Published in final edited form as:

J Phys Act Health. 2014 July ; 11(5): 950–960. doi:10.1123/jpah.2012-0192.

Multilevel Correlates of Physical Activity for Early, Mid, and Late Adolescent Girls

Deborah Young,
Dept of Research and Evaluation, Kaiser Permanente Southern California, Pasadena, CA.

Brit I. Saksvig,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Tong Tong Wu,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Kathleen Zook,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Xia Li,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Steven Champaloux,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Mira Grieser,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Sunmin Lee,
Dept of Epidemiology and Biostatistics, University of Maryland SPH, College Park, MD.

Margarita S. Treuth
Dept of Physical Therapy, University of Maryland, Eastern Shore, Princess Anne, MD.

Abstract

Background: We examined associations among multilevel variables and girls' physical activity to determine whether they vary at different adolescent ages.

Methods: All field sites of the Trial of Activity for Adolescent Girls contributed participants from 6th (n = 1576) and 8th grades (n = 3085). The Maryland site contributed an 11th grade sample (n = 589). Questionnaires were used to obtain demographic and psychosocial information (individual- and social-level variables); height, weight, and triceps skinfold to assess body composition; interviews and surveys for school-level data; and geographical information systems and self-report for neighborhood-level variables. Moderate to vigorous physical activity minutes (MVPA) were assessed from accelerometers. Mixed models (13 individual, 5 social, 15 school, 12 neighborhood variables) were used to determine multilevel associations.

Results: Variables at individual, social, school, and neighborhood levels were associated with MVPA, but differed across grades. Lower percent body fat, higher social support from friends, and lower school math scores were associated with higher MVPA at 6th and 8th grade. Higher physical

activity self-efficacy was associated with higher MVPA at 11th grade. Only lower physical activity barriers were associated with higher MVPA at all grades.

Conclusion: MVPA is a complex behavior with fluid, multilevel correlates that differ among girls across middle and high school.

Keywords

moderate-to-vigorous physical activity; racial/ethnic diversity; multilevel models

The importance of regular physical activity for the health of all Americans has been established.[1] Unfortunately, most do not participate in sufficient physical activity. Even youth are not meeting national recommendations.[2] Using accerelometry data in the National Health and Examination Survey, Troiano et al found that only 8% of adolescents achieved the recommendations of 60 minutes per day.[2] Further, there is a precipitous decline in physical activity throughout adolescence and boys are more physically active than girls at all ages.[3] Thus, girls are at particular risk for physical inactivity and its associated chronic diseases that manifest, for the most part, in adulthood.

Previous studies have examined factors that may influence youth physical activity participation.[4] A wide range of psychosocial[5-7] and social and physical environmental factors[8-10] may influence physical activity behavior. For example, adolescent physical activity is associated with greater self-efficacy,[11,12] fewer barriers,[13] more social support,[8,14,15] greater access to recreational facilities,[16] and availability of physical activity resources.[17,18] The literature consistently finds that factors differ for boys and girls.[19-21] Patnode et al[20] and Wenthe et al[22] both found that self-efficacy and peer support correlated with physical activity in boys but not girls.

Most prior work has used analyses that fail to recognize ecologic, multilevel factors even though it is known that physical activity is determined at multiple levels.[23] Studies that simultaneously evaluate the contextual influences of physical activity using multilevel approaches are beginning to emerge.[13,17,20,24,25,26] No studies have examined how predictors may differ at varying ages during adolescence, although adolescence is a time of rapid physical and social change.

In this study, we examined potential correlates of physical activity among adolescent girls at 3 distinct time points. Physical activity was measured with an objective measure, which is considered the state of the art for physical activity assessment. Variables were selected using a social ecological framework that acknowledges physical activity is influenced by factors operating at intrapersonal, interpersonal, organizational, community, and policy levels.[27] If effective public health interventions and policies are to be implemented to halt physical activity decline, it is critical to evaluate associations across multiple levels because that is how physical activity is experienced in a girl's life.

Methods

Design

Four cross-sectional samples of girls from the Trial of Activity for Adolescent Girls (TAAG) were used. The TAAG study design[28] and trial results are published elsewhere.[29] Briefly, TAAG was a group-randomized, multisite trial designed to reduce the decline in physical activity in middle school girls. Thirty-six schools from 6 field sites participated. Girls randomly selected from class lists were recruited and measured in the winter/spring of 6th grade (2003), 8th grade (2005), and 8th grade (2006). The Maryland site girls were remeasured when they were in 11th grade (2009). Eligibility requirements were minimal: girls had to speak and read English, participate in physical education classes, and have no contraindications for participating in a submaximal exercise test. All participating institutions' Institutional Review Boards approved the study; parent permission and child assent were obtained. Staff were trained and certified before all data collection periods.

The sampling design for this study is displayed in Figure 1. Each sampling period created a cross-sectional sample, although there was overlap in 2003 and 2005 and between 2006 and 2009. About 30% (n = 985) of the girls measured in 2005 were also in the 6th grade sample. In 2006, another cross-sectional sample from all 36 middle schools was created. For this study, we only included the data from the 8th grade girls from the 6 middle schools at the Maryland site (8th grade-MD and 11th grade-MD). We include 2 8th-grade samples to be able to examine the comparability of Maryland samples to the broader geographically diverse TAAG samples.

Measures

Accelerometry.—Physical activity, the dependent variable, was measured with Actigraph accelerometers (MTI model 7164, Fort Walton Beach, FL). They were programmed to collect data in 30-second intervals. Girls wore the monitors for 1 week on the right hip at all times except while sleeping, bathing, or swimming.

Accelerometer data were reduced using methods TAAG investigators developed.[30] Occasional missing accelerometry data were replaced using previously published imputation methods based on the Expectation Maximization algorithm.[31] For the 6th grade, 8th grade, and 8th grade-MD samples, about 12 hours (11%) of data per girl were imputed;[29] for the 11th grade-MD sample 2% of the accelerometry data were imputed. Count thresholds (counts/30 second) were used to assign the interval to a physical activity intensity category: sedentary (< 50), light (51–1499), moderate (1500–2600), and vigorous (> 2600). The cutpoint of 1500 counts/30 second reflected approximately 4.6 METs, which is the metabolic equivalent of the lower end of moderate-intensity physical activity for 8th-grade girls.[30] Using these cutpoints, accumulated daily minutes of moderate to vigorous physical activity (MVPA) was determined.

