

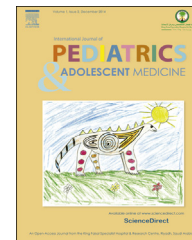
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## ORIGINAL RESEARCH ARTICLE

# Associations between child and sibling levels of vigorous physical activity in low-income minority families

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**Abstract** *Background and objectives:* A child's level of habitual physical activity is partly determined by a familial component, but the literature is limited regarding sibling influences. Multiple studies suggest that targeting siblings is an effective strategy for improving child health behaviors.

*Patients and methods:* We analyze Moving to Opportunity for Fair Housing (MTO) data to study associations between the odds of a child attaining 20 min or more of vigorous physical activity at least 3 days every week and parallel measures from an older sibling and a parent. We include covariates representing the social environment such as household income and neighborhood safety.

*Results:* There were 1347 study units that consisted of a child (age 11.2 y ± 2.6), an older sibling (age 14.8 y ± 2.8), and a parent (age 38.3 y ± 7.5). A child's odds of vigorous physical activity for 20 min or more was increased if the older sibling (OR 1.67; 95% CI 1.32–2.11) or parent (OR 1.36; 95% CI 1.08–1.72) had a comparable activity level compared to children whose older siblings or parents did not exhibit a comparable level of activity.

*Conclusions:* A younger sibling's level of physical activity is positively associated with an older sibling's and/or parent's level of physical activity. Family-based approaches, especially those incorporating siblings, may be effective at increasing physical activity in children.

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## 1. Introduction

Despite clear benefits, physical activity among children is inadequate and perhaps even decreasing over time [1–3]. Increasing the physical activity of children in the U.S. is a public health priority, especially in light of the current obesity epidemic [4]. Research is needed to expand our understanding of which factors influence the physical activity of children at various developmental stages and in different familial and contextual situations [5].

Several studies suggest that familial context influences an individual's level of habitual physical activity [6–12]. In many health behavior models, such as social learning theory [13] and social support theory [14], the family is conceptualized as an important socializing agent, constituting an interactive-interdependent network and a source of multiple environmental influences [15–17]. Family dynamics including family rules, emotional support, encouragement, reinforcement from other family members, and family member participation are important determinants of a family's health-behavior patterns [18]. Family-based interventions that promote physical activity in children by establishing positive modeling or by increasing social support may yield more beneficial and enduring effects [12,17,19].

Studies of parent-offspring correlations with respect to physical activity participation have demonstrated low to moderate familial resemblance in exercise behaviors [20]. Similar results have been reported in studies of spousal physical activity [21]. In addition, heritability estimates for physical activity have been highly variable, ranging from no genetic effect in family designs to high heritability coefficients in twin studies [22,23].

Given that much of the research regarding familial physical activity associations has focused exclusively on parent-child relations, our objective in this study was to examine the relationship between a child's physical activity and that of an older sibling, as well as that between a child and a parent. While there is a fair amount of literature regarding associations between siblings with respect to risky behaviors such as tobacco use, teenage pregnancy, and delinquency, the literature regarding sibling influences on youth physical activity is limited. For example, research indicates that sibling effects are statistically stronger than the effects of cigarette price and youth access control policies on teen smoking [24]. Analyses of sister pairs from the National Longitudinal Survey of Youth identified associations wherein an older sister's teenage pregnancy predicted a younger sister's teenage pregnancy [25]. Sibling correlations regarding delinquent behaviors are greater than any of the correlations between peers defined as adolescents' best friends or between schoolmates living in the same neighborhood [26]. Such findings suggest that important peer effects may operate through sibling interactions. In addition, interventions targeting siblings, in addition to parents or other family members, may have multiplier effects in deterring risky youth behaviors.

We hypothesized that children with physically active families are more likely to be active. We further hypothesized that siblings and parents have distinct influences on a child's physical activity.

## 2. Patients and methods

### 2.1. Study design

This was a cross-sectional study, using interim data collected from the Moving to Opportunity for Fair Housing (MTO) study by the U.S. Department of Housing and Urban Development. In this study, families in public housing in five metropolitan areas (Baltimore, Boston, Chicago, Los Angeles, and New York) were recruited and randomized to one of three study groups:

1. remained in public housing (control group);
2. moved to any neighborhood outside of public housing (Section 8 group);
3. moved to a low-poverty neighborhood, defined as having less than 10% of its residents with household incomes below the federal poverty line (experimental group).

