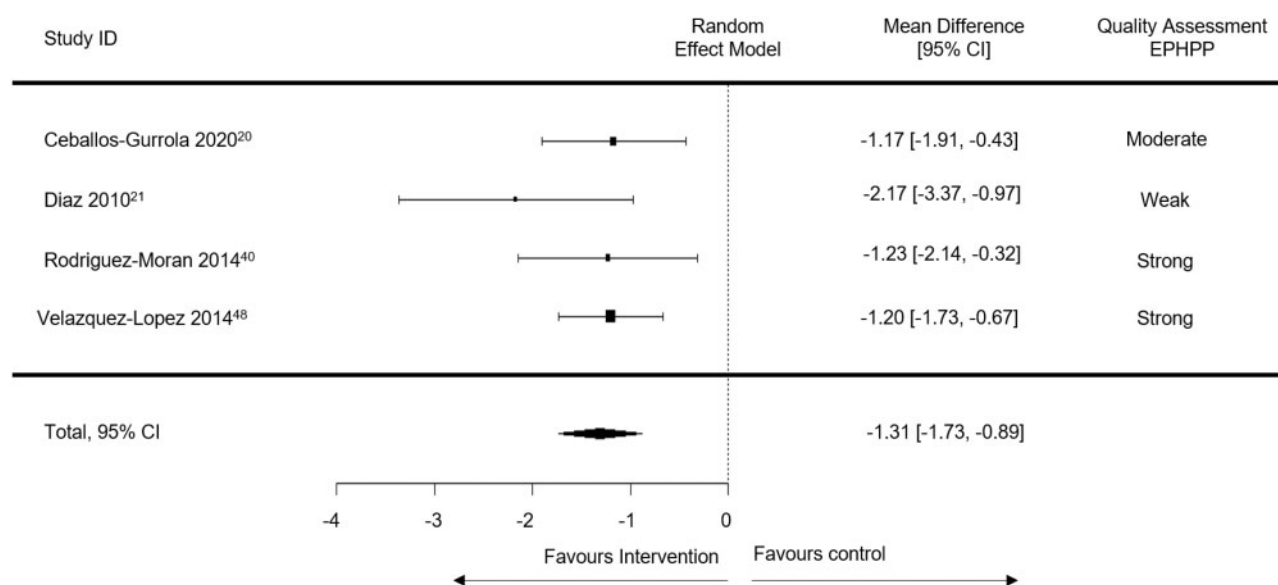


Figure 4 Meta-analysis with 12 months' data ($I^2 = 50\%$). Weight of each study: Ceballos-Gurrola et al,²⁰ 19.2%; Diáz et al,²¹ 21.6%; Rodríguez-Morán et al,⁴⁰ 35.6%; Velázquez-López et al,⁴⁸ 23.5%. Total number of participants in the intervention groups: 116; total number of participants in the control groups: 121. EPHPP, Effective Public Health Practice Project CI, Confidence Interval.

sample of 237 participants (age range, 11–13 years old), were suitable to be included in a meta-analysis, and only 2 of these were of strong quality. Moreover, these 4 RCTs were delivered in different settings. Also, from the 29 studies included in this review, evidence regarding weight-related outcomes improvement was heterogeneous and inconclusive. Most of the evidence was of low quality, which increased the risk of bias. Across all the studies, several interventions with different durations and intensities were found. Still, no long-term

interventions (≥ 12 mo) were identified in this systematic review.

Overall, the purposes of the interventions in the 29 studies identified mainly were to reduce energy intake, increase energy expenditure, and decrease sedentary behavior. Some interventions ($n = 8$) also included a psychological or behavioral component, and 3 included pharmacologic treatment. One abstract reported the comparison of 2 types of bariatric surgery among adolescents. There is still no gold standard childhood

