Published in final edited form as:
*J Dev Behav Pediatr*. 2008 October ; 29(5): 385–393. doi:10.1097/DBP.0b013e318182a98e.

# Maternal depressive symptoms and physical activity in very low-income children

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## Abstract

**Objective—**To test the contribution of maternal depression during late infancy to physical activity in children five years later.

**Method—**Children (n=168) from very low-income households in semi-urban Mexico were assessed as toddlers (15 mo, Time 1) and at pre-school age (4–6 y, Time 2). Child low activity level (<20 minutes of activity daily for <7 d/wk) at Time 2 was the primary outcome measure and maternal depressive symptoms (Center for Epidemiologic Studies – Depression Scale) by self report at Time 1 was the primary independent variable. Covariates tested included child age, sex, BMI percentile, television viewing and behavior (Behavior Problem Index sub-scales), current maternal depressive symptoms, age, BMI and physical activity level, and family socio-economic status; all covariates were assessed at Time 2 except for socio-economic status.

**Results—**At 4–6 years old, 27.5% of children were categorized with low activity level. Exposure to high maternal depressive symptoms at child age 15 months was associated with an increased risk of having a low activity level at age 4–6 years (OR, 2.38; 95% CI, 1.05–5.40); results were unchanged with the inclusion of current maternal depressive symptoms. High child TV-viewing was significantly associated with low activity level (OR, 5.44; 95% CI, 2.06–14.3), but did not change the effect of maternal depressive symptoms in early childhood. Tests of mediation revealed that current child internalizing behavior, but not externalizing behavior, significantly attenuated the association between early high maternal depressive symptoms and later childhood activity level.

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**Competing interests:** The authors do not declare any competing interests.

**Author Contributions:** All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

**Conclusion—**Exposure to maternal depressive symptoms in late infancy is a risk factor for low activity level in later childhood and the association may be mediated by child internalizing factors.

### Keywords

poverty; nutrition transition; depression; physical activity

## INTRODUCTION

Results from Mexico's most recent nationally representative Health and Nutrition Survey indicate that over 25% of Mexican children aged 5 to 11 are currently classified as overweight. [1] The prevalence of overweight among some sub-groups or in some regions is much higher; for example, over 31% of adolescents were overweight in one recent report from Mexico City. [2] Overweight during childhood puts children at higher risk for numerous conditions, such as early-onset type II diabetes mellitus.[3] We have shown previously that the prevalence of overweight and risk for overweight was equal to or greater than 20% in a large sample of low-income, rural Mexican children 2–6 years old.[4] These findings are similar to what was reported recently in the Mexico's 2006 National Nutrition Survey.[5]

The prevalence of chronic diseases associated with obesity is already very high in Mexico, and is increasing.[5, 6] Insufficient physical activity is a critical risk factor for obesity,[7, 8] diabetes, and cardiovascular disease.[9] Physical activity is important for child development because it improves cardiovascular and musculoskeletal health, as well as increasing aerobic capacity, muscular strength and endurance.[10] Levels of physical activity have been shown to be far less than recommended in Mexican adults[6] and adolescents,[11, 12] as have levels of aerobic fitness in school-aged children.[13, 14]

Increased television viewing[8, 15] and a greater prevalence of internalizing behaviors[16, 17] are both risk factors for low physical activity in children. These behaviors in children are also associated with greater depressive symptomatology in their mothers. However, the association between maternal depressive symptoms and child physical activity has not previously been examined. A large proportion of women of child-bearing age in Mexico have a high scores on scales of depressive symptoms [18, 19] Children of depressed mothers are at a higher risk for psychopathology than children of non-depressed mothers, and this risk extends from infancy through adolescence.[20–22] Maternal depression has been linked with inadequate parenting behavior[23] and with increased television viewing in their children.[24] No previous studies have evaluated physical activity in children and how it is associated with high maternal depressive symptoms.

To address this important research gap, the current analyses explore the associations between maternal depressive symptoms at child's age 15 months and physical activity in young children 4 to 6 yrs of age and whether this relationship is modified by concurrent depressive symptoms in the mother. In addition, we examined other variables, including child BMI and behavior, maternal BMI and physical activity, and patterns of child television viewing that could be factors contributing to the associations between high maternal depressive symptoms and child activity. We hypothesized that exposure to maternal depressive symptoms in early childhood would be related to later physical activity in these very low-income children, and that child behaviors may be part of the pathway mediating the association.

# METHODS

## Participants

All study participants were previously part of a randomized controlled micronutrient supplementation trial with pregnant women and later with the children born to those women. No differences in child birth size were seen between the control and intervention groups in the original study, and detailed methods and results have been published elsewhere.[25, 26] The original sample consisted of 873 pregnant women who were identified by community surveillance between 1998 and 2000, who were eligible and willing to participate and who were randomly assigned to treatment.[25] The psychosocial measures, including maternal depressive symptoms when the children were 15 months old (Time 1) were assessed as part of a sub-study (n=242) designed to look at maternal caregiving practices and growth and development outcomes.[27] From April to August 2005 (Time 2), we attempted to relocate all women from the original sample with the objective of monitoring weight change and chronic disease risk factors over time.[28–30] Additional funds were obtained for the assessment of anthropometry, physical activity and potential predictors of these of a sample of 265 children. To strengthen the design of this component, we attempted to recruit the 242 mother-child pairs who had participated in the original maternal caregiving sub-study and then interviewed additional women who comprised a convenience sample of those who had not yet been interviewed when funds were received. For the analysis presented here we include only those mother-child pairs for whom complete data were available for our analysis from Time 1 and Time 2.

We were able to locate and interview 178 of the 242 (73.5%) of the sample of children for whom data were available at Time 1. Of these, 163 (91.6%) had complete data for all covariates of interest and were included in the current analysis. For the 15 mother-child pairs who were missing information on covariates, 1 was missing maternal age, 2 were missing child body mass index, 1 was missing hours the child watched television, 7 were missing internalizing score, and 4 were missing externalizing score. There were no statistically significant differences between the 163 mother-child pairs included in this analysis and the 15 who had missing information on key measured variables such as low activity, maternal depressive symptoms and family SES. Nor were the 163 children different from the n=87 children included in Time 2 who had not been part of the original Time 1 sub-study for measured variables including, maternal depressive symptoms at Time 2, SES, child weight status, and child TV watching.