Interim data were collected five years after randomization among participating families. Up to two children per household were interviewed. Recruitment and selection procedures are described in detail on the study's web site (<http://www.hud.gov/progdesc/mto.cfm>). MTO is authorized under Section 152 of the Housing and Community Development Act of 1992 and is jointly administered by HUD's Offices of Policy Development and Research, Fair Housing and Equal Opportunity, and Public and Indian Housing. Adult research subjects provided written informed consent, and child subjects provided assent, to have de-identified data analyzed for research purposes. The institutional review board of the Indiana University School of Medicine approved this study.

### 2.2. Setting/participants

The MTO study obtained self-reported data from up to two children aged 7–18 years per family at the time of interim data collection (total child subjects = 4612). From this group, we included data for 1347 family units after excluding subjects because they had no siblings or had a sibling of the same age. At baseline, two-thirds of the subjects were African American, and approximately one-third was Latino. The average total household income was \$9300, and approximately 60% of participating families received federal public assistance. Representation was approximately equivalent across MTO project sites – Baltimore, MD (14%); Boston, MA (20%); Chicago, IL (24%); Los Angeles, CA (20%); New York, NY (22%). The subjects in this analysis were also evenly distributed across MTO study arms: voucher to move to low-poverty neighborhood (41%); voucher to move to any neighborhood (31%); control group (28%).

## 3. Measures

### 3.1. Outcome

Physical activity was defined using a U.S. Centers for Disease Control and Prevention Youth Risk Behavior Survey

item [27]. This was a self-reported measure obtained via an interviewer who asked, “On how many of the past 7 days did you exercise or participate in physical activity for at least 20 min that made you sweat and breathe hard, such as basketball, soccer, running, swimming, fast bicycling, fast dancing, or similar aerobic activities?” This same measure was used for the child, his/her sibling, and his/her parent.

### 3.2. Independent variables

This study examined whether an older sibling’s or parent’s level of physical activity are independently associated with a child’s level of physical activity. Analyses were adjusted for individual, family, and neighborhood factors that have been found to be associated with physical activity in previous studies.

Individual-level covariates included gender, race/ethnicity (black or Latino), and age (as a continuous variable in years). The family-level demographic characteristics included measures of household poverty (household income with respect to the federal poverty line (FPL)): <50% of the FPL, 50–99% of the FPL, 100–149% of the FPL, >149% of the FPL; household size; age difference between siblings (as a continuous variable in years); and gender (discordant or same sex siblings). Parent perceptions of neighborhood safety were also included. Two dichotomous variables – very safe/safe or unsafe/very unsafe – were derived from interview questions asking, “How safe do you feel on the streets near your home during the day?” and “How safe do you feel on the streets near your home at night?” Variables were also included for the five cities serving as MTO sites as well as the MTO intervention arm.

### 3.3. Analysis

We performed bivariate statistics to describe the population of children, older siblings and parents. We used logistic regression to investigate the odds of a child participating in 20 min or more of vigorous physical activity at least 3 days every week given an older sibling and/or parent who exhibited a similar level of physical activity, adjusting for

child, family, and neighborhood characteristics as well as metropolitan site and study arm. We also conducted multiple regression models in which sibling and parent physical activity were represented as ordered, categorical variables, i.e., the number of days per week the sibling or parent participated in at least 20 min of vigorous physical activity.

In light of epidemiologic studies reporting differences in physical activity between boys and girls, across subgroups defined by race and ethnicity, and across age groups, we conducted stratified analyses for each of these demographic characteristics for the younger child. The age-stratified analyses assessed children younger than eleven years of age compared to children aged eleven years or older. If effect modification was present in the stratified models, we included interaction terms in the adjusted regression models.

All models calculated 95% confidence intervals using robust variance estimates. All analyses incorporated survey weights and were performed using Stata 9.0 for Windows (Stata Corp, College Station, TX).

