Supplement Article

An intervention to promote physical activity in Mexican elementary school students: building public policy to prevent noncommunicable diseases

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Physical activity is an important component of strategies for health promotion and prevention of noncommunicable diseases. It is also associated with decreased risk for cardiovascular disease in overweight and obese adults and children. This article addresses the initial description of a physical activity intervention for children attending public elementary schools in Mexico. The objective was to develop a replicable model based on a strategic public, private, academic, and social partnership that would have a short-term impact on the metabolic health of children and be useful for building effective public policy. Forty-nine schools (20 000 students) participated, and 5 schools were selected for evaluation. The intervention included a 30-minute supervised middle-effort interchangeable routine, 5 days a week for a complete school year, adapted for different school conditions and students of different ages. Evaluation included anthropometric measurements and biochemical markers. Actual prevalence of combined overweight and obesity in these children was 31.9%. The intervention was successfully implemented in all schools. No change in body mass index, waist circumference, or other anthropometric indicators was found. However, changes in biochemical markers showed a significant decrease in blood glucose, total cholesterol, and cholesterol-low-density lipoproteins, reflecting a positive effect on cardiovascular health indicators.

INTRODUCTION

Childhood obesity is a growing global problem and, even though Mexican Health authorities have developed strategies aimed directly at ameliorating this problem, only local and nonevaluated programs are now operating in the Public System of Elementary Education in Mexico, which includes 15 million students.[1,2] The present article describes the process of design, implementation, and evaluation of a physical activity intervention for children attending public elementary schools in Estado de Mexico, a neighboring state of Mexico City. The main idea behind this effort was to develop an intervention during one school year that looked for evidence of impact on certain health biomarkers of children in the short term and that, if successful, could be replicated in any school facility within the Mexican public elementary education system. Considering that the prevention of noncommunicable diseases and health promotion in schools requires collaborative work

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from all sectors, the implementation of an intervention was an opportunity to test a strategic public, private, academic, and community alliance. The intervention is expected to provide useful information for public policy decision-makers.

CHILDHOOD OBESITY AND DIABETES EPIDEMIC IN MEXICO

In the past 3 decades, the prevalence of overweight and obesity in children has risen dramatically, mainly in low- and middle-income countries.[3–5] The impending disease burden has been described by medical professionals as "a public health disaster waiting to happen," "a massive tsunami," and "a health time-bomb."[3] Although prevalence seems to be leveling off in some high-income countries, it is still increasing in most Latin American countries.[3,6]

Mexico is in epidemiologic transition, with an increased disease, mortality, and disability burden from noncommunicable diseases even though chronic child malnutrition and specific micronutrient deficiencies coexist.[7–9] A particular characteristic of the epidemiological transition in Mexico is the rapid pace of change with regard to the overlapping of malnutrition and micronutrient deficiencies with overweight, obesity, and chronic diseases in the contexts of poverty and social disparities.[3,6,10–12]

According to the last Mexican National Health and Nutrition Survey (ENSANUT 2012), the combined prevalence of overweight and obesity, using World Health Organization criteria, was 34.4% (overweight, 19.8%; obesity, 14.6%), 32% for girls (overweight, 20.2%; obesity, 11.8%) and 36.9% for boys (overweight,19.5%; obesity, 17.4%).[6] Trend analysis indicates that these numbers have not increased in the last 6 years and that the prevalence has remained unchanged from 2006 to 2012.[13] These numbers are alarming because one-third of the population between the ages of 5 and 11 years has excess body weight and probably more than half of these children will become obese adults; according to available evidence, this will likely result in an increased burden of diabetes and other noncommunicable diseases in the near future.[14–18]

Apart from being a risk factor for adult obesity and chronic disease, excess adiposity in children raises the risk for a number of adverse physical and psychosocial health outcomes, including hyperlipidemia, hypertension, insulin resistance, impaired glucose tolerance, and micronutrient deficiencies (double burden of disease).[19–21] It also increases the risk of orthopedic, neurological, pulmonary, gastrointestinal, endocrine, and hepatic disorders, especially when obesity is severe.[3,4,22]