Individual Level Factors.—Psychosocial variables were assessed from a student survey. *Physical activity self-efficacy* was measured from summing an 8-item instrument developed for 8th and 9th grade girls,[32,33] with Cronbach's alpha ranging from 0.81–0.84 and test-

retest correlation between 0.67 to 0.69.[34] *Perceived physical activity barriers* were assessed from the sum of 10 items adapted from a previously published instrument,[35] with an internal consistency coefficient of 0.46.[36] Participants provided 5-point Likert scale responses ranging from never to very often to items such as "physical activity is boring," "I don't know how to do the physical activity that I want to do," and "I don't have time to do physical activity." *Physical activity outcome-expectancy value* was measured from 9 items consisting of belief and corresponding value statements.[33,35,37,38] Each belief item was multiplied by its value and results were summed to create a score. Cronbach's alpha ranged from 0.92–0.94 and the test-retest correlation was 0.58.[34] *Physical activity enjoyment* was assessed from 7 items taken from the 12-item Physical Activity Enjoyment Scale (PACES).[39] TAAG investigators reported internal consistency of 0.86.[36] *Physical education enjoyment* was assessed by asking participants to rate the sentence "I enjoy PE" on 5-point scale ranging from "disagree a lot" to "agree a lot." *Depressive symptoms* was measured from the Center for Epidemiological Studies-Depression Scale (CES-D).[40] For 11th grade, participants completed the 8-item *global esteem* scale, the 6-item global *physical self-concept* scale, and the 6-item *body fat* scale from the Physical Self-Description Questionnaire.[41] We found Cronbach's alpha for the scales to be 0.85. 0.93, and 0.93, respectively.

Data collectors measured height and weight after the girls removed their shoes and heavy clothing. Height was measured to the nearest mm using a Shorr measuring board. Body weight was measured to the nearest 0.1 kg with a calibrated scale. Body mass index (BMI; kg/m^2) was calculated. Triceps skinfold thickness was measured and a previously developed equation was used to estimate percent fat.[42] Every 15th participant was duplicate measured by a master trainer; if values differed by more than 10% staff were recertified.

Girls self-identified as non-Hispanic white, black or African American, Hispanic or Latino, Asian/Pacific Islander, American Indian or Alaska Native, or other. Girls' report of participation in the subsidized school lunch program and parental education level were used as proxies for socioeconomic status.

Social Level Factors.—Social support for physical activity was assessed using family and peer social support scales.[43] The peer scale consisted of 3 items, with test-retest correlation of 0.86 and internal consistency ranging from 0.74– 0.79.[34] The family support scale had 5 items, with questions including "during a typical week, how often has a member of your household (for example, your father, mother, brother, sister, grandparent or other relative) encouraged you to do physical activities or sports." Two questions related to adult supervision after school were operationalized as time spent home alone.[44] Two scales were developed by TAAG investigators to assess perceived support of girls' physical activity in school from teachers and boys.[45] The teachers' scale consisted of 2 items and the boys' scale included 3 items. The Cronbach's alpha for the scales were 0.82 and 0.66 for teachers and boys, respectively.[46]

A social networks instrument was administered in 11th grade, which asked the girls to identify her 3 closest friends and respond to questions about physical activity with these friends.[47] For this study we used the question "how often are you physically active or exercise with this friend?" Response options were never, hardly ever, 1–2 times a week, and

more than 1–2 times/week, and coded as 0–3. The responses for the 3 friends were summed to create a friend in social network's physical activity score.

School Level Factors.—Study staff administered a structured interview to middle school (n = 36) and high school (n = 9) principals. The middle school interview included 47 questions; the high school interview was shortened to 39 items. They included physical education policies, physical activity promotions, policies that support or constrain physical activity, transportation policies for active commuting, free play allowed before or after school or during lunch (unstructured physical activity) opportunities, and collaborations with community organizations that provide physical activity programs. The interview took 20–30 minutes to administer. Responses were coded as yes/no; each girl was linked to her school to be able to report the prevalence of girls whose school had a given policy.

Information about physical activity programs was obtained through an interview. The person responsible for scheduling school facilities recalled the programs offered during the current school year.[48] The number of programs were summed for each school and the average number of programs across schools was calculated.

Neighborhood Level Factors.—Neighborhoods were defined as the block groups surrounding participants' homes. Using ArcGIS, the girl's home was used as a geo-reference to determine the distance from participants' residence to their own school, to the nearest school, and number of parks within a 1-mile radius. Census blocks and tracts were used to attach demographic data from the 2000 US Census within a one-half mile radius of the girls' primary residence. Street grids were used to calculate a neighborhood street connectivity (alpha) index within a one-half mile radius.

Perceived access to a list of 14 physical activity facilities, including basketball courts, parks, swimming pools, tennis courts, was queried with the following question: "Is it easy to get to and from this place from home or school?" with response options of yes, no, and don't know.[49] Perceived access for each facility was positively associated with the number of objectively measured facilities within a one-half mile radius of girls' homes, with the exception of martial arts studios and dance/gymnastics clubs.[49] Five items were used to assess perceived neighborhood safety, with queries about crime, street lighting, safety to walk or jog, and seeing others playing in the neighborhood.[50] The 5-item response options ranged from "disagree a lot" to "agree a lot." Test-retest kappa coefficients for each item ranged from 0.38–0.52 among 6th and 8th grade girls.[50]

Analysis.—The variables we considered to correlate with physical activity were derived from the TAAG social ecological model, which posited that physical activity behavior results from a mix of factors across individual, social, organizational, environmental, and policy levels.[27] There was a large pool of candidate variables available, causing 2 analytic problems: (1) a large number of variables, which can cause model estimation instability; and (2) correlated variables, risking multicollinearity. Thus, a subset of variables was selected using the LASSO (least absolute shrinkage and selection operator) variable selection technique. To select a manageable number of variables, we minimized the following Euclidean sum of squared error, plus a LASSO penalty on the regression coefficients:

$$\min_{b} \sum_{i=1}^{n} \left(y_i - a - \sum_{j=1}^{p} x_{ij} b_j \right)^2 + 1 \sum_{j=1}^{p} |b_j|,$$

where $1 \sum_{j=1}^{p} |b_j|$ is the LASSO penalty, p is the number of variables in the pool, and λ is the tuning parameter, which controls the number of predictors kept in the model—the bigger λ is, the fewer variables will be selected. The dependent variable was MVPA, and individual, social, and perceived neighborhood variables were used for LASSO variable selection. Due to the fewer number of variables assessed at the school level, LASSO was not employed for this level. We ran the LASSO process for each cross-sectional sample. Table 1 displays the variables selected from the LASSO process at each time point.

The final set of variables measured at the individual level and included in the multilevel models is marked in **bold** (Table 1). Variables were included if they were selected from the LASSO procedure in at least 3 of the 4 cross-sectional samples, with the following exceptions: Race/ethnicity, sports participation, and physical activity self-efficacy were included due to the evidence base of their association with youth physical activity; perceived sidewalks on neighborhood streets was included because there were only 2 neighborhood level variables selected for the 11th grade sample and we wanted sufficient opportunity for neighborhood level variables to be represented in the models.

The school and objectively-measured neighborhood level variables to be included in multilevel models were initially chosen based on the TAAG social ecological model and existing literature. Pearson correlations were run among the school and neighborhood variables, respectively, and variables with low correlation coefficients with each other were selected.