## Main outcome measure: physical activity

Physical activity was assessed in children via interview at Time 2, and the assessment was based on the International Physical Activity Questionnaire (IPAQ), which has been widely used in adults,[31, 32] adolescents,[33] and children.[34, 35] The use of the IPAQ has been validated in a 12-country study,[31] as well as in individual studies in Latin America, including Brazil[33, 36] and Mexico,[37] and is considered to be a good approximation of the gold standard measurement of physical activity.[38]

As part of the IPAQ, mothers were asked to report the activity level of their children by reporting how many days in the past 7 days their child had completed vigorous, age-appropriate, sweat-producing activities for 20 minutes; culturally appropriate examples were provided in order to make it easier for mothers to respond accurately. Current recommendations for physical activity level in children are 60 minutes each day of moderate to vigorous activity.[39] The use of this cut-off would have resulted in almost all children being classified as low active and would not have provided sufficient variation in our analysis. Thus, we classified <20 minutes, 7 days a week as definitively less than recommended and coded these children

as being "low active". Using this cut-off allowed us to identify the least active segment of our population while providing sufficient sample size to permit exploration of association in the model (approximately 1/3 of children were below this cut-point).

## Main independent variable: maternal depressive symptoms

Maternal depressive symptoms were measured at two time points using the Spanish language version of the Center for Epidemiological Studies Depression (CES-D) Scale, which is a 20-question tool that has been validated in Spanish-speaking populations in Mexico[40] and in the United States.[41] The symptoms included in the CES-D are depressed mood, loss of interest and/or pleasure in activities, fatigue, feelings of excessive guilt and/or worthlessness, sleep and appetite disturbances, and social difficulties. The scale has shown some variation according to ethnic and cultural differences in terms of the types of symptoms more commonly reported.[41, 42] The CES-D is most often used as a self-report scale but was administered by an interviewer in this study due to the low literacy levels of participants. Before using this instrument, we went through an extensive process to translate and modify it order to adapt it appropriately to the conditions of poverty in which the families were living. We started with a version of the test that had already been translated an used in Spanish.[40] Then, we did cognitive testing with several groups of women from communities of similarly low socio-economic status to ensure that the questions used in the CES-D were conveying the intended meaning. Thereafter, we reworded the questions as necessary in order to make sure that the language being used was as simple as possible. Then we did individual structured interviews asking open-ended questions examining what each question was conveying so that the major point of each question had not been altered by simplification of language. In an iterative process, we field-tested and revised questionnaires to develop the final instrument. We have used this scale in large studies in both urban and rural Mexico.[18, 19, 22]

The generally accepted cutoff for the CES-D used in the United States and many other countries to represent that a respondent is "at risk" for clinical depression is 16 on the scale of 0 to 60, with 0 representing no depressive symptoms.[43] Salgado de Snyder and colleagues recommend a higher cutoff for rural Mexican women,[40] but this higher cutoff is not widely used due to various limitations. Consistent with the standard convention, and in order to facilitate clinical interpretation of our results, we dichotomized depressive symptoms at a score of 16. The CES-D was administered at two time points: At Time 1 when the children were 15 months old and again in the current survey when the children were 4–6 years old (Time 2). Chronbach's alpha for the CES-D in this population was 0.82 at Time 1 and 0.87 at Time 2. The correlation of the CES-D scores from Time 1 and Time 2 was 0.30.

## Additional variables

**Anthropometry—**Height and weight of the mothers and children were obtained at Time 2; all anthropometric measurements were obtained by highly trained staff according to standard procedures.[44] Mother and child weights were measured in light clothing without shoes to the nearest 100g on a digital Tanita Mother-Baby scale (Tanita Mother-Baby scale, model 1582, Tanita Corp., Arlington Heights, IL, USA). Height measurements were measured in a standard position with a portable convertible stadiometer (Schorr Industries, Glen Burney, MD, USA) and recorded to the nearest millimeter. Stunting was defined as having a Z-score for height-for-age (HAZ) less than or equal to −2 S.D. below the median.[45] Child's date of birth was validated using birth records.

Body mass index (BMI) was calculated for children and adults as weight in kilograms divided by height in meters squared. In children, BMI was converted to age and sex specific z-scores according to the 2000 CDC Growth Charts as a reference population.[46] Overweight was defined as BMI for age percentile greater than or equal to the 85$^{th}$ percentile of the reference

curve developed by the Centers for Disease Control and was used as a dichotomous variable in the analyses.[47] In adults, body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Overweight in adults was defined as BMI greater than 25.0 and was used as a dichotomous variable in the analyses.[48] Values of BMI greater than 60 and HAZ greater than 9.0 were excluded as implausible (<0.05% values were removed).

**Child behavior and TV viewing—**Child behaviors were assessed at Time 2 using a Spanish translation and adaptation of the Behavior Problems Index (BPI) administered through personal interview to the participating mothers who were asked to report on the behaviors of their children.[49] This tool has been used in many contexts and populations,[50–52] and the Chronbach's alpha for the BPI in this population was 0.74. Ordinarily, the BPI is broken into six categories: antisocial, anxious/depressed, headstrong, hyperactive, immature dependency, and peer conflict/social withdrawal. However, for ease of analysis and interpretation, we reduced the data to just two categories: internalizing and externalizing. We excluded from the factor analysis BPI characteristics that were answered "I don't know" by >5% of the sample to maintain quality of the data; BPI questions falling into this category were about disobedience at school, feeling scared, being a perfectionist, and acting overly guilty. We then used factor analyses to generate factor scores for each child on externalizing (eg, "impulsive" or "demands a lot of attention") and internalizing (eg, "fearful" or "anxious") behaviors (Table 1). For the mediation analyses of externalizing and internalizing behaviors, the scores were divided by tertile, to reflect low, medium and high expression of the behaviors, and to account for potentially non-linear effects. We grouped the lower two tertiles together to create a dichotomous variable and to enable a comparison of those with the highest scores to the other two tertiles.