## 4. Results

Children in this study cohort were representative of the larger MTO study group (Table 1). The majority of parents included were female. Median household size was 4 members with a household income below the federal poverty level.

Subjects were more similar to their older siblings in reported levels of weekly physical activity than to their parents (Fig. 1). Approximately one-quarter of the sampled children and their older siblings reported vigorous physical activity 6–7 days per week with a relatively even distribution for the remaining weekly frequencies. There was a bimodal distribution of parent vigorous physical activity with approximately one-third reporting either no weekly vigorous physical activity and/or roughly one-third reporting vigorous physical activity six or seven days per week (35%).

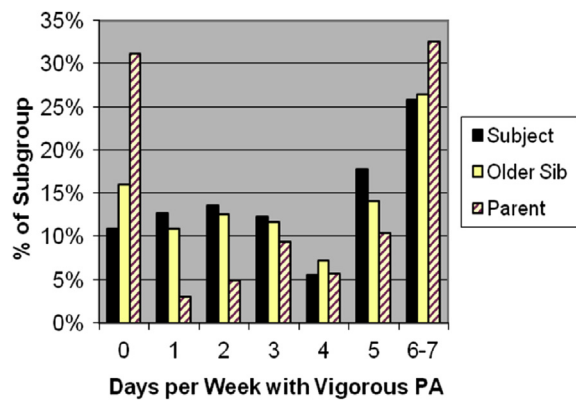
In multivariate analyses, the adjusted odds of the younger sibling participating in 20 min or more of physical

**Table 1** Sample characteristics (*n* = 1347).

	Child	Older sibling	Parent/Guardian
Age	11 y (SD ± 3 y)	15 y (SD ± 3 y)	38 y (SD ± 8 y)
Female	741 (51%)	743 (51%)	1461 (98%)
Sex discordance between siblings		775 (52%)	
African American <sup>a</sup>	923 (64%)		
Latino <sup>b</sup>	479 (33%)		
Median household size	4 members (interquartile range 3–6 members)		
Median income			\$16,362 (interquartile range \$7990–\$22,000)
High school graduate			714 (53%)

<sup>a</sup> Race – self-reported by parent.

<sup>b</sup> Ethnicity – self-reported by parent.



**Figure 1** Self-reported levels of vigorous physical activity by child, sibling and parent subjects.

activity for at least 3 days increased when his/her older sibling (OR 1.67; 95% CI 1.32–2.11) or parent (OR 1.36; 95% CI 1.08–1.72) was similarly active, compared to younger siblings who were less active (Table 2). None of the other covariates, including parent perceptions of neighborhood safety, were significantly associated with younger sibling physical activity.

When the physical activity independent variables for siblings and parents were represented as an ordered categorical variable, a significant positive test for trend was

noted between siblings for each additional day reported being vigorously active for 20 min or more ( $p < 0.05$ ), but no such trend was discernable for the association between child and parent vigorous activity (Fig. 2).

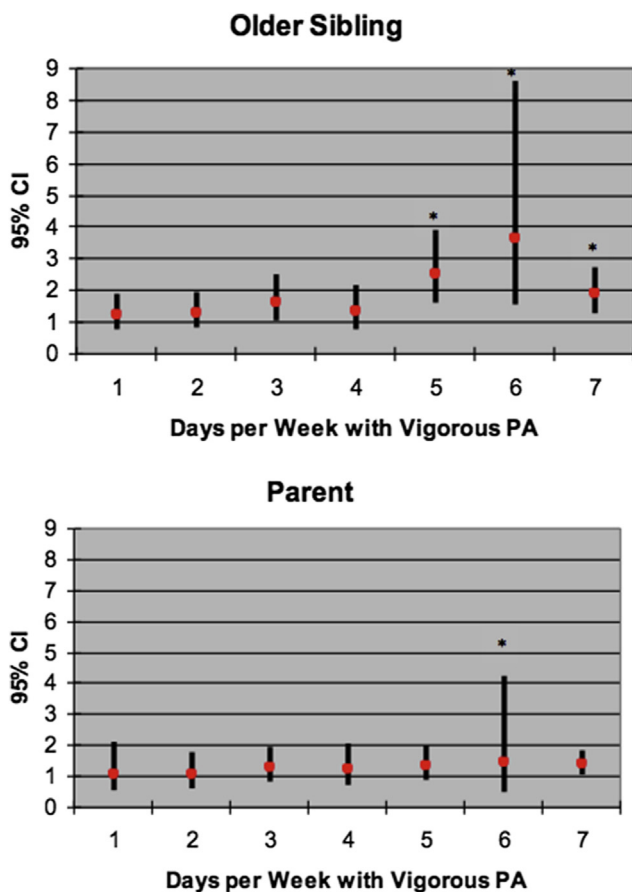
In analyses stratified by gender, there was some indication of differential associations between parent/older sibling and subject vigorous physical activity. Among boys, parent (OR 1.73; 95% CI 1.19–2.52) and older sibling (OR 1.88; 95% CI 1.29–2.76) physical activity remained the only significant correlates of child physical activity. Among girls, older sibling (OR 2.37; 95% CI 1.56–3.62) physical activity had a significant positive relationship to child activity, but parent physical activity did not. For girls, the presence of gender discordance between siblings (i.e., girls with older brothers) was also a significant correlate of physical activity (OR 1.63; OR 1.09–2.44).