The same set of variables was used for each of the multilevel models, with the exception of the 11th grade model. The variables global physical score, self-esteem, and physical activity friends in a girls' social network were only assessed in 11th grade. The LASSO process selected these variables, and thus, we included them.

Multilevel Modeling.—Multilevel models combining fixed-effects regression methods (individual, social, and neighborhood level variables) and generalizing the variance components (school level) were used to predict MVPA. Four multilevel models were fit using SAS PROC MIXED. Covariate terms included variables at the individual, social, and neighborhood levels, with other covariates at the school level. Although conceptually we differentiate social and neighborhood levels, they were assessed for each girl. The girls reported the social and perceived neighborhood variables and the GIS-derived neighborhood variables were measured for each girl's home address, resulting in data points for each girl. Variables measured at the level of the girl were treated as fixed effects and those measured at the level of the school were treated as random effects. Because there was no intervention effect in 2005, a modest effect in 2006,[29] and no differences in the variables included in our models between intervention and control schools, the school-level treatment condition was not included. Missing observations measured at the level of the girl were imputed by the

Sequential Regression Imputation Method.[51] About 10% of the data were imputed in the 6th and 8th grade datasets, with less than 1% imputed at 11th grade.

Statistical significance was set at $P < .05$. Because of rounding errors when compiling the tables, values displayed in the tables as $P = .05$ are described as statistically significant. We evaluated the differences in MVPA correlates by grade by reporting the significant results of each model. The similarities of the 2 data sets of 8th-grade girls were compared using nonpaired *t* tests and chi square tests.

Results

Recruitment yielded 80% and 85% of randomly-selected girls in 6th and 8th grade.[29] At the Maryland site, we recruited 92% of the randomly-selected girls comprising 8th grade-MD, and additionally measured 69 girls who were not randomly selected (to avoid excluding girls in schools with smaller class sizes). In 11th grade-MD, 81% of the girls recruited and measured were previously measured in 8th grade-MD. The recruitment methods are reported in Jones et al.[52]

The race/ethnicity composition of the samples was remarkably similar across time, with less than 50% being white and approximately 20% African American. There were fewer Hispanic participants in the Maryland-only samples and fewer students participating in the free and reduced-price meal program (Table 2). Prevalence of overweight and obesity was similar at each grade level. The average number of daily MVPA minutes was about 1 minute lower at each time point.

Table 3 displays the descriptive information for the variables used in the multilevel models. For the individual level variables, only outcome expectancies and sports team participation substantively differed, with mean scores lower at 11th grade. In contrast, 3 social variables differed. Mean scores of social support from friends and social support from family were lower and mean hours spent alone each week was higher across each grade. Neighborhood level variables were similar across grades, although mean scores for perceived access to recreational facilities were higher for the high school compared with the middle school girls.

There were statistically significant differences between the 8th grade and 8th grade-MD samples across all levels. Most of the mean differences between the 2 samples at the individual and social levels were small (eg, less than a 1-unit difference). However, some of the school and neighborhood variables between the 8th grade and 8th grade-MD substantially differed. For example, 71% of the 8th grade girls' schools had intramural sports compared with 82% of the 8th grade-MD girls' schools. In addition, the 8th grade sample neighborhoods had lower population density, the girls' homes were a further distance to school, and more parks were close to home than the 8th grade-MD sample (Table 3).

There were considerable differences between the middle schools and high schools. For instance, while 82% of the 8th grade-MD girls attended middle schools in which intramural sports programs were available, only 42% of 11th grade-MD had intramural sports at their high schools (Table 3). Unstructured physical activity opportunities before school were available for about one-half of the girls during the middle school, but only 4% of the girls

when in high school. In contrast, the number of physical activity programs in the schools was almost double in the high schools compared with the middle schools.

Table 4 displays the results of the multilevel analysis. At all time points, correlates in all levels reached statistical significance, although the variables were different. The only variable that was statistically significant at the 6th, 8th, 8th-MD, and 11th grades was physical activity barriers, an individual level variable. A higher barrier score, indicating more barriers, was associated with less MVPA. Higher percent fat was inversely associated with MVPA only in 6th and 8th grade. Greater enjoyment of physical activity at 6th and 11th grade-MD was associated with fewer MVPA minutes. Self-efficacy was associated with MVPA only in the 11th grade-MD.

At the social level, friend social support was a significant correlate at 6th and 8th grades. Positive support from boys was associated with MVPA in the 11th grade-MD, and physical activity within the participants' friendship network had a positive trend ($P = .09$). The greater amount of average time spent home alone was associated with more MVPA in 8th grade and 8th grade-MD.

School-level socioeconomic status, school academic performance, and school policies were associated with MVPA (Table 4). In the 6th and 8th grade-MD the greater proportion of students achieving state mathematics performance levels, the lower the MVPA. Positive school policies, such as intramural programs (11th grade-MD) and improving the school grounds (8th grade-MD) was associated with higher MVPA. The ability to use school grounds for unstructured free play during school was significantly associated with 6th and 8th grade MVPA.

The neighborhood environment was associated with MVPA in all samples. Greater perceived access to physical activity facilities was associated with higher MVPA in 6th grade. Fewer sidewalks was associated with greater MVPA in 11th grade-MD. Greater perception of neighborhood safety correlated with more MVPA in 8th grade and 8th grade-MD, with a trend in 11th grade-MD ($P = .08$). Shorter distance to the participant's school was associated with greater MVPA in 6th grade only, whereas greater distance to any school was associated with less MVPA in 11th grade-MD. The number of parks within a 1-mile distance from a participant's home positively correlated with MVPA in 8th grade.

Discussion

Using a social ecological model to identify multilevel variable candidates of physical activity among adolescent girls in 3 grade levels, we found correlates at individual, social, school, and neighborhood levels across grades, although the specific variables were different for each grade. Only the physical activity barriers score was consistently negatively associated with MVPA minutes in 6th grade, 8th grade, 8th grade-MD, and 11th grade-MD. To our knowledge, we are the first to include potential correlates measured at the school and neighborhood levels. This is breaking new ground by reporting that variables associated with MVPA are different during different phases of adolescence. The results demonstrate that it is important to consider both the context in which physical activity occurs and the age of the

adolescent when investigating correlates of physical activity behavior. This information may also be useful to planning interventions for adolescent girls. For example, while physical activity barriers should be addressed at all adolescent ages, interventions may want to consider strategies to increase self-efficacy only with older adolescent girls.

Other investigators have found barriers to be associated with physical activity among adolescents, even after adjusting for other psychosocial variables.[13,20,25] Patnode and colleagues found barriers to be marginally associated with objectively-measured physical activity among girls in a hierarchical model that included demographic, individual, and neighborhood variables.[20] No previous studies demonstrated this association at different time points during adolescence.