The rapid rise in childhood overweight and obesity not only implies health consequences, it also impacts educational and recreational activities, with increased economic burdens at familial and societal levels.[23] Moreover, overweight and obesity are critical indicators of the environment in which children are conceived, born, and raised.[24]

Strong evidence shows that sedentary lifestyle and unhealthy diet increase the risk of noncommunicable diseases and shorten life expectancy.[25–28] Physical inactivity causes 5.3 million annual deaths worldwide, and 6%–10% of deaths caused by noncommunicable diseases are attributed to physical inactivity.[25,29] In Mexico, this risk factor contributes 4% of total deaths.[30] Also, ENSANUT 2012 showed that 58.6% of children aged 10–14 years were not engaged in any physical activity in the 12-month period before the survey.[6] Only 33% of children reported complying with the recommendation of having two hours or less of screen time, while 39.3% spent 2–4 hours per day and 27.7% spent 4 or more hours daily in this sedentary activity. The prevalence of 2 hours or less of screen time was significantly higher in rural areas (49.2%) compared to urban areas (26%). Other studies have confirmed these findings in Mexican school-age children.[31,32]

ROLE OF PHYSICAL ACTIVITY IN THE PREVENTION OF CHILD OBESITY AND DIABETES

Obesity is a process influenced by coexisting biological, behavioral, social, and economic factors.[30] Despite this complexity, it can be simply stated that increased adiposity results when calorie intake exceeds energy expenditure. With this equation in mind, many interventions have been directed toward increasing energy expenditure through physical activity in adults and children.[33–36]

Physical activity interventions in children have been shown to have mixed results on their health.[33–35,37–40] Most of the studies have been directed toward improving biomarkers of cardiometabolic risk including anthropometric measurements such as body mass index (BMI)/age and waist circumference, arterial blood pressure, and biochemical biomarkers such as serum glucose, insulin, and lipid profile. The usual components of a lipid profile are total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides. The most solid criteria for the evaluation of these biomarkers are provided by the American Heart Association and the National Heart, Lung, and Blood Institute.[41]

Prospective follow-up studies have concluded that altered biomarkers during childhood are predictors of the adult-life values,[42] and the American Academy of

Pediatrics has signaled that childhood obesity increases the risk for coronary disease.[43] In general terms, increasing physical activity in children is associated with increased life expectancy and decreased risk for cardiovascular disease and diabetes.[39,44–47]

Ekelund et al.[48] conducted a meta-analysis that included 14 studies on the effects of exercise in children aged 4–18 years. Their analysis revealed that moderate or vigorous exercise is reflected in decreased waist circumference, decreased serum concentrations of fasting insulin, and lower triglyceride values after adjusting for sex and age. This review states that increasing the amount of time spent exercising results in more health benefits for children, independent of the time spent in sedentary activities.[48] Another meta-analysis, by Kelley et al.,[49] evaluated the effect of programs that included aerobic exercise in children and their benefits for cardiovascular markers. The included publications described the effects of aerobic exercise with an intensity of 44%–90% VO_{2max} (maximum oxygen uptake), a duration of 5–16 weeks, a frequency of 3–5 times per week, and a duration of 20–60 minutes per session in children aged 5–19 years. No effects on body weight were found; however, an increase of 7% in VO_{2max} was demonstrated. A significant 12% decrease in triglycerides without changes in total cholesterol, cholesterol-HDL, or cholesterol-LDL was found. A correlation between increased exercise intensity and decreased LDL concentration was documented. Escalante et al.[50] reviewed the effect of different 60-minute physical activity routines, 3 times per week, on lipid profiles of children with obesity. They compared the effects of aerobic exercise and mixed exercise routines (aerobic, strength, and flexibility), finding differential effects. Aerobic exercise had a greater diminishing effect on serum triglycerides and a moderate effect on cholesterol-LDL. Combined routines had only a moderate effect in increasing cholesterol-HDL.