Because of the important associations between TV viewing and physical activity, mothers were asked at Time 2 how much television their children watched.[53] This variable was split into a dichotomous variable of high TV viewing (>10 hours per week) in comparison with lower viewing, which is similar to cut-offs used in other studies.[24, 52]

**Maternal SES and physical activity—**Mothers were interviewed by trained personnel at Time 1 and Time 2. A detailed description of socio-economic status (SES), which included details of education, housing conditions, ethnicity, family size, occupation and possession of common assets (e.g. blender, television, refrigerator) was obtained at Time 1. A composite measure of SES was determined from a principal component analysis of a large number of assets that have been found to reflect SES in semi-rural populations.[54, 55] All participants in this study were poor and the index provided a relative comparison of families within the sample with no reference to the larger Mexican population. The index scores were used to classify the population into SES tertiles, which were used as indicator variables in our models.

Mothers were also asked the number of days in which they had completed "moderate" activity for 30 minutes or "vigorous" activity for 20 minutes during a typical week at Time 2. The questions were described in detail using a variety of culturally appropriate examples.

## Data analysis

We used logistic regression to examine whether high maternal depressive symptomology (ie, CES-D score >16) was associated with low child physical activity levels. We began with a bivariate model for high maternal depressive symptoms at Time 1 and low child physical activity. Next we modeled the bivariate association between depressive symptoms at Time 2 and low child physical activity. We then tested the effects of having high depressive symptoms at both Time 1 and Time 2 in the same model. We evaluated potential confounders (child age, sex, mother's age, family SES, child television watching, child physical activity, maternal

physical activity, child weight status and maternal weight status) by sequentially adding them to the model.

Next, we used the "causal step" method proposed by Baron and Kenny to evaluate covariates that we hypothesized *a priori* to be mediators in the relationship between high maternal depressive symptoms and low child physical activity;[56] these included internalizing and externalizing child behaviors. The causal steps method involves fitting four models to assess mediation. In the first model, the effect of the independent variable (maternal depressive symptoms at Time 1) on the dependent variable (low child physical activity) was assessed (Model 1). Next, the effect of the independent variable (maternal depressive symptoms at Time 1) on the mediator (child behavior) was assessed (Model 2). Third, the path from the mediator to the dependent variable was assessed. Fourth, the mediator was added in the presence of the independent variable; if the independent variable no longer exhibited a significant effect on the dependent variable, then the effect is considered to have been completely mediated. If there is an effect, but it is attenuated, then there is partial mediation. For each of our potential mediating variables, we evaluated these four models.

### Ethical review

The protocol for the follow-up study was approved by the Ethics, Biosecurity and Research Commissions of the National Institute of Public Health in Mexico and by the Center for the Protection of Human Subjects at the University of California, Berkeley. The original protocol was reviewed and approved by the INSP review commissions and by the Internal Review Board of Emory University. An informed consent declaration was signed by all women willing to participate at both Time 1 and Time 2; women were also asked to provide consent for their children after receiving complete information about the study objectives, procedures, risks and benefits. At time 2, women were also asked to provide consent that some of the information from the original study could be used for the follow-up analysis.

## RESULTS

A total of 163 (91.6%) children had complete data available from Time 1 and 2. The final analysis sample of children was aged 5.0±0.4 years old. About half the sample was male, and over 25% of the sample was overweight or at risk for overweight. Despite the low economic status of the population, over 90% of the families reported having a television at Time 2.

Approximately 30% of the sample of children was classified as "low active" (Table 2). In bivariate analyses, low activity was significantly associated with high maternal depressive symptoms at Time 1, internalizing behaviors, and television viewing. Low activity was not significantly associated with child gender, child age, child weight status, maternal depressive symptoms at Time 2, maternal physical activity or weight status, or family SES status.

### Maternal depressive symptoms and later child physical activity

Being exposed to high maternal depressive symptoms at Time 1 was significantly predictive of lower child activity levels at Time 2 in a bivariate analysis (OR 2.26, 95% confidence interval (1.14, 4.47)) (data not shown). After adjusting for child's age and sex, mother's age, family SES, child television watching, child and mother's weight status, and mother's activity level and current depressive symptoms, the association between *early* exposure to high maternal depressive symptoms (Time 1) and low child physical activity remained significant (OR 2.38, 95% CI: 1.05, 5.40) (Table 3). TV-viewing was significant in the model (OR 5.44, 95% CI: 2.06, 14.3) but did not attenuate the contribution of high depressive symptoms at Time 1. None of the other variables was significant.

### Potential mediators of association between high maternal depressive symptoms and child activity

We evaluated current child behavior – both externalizing (e.g. attention problems, aggressive behavior and rule-breaking) and internalizing behaviors (e.g. anxiety, depression, withdrawal) – as potential mediators of the relationship between early childhood high maternal depressive symptoms and later low levels of child physical activity.

Child internalizing behaviors satisfied all the criteria for partial mediation. High maternal depressive symptoms were significantly associated with higher odds of child internalizing behaviors (OR: 2.38, 95% CI: 1.20 – 4.75), and when child internalizing behaviors were included in the model of the association between high maternal depressive symptoms and low child physical activity levels, the effect of early high depressive symptoms was partially attenuated (OR: 1.97, 95% CI: 0.97 – 3.98), meaning the p-value was reduced to no longer significant and the estimate of effect was diminished. Additionally, child internalizing remained significantly associated with low child activity levels (OR: 2.22, 95% CI: 1.08 – 4.56).

In contrast, child externalizing behaviors were not significantly associated with high maternal depressive symptoms at Time 1, and were not significant in the logistic regression on child physical activity in the presence of high maternal depressive symptoms. Thus, externalizing behaviors did not appear to play a mediating role in the association of early depressive symptoms and low physical activity in later childhood.