Table 3. Quality assessment of included interventions^a

Reference	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Overall rating	Funding	COI
Ceballos-Gurrola 2020 ²⁰ Díaz 2010 ²¹	Moderate Weak	Strong Strong	Weak Strong	Moderate Strong	Strong Strong	Moderate Weak	Moderate Weak	NR Funded by an international agency	NR Nothing to declare
Elizondo-Montemayor 2013 ²² Elizondo-Montemayor 2014 ²³	Moderate Weak	Moderate Moderate	Weak Weak	Moderate Moderate	Strong Strong	Weak Strong	Weak Weak	No funding received Funded by a private university	Nothing to declare Nothing to declare
Escalante-Izeta 2013 (abstract) ²⁴ García-Morales 2006 ²⁵ Garibay-Nieto 2017 ²⁶ González-Heredia 2014 ²⁷ Hall-López 2017 ²⁸	Weak Moderate Weak Moderate Moderate	Moderate Strong Strong Strong Moderate	Weak Strong Strong Weak Weak	Moderate Strong Moderate Moderate Moderate	Weak Strong Strong Strong Strong	Weak Moderate Weak Weak Weak	Weak Strong Weak Weak Weak	NR Abbott Laboratories Science Mexican Council NR Funded by a public university	NR NR NR Nothing to declare Nothing to declare
Huang 2010 ²⁹⁻³¹	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	Funded by a public pediatric hospital	Nothing to declare
Jimenez 2017 (abstract) ³² Laguna-Alcaraz 2017 ³³ López-Alarcon 2019 ³⁴	Weak Moderate Strong	Moderate Moderate Strong	Weak Weak Strong	Moderate Moderate Strong	Weak Strong Strong	Weak Weak Strong	Weak Weak Strong	No funding received Funded by public health institute and National Council of Education and Science Mexican Council	NR Nothing to declare Nothing to declare
López-Alarcon 2020 ³⁵	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate	Funded by public health institute	Nothing to declare
Luna-Ruiz 2007 ³⁶ Martín-Mosqueda 2012 ³⁷ Moran 2017 ³⁸ Pompa-Guajardo 2018 ³⁹ Rodríguez-Morán 2014 ⁴⁰	Moderate Weak Moderate Weak Moderate	Moderate Moderate Moderate Moderate Strong	Weak Weak Weak Weak Strong	Moderate Moderate Moderate Moderate Moderate	Strong Strong Strong Strong Strong	Strong Weak Strong Moderate Moderate	Moderate Weak Moderate Moderate Strong	NR NR NR NR Partially funded by public health institute	NR NR NR NR Nothing to declare
Romero-Pérez 2020 ⁴¹ Rosado 2008 ⁴²	Moderate Strong	Strong Strong	Weak Strong	Moderate Moderate	Strong Strong	Weak Moderate	Weak Strong	No funding received Funded by industry (Kellogg's)	Nothing to declare Nothing to declare
Rosas-Nexticapa 2017 ⁴³	Weak	Strong	Weak	Moderate	Strong	Weak	Weak	Funded by the National Council of Education and Science Mexican Council	NR
Sáenz-Soto 2004 ⁴⁴ Santiago-Lagunes 2018 (Abstract) ⁴⁵ de Sanchez 2004 ⁴⁶ Velázquez-López 2009 ⁴⁷	Weak Weak Weak Moderate	Moderate Moderate Moderate Moderate	Strong Weak Weak Weak	Moderate Moderate Moderate Moderate	Strong Strong Strong Strong	Moderate Weak Strong Weak	Moderate Weak Strong Weak	NR NR NR Unclear if funded by public health institute	NR NR NR Nothing to declare

(continued)

Table 3. Continued

Reference	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Overall rating	Funding	COI
Velázquez-López 2014 ⁴⁸	Moderate	Strong	Strong	Strong	Strong	Strong	Strong	Funded by public health institute	Nothing to declare
Violante-Ortiz 2005 ⁴⁹	Weak	Moderate	Strong	Moderate	Strong	Weak	Weak	NR	NR
Virgen-Ortiz 2007 (letter to the editor) ⁵⁰	Weak	Moderate	Weak	Moderate	Strong	Weak	Weak	NR	NR

Abbreviations: COI, conflict of interest; NR, not reported.

^aQuality assessed using the Effective Public Health Practice Project Quality Assessment Tool¹² for quantitative studies.

obesity treatment. However, some effectiveness has been shown in multicomponent interventions.⁵¹

In 12 studies, parents were included in the activities, and in 3, siblings were included as well. The involvement of parents has been described as a critical factor for the effectiveness of childhood obesity treatments.⁵² Family-based obesity therapy provides interventions for both children and their parents, but children benefit more compared with their parents.⁵³

We found that most interventions to treat obesity in Mexican children and adolescents were delivered in a clinical setting (n = 17 of 29). Also, from the included studies, no environmental changes were identified. Childhood obesity treatment ideally should be provided within an integrated care system, including primary care practice, a tertiary care center, and support at home, school, and in community settings.⁵¹ The conception of a support network for young people while attempting to lose weight and maintain a healthy weight needs to target different settings and include several stakeholders. Likewise, environmental changes need to be made to facilitate behavioral change.⁵⁴

It is noteworthy that Mexico has led the implementation of different nationwide strategies to tackle obesity among the general population. For instance, Mexico recently introduced a 1 peso/L excise tax on sugar-sweetened beverages.^{55,56} More recently, a front-of-pack labelling system has been implemented.⁵⁷ Still, effective and targeted strategies are needed urgently to tackle this problem among children and adolescents. Some institutional documents about generic obesity prevention and diagnostic procedures can be found.^{58–60} However, such documents are not targeted to populations <18 years old, do not contemplate a comprehensive treatment of obesity, and are mainly limited to primary health care.