Physical activity self-efficacy, when evaluated in a multilevel context, was not associated with MVPA until the 11th grade. Although self-efficacy is typically considered a strong predictor of physical activity, this assumption may not hold up in adolescent populations. A review of physical activity correlates of children and adolescents conducted by Sallis and colleagues showed that only 7 of 13 studies found a positive association between self-efficacy and physical activity.[53] In multilevel studies, Heitzler et al[13] and Patnode et al[20] reported that self-efficacy was not associated with physical activity among adolescents. For younger adolescent girls, perhaps self-efficacy is not as important for supporting physical activity as other individual, social, and neighborhood factors. It may become a more important contribution in later adolescence and into adulthood when individuals have more control over planning their physical activity participation. In addition, self-efficacy, as well as other variables, may interact with social, school, and neighborhood variables in unique ways that we did not explore.

Although friend social support was associated with MVPA at 6th and 8th grades, family social support was not at any grade level. The Sallis et al review indicated parent support, along with support from others, was associated with physical activity among adolescents.[53] More recent work by Wenthe et al[21] and Trost et al[15] also found family support to be associated with MVPA in boys and girls, although Heitzler and colleagues did not.[13] It is possible that unmeasured confounders, such as those at the school or neighborhood levels, in the prior work explained their associations. Further, our results suggest a trend for social variables to be different at different ages; for example, the positive support for physical activity from boys scale was associated with physical activity only in 11th grade-MD while time spent home alone was associated in 8th grade and 8th grade-MD. Although interest in the opposite sex develops throughout adolescence, the older adolescent girls are likely to be more cognizant of positive cues from boys than the younger girls. The differences we found may not be detected when samples are constituted from a combination of age ranges across adolescence.

We cannot explain why, after controlling for all other variables in the model, attending a math proficient middle school was associated with lower MVPA. Contrasting with our results, evidence is emerging that suggests physical activity participation is associated with higher academic performance in youth.[54-56] However, most studies examined student-level achievement rather than school-level achievement, as we did. We speculate that high-

achieving schools may place a greater emphasis on academic requirements, taking precedence over other school subject requirements or noncurricular activities, and this emphasis may subtly influence the activity levels of their students.

We found that perceived and objective access or supportive infrastructure (eg, parks, schools) correlated with MVPA, although neighborhood sociodemographics or street connectivity did not. From a literature review, Ding and colleagues found the neighborhood features of land-use mix and residential density were most consistently associated with physical activity among adolescents.[57] They concluded that the evidence is growing to support policies to improve mixed land use, access to recreational facilities, schools, and parks, and pedestrian-friendly streets. Our results indicating associations for perceived access to facilities, perceived neighborhood safety, distance to schools, and number of parks surrounding one's residence support Ding et al's conclusions.

The association between perceived and objective access to physical activity infrastructure and MVPA differed by age group. For the 6th grade girls, greater perceived access to recreational facilities and shorter distance from home to school was associated with MVPA. The younger girls may only perceive easy access for the facilities in which they use. We previously reported that girls living closer to their school were more likely to travel by walking before and after school, and that this type of travel was associated with greater MVPA in 6th and 8th grade TAAG girls.[58,59] This may explain why distance to school was correlated with MVPA in 6th grade. However, in 8th grade fewer girls reported travel by walking before school, which may be why the associations did not remain significant. However, the 8th grade girls reported more travel by walking after school, perhaps reflecting more autonomy for older girls to walk in their neighborhoods rather than directly walking home from school. This autonomy can expand their perceptions of aspects of their neighborhood, which may explain the association between perceived neighborhood safety and MVPA in 8th and 11th grades, but not 6th grade.

The study has strengths and limitations. The samples had race/ethnic diversity and there was geographic diversity in the 6th and 8th grade samples. The participant sample size was sufficient to examine correlates at 3 distinctive grade levels. The multilevel variables were chosen based on a theoretically-derived ecological model. Physical activity was assessed using an objective measure. Limitations include the cross-sectional study design, which precludes making assumptions about causality. We cannot exclude the possibility that our results were due to innate differences in the samples. However, the similarities of the results in the 8th grade and 8th grade-MD samples minimize the likelihood of this limitation. The study was conducted between 2003 and 2009 and environmental changes during this time period, rather than differing developmental periods, may explain our results. However, (1) the results are largely consistent with the literature and (2) there were cohorts imbedded in the cross-sectional samples, minimizing this possibility. Because the 11th grade sample was limited to Maryland, there may have been insufficient local variations in the school and neighborhood level variables. Some of the objective neighborhood variables were assessed from 2000 US Census data, although the study took place in 2003–2009. Although not likely, neighborhood demographics may have changed. We only examined main effects in our multilevel models. The social ecological model posits that variables interact to influence

behavior. Because of the size of our models and the complexity of this study, we did not include interaction terms in models. Finally, while our samples are diverse, our results cannot be generalized to the US population.

In conclusion, our findings suggest that associations with physical activity occur across the individual, social, school, and neighborhood levels and differ at 6th, 8th, and 11th grades. To achieve behavior change among adolescent girls, intervention planners must not only consider psychosocial variables, but also the school and neighborhood contexts in which they live. They also must recognize that factors will differ across the adolescent developmental periods.

Acknowledgments

The authors thank the participants for their continued willingness to be part of the study. The project described was supported by Award Number R01 HL094572 from the National Heart, Lung, and Blood Institute. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Heart, Lung, and Blood Institute or the National Institutes of Health.

References

1. 2008 Physical Activity Guidelines for Americans. 2008; http://www.health.gov/paguidelines.
2. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc. 2008;40(1):181–188. doi:10.1249/mss.0b013e31815a51b3 [PubMed: 18091006]
3. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. JAMA. 2008;300(3):295–305. doi:10.1001/jama.300.3.295 [PubMed: 18632544]
4. Sallis JF. Overcoming inactivity in young people. Phys Sportsmed. 2000;28:31–32. doi:10.3810/psm.2000.10.1245
5. Dishman RK, Motl RW, Saunders R, et al. Self-efficacy partially mediates the effect of a school-based physical-activity intervention among adolescent girls. Prev Med. 2004;38:628–636. doi:10.1016/j.ypmed.2003.12.007 [PubMed: 15066366]
6. Strauss RS, Rodzilsky D, Burack G, Colin M. Psychosocial correlates of physical activity in healthy children. Arch Pediatr Adolesc Med. 2001;155:897–902. doi:10.1001/archpedi.155.8.897 [PubMed: 11483116]
7. Stucky-Ropp RC, DiLorenzo TM. Determinants of exercise in children. Prev Med. 1993;22:880–889. doi:10.1006/pmed.1993.1079 [PubMed: 8115345]
8. Anderssen N, Wold B. Parental and peer influences on leisure-time physical activity in young adolescents. Res Q Exerc Sport. 1992;63:341–348. doi:10.1080/02701367.1992.10608754 [PubMed: 1439157]
9. McKenzie TL, Sallis JF, Nader PR, Broyles SL, Nelson JA. Anglo- and Mexican-American preschoolers at home and at recess: activity patterns and environmental influences. J Dev Behav Pediatr. 1992;13(3):173–180. doi:10.1097/00004703-199206000-00004 [PubMed: 1613112]
10. Sallis JF, McKenzie TL, Alcaraz JE. Habitual physical activity and health-related physical fitness in fourth-grade children. Am J Dis Child. 1993;147:890–896. [PubMed: 8352224]
11. Dishman RK, Motl RW, Saunders R, et al. Enjoyment mediates effects of a school-based physical-activity intervention. Med Sci Sports Exerc. 2005;37:478–487. doi:10.1249/01.MSS.0000155391.62733.A7 [PubMed: 15741848]
12. Motl RW, Dishman RK, Ward DS, et al. Examining social-cognitive determinants of intention and physical activity among black and white adolescent girls using structural equation modeling. Health Psychol. 2002;21:459–467. doi:10.1037/0278-6133.21.5.459 [PubMed: 12211513]
13. Heitzler CD, Lytle LA, Erickson DJ, Barr-Anderson D, Sirard JR, Story M. Evaluating a model of youth physical activity. Am J Health Behav. 2010;34:593–606. [PubMed: 20524889]