## DISCUSSION

The results of this study of low-SES families in semi-urban Mexico indicate that exposure to high maternal depressive symptoms at the age of 15 months is a risk factor for low physical activity in later childhood, irrespective of concurrent maternal depressive symptoms. Current child TV viewing was significantly associated with an increased risk of low activity in children, but did not alter the significant and independent contribution of early high maternal depressive symptoms. Child age and sex, maternal physical activity and household socio-economic status did not contribute significantly to low activity in young children.

While there is an extensive literature in high-income countries on the adverse impact of maternal depression on children's social and psychological development,[21, 57] this study is the first to our knowledge to demonstrate an association between worse maternal mental health and children's lowered physical activity, a key risk factor for obesity and chronic disease. Our finding that early maternal depressive symptoms uniquely predicted children's behavioral problems and activity levels at age 5 – over and above the contribution of concurrent maternal depressive symptoms – is consistent with prior research showing later decrements in functioning for children exposed to maternal depression early in their development.[23, 58, 59] These results are inconsistent, however, with literature demonstrating that exposure to maternal depression in later childhood and adolescence continues to be linked concurrently with higher levels of behavioral problems and lower levels of self-esteem and social competence.[21]

The relative influence of maternal depression at earlier versus later stages of child development has been the focus of much recent research, with mixed evidence for the view that there is heightened sensitivity to maternal psychopathology for infants and very young children. A more chronic and severe course of maternal depression throughout the child's development has been associated with worse behavioral problems in several studies,[60] although this relationship appears to be stronger for externalizing rather than internalizing symptoms.[61] In the present study, maternal depressive symptoms were assessed at two time points and while this design provides a major advantage over a cross-sectional study, the frequency of

assessments was not sufficient to adequately describe the dynamic course of maternal depression over time. It is also important to note that we did not seek to conduct formal diagnoses of major depression from the depressive symptoms assessed in our sample of mothers; thus, our findings provide evidence for the relevance of depressive symptoms for child inactivity, but do not constitute an investigation of the role of major depression. Future research that assesses maternal mental health and depression over multiple time points would be useful in mapping the course of the disorder and would further enable the use of statistical techniques such as growth mixture modeling that permit more definitive conclusions regarding the timing of maternal mental health on child activity levels.

To understand potential pathways explaining the association between maternal depressive symptoms and children's low physical activity, we examined whether children's current internalizing and externalizing problems served as mediators of this relationship. Current child internalizing behavior was a statistically significant mediator that partially attenuated the relationship between high maternal depressive symptoms in early childhood and later risk for low physical activity and current externalizing behavior was not. Prior research has shown that toddlers of depressed mothers show reduced social competence, react more negatively to stressful events and appear to have a delay in the acquisition of effective self-regulation strategies when compared with toddlers of non-depressed mothers.[20]

Our findings suggest several possible routes by which maternal depressive symptoms may influence children's psychosocial development and, in turn, children's levels of physical activity. We consider the finding regarding internalizing symptoms first: It is likely that children who are more anxious or depressed may be less motivated to engage in active play, particularly if it would require social interactions with other children.[62] An alternative explanatory mechanism is that mothers who are more depressed facilitate fewer opportunities for active play for their children, perhaps because they themselves are more socially withdrawn, or because they harbor more anxieties about permitting their children to explore their environment and interact with other children.[23] Because the present study assessed internalizing symptoms and physical activity levels at one time point only (Time 2), it is not possible to determine the directionality of the association between children's internalizing symptoms and physical activity levels; future research that assesses both dimensions at several time points throughout childhood would address this limitation.

Children's externalizing problems did not mediate the relationship between maternal depressive symptoms and children's activity level, and this finding suggests several possible interpretations. First, the externalizing spectrum of problems is characterized by hyperactive and aggressive patterns of behavior.[63] Thus, unlike children experiencing the internalizing spectrum of anxious/depressive symptoms, children with higher externalizing problems would actually be expected to be more physically active *if* the types of play activities were more individualized and did not demand cooperation and positive relationships with other children. If, on the other hand, play opportunities required peer cooperation and acceptance (e.g. soccer, other ball sports, tag), externalizing problems would likely get in the way of children's sustained participation. The present study did not gather data about the specific kinds of active play engaged in by children from this small town in Mexico, and how they are facilitated by the efforts of adult caregivers and the quality of peer relationships. Future research that addresses this limitation could help refine these mediating analyses and clarify the social processes that link maternal depressive symptoms, children's internalizing and externalizing problems, and children's physical activity levels.

We did not find any differences in physical activity by SES, in contrast to other studies from Mexico and Latin America, which have found greater physical activity in higher-income populations.[8, 10] However, this discrepancy is likely to be due to the fact that the population

from which we sampled was fairly homogenous. Our indictor of socio-economic status provides a relative comparison of the participants in this study without any objective measure of economic wellbeing or comparison to the larger Mexican population. The community where this study took place is poor (as characterized by the lack of infrastructure and the high percentage of persons living in homes with dirt floors, without formal education above a primary level, among other factors). There are no parks or formal safe and clean spaces for physical activity (either free or paid) in the community. A number of such factors including access to recreational space, neighborhood design, weather, or safety have been shown to be predictors of physical activity [64, 65] and future studies should include a more formal documentation of these variables. However, given that all study participants came from the same very low-income, semi-urban region of Mexico, it is likely that the environmental conditions for all children were homogenous.

Stunting, defined as growth retardation secondary to undernutrition, is highly prevalent in many regions of Mexico, and 19.6% of children in this sample were stunted at the follow-up visit. Although we were not testing any main hypotheses relating to stunting, we did want to rule out the possibility that stunting was a critical factor mediating the association between early childhood high maternal depressive symptoms and later physical activity. However, we found no evidence that stunting was related either to high maternal depressive symptoms or to physical activity.