There were also differences in associations when analyses were stratified by race/ethnicity. Among black subjects, older sibling physical activity (OR 2.05; 95% CI 1.45–2.90), parent physical activity (OR 1.92; 95% CI 1.36–2.71), and male sex (OR 1.44; 95% CI 1.03–2.03) were significant correlates of child physical activity. Among Latino subjects, older sibling physical activity (OR 1.63; 95% CI 1.01–2.60) and male sex (OR 1.94; 95% CI 1.22–3.07) were significant correlates of child physical activity. There was no significant relationship between child and parent physical activity for stratified analyses examining only

**Table 2** Associations between child, sibling, and parent physical activity: results of multivariate analysis/logistic regression models.

Indicator	Entire study group OR (95% CI)	Stratified analyses by sex	
		Younger male child OR (95% CI)	Younger female child OR (95% CI)
<b>Family member PA</b>			
• Sibling	1.67 (1.32–2.11)	1.88 (1.29–2.76)	2.37 (1.56–3.62)
• Parent	1.36 (1.08–1.72)	1.73 (1.19–2.52)	1.38 (0.93–2.06)
<b>Younger child factors</b>			
<b>Gender</b>			
• Male (referent)	1.00	–	–
• Female	1.13 (0.65–1.94)	–	–
<b>Race/Ethnicity</b>			
• African American (referent)	1.00	1.00	1.00
• Latino	0.73 (0.52–1.03)	0.65 (0.40–1.04)	0.90 (0.55–1.46)
<b>Sibling factors</b>			
Gender discrepancy	1.13 (0.86–1.48)	0.84 (0.58–1.22)	1.63 (1.09–2.44)
• Age difference	1.01 (0.95–1.08)	1.00 (0.92–1.10)	1.01 (0.92–1.10)
<b>Parent factors</b>			
• High school graduate	1.02 (0.78–1.35)	1.00 (0.69–1.46)	1.07 (0.71–1.59)
<b>Family factors</b>			
<b>Household income</b>			
• <50% FPL (ref)	1.00	1.00	1.00
• 50–99% FPL	1.01 (0.74–1.39)	0.95 (0.62–1.46)	1.01 (0.63–1.63)
• 100–149% FPL	0.80 (0.55–1.17)	0.68 (0.40–1.17)	0.89 (0.52–1.55)
• >149% FPL	0.93 (0.59–1.46)	0.81 (0.43–1.54)	0.98 (0.53–1.81)
• Household size	1.03 (0.95–1.13)	0.91 (0.79–1.04)	0.99 (0.87–1.14)
<b>Neighborhood factors</b>			
Safe at night	1.10 (0.79–1.55)	1.22 (0.77–1.93)	0.87 (0.52–1.43)
Safe during the day	1.07 (0.71–1.62)	1.11 (0.63–2.00)	1.11 (0.60–2.08)

Models also adjusted for project site and study arm assignments, none of which were significant correlates of child physical activity.



