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. 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. These increasing levels position Mexico among the countries with higher levels of overweight worldwide. According to the Organization for Economic Cooperation and Development’s estimations, such rates will continue to increase if no effective strategies are implemented. Currently, no national intervention...
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, 7,363 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 5 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 2,302 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 camps19,46; the setting was unclear in 1 of the studies.24 (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 study;27 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
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 and the effect of the intervention was unclear in 5 studies. 34,32,37,39,45 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 1 PRISMA flowchart. COMO, Childhood and Adolescent Obesity in Mexico: Evidence, Challenges, and Opportunities.
Rosado et al. 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 al. 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 al. 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 al. recorded at 6 months (Figure 3) and another with data at 12 months (Figure 4). 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 al. (−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, and the rest (n = 18) were considered of low quality. In 11 studies, participants were randomly assigned into different study groups; in 7 of these, the randomization methods were reported, and in 6, blinding of participants and personnel was reported. In most of the included studies (n = 20), individuals were somewhat likely to represent the target population. In 12 of the 29 studies, some relevant confounders were identified and controlled for. 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.

Thirteen of the 29 studies did not report any funding source, and 3 reported not receiving funding for the intervention. For 1 study, authors reported receiving funding from the food industry, and in another, authors reported receiving funding from a pharmaceutical company. National funding was reported in 2 studies, and for 1 study, authors reported receiving support from international organizations. Six of the 29 studies reported receiving funding from public institutions (eg, public hospitals, public universities), and 1 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, with an overall
| 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\(^\text{a}\) | 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 x 4 times/wk) + 28 phototherapy sessions (40 min x 2 times/wk) Delivered by: NR | ✓ | ✓ | NR | NR | Phototherapy was implemented in 1 of the interventions groups. |
| Díaz 2010\(^\text{a}\) | 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 2014\(^\text{b}\) | 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 2013\(^\text{a}\) | 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) | 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 | |

(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 |
|-------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------|--------------------------------------------------------------------------------|---------------------|------------|-----------------------------|-----------------------------|-------------------------|
| Garcia-Morales 2006\(^\text{25}\) | Mexico City (Mexico City) Outpatients attending the Endocrinology Department of a public children’s hospital 2001–2003 | 51 | 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: practitioners, pediatric nutritionist, and registered nutritionist (for anthropometry) | ✓ | ✓ | NR | ✓ | NR |
| Garibay-Nieto 2017\(^\text{26}\) | Mexico City (Mexico City) Pediatric obesity clinic at a public hospital 2012–2014 | 83 | 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\(^\text{27}\) | Ciudad Obregon (Sonora) Family medicine unit of a public hospital NR | 60 | 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\(^\text{28}\) | Mexicali (Baja California) Public elementary school NR | 26 | 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\(^\text{29–31}\) | Mexico City (Mexico City) Public children’s hospital NR | 97 | 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. |
| 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) | 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 |
| Lagun-Alcaraz 2017 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. | NR 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-Alcarcon 2019 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. | NR 1-mo NR Delivered by: nutritionist did anthropometry: however, the role was unclear | NR | NR | NR | NR | NR |
| López-Alcarcon 2020 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 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. |
| 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 2012²⁷  | 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 2017²⁸          | 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 2018²⁹ | Unclear (Nuevo Leon) Summer camp. No additional details provided NR | 102 38% 10.2 (1.5) y | 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 2014⁰  | Durango City (Durango) | 115 47.8% 13.2 (0.9) y | | 4 mo NR | ✓ | ✓ | ✓ | NR | Parents were invited to participate in |
| 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 | NR (Sonora) Primary schools (unclear if public or private) | 105 57.1% 10 (0.8) y | PA practice group sessions intervention | 5 mo NR | 40 sessions (50 min each × 2 times a week) | NR | ✓ | NR | NR | NR | Mothers were involved in the intervention. |
| Rosado 2008 | 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 | NR | | ✓ | NR | NR | NR | Supplements of DHA |
| Rosas-Nexticapa 2017 | Xalapa (Veracruz) 5 Public elementary schools NR | 121 53.7% 30 (3.0) y | 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) | NR | | | × | NR | NR | NR | Mothers were involved in the intervention. |
| Sáenz-Soto 2004 | Monterrey (Nuevo Leon) Pediatric clinic of a third-level hospital | 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. |
| 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)67 | Mexico City (Mexico City) Obesity and Adolescents Clinic of the National Institute of Pediatrics (public service) | 27 NR 27 NR | Individualized lifestyle intervention | 8 mo NR | | | | | |
| de Sanchez 200468 | 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: multidisciplinary health team (no additional detail provided) | | | | |
| Velázquez-López 200967 | 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) | | | | | |
| Velázquez-López 201468 | 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: nutrition graduates | | | | |
| Violante-Ortiz 200569 | 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 | | | | | |
| Virgen-Ortiz 2007 (letter to the editor)50 | Colima City (Colima) Private school NR | 169 NR NR | PA practice and a diet modification intervention | 4 mo 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.
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