14. Kirby J, Levin KA, Inchley J. Parental and peer influences on physical activity among Scottish adolescents: a longitudinal study. J Phys Act Health. 2011;8(6):785–793. [PubMed: 21832293]
15. Trost SG, Sallis JF, Pate RR, Freedson PS, Taylor WC, Dowda M. Evaluating a model of parental influence on youth physical activity. Am J Prev Med. 2003;25:277–282. doi:10.1016/S0749-3797(03)00217-4 [PubMed: 14580627]
16. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. Am J Prev Med. 1998;15:379–397. doi:10.1016/S0749-3797(98)00076-2 [PubMed: 9838979]
17. Millstein RA, Strobel J, Kerr J, et al. Home, school, and neighborhood environment factors and youth physical activity. Pediatr Exerc Sci. 2011;23:487–503. [PubMed: 22109776]
18. Sallis JF. Progress in behavioral research on physical activity. Ann Behav Med. 2001;23:77–78. doi:10.1207/S15324796ABM2302_1 [PubMed: 11394557]
19. Butt J, Weinberg RS, Breckon JD, Claytor RP. Adolescent physical activity participation and motivational determinants across gender, age, and race. J Phys Act Health. 2011;8(8):1074–1083. [PubMed: 22039125]
20. Patnode CD, Lytle LA, Erickson DJ, Sirard JR, Barr-Anderson D, Story M. The relative influence of demographic, individual, social, and environmental factors on physical activity among boys and girls. Int J Behav Nutr Phys Act. 2010;7:79. doi:10.1186/1479-5868-7-79 [PubMed: 21047429]
21. Wenthe PJ, Janz KF, Levy SM. Gender similarities and differences in factors associated with adolescent moderate-vigorous physical activity. Pediatr Exerc Sci. 2009;21:291–304. [PubMed: 19827453]
22. Hearst MO, Patnode CD, Sirard JR, Farbakhsh K, Lytle LA. Multilevel predictors of adolescent physical activity: a longitudinal analysis. Int J Behav Nutr Phys Act. 2012;9:8. doi:10.1186/1479-5868-9-8 [PubMed: 22309949]
23. Sallis JF, Owen N. Physical activity and behavioral medicine. Thousand Oaks, CA: Sage; 1999.
24. Duncan SC, Duncan TE, Strycker LA, Chaumeton NR. A multilevel approach to youth physical activity research. Exerc Sport Sci Rev. 2004;32:95–99. doi:10.1097/00003677-200407000-00004 [PubMed: 15243204]
25. Kelly EB, Parra-Medina D, Pfeiffer KA, et al. Correlates of physical activity in black, Hispanic, and white middle school girls. J Phys Act Health. 2010;7:184–193. [PubMed: 20484757]
26. McKay CM, Bell-Ellison BA, Wallace K, Ferron JM. A multilevel study of the associations between economic and social context, stage of adolescence, and physical activity and body mass index. Pediatrics. 2007;119:S84–S91. doi:10.1542/peds.2006-2089M [PubMed: 17272590]
27. Elder JP, Lytle L, Sallis JF, et al. A description of the social-ecological framework used in the trial of activity for adolescent girls (TAAG). Health Educ Res. 2007;22(2):155–65. [PubMed: 16855014]
28. Stevens J, Murray DM, Catellier DJ, et al. Design of the Trial of Activity in Adolescent Girls (TAAG). Contemp Clin Trials. 2005;26:223–233. doi:10.1016/j.cct.2004.12.011 [PubMed: 15837442]
29. Webber LS, Catellier DJ, Lytle LA, et al. Promoting physical activity in middle school girls: Trial of Activity for Adolescent Girls. Am J Prev Med. 2008;34:173–184. doi:10.1016/j.amepre.2007.11.018 [PubMed: 18312804]
30. Treuth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. Med Sci Sports Exerc. 2004;36:1259–1266. doi:10.1249/01.MSS.0000113666.98463.B0 [PubMed: 15235335]
31. Catellier DJ, Hannan PJ, Murray DM, et al. Imputation of missing data when measuring physical activity by accelerometry. Med Sci Sports Exerc. 2005;37:S555–S562. doi:10.1249/01.mss.0000185651.59486.4e [PubMed: 16294118]
32. Motl RW, Dishman RK, Felton G, Pate RR. Self-motivation and physical activity among black and white adolescent girls. Med Sci Sports Exerc. 2003;35(1):128–136. doi:10.1097/00005768-200301000-00020 [PubMed: 12544646]
33. Motl RW, Dishman RK, Trost SG, et al. Factorial validity and invariance of questionnaires measuring social-cognitive determinants of physical activity among adolescent girls. Prev Med. 2000;31:584–594. doi:10.1006/pmed.2000.0735 [PubMed: 11071840]