There are some limitations to this study. First, we do not have data about other factors that may be associated with childhood physical activity in this population, such as parenting style, which has been shown to be directly associated with maternal depression.[23] Future studies should use include detailed assessments additional maternal factors, such as sensitivity and responsiveness, frequency of hostile or coercive behavior, engagement with the child, and frequency of positive social interactions. A second major limitation is that we used a measure of depressive symptoms that was not developed in Mexico, and thus may be culturally biased. A wide anthropological literature demonstrates the importance of interpreting depressive symptoms within a cultural context because cultural factors influence which symptoms are experienced within the condition of “depression,” what words or expressions are used to describe those symptoms, and what decisions are made about how to move forward with treatment.[66] However, we went through an extensive process to translate and modify the CES-D in order to adapt it appropriately to the conditions of poverty in which the families were living. Also, we adjusted the language to ensure that women of a low literacy level could comprehend the questions, but we were not able to psychometrically validate the instrument. Third, we were limited in the sensitivity of some of our measures due to time constraints in the questionnaire. We used a very crude assessment of television viewing, for example, which can be measured much more sensitively.[15] In addition, the IPAQ has not been used widely in this population; future research should use a more sensitive measure for physical activity. Fourth, many measures, including child activity, child behaviors and maternal depressive symptoms were based on maternal self-report, which may have been biased. Fifth, some research suggests that excessive levels of outdoor air pollution are an important factor contributing to reduced physical activity in Mexican school-aged children,[67] and we did not measure this variable. However, this issue is mostly relevant for those living in Mexico City and other large urban centers in Mexico, and not in the semi-urban regions where this study took place. Finally, due to the fact that child internalizing symptoms and child activity were both assessed at Time 2, we are not able to disentangle temporality in order to determine causality. In contrast, the advantage of using the maternal depressive symptoms measures is that we had assessments from both Time 1 and Time 2.

Inadequate physical activity has become a critical public health issue in Latin America and around the world because it is a risk factor for obesity, cardiovascular diseases, diabetes and

cancer, and its prevalence is increasing.[10] The study reported here has shown an association between high maternal depressive symptoms during early childhood and low physical activity in children five years later in a low-income semi-urban population in Mexico. Several community-based intervention campaigns to promote physical activity have been successfully initiated in Latin America, including Agita, in Brazil and Muévete Bogatá in Colombia.[68] Our findings suggest that another approach to increasing physical activity in children may be by addressing mental health issues in mothers while their children are very young.

## Acknowledgments

We gratefully acknowledge the contributions of Ann DiGirolamo, Ph.D. (Emory University) and Usha Ramakrishnan, Ph.D. (Emory University) to initial study design and instrument development and for allowing us to use data from the original trial. We thank Raquel García Feregrino for overseeing data collection for this study. We also thank the families who participated in the research. This study was supported by the Berkeley Consortium on Population Health, which received funding from NIMH (R21 MH70950, PI Tom Boyce). Earlier data collection was supported by the Micronutrient Initiative, The National Council for Science and Technology (CONACyT), the Mexican Government and NIH.

## REFERENCES

1. Hernandez B, Cuevas-Nasu L, Shamah-Levy T, Monterrubio E, Ramirez-Silva CI, Garcia-Feregrino R, et al. Factors associated with overweight and obesity in Mexican school-age children: Results from the National Nutrition Survey 1999. Salud Publica Mex 2003;45:S551–S557. [PubMed: 14746049]
2. Halley Castillo E, Borges G, Talavera JO, Orozco R, Vargas-Alemán C, Huitrón-Bravo G, et al. Body mass index and the prevalence of metabolic syndrome among children and adolescents in two Mexican populations. J Adolesc Health 2007;40(6):521–526. [PubMed: 17531758]
3. Cruz M, Torres M, Aguilar-Herrera B, Perez-Johnston R, Guzman-Juarez N, Aranda M, et al. Type 2 diabetes mellitus in children - an increasing health problem in Mexico. J Pediatr Endocrinol Metab 2004;17(2):183–190. [PubMed: 15055352]
4. Fernald LCH, Neufeld LM. Overweight with concurrent stunting in very young children from rural Mexico: prevalence and associated factors. Eur J Clin Nutr 2007 May;61(5):623–632. [PubMed: 17136036]
5. Instituto Nacional de Salud Pública. Encuesta Nacional de Salud y Nutrición [National Survey of Health and Nutrition]. 2006Available at: http://www.insp.mx/ensanut/ensanut2006.pdf
6. Velázquez Monroy O, Barinagarrementería Aldatz FS, Rubio Guerra AF, Verdejo J, Méndez Bello MA, Violante R, et al. [Morbidity and mortality by ischemic heart disease and stroke in Mexico. 2005] [Article in Spanish]. Arch Cardiol Mex 2007;77(1):31–39. [PubMed: 17500190]
7. Janssen I, Katzmarzyk PT, Boyce WF, Vereecken C, Mulvihill C, Roberts C, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. Obes Rev 2005;6(2):123–132. [PubMed: 15836463]
8. Hernández B, Gortmaker SL, Colditz GA, Peterson KE, Laird NM, Parra-Cabrera S. Association of obesity with physical activity, television programs and other forms of video viewing among children in Mexico City. International Journal of Obesity 1999;23:845–854. [PubMed: 10490786]
9. US Department of Health and Human Services; Center for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion. Physical activity and health: a report of the Surgeon General. Atlanta, GA: US Department of Health and Human Services; 1996.
10. Pratt M, Jacoby ER, Neiman A. Promoting physical activity in the Americas. Food and Nutrition Bulletin 2004;25(2):183–193. [PubMed: 15214265]
11. Yamamoto-Kimura L, Posadas-Romero C, Posadas-Sánchez R, Zamora-González J, Cardoso-Saldaña G, Méndez Ramírez I. Prevalence and interrelations of cardiovascular risk factors in urban and rural Mexican adolescents. J Adolesc Health 2006;38(5):591–598. [PubMed: 16635772]
12. Lazcano-Ponce EC, Hernández B, Cruz-Valdez A, Allen B, Díaz R, Hernández C, et al. Chronic disease risk factors among healthy adolescents attending public schools in the state of Morelos, Mexico. Arch Med Res 2003;34(3):222–236. [PubMed: 14567403]