STRATEGIC ALLIANCES TO DEVELOP A PHYSICAL ACTIVITY PROGRAM FOR ELEMENTARY SCHOOL CHILDREN

The etiology of childhood obesity is complex, and the interactions of different factors at different levels make clear that interventions should include the actions and scopes of different actors in the private, public, academic, and community sectors. International commitments and national strategies, as well as publications that present the current status of obesity and chronic disease, include the coordinated approach and participation of all social actors as an indispensable component of actions aimed at addressing obesity and chronic disease.[1,51,52] Under these conditions, academic institutions must recognize the need to implement strategic alliances with partners in the private and public sectors that share public health objectives and can contribute within their field of action, building toward a common goal. Provision of funds, sharing of knowledge and experience, and human resources working in different fields with differentiated skills and capacities should add up to structure interventions to face such a complex public health issue. Results derived from such teamwork can prove useful for structuring interventions that are adjusted to reality and can be operationalized in the field, adding to public programs already being implemented, allocating resources directed toward a common goal; achieving specific objectives, and generating information at different levels that is useful to all actors and which may lead to positive impacts on children's health.[53]

COMPONENTS OF A PHYSICAL ACTIVITY PROGRAM FOR ELEMENTARY SCHOOL CHILDREN IN MEXICO

Implementation of a physical activity intervention for elementary school students is not a simple task.[54] The success of a program of this nature is dependent on the adequate synchronization of components involved, including public programs already in place, site facilities, and local involvement of the community, including central educative authorities, teachers, students, and their families (Figure 1). The interaction and role of actors in this context should be considered in order to achieve reproducibility in different settings and in order for the generated proposal and information to be used to build public policy. The program described below included coverage of all identified components and an intensive and complex communication process with all participants. Group meetings at central offices and in every participant school were conducted as shown in Figure 1.

PHYSICAL ACTIVITY INTERVENTION

The "*Programa de Actividad Física 6+6*" (6 + 6 Physical Activity Program) was designed and implemented by teachers in charge of the physical education activities in public schools of the area F209, Estado de Mexico. These teachers were trained specialists who each had a degree in physical education for children and worked for the elementary education system. At least 1 teacher was present throughout the study in each of the participating schools. Program contents were based on already published protocols for physical activity in the school setting. The intensity of all activities reached 3–6 metabolic