**Figure 2** Adjusted odds\* of child meeting CDCP guidelines for weekly vigorous physical activity (PA) (older sibling & parent PA as categorical variables). Footnote: \*significant at  $p < 0.05$ .

Latino children. Furthermore, the different associations between child physical activity and adult physical activity among black and Latino children approached significance ( $p = 0.08$ ). There was no significant interaction between child physical activity and sibling physical activity by race/ethnicity.

Among children younger than 11 years, older sibling physical activity (OR 2.29; 95% CI 1.51–3.49) and parent physical activity (OR 1.73; 95% CI 1.16–2.61) were significant correlates of child physical activity. Among older children, older sibling physical activity (OR 1.61; 95% CI 1.12–2.34) and parent physical activity (OR 1.52; 95% CI 1.05–2.20) were also significant correlates of child physical activity. Male sex was associated with child physical activity in both groups of children, and the presence of gender discordance was associated with child physical activity among older children.

## 5. Discussion

In this sample of low-income minority youth, older sibling and parent levels of physical activity were significant and positive predictors of a younger sibling’s level of vigorous physical activity after adjusting for several individual, family, and neighborhood characteristics. Whether

considering the entire study group or analyses stratified by age, sex and race, an older sibling’s amount of activity was repeatedly a stronger predictor of a child’s activity than a parent’s level of activity, even after adjusting for discrepancies in age and gender between the siblings.

Overall, studies of child physical activity that include covariates measuring both multiple family members and neighborhood or community factors are few despite the fact that recommendations to address the paucity of physical activity research involving families and neighborhoods/communities have existed for at least a decade [28–31]. Though existing research has linked family factors to youth physical activity, this is the first study, to our knowledge, that examines parent and older sibling associations with a child’s level of vigorous physical activity.

Research that conceptualizes siblings as a unique influence on physical activity behaviors, independent from other familial factors, is relatively sparse. In fields such as adolescent drug use, there is now a growing recognition that sibling effects must be included to obtain a more representative view of family life [32]. Much of the research that examines family associations in physical activity focuses on parent–child relationships, while studies reporting independent sibling influences on child activity are primarily regional and limited to small sample sizes [9,17,33]. In contrast, this study’s findings are based on a relatively large dataset that includes families residing in four regions of the US.

The effect of siblings on health behavior has been explained using several theories, including social learning theory, the behavioral genetic perspective, and ecologic perspectives. Social learning theory emphasizes the importance of observing and modeling the behaviors, attitudes, and emotional reactions of others [34]. From this perspective, it is assumed that siblings would promote physical activity through modeling such behaviors or express favorable attitudes towards an active lifestyle. The behavioral genetic perspective attributes associations between sibling behavior to genetic similarity between individuals [35]. Ecologic perspectives explain familial physical activity relationships using concepts such as family-level norms, shared living conditions and/or home-neighborhood level availability of physical activity resources [36].

Supporting the validity of social learning as a theoretical basis for sibling influences on health behavior, researchers have found that older siblings are more influential than younger siblings in affecting adolescent drug use [37]. If the association were purely genetic, then younger siblings would be similarly correlated as older siblings with adolescent drug use. Behavioral genetic researchers have found that almost half of all personality traits are attributable to genetic factors [22,38,39]. Although increasing attention is being given to ecologic or environmental targets for interventions to promote physical activity, additional research is needed to establish the validity of different conceptual models of family influences and to distinguish the specific role of sibling relationships in physical activity or other health behaviors.

Results from stratified analyses demonstrate that associations vary between older sibling, parent, and younger sibling physical activity depending on the age, gender, and race/ethnicity of a child. The relationship between a

child's physical activity and that of an older sibling's may be especially strong among girls, particularly when compared to the relationship between a child's physical activity and that of a parent. A stronger association between sibling physical activity compared to child-parent physical activity was observed for the Latino subjects. The results of the stratified analyses also suggested that gender discordance between siblings is an important factor that influences child physical activity. The presence of an older brother was a significant positive correlate of physical activity for girl subjects. The presence of gender discordance between siblings was also a significant positive correlate of physical activity among Latino subjects. Familial resemblance in physical performance, exercise response, and long-term exercise frequency has been demonstrated in adults [39–41] and, to a more limited extent, in children [22,42], although the literature has not been entirely consistent in documenting these similarities.