13. Peña Reyes ME, Tan SK, Malina RM. Urban-rural contrasts in the physical fitness of school children in Oaxaca, Mexico. Am J Hum Biol 2003;15(6):800–813. [PubMed: 14595872]
14. Coleman KJ, Heath EM, Alcalá IS. Overweight and aerobic fitness in children in the United States/Mexico border region. Rev Panam Salud Publica 2004;15(4):262–271. [PubMed: 15193182]
15. Bryant MJ, Lucove JC, Evenson KR, Marshall S. Measurement of television viewing in children and adolescents: a systematic review. Obes Rev 2007;8(3):197–209. [PubMed: 17444962]
16. Storch EA, Milsom VA, Debraganza N, Lewin AB, Geffken GR, Silverstein JH. Peer victimization, psychosocial adjustment, and physical activity in overweight and at-risk-for-overweight youth. J Pediatr Psychol 2007;32(1):80–89. [PubMed: 16601255]
17. Sweeting H, Wright C, Minnis H. Psychosocial correlates of adolescent obesity, 'slimming down' and 'becoming obese'. J Adolesc Health 2005;37(5):409. [PubMed: 16227129]
18. Burke H, Fernald LC, Gertler PJ, Adler NE. Depressive symptoms are associated with blunted cortisol stress responses in very low-income women. Psychosomatic Medicine 2005 Mar-Apr;67(2):211–216. [PubMed: 15784785]
19. Fleischer NE, Fernald LCH, Hubbard AE. Correlates of depression in a large sample of low-income women in Mexico. Epidemiology 2007;18(6):678–685. [PubMed: 18049184]
20. Goodman, SH. Genesis and epigenesis of psychopathology in children with depressed mothers. In: Cicchetti, D.; Walker, EF., editors. Neurodevelopmental mechanisms in psychopathology. Cambridge: Cambridge University Press; 2003. p. 428-460.
21. Radke-Yarrow, M. Cambridge: Cambridge University Press; 1998. Children of depressed mothers: from early childhood to maturity.
22. Fernald LCH, Burke HM, Gunnar MR. Salivary cortisol levels in children of low-income women with depressive symptoms. Dev Psychopathol 2008;20:423–436. [PubMed: 18423087]
23. Lovejoy MC, Graczyk PA, O'Hare E, Neuman G. Maternal depression and parenting behavior: a meta-analytic review. Clinical Psychology Review 2000;20(5):561–591. [PubMed: 10860167]
24. Burdette HL, Whitaker RC, Kahn RS, Harvey-Berino J. Association of maternal obesity and depressive symptoms with television-viewing time in low-income preschool children. Arch. Pediatr. Adol. Med 2003;157(9):894–899.
25. Ramakrishnan U, Gonzalez-Cossio T, Neufeld LM, Rivera J, Martorell R. Multiple micronutrient supplementation during pregnancy does not lead to greater infant birth size than does iron-only supplementation: A randomized controlled trial in a semirural community in mexico. Am J Clin Nutr 2003;77:720–725. [PubMed: 12600867]
26. Ramakrishnan U, González-Cossío T, Neufeld LM, Rivera J, Martorell R. Effect of prenatal multiple micronutrient supplements on maternal weight and skinfold changes: A randomized double-blind clinical trial in Mexico. Food Nutr Bull 2005;26:273–280. [PubMed: 16222918]
27. DiGirolamo AM, Ramakrishnan U, Neufeld L, Rivera JA, Flores R, Martorell R. Effects of caregiver depression and behavior on child growth in Mexico. The FASEB Journal 2006;20(A615)
28. Jones-Smith JM, Fernald LCH, Neufeld LM. Birth size and accelerated growth during infancy increase odds of childhood overweight in Mexican children. Journal of the American Dietetic Association 2007;107(12):2061–2069. [PubMed: 18060891]
29. Neufeld LM, Hernández-Cordero S, Fernald LCH, Ramashkrishnan U. Overweight and obesity nearly doubled over a 6 year period in young women living in poverty in Mexico. Obesity Research. 2008 January;epub
30. Neufeld LM, Jones-Smith JM, Garcia R, Fernald LCH. Anthropometric predictors for the risk of chronic disease in non-diabetic, non-hypertensive young Mexican women. Public Health Nutrition 2008;11:159–167. [PubMed: 17601359]
31. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003;35(8):1381–1395. [PubMed: 12900694]
32. Quinn A, Doody C, O'shea D. The effect of a physical activity education programme on physical activity, fitness, quality of life and attitudes to exercise in obese females. J Sci Med Sport. 2007 Sep 12;[Epub ahead of print]