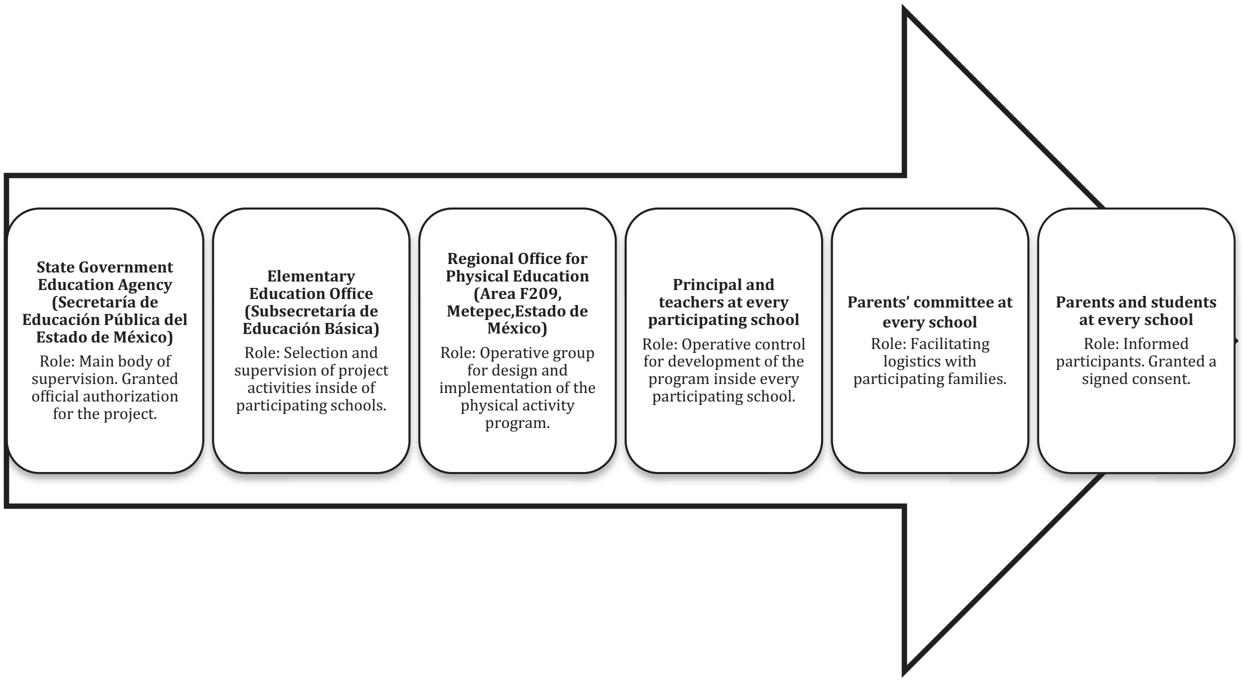

Figure 1 **Flow diagram of program participants and roles, including actors from government and the community.**

equivalent tasks per week, according to the IPAQ (The International Physical Activity Questionnarie) instrument.[55] Forty-nine schools were randomly selected for this intervention within the area of the Toluca Valley, including Metepec, Ocoyoacac, Huixquilucan, and Lerma. Intervention locations included rural and urban schools in the elementary education system of the Estado de México, which has a total population of around 20 000 children. Among the 49 sites, 5 schools were selected according to location and size for complete evaluation of the intervention, ensuring a population-representative sample size calculation and taking a conservative 20% reduction after intervention in any of the biochemical variables. A total of 1888 children participated from the following schools: Miguel Hidalgo y Costilla, Atarasquillo, Lerma; Mario Colín Sánchez, Colonia Infonavit, Lerma; Niños Héroes de Chapultepec, Río Hondito, Ocoyoacac; José Vasconcelos, Colonia Cholula, Ocoyoacac; and Leona Vicario, Ocoyoacac. This paper presents results only from the 5 schools that were fully evaluated. No attempt to modify other factors such as diet or extracurricular activities was made.

Two main factors were considered in the implementation of the specific routines of the program: 1) the type and size of the local facilities, and 2) the age of the children. The intervention was adapted to each school's curriculum and activities that included daily time allotted for physical activities within the school facilities or outside spaces.

A summary of the intervention is shown in Figure 2. 1) The duration and operation of the program was calculated and organized for one annual school cycle (2014), including children aged 6–11 years attending grades 1–5 of elementary school. 2) The program included a 30-minute variable routine to be performed 5 days a week and that was adapted for different ages. It was structured with 6 modules for 6 weeks of activities, followed by a resting period (1 week). After the week of rest, a second 6-week cycle started with new routines. 3) Each module started with 5 minutes of warming up, followed by 20 minutes of moderate activities and 5 minutes of relaxation and cooling. An important component was the promotion of brisk walking within the school grounds. This activity allowed free exchange between peers and teachers. Two or 3 days per week, brisk walking was substituted with play and games. "The dynamic balloon" is an example of game and play promotion in which 2 groups are assigned to a specific play area and a big balloon is provided for the children to play with under established rules. During "Mini-Hockey," students emulated a hockey game with handmade sticks and balls. A total of 20 different games were played during the intervention. 4) The program was conducted every day by 1 pretrained teacher per group of 30–35 students and supervised by the physical activity teacher in charge of every school. 5) A local supervisor who reported on a daily basis to authorities and researchers conducted follow-up of program compliance.