There are several limitations to this study. First, the physical activity measure is self-reported, and thus, it may not reflect actual activity levels. Although direct measurement of physical activity through methods such as accelerometry would be ideal, these approaches are especially challenging for population-based research due to high costs and increased respondent burden [43]. With respect to the Youth Risk Behavior Survey (YRBS) item specifically used as an outcome for our study, the test reliability for vigorous physical activity has been found to be moderate in middle school students of similar age to our study population's younger siblings. Consistent with several studies of the validity of self-report measures of child physical activity, the YRBS item we used has also been determined to over-estimate rates of children achieving more than three days per week with at least twenty minutes of vigorous physical activity. We were unable to obtain more detailed information regarding particular types of physical activity, such as team sports, resistance training, or dance. Although it is widely recognized that improved self-report items for measuring physical activity are needed, the results of our study are based on survey items still in use for monitoring child physical activity, despite challenges with validity, the items allow for comparison of our findings with national U.S. surveillance data. In addition, it is unlikely that differential reporting occurred between the younger children and their siblings or parents within this population. Furthermore, the validity and reliability of the physical activity items increases when examined for older adolescents and adults. Second, the physical activity data are not collected from all family members. In this study, the vast majority of parents are represented by the participant's mother. Parents influence children's physical activity through a number of potential links, from genetic influences to direct or indirect forms of socialization or facilitation. All of these types of influences probably vary according to paternal versus maternal relationships, as well as gender matching between child and parent. Third, the study design does not allow accounting for the time of year/season of the interview. It is unlikely, however, that seasonality would systematically affect family activity relationships. Fourth, as the study design is cross-sectional, our findings do not necessarily suggest causal relationships. For example, it is possible that the

younger sibling encourages his or her older siblings and/or parents to exercise. Finally, the stronger associations noted between sibling physical activity may be attributable to known decays in physical activity as one ages. Physical activity seems to change with age, such that physical activity declines beginning in adolescence. We were unable to obtain data regarding the physical fitness of the study subjects. Furthermore, this study cannot substantiate whether a change in activity by a sibling or parent would create a change in the activity of a child.

More research is necessary to further explain how and why family members contribute differently to child physical activity behaviors. It is possible that parent or sibling attitudes towards exercise may translate into influential modeling as social support has been identified as an important factor for levels of physical activity and dietary patterns [44]. While multi-generational studies suggest that a child's physical activity may be partly determined by genotype [22], studies regarding parent education and/or occupation status as predictors of child weight status have had mixed results [45,46]. This study may have missed other substantial physical and social environmental determinants, as we only included responses from the family interview about perceptions of safety. We were not able to incorporate social factors such as social norms related to exercise (e.g., if a family observes its neighbors exercising, then the family may be more likely to also exercise), though collective efficacy at the neighborhood level has been associated with obesity risk [47]. Finally, prior analyses of data from the randomized controlled study of the MTO data found that teenage girls and adults had increased levels of physical activity in the intervention arms [48]. In this analysis, we controlled for MTO study assignment (each of two intervention groups compared to the control group) and did not observe a significant association between study assignment and parent, sibling, and child physical activity. Our analysis differed from the analysis by Orr et al. in that we focused on younger subjects and included a broader set of covariates. The contrasting findings between our study and those reported by Orr et al. in the MTO Interim Impacts Evaluation may point to changes in the relative influences of family factors and environmental factors as a child progresses through adolescence and presumably becomes more independent.

Increasing children's physical activity would result in many health benefits. The complex interplay between variables from multiple domains that determine a child's physical activity merits further study. This study suggests that health promotion efforts to increase youth physical activity may benefit from incorporating sibling-based and family-based approaches. Several high-quality studies have demonstrated that family-based approaches are effective in preventing adolescent smoking [49]. Further research, however, is needed to develop strategies for helping family members increase each other's propensity to be physically active.

## Conflicts of Interest

The authors, whose names are listed below, certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as

honoraria; educational grants participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; or expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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