| Reference                  | Selection bias | Study design | Confounders | Blinding | Data collection methods | Withdrawals and drop-outs | Overall rating | Funding | COI                          |
|----------------------------|----------------|--------------|-------------|----------|-------------------------|---------------------------|----------------|---------|------------------------------|
| Ceballos-Gurrola 2020      | Moderate       | Strong       | Weak        | Moderate | Strong                   | Moderate                   | NR            | NR      | Nothing to declare           |
| Díaz 2010                  | Weak           | Strong       | Strong      | Strong   | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |
| Elizondo-Montemayor 2013   | Moderate       | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |
| Elizondo-Montemayor 2014   | Weak           | Moderate     | Weak        | Moderate | Strong                   | Strong                    | NR            | NR      | Nothing to declare           |
| Escalante-Izeta 2013 (abstract) | Weak          | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |
| García-Morales 2006        | Moderate       | Strong       | Strong      | Strong   | Strong                   | Moderate                   | NR            | NR      | Abbott Laboratories          |
| Garibay-Nieto 2017         | Weak           | Strong       | Strong      | Moderate | Strong                   | Weak                      | NR            | NR      | Science Mexican Council      |
| González-Heredia 2014      | Moderate       | Strong       | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |
| Hall-López 2017            | Moderate       | Moderate     | Strong      | Moderate | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |
| Huang 2010                 | Moderate       | Strong       | Strong      | Strong   | Strong                   | Strong                    | NR            | NR      | Funded by a public university |
| Jimenez 2017 (abstract)    | Weak           | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |
| Laguna-Alcaraz 2017        | Moderate       | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Funded by public health institute |
| López-Alarcon 2019         | Strong         | Strong       | Strong      | Strong   | Strong                   | Strong                    | NR            | NR      | Nothing to declare           |
| López-Alarcon 2020         | Moderate       | Strong       | Strong      | Weak     | Strong                   | Moderate                   | Funded by public health institute | NR      | Nothing to declare           |
| Luna-Ruiz 2007             | Moderate       | Moderate     | Weak        | Moderate | Strong                   | Moderate                   | NR            | NR      | NR                           |
| Martín-Mosqueda 2012       | Weak           | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | NR                           |
| Moran 2017                 | Moderate       | Weak         | Moderate    | Strong   | Moderate                 | Weak                      | NR            | NR      | NR                           |
| Pompa-Guajardo 2018        | Moderate       | Weak         | Moderate    | Strong   | Moderate                 | Weak                      | NR            | NR      | NR                           |
| Rodríguez-Morán 2014       | Moderate       | Strong       | Moderate    | Strong   | Moderate                 | Strong                    | Partially funded by public health institute | NR      | Nothing to declare           |
| Romero-Pérez 2020          | Moderate       | Strong       | Weak        | Moderate | Strong                   | Weak                      | No funding received | NR      | Nothing to declare           |
| Rosado 2008                | Strong         | Strong       | Strong      | Moderate | Strong                   | Strong                    | Funded by industry (Kellogg’s) | NR      | Nothing to declare           |
| Rosas-Nexticapa 2017       | Weak           | Strong       | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Funded by the National Council of Education and Science Mexican Council |
| Sáenz-Soto 2004            | Weak           | Moderate     | Strong      | Moderate | Moderate                 | Moderate                   | NR            | NR      | NR                           |
| Santiago-Lagunes 2018 (Abstract) | Weak          | Moderate     | Weak        | Strong   | Moderate                 | Weak                      | NR            | NR      | NR                           |
| de Sanchez 2004            | Weak           | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Unclear if funded by public health institute |
| Velázquez-López 2009       | Moderate       | Moderate     | Weak        | Moderate | Strong                   | Weak                      | NR            | NR      | Nothing to declare           |

(continued)
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. 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.

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. 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. 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.

**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). 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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