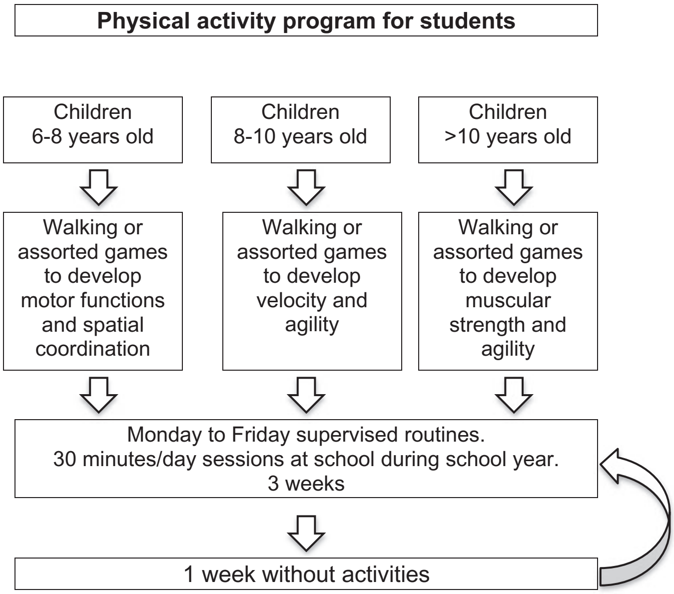

Figure 2 **Description of the school-based physical activity program.**

EVALUATION AND IMPACT

The intervention project was reviewed and approved by the Institutional Review Board of the Facultad de Medicina, Universidad Nacional Autónoma de Mexico (Register 043/2012). Impact was assessed in 5 schools that were randomly selected by the group of physical education teachers. A total of 1888 children were included. The study design was a cohort of pre–post assessment on the same children. A basal measurement was obtained before the program started, and follow-up visits to schools were programmed at the end of the school cycle. Every school was visited by a fieldwork group consisting of a medical doctor, 4 pediatric nurses, 4 nutritionists, and 4 assistants. The medical doctor acted as the group coordinator, nurses obtained blood samples, nutritionists were in charge of anthropometry, and assistants were in charge of school logistics.

Measurements included anthropometric measurements and biochemical markers. All operators were previously standardized for height, weight, waist circumference, and arterial pressure measurements according to references in Table 1.[56–59] Certified nurses were provided by Hospital Materno-Perinatal Monica Pretelini. Blood samples were obtained after a fasting period of 8 hours.

Clinical chemistry was carried out in the laboratory of the Facultad de Medicina of Universidad Nacional Autónoma de Mexico in Mexico City using standardized enzymatic methods for glucose, triglycerides, total cholesterol, and HDL-cholesterol. LDL cholesterol was calculated using Friedewald's method. Anthropometrics and biochemical data were interpreted according to international validated values and charts described in Table 1.

MAIN OUTCOMES OF THE PROGRAM

Basal conditions in the study group revealed that joint prevalence of overweight and obesity was 31.9%, with no difference by sex (Figures 3 and 4). This prevalence is very close to that described in the last national survey in Mexico, ENSANUT 2012.[6] A surprising finding in this population is that the prevalence of these problems is almost the same in all age and sex groups. A direct implication of this is the need to focus on children younger than 6 years to study the determinants of childhood obesity in Mexico.

The study showed that 3.7% of children were affected by abdominal obesity according to waist circumference classification, prehypertension was diagnosed in 17% of children, hypercholesterolemia was found in 3%, and 18% of children had elevated triglycerides. Within the normal rank, high blood glucose values were found in 34% of children, but no prediabetic or diabetic conditions were identified. Using the criteria of the International Diabetes Federation/International Society for Pediatric and Adolescent Diabetes for metabolic syndrome identification in children, including only boys and girls, a prevalence of 10% was found. Statistical comparisons were carried out using IBM SPSS Statistics for Mac, Version 20.0 (IBM Corp; Armonk, New York).