34. Lytle LA, Murray DM, Evenson KR, et al. Mediators affecting girls' levels of physical activity outside of school: findings from the trial of activity in adolescent girls. Ann Behav Med. 2009;38(2):124–136. doi:10.1007/s12160-009-9127-2 [PubMed: 20012810]
35. Taylor WC, Sallis JF, Dowda M, Freedson PS, Eason K, Pate RR. Activity patterns and correlates among youth: Differences by weight status. Pediatr Exerc Sci. 2002;14:30–44.
36. Johnson CC, Murray DM, Elder JP, et al. Depressive symptoms and physical activity in adolescent girls. Med Sci Sports Exerc. 2008;40(5):818–826. doi:10.1249/MSS.0b013e3181632d49 [PubMed: 18408618]
37. Dishman RK. The impact of behavior on quality of life. Qual Life Res. 2003;12:43–49. doi: 10.1023/A:1023517303411 [PubMed: 12803310]
38. Ajzen I The theory of planned behavior. Organ Behav Hum Decis Process. 1991;50:179–211. doi: 10.1016/0749-5978(91)90020-T
39. Motl RW, Dishman RK, Saunders R, Dowda M, Felton G, Pate RR. Measuring enjoyment of physical activity in adolescent girls. Am J Prev Med. 2001;21:110–117. doi:10.1016/S0749-3797(01)00326-9 [PubMed: 11457630]
40. Radloff LS. The use of the Center for Epidemiologic Studies - Depression Scale in adolescents and young adults. J Youth Adolesc. 1991;20:149–166. doi:10.1007/BF01537606 [PubMed: 24265004]
41. Marsh HW, Redmayne RS. A multidimensional physical self-concept and its relations to multiple components of physical fitness. J Sport Exer Psychol. 1994;16:43–55.
42. Loftin M, Nichols J, Going S, et al. Comparison of the validity of anthropometric and bioelectric impedance equations to assess body composition in adolescent girls. Int J Body Compos Res. 2007;5:1–8. [PubMed: 18163160]
43. Sallis JF, Taylor WC, Dowda M, Freedson PS, Pate RR. Correlated of vigorous physical activity for children in grades 1 through 12: Comparing parent-reported and objectively measures physical activity. Pediatr Exerc Sci. 2002;14:30–44.
44. Rushovich BR, Voorhees CC, Davis CE, et al. The relationship between unsupervised time after school and physical activity in adolescent girls. Int J Behav Nutr Phys Act. 2006;3:20. doi: 10.1186/1479-5868-3-20 [PubMed: 16879750]
45. Birnbaum AS, Evenson KR, Motl RW, et al. Scale development for perceived school climate for girls' physical activity. Am J Health Behav. 2005;29(3):250–257. doi:10.5993/AJHB.29.3.6 [PubMed: 15899688]
46. Barr-Anderson DJ, Neumark-Sztainer D, Schmitz KH, et al. But I like PE: factors associated with enjoyment of physical education class in middle school girls. Res Q Exerc Sport. 2008;79(1):18–27. [PubMed: 18431947]
47. Voorhees CC, Murray D, Welk G, et al. The role of peer social network factors and physical activity in adolescent girls. Am J Health Behav. 2005;29:183–190. doi:10.5993/AJHB.29.2.9 [PubMed: 15698985]
48. Young DR, Steckler A, Cohen S, et al. Process evaluation results from a school- and community-linked intervention: the Trial of Activity for Adolescent Girls (TAAG). Health Educ Res. 2008;23(6):976–986. doi:10.1093/her/cyn029 [PubMed: 18559401]
49. Scott MM, Evenson KR, Cohen DA, Cox CE. Comparing perceived and objectively measured access to recreational facilities as predictors of physical activity in adolescent girls. J Urban Health. 2007;84:346–359. doi:10.1007/s11524-007-9179-1 [PubMed: 17401691]
50. Evenson KR, Birnbaum AS, Bedimo-Rung AL, et al. Girls' perception of physical environmental factors and transportation: reliability and association with physical activity and active transport to school. Int J Behav Nutr Phys Act. 2006;3:28. doi:10.1186/1479-5868-3-28 [PubMed: 16972999]
51. Raghunathan TE, Lepkowski JM, VanHoewyk J, Solenberger PA. A multivariate technique for multiply imputing missing values using a sequence of regression models. Surv Methodol. 2001;27:85–95.
52. Jones L, Saksvig BI, Grieser M, Young DR. Recruiting adolescent girls into a follow-up study: benefits of using a social networking website. Contemp Clin Trials. 2012;33(2):268–272. doi: 10.1016/j.cct.2011.10.011 [PubMed: 22101207]

53. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000;32(5):963–975. doi: 10.1097/00005768-200005000-00014 [PubMed: 10795788]

54. Singh A, Uijtdewilligen L, Twisk JW, van Mechelen W, Chinapaw MJ. Physical activity and performance at school: a systematic review of the literature including a methodological quality assessment. Arch Pediatr Adolesc Med. 2012;166:49–55. doi:10.1001/archpe-diatrics.2011.716 [PubMed: 22213750]

55. Rasberry CN, Lee SM, Robin L, et al. The association between school-based physical activity, including physical education, and academic performance: a systematic review of the literature. Prev Med. 2011;52:S10–S20. doi:10.1016/j.ypmed.2011.01.027 [PubMed: 21291905]

56. Trudeau F, Shephard RJ. Physical education, school physical activity, school sports and academic performance. Int J Behav Nutr Phys Act. 2008;5:10. doi:10.1186/1479-5868-5-10 [PubMed: 18298849]

57. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth a review. Am J Prev Med. 2011;41(4):442–455. doi:10.1016/j.amepre.2011.06.036 [PubMed: 21961474]

58. Saksvig BI, Catellier DJ, Pfeiffer K, et al. Travel by walking before and after school and physical activity among adolescent girls. Arch Pediatr Adolesc Med. 2007;161(2):153–158. doi:10.1001/archpedi.161.2.153 [PubMed: 17283300]

59. Saksvig B, Webber LS, Elder JP, et al. A cross-sectional and longitudinal study of travel by walking before and after school among eighth-grade girls. J Adolesc Health. 2012;51(6):608–14. [PubMed: 23174472]

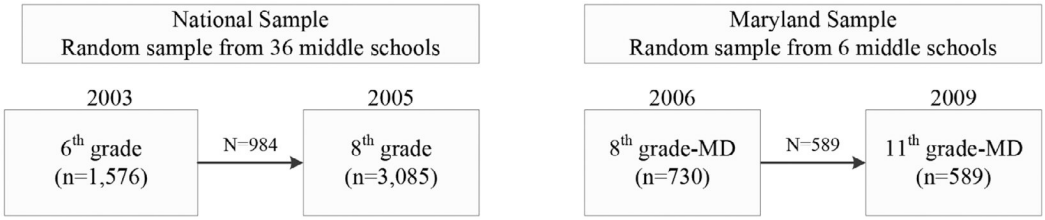

Figure 1 —.
Sampling design for study participants.