From the 4 RCTs included in the meta-analysis, the studies of Rodríguez-Morán et al⁴⁰ and Díaz et al²¹ showed the most beneficial effect across studies. However, the Rodríguez-Morán et al⁴⁰ study was considered to have a strong quality, whereas the study of Díaz et al²¹ was considered to be of low quality. The intervention delivered by Rodríguez-Morán et al⁴⁰ included an individualized low-calorie diet, individualized PA advice, group exercise sessions (including parents), and individualized cognitive behavioral therapy as adjuvant treatment. This intervention was delivered in a public clinic by a multidisciplinary team (including doctors, psychologists, nutritionists, and graduates in physical education and sport). Although it was a short-term intervention (4 mo), the frequency was greater than in other included studies. Participants received 20 nutrition sessions (1 h/wk), plus 80 after-school PA sessions, plus individualized

cognitive behavioral therapy sessions (when necessary). This intervention's effect size was significant, favoring the intervention group, and might indicate the importance of an individualized, frequent, and multidisciplinary effort, considering close relatives for treating childhood obesity in a Mexican context. Nevertheless, better-quality research needs to be done in Mexico to determine the optimal length, intensity, and long-term effectiveness of obesity treatment interventions among children and adolescents.

A multicomponent and individualized study that comprises dietary modifications, PA practice, behavioral strategies, and active parental involvement has been suggested in other countries.^{6,7,51} Long-term results are needed to measure and identify effectiveness pointers, and might help create an integrated long-lasting health care model that aids in preventing and treating obesity. Such a health care model should make available the integration of follow-up visits to monitor and maintain behavioral change as needed, facilitating the provision of the required intensity and frequency of treatment sufficient to achieve meaningful outcomes.^{61,62}

While conducting this systematic review, we found some challenges, including for instance, the poor description of methods across the included papers. The lack of high-quality RCTs also is noticeable. Ten of the 29 studies were RCTs, but only 4 could be included in a meta-analysis. The sample sizes of the included RCTs were relatively small. Few studies with small sizes could introduce into the model bias or variability because of sampling. Some other limitations of this systematic review include the heterogeneity of included studies in terms of intervention design, sample size and characteristics, intervention approach, primary measures used to assess intervention effects, length of follow-up, analytical approaches, and overall quality. Such variability made it challenging for cross-comparisons. Also, the retrieved evidence came from 11 of 32 states in Mexico, so the results might not reflect a nationwide picture.

This work's strengths include, to our knowledge, being the first systematic review conducted about intervention to treat obesity in Mexican children and adolescents. This is relevant considering that most of the published systematic reviews include only English publications, excluding valuable evidence from non-English-speaking low- or middle-income countries such as Mexico. The exhaustive search for evidence was done across 13 databases and 1 search engine, in 2 languages (whenever possible), which helped us capture relevant publications. The included studies' particular characteristics were extracted, and the quality of evidence was appraised, which was considered in the synthesis.

No cost-effectiveness studies regarding Mexican interventions to prevent or tackle childhood obesity

were identified in the COMO project. However, some economic models have suggested that the costs of childhood obesity in Mexico from 2006 to 2050 (considering only 2 comorbidities: diabetes and hypertension) will be much higher than the health care system can stand, jeopardizing the health and well-being of the population.^{63,64} Early intervention is essential, because less weight change is needed at younger ages to achieve a healthy weight than the amount of weight loss necessary at older ages.⁶⁵ Moreover, it has been acknowledged that the ability to estimate a national impact systematically and cost-effectiveness of implementation of childhood obesity interventions enables comparison within and across sector-specific interventions to inform primary prevention investment.⁶⁶

CONCLUSION

Efforts to identify vulnerable populations and implementation barriers among different populations are needed in Mexico. Long-term nationwide interventions and comprehensive recommendations that can guide health professionals and other stakeholders in the obesity treatment at individual and community levels are essential to change the upward trends in obesity prevalence. Such efforts need to be comprehensive, multidisciplinary, and target several risk factors in the long term. This review is part of a broader project aiming to synthesize and use data to comprehend the extent, nature, effects, and costs of childhood or adolescent obesity in Mexico (ie, the COMO Project).⁹ Because of the increasing levels of obesity in Mexico, every action measuring or attempting to tackle obesity in Mexico should be acknowledged. Any effort should be considered an experiment, where effects must be documented and evaluated to benefit every other initiative or strategy. Such efforts need to enhance their methodological quality, including different settings, stakeholders, and target different health risk behaviors. Interventions should be designed using a comprehensive approach within the national sociopolitical, cultural, and economic contexts.

Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

[Appendices 1](#) and [2](#) (which contain [Table S1](#) and [Table S2](#)) are supplied as supporting information.

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