The intervention was successfully implemented during the school year 2013–2014 from November to June. Physical education teachers at each school kept a

Table 1 **Biomarkers measured in the school-based intervention**

Biomarker	Method	Interpretation
Weight	Weight/age, WHO (2008)[56]	>1.0 = 4 = overweight −2.0 or more to ≤1.0 = 3 = normal −3.0 or more to less than −2.0 = 2 = underweight Less than −3.0 = 1 = severely underweight Nonapplicable (>10 y) = 0
Height	Z score height/age, WHO (2008)[56]	>3.0 = high −2.0 or more to ≤3.0 = 3 = normal Less than −2.0 to −3.0 or more = 2 = stunted Less than −3.0 = 1 = severely stunted
BMI	Percentile BMI/age, WHO (2008)[56]	>3.0 = 6 = severe obesity >2.0 to ≤3.0 = 5 = obesity >1.0 to ≤2.0 = 4 = overweight ≤1.0 to −2.0 or more = 3 = normal Less than −2.0 to −3.0 or more = 2 = moderate thinness Less than −3.0 = 1 = severe thinness
WC	Percentile WC/sex/age, Fernandez et al. (2004)[57]	Normal: <90% Abdominal obesity: ≥90%
Fasting glucose	Glucose/age, IDF/ISPAD (2011)[58]	Normal: <100 mg/dL Prediabetes: 100–125 mg/dL Diabetes: ≥126 mg/dL
TC	TC/age, IDF/ISPAD (2011)[58]	Acceptable: <170 mg/dL High limit: 170–199 mg/dL Elevated: ≥200 mg/dL
TG	TG/age, IDF/ISPAD (2011)[58]	Acceptable: <75 mg/dL (0–9 y); <90 mg/dL (10–19 y) High limit: 75–99 mg/dL (0–9 y); 90–129 mg/dL (10–19 y) Elevated: ≥100 mg/dL (0–9 y); ≥130 mg/dL (10–19 y)
LDL	LDL/age, IDF/ISPAD (2011)[58]	Acceptable: <110 mg/dL High limit: 110–129 mg/dL Elevated: ≥130 mg/dL
HDL	HDL/age, IDF/ISPAD (2011)[58]	Acceptable: >45 mg/dL Low limit: 40–45 mg/dL Low: <40 mg/dL
Systolic arterial pressure	Percentile Systolic arterial pressure/height/sex/age, NHBEP (2004)[59]	Normal <90% Prehypertension: ≥90% and <95% Stage 1 hypertension: ≥95% and <99% Stage 2 hypertension: ≥99%
Diastolic arterial pressure	Percentile Diastolic arterial pressure/height/sex/age, NHBEP (2004)[59]	Normal: <90% Prehypertension: ≥90% and <95% Stage 1 hypertension: ≥95% and <99% Stage 2 hypertension: ≥99%
Cardiometabolic risk	Metabolic syndrome	Children older than 10 y; presence of abdominal obesity and at least 2 or more of high triglycerides, low HDL, hypertension, or hyperglycemia, Fernandez et al. (2004)[57]

Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; IDF/ISPAD, International Diabetes Federation/International Society for Pediatric and Adolescent Diabetes; LDL, low-density lipoprotein; NHBEP, National High Blood Pressure Education Program; TC, total cholesterol; TG, triglyceride; WC, waist circumference; WHO, World Health Organization.