Table 1

Variables at Each Time Point That Were Selected Across Individual, Social, and Neighborhood Levels, Measured at the Individual Level*

	6th grade 2003 All sites	8th grade 2005 All sites	8th grade 2006 MD only	11th grade 2009 MD only
Individual level				
White	√			
African American	√	√		
Hispanic		√		
Parental education	√			
Participation in the school free or reduced price lunch program	√			
Body mass index[a]	√		√	√
Percent fat	√	√	√	√
School sports team participation	√			
Outside school sports team participation	√		√	
Currently taking a physical education class		√		
Difficulty getting home from a community activity	√	√		
Self-management strategies	√	√	√	√
Physical activity self-efficacy	√	√		
Physical activity enjoyment	√	√	√	√
Physical activity barriers	√	√	√	√
Outcome expectancies (sum)	√	√	√	√
Outcome expectancies (value)[b]	√	√	√	√
Physical education enjoyment	√	√	√	
Depressive symptoms	√	√	√	√
Global physical score				√
Self-esteem				√
Social level				
Provide physical activity social support to friends	√	√		
Physical activity social support from friends	√	√	√	√
Physical activity social support from family	√	√	√	
Positive support for physical activity from teachers	√	√	√	

	6th grade 2003 All sites	8th grade 2005 All sites	8th grade 2006 MD only	11th grade 2009 MD only
Positive support for physical activity from boys	√	√	√	√
Hours spent alone after school per week	√	√	√	√
Friends in social networks who are physically active				√
Neighborhood level				
Perceived access to recreational facilities	√	√		√
Perceived places to go in walking distance of home	√	√	√	
Perceived sidewalks on neighborhood streets	√			√
Perceived bicycle or walking trails in neighborhood	√			
Perceived safety to walk or jog in neighborhood	√	√	√	
Walker and bikers seen in neighborhood			√	
Perceived crime in neighborhood		√		
Children seen playing outdoors in neighborhood	√	√		
Interesting things to view in neighborhood	√			
Neighborhood streets are well-lit		√		

[*] Variables were chosen from the least absolute shrinkage and selection operator variable selection technique. Those identified in **bold** were used in the multilevel models.

Note. 6th grade (2003): 30 of 46 candidate predictors were statistically significant ($P < .05$); 8th grade (2005): 25 of 46 candidate predictors were statistically significant; 8th grade (2006): 18 of 46 candidate predictors were statistically significant; 11th grade (2009): 16 of 78 candidate predictors were statistically significant

[a] Calculated as weight in kilograms divided as height in meters squared; not included in model because of high correlation with percent fat.

[b] Not included in model because of high correlation with outcome expectancies (sum).

Table 2

Demographic, Body Composition, and Physical Activity Information for the Trial of Activity for Adolescent Girls (TaAG and TAAG2): 6th Grade (2003, All Sites), 8th Grade (2005, All Sites), 8th Grade (2006, Maryland Site Only), and 11th Grade (2009, Maryland Site Only)[a]

	6th grade 2003 all sites	8th grade 2005 all sites	8th grade 2006 Maryland site	11th grade 2009 Maryland site
Sample size	n = 1576	n = 3085	n = 730	n = 589
Age, y	12.0 (0.5)	14.0 (0.5)	13.8 (0.5)[b]	16.9 (0.4)
White, n (%)	698 (44%)	1409 (46%)	325 (45%)[b]	279 (47%)
African American, n (%)	351 (22%)	671 (22%)	172 (24%)	126 (21%)
Hispanic, n (%)	343 (22%)	649 (21%)	103 (14%)	78 (13%)
Other race/ethnicity, n (%)	184 (12%)	356 (16%)	129 (18%)	106 (18%)
Participation in the free or reduced price lunch program, n (%)	664 (42%)	1176 (38%)	209 (29%)[b]	125 (21%)
Body mass index	20.9 (4.9)	22.8 (5.3)	22.6 (5.2)	23.9 (5.3)
Percent fat	28.0 (9.3)	31.5 (8.4)	31.0 (8.8)	31.1 (6.9)
Overweight status, n (%)[c]	534 (34%)	1078 (35%)	249 (34%)	174 (30%)
Obese status, n (%)[c]	265 (17%)	535 (17%)	128 (18%)	83 (14%)
Daily minutes of moderate to vigorous physical activity	23.7 (11.7)	22.2 (11.2)	21.3 (10.7)[b]	20.1 (11.8)

[a] Data are expressed as mean (standard deviation) except where otherwise indicated.

[b] *P*-value < .05 between 8th grade 2005 all sites and 8th grade 2006 Maryland site.

[c] Overweight and obesity defined as ≥ 85th and ≥ 95th age and sex based percentiles, respectively.

Table 3

Individual-, School-, and Neighborhood-Level Variables for the Trial of Activity for Adolescent Girls (TAAG and TAAG2): 6th Grade (2003, All Sites), 8th Grade (2005, All Sites), 8th Grade (2006, Maryland Site Only), and 11th Grade (2009, Maryland Site Only)[a]

	6th grade 2003 all sites	8th grade 2005 all sites	8th grade 2006 Maryland site	11th grade 2009 Maryland site
Individual level				
Physical activity enjoyment	30.4 (5.7)	29.3 (5.9)	28.9 (5.8)	28.5 (5.8)
Physical activity barriers	20.6 (6.4)	20.9 (6.4)	21.7 (6.2)[b]	21.9 (6.1)
Physical activity outcome expectancies	156.5 (48.8)	157.6 (47.4)	157.5 (46.2)	148.4 (47.5)
Physical activity self-efficacy	29.6 (6.3)	29.4 (6.3)	28.4 (6.5)[b]	28.4 (6.3)
Physical activity self-management strategies	26.2 (6.4)	26.2 (6.3)	26.2 (6.1)	26.7 (5.9)
Physical education enjoyment	4.1 (1.2)	3.7 (1.3)	3.6 (1.3)	3.6 (1.3)
Depressive symptoms	14.8 (9.5)	15.4 (9.8)	15.9 (9.6)	15.4 (9.0)
Number of sports teams played on outside of school	2.7 (2.3)	2.3 (1.8)	2.3 (1.8)	0.7 (1.2)
Global physical score[c]	–	–	–	19.5 (7.4)
Self-esteem[c]	–	–	–	7.8 (6.5)
Social level				
Social support from friends	9.2 (2.9)	8.6 (2.9)	8.4 (3.0)	7.9 (3.1)
Social support from family	17.0 (4.4)	15.9 (4.9)	15.4 (5.0)[b]	13.9 (4.8)
Hours spent alone per week	5.8 (7.7)	6.9 (7.9)	7.9 (8.2)[b]	10.0 (8.9)
Positive support for physical activity from teachers	7.8 (2.3)	7.6 (2.3)	7.3 (2.3)[b]	7.2 (2.3)
Positive support for physical activity from boys	9.9 (3.3)	10.0 (3.2)	10.1 (3.2)	10.2 (3.0)
Friend in social network's physical activity[c]	–	–	–	3.8 (2.1)
School level				
Percent students in school passing state math examination	52.5 (25.3)	60.5 (23.4)	56.7 (15.8)[b]	88.2 (6.2)
Girls whose school has bike racks, n (%)	1348 (88%)	2685 (92%)	727 (100%)[b]	417 (92%)
Number of weeks per year physical education is required	29.9 (9.4)	27.5 (9.3)	32.6 (4.6)[b]	36.4 (5.7)
Girls whose school has interscholastic sports, n (%)	1309 (83%)	2616 (85%)	599 (82%)	412 (91%)