33. Azevedo MR, Araújo CL, Cozzensa da Silva M, Hallal PC. Tracking of physical activity from adolescence to adulthood: a population-based study. Rev Saude Publica 2007;41(1):69–75. [PubMed: 17273636]
34. Amorim PR, de Faria RC, Byrne NM, Hills AP. Physical activity and nutritional status of children of low socioeconomic status. Two interrelated problems: undernutrition and overweight. Asia Pac J Clin Nutr 2006;15(2):217–223. [PubMed: 16672206]
35. Kelishadi RREM, Gouya MM, Ardalan G, Gheiratmand R, Delavari A, Motaghian M, et al. Association of Physical Activity and the Metabolic Syndrome in Children and Adolescents: CASPIAN Study. 2007;1:46–52.67
36. Matsudo S, Araújo T, Marsudo VAD, Andrade E, Oliveira LC, Braggion G. Questinário internacional de atividade f1sica(IPAQ): estudo de validade e reprodutibilidade no Brasil / International physical activity questionnaire (IPAQ): study of validity and reability in Brazil. Rev. bras. ativ. fís. saúde 2001;6(2):5–18.
37. Venegas Ochoa U, Llerenas Tejeda C, Aguayo Godínez A, Navarro Solares JC, Corbalá Solares J, Campos A, et al. [Physical activity and inactivity among female health service workers][Article in Spanish]. Ginecol Obstet Mex 2006;74(9):471–475. [PubMed: 17133961]
38. Sirard JR, Pate RR. Physical Activity Assessment in Children and Adolescents. Sports Medicine 2001;31(6):439–454. [PubMed: 11394563]
39. USDHHS/USDA. Dietary Guidelines for Americans. Washington D.C: U.S. Department of Health and Human Services and U.S. Department of Agriculture; 2005.
40. Salgado de Snyder VN, Maldonado M. Características psicométricas de la Escala de Depresión del Centro de Estudios Epidemiológicos en mujeres mexicanas adultas de áreas rurales [*Psychometric characteristics of the Center for Epidemiologic Studies Depression Scale in adult Mexican women from rural areas*]. Salud Publica Mex 1994;36(2):200–209. [PubMed: 8073336]
41. Golding JM, Aneshensel CS. Factor structure of the Center for Epidemiologic Studies Depression Scale among Mexican Americans and non-Hispanic Whites. Psychological Assessment 1989;1(3): 163–168.
42. Garcia M, Marks G. Depressive symptomatology among Mexican-American adults: An examination with the CES-D Scale. Psychiatry Research 1989;27(2):137–148. [PubMed: 2710862]
43. Radloff L. The CES-D scale: A self report depression scale for research in the general population. Applied Psychological Measurement 1977;1:385–401.
44. Habicht JP. Estandarización de métodos epidemiológicos cuantitativos sobre el terreno [Standardization of quantitative epidemiological methods in the field] [Article in Spanish]. Bol Oficina Sanit Panam 1974 May;76(5):375–384. [PubMed: 4277063]
45. Hamill PV, Drizd TA, Johnson CL, Reed RB, Roche AF. NCHS growth curves for children birth-18 years. United States. Vital.Health Stat.11 1977;(165):i–iv. 1–74. [PubMed: 611680]
46. CDC. Centers for Disease Control, National Center for Health Statistics. 2000. http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/datafiles.htm
47. Statistics NCfH. CDC Growth Charts, United States. 2005. Available at http://www.cdc.gov/growthcharts;
48. WHO. Geneva: World Health Organization; 1995. Physical Status: The use and interpretation of anthropometry.
49. Zill N. Behavior Problems Index based on parent report. 1990available at http://www.childtrends.org/Files/199103BehaviorProblemsIndexZill.pdf
50. Pachter LM, Auinger P, Palmer R, Weitzman M. Do parenting and the home environment, maternal depression, neighborhood, and chronic poverty affect child behavioral problems differently in different racial-ethnic groups? Pediatrics 2006;117(4):1329–1338. [PubMed: 16585331]
51. Kahn RS, Wilson K, Wise PH. Intergenerational health disparities: socioeconomic status, women's health conditions, and child behavior problems. Public Health Rep 2005;120(4):399–408. [PubMed: 16025720]
52. Lumeng JC, Gannon K, Cabral HJ, Frank DA, Zuckerman B. Association between clinically meaningful behavior problems and overweight in children. Pediatrics 2003;112(5):1138–1145. [PubMed: 14595059]

53. Grunda A, Krausea H, Siewersa M, Rieckerta H, Müllera MJ. Is TV viewing an index of physical activity and fitness in overweight and normal weight children? Public Health Nutrition 2001;4:1245–1251. [PubMed: 11796088]
54. Falkingham, J.; Namazie, C. London: DFID (Department for International Development) Health Systems Resource Centre; 2002. Measuring health and poverty: a review of approaches to identifying the poor.
55. Filmer D, Pritchett LH. Estimating wealth effects without expenditure data--or tears: An application to educational enrollments in states of India. Demography 2001;38(1):115–132. [PubMed: 11227840]
56. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 1986;51:1173–1182. [PubMed: 3806354]
57. Goodman SH, Gotlib IH. Risk for psychopathology in the children of depressed mothers: a developmental model for understanding mechanisms of transmission. Psychol Rev 1999;106(3):458–490. [PubMed: 10467895]
58. Essex MJ, Klein MH, Miech R, Smider NA. Timing of initial exposure to maternal major depression and children's mental health symptoms in kindergarten. British Journal of Psychiatry 2001;179:151–156. [PubMed: 11483477]
59. Alpern L, Lyons-Ruth K. Preschool children at social risk: Chronicity and timing of maternal depressive symptoms and child behavior problems at school and at home. Development and Psychopathology 1993;5:371–387.
60. Brennan PA, Hammen C, Andersen MJ, Bor W, Najman JM, Williams GM. Chronicity, severity, and timing of maternal depressive symptoms: Relationships with child outcomes at age 5. Developmental Psychology 2000;36:759–766. [PubMed: 11081699]
61. Ashman SB, Dawson G, Panagiotides H. Trajectories of maternal depression over 7 years: Relations with child psychophysiology and behavior and role of contextual risk. Development and Psychopathology 2008;20:55–77. [PubMed: 18211728]
62. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes (Lond) 2008;32(1):1–11. [PubMed: 18043605]
63. McMahon RJ. Diagnosis, assessment, and treatment of externalizing problems in children: The role of longitudinal data. Journal of Consulting & Clinical Psychology 1994;62(5):901–917. [PubMed: 7806720]
64. Bauman AE, Sallis JF, Dzewaltowski DA, Owen N. Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. Am J Prev Med 2002;23(2 Suppl):5–14. [PubMed: 12133733]
65. Humpel N, Owen N, Leslie E. Environmental factors associated with adults participation in physical activity: a review. Am J Prev Med 2002;22:188–199. [PubMed: 11897464]
66. Kleinman A. Culture and depression. New England Journal of Medicine 2004;31(10):951–953. [PubMed: 15342799]
67. Villarreal-Calderón A, Acuña H, Villarreal-Calderón J, Garduño M, Henríquez-RoldáN CF, Calderón-Garcidueñas L, et al. Assessment of physical education time and after-school outdoor time in elementary and middle school students in south Mexico City: the dilemma between physical fitness and the adverse health effects of outdoor pollutant exposure. Arch Environ Health 2002;57(5):450–460. [PubMed: 12641189]
68. Matsudo V, Matsudo S, Andrade D, Araujo T, Andrade E, de Oliveira LC, et al. Promotion of physical activity in a developing country: The Agita Sao Paulo experience. Public Health Nutr 2002;5(1A):253–261. [PubMed: 12027292]