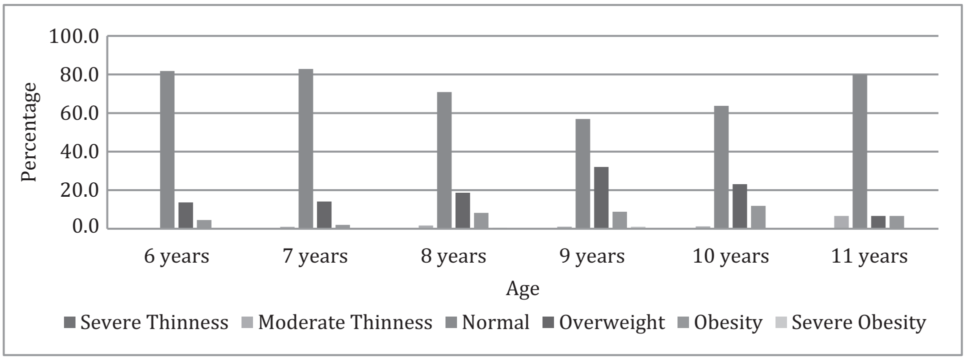

Figure 3 **Descriptive classification of baseline BMI in girls by age group.**

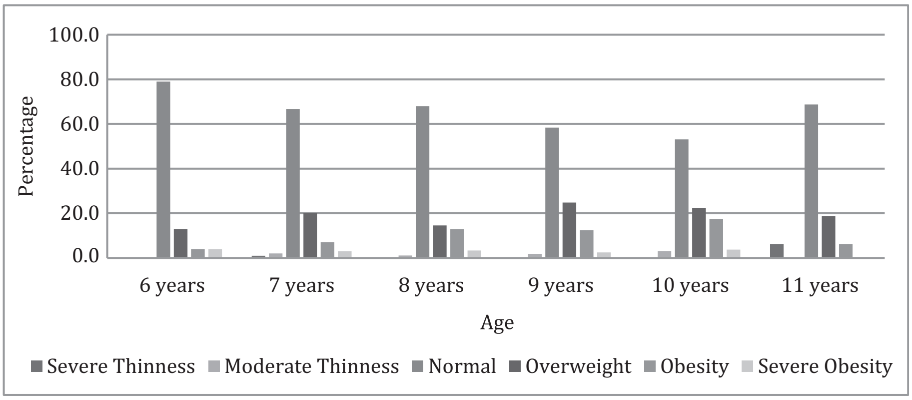

Figure 4 **Descriptive classification of baseline BMI in boys by age group.**

Table 2 **Absolute changes in anthropometric and biochemical variables**

Variable	Values before intervention		Values after intervention		Statistical significance	
	Boys	Girls	Boys	Girls	Boys	Girls
Glucose (mg/dL)	96.0 ± 9.0	96.3 ± 8.7	93.4 ± 8.0	93.3 ± 7.8	<0.001	<0.001
Triglycerides (mg/dL)	102.6 ± 40.6	105.5 ± 40.8	97.7 ± 41.5	101.3 ± 45.6	0.014	0.048
Total cholesterol (mg/dL)	140.5 ± 28.2	141.8 ± 29.0	134.5 ± 25.1	135.3 ± 25.9	<0.001	<0.001
Cholesterol-LDL (mg/dL)	67.8 ± 17.6	69.5 ± 19.1	66.5 ± 16.0	66.2 ± 15.8	NS	<0.001
Cholesterol-HDL (mg/dL)	45.9 ± 13.8	45.2 ± 12.4	43.9 ± 10.9	44.38 ± 10.3	NS	NS
BMI (kg/m^2)	17.3 ± 2.9	17.2 ± 3.0	17.4 ± 3.1	17.3 ± 2.8	NS	NS
Diastolic blood pressure (mm Hg)	64.2 ± 11.5	63.5 ± 10.9	62.7 ± 11.7	62.4 ± 12.2	0.014	NS
Systolic blood pressure (mm Hg)	106.1 ± 12.2	105.3 ± 12.5	106.3 ± 13.4	104.8 ± 14.4	NS	NS

Abbreviations: BMI, body mass index; NS, not significant.

register of each participant's adherence throughout the course of the intervention; average adherence during the entire school year was 91%.

No significant changes were found in BMI or waist circumference after the intervention, even after correcting for children's growth, as many other similar studies have reported. However, implementation of the physical activity program was associated with benefits for metabolic health in children. Analysis of variance comparing values before and after the intervention was used to test differences in continuous variables. Odds ratios (95% confidence intervals) were calculated to compare proportions in score improvement.

The intervention had a significant positive effect on absolute concentrations of blood glucose, triglycerides, and total cholesterol levels in the child population, with benefits for both girls and boys (Table 2). Cholesterol-LDL levels decreased significantly in girls, but not in boys. Mean diastolic blood pressure values showed the opposite effect, decreasing in boys but not in girls (Table 2).

If the absolute values of the abovementioned biomarkers are transformed to correspondent classifications according to the interpretation in Table 1 and if the values obtained before and after the intervention are compared, the effects of the program may reach high impact in the biochemical markers of children. Postintervention prevalence of prediabetes and elevated cholesterol decreased by around 50%. The number of boys who had increased concentrations of triglycerides and were classified as being at cardiometabolic risk decreased significantly; however, reductions in girls were not significance (Table 3). Taken together, these changes reflect a strong positive effect of the intervention on the metabolic and cardiovascular health of participating children.

All children with identified problems (extreme thinness, overweight, or obesity) were referred to the local pediatric hospital for attention, and information on follow-up was discussed with parents.

CONCLUSION

Prevention of childhood overweight and obesity and future noncommunicable diseases like diabetes is a critical target of any strategy to promote a good quality of life. Life course studies suggest that interventions during early life are more likely to have sustained effects on

Table 3 **Score improvement after intervention**

Variable	Boys[a]	Girls[a]
Glycemia	0.49 (0.39–0.62), <0.001	0.36 (0.28–0.47), <0.001
Blood cholesterol	0.56 (0.40–0.79), 0.006	0.61 (0.44–0.86), 0.003
Blood triglycerides	0.69 (0.54–0.87), 0.016	0.855 (0.72–1.00), 0.055
Cardiometabolic risk	0.74 (0.59–0.92), 0.007	0.86 (0.72–1.02), 0.088
Waist circumference	0.89 (0.65–1.23), 0.462	0.92 (0.66–1.27), 0.565
Diastolic blood pressure	0.81 (0.65–1.00), 0.053	0.82 (0.66–1.02), 0.068
Systolic blood pressure	0.97 (0.81–1.16), 0.748	0.99 (0.82–1.18), 0.890
BMI	0.98 (0.78–1.23), 0.876	1.01 (0.80–1.27), 0.959

[a]Values expressed as odds ratio (95% confidence interval) and *p* value
Abbreviation: BMI, body mass index.

health in the long term, particularly because they influence responses later in life.[51] Despite the recognition of the importance of physical activity on health and development, the implementation of population-based strategies to improve and sustain physical activity and active recreation has either not occurred, not been fully-evaluated, or has mild results.[60] Additionally, the scarcity of well-documented, effective interventions in low- and middle-income countries substantially limits the evidence. The design of evidence-based interventions is, therefore, needed to fill in the gaps and to build and implement effective policy approaches to health promotion and obesity and diabetes prevention.

The program described in this article was successfully developed with the participation of a variety of institutions based in the private, public, and academic sectors. It proved to be a self-sustained program that had positive effects on children's health and can be replicated in practically any school within the National Public School System in Mexico. The main conclusions are that the possibility of implementing an inexpensive intervention with important short-term health effects exists, that collaborative work can be achieved, and that common goals can be reached.

An aspect that should be highlighted is that effecting a change in BMI was not the immediate goal of this program. Building public policy and generating knowledge require many steps before changes in body weight at the population level can be seen, while important health benefits of continuous and moderate physical and recreational activities at the metabolic level can be documented within a short period of time. Indicators of success, other than BMI reduction, should thus be established.

The challenge of bringing together different interests, building professional working teams, and convincing authorities remains. Also, the need to raise awareness of knowledge and information that is useful in the short term for decision-making in the obesity and diabetes prevention arena continues to imply a need to build more effective communication channels among all actors.

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Declaration of interest. The authors have no relevant interests to declare.

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