## Table 1

Factor Analysis of Child Internalizing and Externalizing Behaviors from Behavior Problem Index

| **Externalizing Characteristics** | **Factor Loadings** |
|---|---|
| Argues | 0.52 |
| Vain | 0.30 |
| Cruel | 0.49 |
| Seeks attention | 0.34 |
| Destroys own things | 0.44 |
| Destroys others' things | 0.44 |
| Disobedient | 0.47 |
| Jealous | 0.33 |
| Annoying | 0.40 |
| Fights | 0.64 |
| Makes Problems | 0.30 |
| Lies | 0.42 |
| Internalizing Characteristics | Factor Loadings |
| Lonely | 0.31 |
| Cries easily | 0.24 |
| Guilty | 0.15 |
| Loves | 0.55 |
| Worthless | 0.36 |
| Prefers to be alone | 0.30 |
| Nervous | 0.32 |
| Sick | 0.09 |
| Tires easily | 0.20 |

## Table 2

Characteristics of Children and their Mothers by Child's Physical Activity Level at Age 4–6 Years (n=163)

| Characteristic | Low activity <20 min PA for <7 d/wk (n=49) | High activity ≥20 min PA for 7 d/wk (n=114) |
|---|---|---|
| ***Mothers*** | | |
| CES-D (SD) at Time 1 (child age 15 m) | 16.1 (7.6) | 13.7 (8.3) |
| High depressive symptoms (CES-D>16), % | 26 (53.1%) | 38 (33.3%)* |
| CES-D (SD) at Time 2 (child age 4–6) | 14.4 (8.5) | 14.9(10.6) |
| High depressive symptoms (CES-D>16), % | 18 (36.7%) | 37 (32.4%) |
| BMI (SD) | 28.0 (5.2) | 27.7 (4.5) |
| Underweight (BMI≤18), % | 2 (2.0%) | 1 (0.9%) |
| Normal weight (18≤BMI<25), % | 9 (18.4%) | 35 (30.7%) |
| Overweight (25≤BMI<30), % | 23 (47.0%) | 42 (36.8%) |
| Obese (30≤BMI), % | 15 (35.7%) | 36 (31.6%) |
| Schooling completed (SD), y | 6.4 (3.3) | 7.0 (3.5) |
| Age (SD), y | 29.7 (6.0) | 28.4 (5.3) |
| Moderate or vigorous activity each week (SD), hrs | 5.6 (1.2) | 6.0 (1.8) |
| Family SES | | |
| Lowest tertile SES, % | 18 (36.7%) | 33 (28.9%) |
| Middle tertile SES, % | 9 (18.4%) | 36 (31.6%) |
| Highest tertile SES, % | 22 (44.9%) | 45 (39.5%) |
| ***Children*** | | |
| Sex, % | | |
| Male | 26 (53.1%) | 62 (54.3%) |
| Female | 23 (46.9%) | 52 (43.6%) |
| Age (SD), y | 5.1 (0.6) | 4.9 (0.5) |
| BMI (SD) at age 4–6 years | 15.5 (1.2) | 15.7 (1.2) |
| BMI z-score (SD) at age 4–6 years | −0.03 (1.0) | 0.2 (0.9) |
| Underweight (BMI percentile <5th), % | 1 (2.0%) | 3 (2.6%) |
| Normal weight (BMI percentile 5th-85), % | 39 (79.6%) | 82 (71.9%) |
| At risk for overweight (BMI percentile >85 & <95), % | 8 (16.3%) | 26 (22.8%) |
| Overweight (BMI percentile >=95th), % | 1 (2.0%) | 3 (2.6%) |
| BPI score | | |
| Externalizing factor score (SD)[a] | 0.17 (1.0) | −0.05 (0.8) |
| Internalizing factor score (SD)[a] | 0.18 (0.8) | −0.13 (0.71)* |
| TV-viewing time (SD), h/wk | 7.7 (4.5) | 5.9 (2.6)* |
| >10 hours per week, % | 15 (30.6%) | 11 (9.6%)* |

Abbreviations: PA, physical activity; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CES-D, Center for Epidemiologic Studies Depression Scale; SES, socio-economic status; BPI, Behavior Problems Index.

*p-value<0.05 for comparison of low activity group to high activity group. For continuous variables, difference in means was tested with Students T-test; for categorical variables Pearson's chi-square was used to test for statistical significance of proportions.

[a]Factor analyses were used to generate scores with a standardized mean of 0 for each child on externalizing (e.g. acting out) and internalizing (e.g. withdrawal) behaviors

## Table 3

Adjusted Odds Ratios for Low Child Physical Activity at Age 4–6 Years (n=163)

| | Adjusted Odds Ratio |
|---|---|
| High maternal CES-D, Time 1[1] | **2.38*** (1.05 – 5.40) |
| High maternal CES-D, Time 2 | **0.89** (0.38 – 2.07) |
| Child age (months) | **1.05** (0.99 – 1.11) |
| Child sex (1=male) | **0.83** (0.63 – 1.77) |
| Mother's age, y | **1.04** (0.97 – 1.11) |
| Family SES, middle tertile[2] | **0.48** (0.17– 1.34) |
| Family SES, highest tertile | **1.15** (0.47 – 2.85) |
| Mother's physical activity (h/wk) | **0.84** (0.65 – 1.08) |
| Child TV-viewing (>10 h/wk) | **5.44**** (2.06 – 14.3) |
| Child BMI ≥ 85th percentile for age and sex | **0.63** (0.24 – 1.64) |
| Mother overweight (BMI ≥ 25) | **1.99** (0.79 – 4.96) |

95% confidence intervals in parentheses

* $p<0.05$

** $p<0.01$, BMI: Body mass index; CES-D: Center for Epidemiologic Studies – Depression Scale

[1] Time 1 when child was 15 months old; Time 2 when child was 4–6 years old.

[2] Lowest tertile used as comparison group