	6th grade 2003 all sites	8th grade 2005 all sites	8th grade 2006 Maryland site	11th grade 2009 Maryland site
Girls whose school has intramural sports, n (%)	1080 (69%)	2191 (71%)	599 (82%)[b]	189 (42%)
Girls whose school had grounds changes in prior year, n (%)	532 (35%)	1290 (42%)	239 (33%)[b]	175 (39%)
Girls whose school had policy changes encouraging physical activity in prior year, n (%)	259 (16%)	754 (24%)	112 (15%)[b]	0 (0%)
Girls whose school had unstructured physical activity opportunities before school, n (%)	783 (50%)	1507 (49%)	358 (49%)	18 (4%)
Girls whose school had unstructured physical activity opportunities during school, n (%)	1003 (64%)	1694 (55%)	251 (35%)[b]	141 (31%)
Girls whose school had unstructured physical activity opportunities after school, n (%)	406 (26%)	867 (28%)	490 (67%)[b]	108 (24%)
Number of physical activity programs in the girl's school	10.2 (4.5)	12.9 (8.6)	12.5 (4.7)	20.7 (2.2)
Neighborhood level				
Perceived access to recreational facilities	6.2 (3.3)	6.9 (3.4)	6.6 (3.1)	8.2 (3.0)
Perceived places to go in walking distance from home	3.6 (1.3)	3.6 (1.3)	3.6 (1.4)	3.4 (1.4)
Perceived sidewalks in neighborhood	3.5 (1.6)	3.6 (1.6)	3.9 (1.5)[b]	3.9 (1.5)
Perceived safety to walk or jog in neighborhood	4.0 (1.3)	3.9 (1.3)	3.9 (1.2)	4.0 (1.2)
Percent Hispanic households in neighborhood block group	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)[b]	0.1 (0.1)
Percent African American households in neighborhood block group	0.2 (0.3)	0.2 (0.2)	0.2 (0.2)	0.2 (0.2)
Households below poverty in neighborhood block group[d]	0.1 (0.1)	0.1 (0.1)	100.3 (85.0)	102.5 (88.9)
Population density, 1/2 mile surrounding girl's residence	4373.5 (3782.3)	4812.6 (4879.0)	5999.7 (6082.6)[b]	6041.9 (6835.5)
Street connectivity index	0.2 (0.1)	0.3 (0.1)	0.2 (0.1)[b]	0.2 (0.1)
Distance to girl's school, miles	2.7 (2.0)	2.7 (2.1)	2.1 (2.1)[b]	2.5 (2.7)
Number of parks within 1 mile of girl's residence	3.6 (3.8)	3.5 (4.0)	0.8 (0.9)[b]	0.7 (0.8)
Closest distance to any school, miles	0.8 (0.8)	0.7 (0.7)	0.5 (0.5)[b]	0.5 (0.5)

[a] Data are expressed as mean (standard deviation) except where otherwise noted.

[b] *P*-value < .05 between 8th grade 2005 all sites and 8th grade 2006 Maryland site.

[c] Social network variable only assessed in 11th grade.

[d] Households below poverty level determined by percentage in 2003 and 2005 and by number of households in 2006 and 2009.

Table 4

Multilevel Model Results of Individual-, School-, and Neighborhood-Level Variables Associated With Minutes of Moderate-to-Vigorous Physical Activity in the Trial of Activity for Adolescent Girls (TAAG and TAAG2): 6th Grade (2003, All Sites), 8th Grade (2005, All Sites), 8th Grade (2006, Maryland Site Only), and 11th grade (2009, Maryland Site Only)[a]

	6th grade 2003 all sites		8th grade 2005 all sites		8th grade 2006 MD only		11th grade 2009 MD only	
	Parameter (SE)	***P***	**Parameter (SE)**	***P***	**Parameter (SE)**	***P***	**Parameter (SE)**	***P***
Individual level								
White	1.77 (1.03)	.08	2.32 (0.68)	<.01	1.15 (1.25)	.36	0.31 (1.44)	.83
African American	1.08 (1.2)	.37	0.82 (0.85)	.34	2.25 (1.46)	.12	−0.73 (1.74)	.68
Hispanic	−0.12 (1.11)	.92	1.45 (0.78)	.06	0.02 (1.67)	.99	−0.83 (1.90)	.66
Percent Fat	−0.16 (0.03)	<.001	−0.10 (0.03)	<.001	−0.09 (0.05)	.08	−0.06 (0.08)	.43
Sports team participation outside of school	0.18 (0.13)	.17	0.04 (0.12)	.74	0.31 (0.24)	.20	0.00 (0.48)	.99
Physical activity enjoyment	−0.12 (0.06)	.05	0.06 (0.05)	.21	−0.00 (0.09)	.92	−0.31 (0.11)	.01
Physical activity barriers	−0.13 (0.06)	.02	−0.15 (0.04)	<.001	−0.20 (0.09)	.04	−0.37 (0.11)	<.001
Physical activity outcome expectancies	−0.01 (0.01)	.02	−0.00 (0.00)	.27	0.00 (0.01)	.92	−0.02 (0.01)	.06
Physical activity self-efficacy	0.02 (0.06)	.77	0.00 (0.04)	.97	0.09 (0.10)	.34	0.26 (0.11)	.03
Physical activity self-management strategies	0.07 (0.06)	.28	0.05 (0.04)	.24	−0.04 (0.09)	.68	0.01 (0.95)	.95
Physical education enjoyment	0.52 (0.29)	.07	0.32 (0.19)	.09	0.57 (0.39)	.14	−0.00 (0.41)	.99
Depressive symptoms	0.05 (0.04)	.20	0.05 (0.02)	.03	0.01 (0.05)	.80	0.01 (0.07)	.89
Self-esteem	N/A		N/A		N/A		0.16 (0.11)	.14
Global physical score	N/A		N/A		N/A		0.14 (0.10)	.17
Social level								
Social support from friends	0.35 (0.13)	<.01	0.19 (0.09)	.04	0.32 (0.18)	.08	0.28 (0.23)	.22
Social support from family	0.03 (0.09)	.70	−0.01 (0.06)	.84	−0.08 (0.11)	.45	0.07 (0.13)	.61
Average time spent alone per week	0.05 (0.04)	.19	0.08 (0.03)	<.01	0.12 (0.06)	.04	0.05 (0.06)	.43
Positive support for physical activity from teachers	−0.20 (0.14)	.16	−0.16 (0.10)	.09	−0.19 (0.20)	.35	−0.11 (0.24)	.65
Positive support for physical activity from boys	−0.15 (0.10)	.14	0.02 (0.07)	.76	−0.13 (0.15)	.39	0.38 (0.19)	.04
Friend in social network's physical activity	N/A		N/A		N/A		0.45 (0.26)	.09
School level								
Percent students participating in free or reduced lunch program	−0.02 (0.03)	.54	−0.05 (0.03)	.10	−1.45 (0.35)	<.001	0.11 (0.18)	.53
Percent students passing state math test	−0.11 (0.03)	<.001	−0.07 (0.04)	.07	−0.85 (0.20)	<.001	0.32 (0.29)	.28

	6th grade 2003 all sites		8th grade 2005 all sites		8th grade 2006 MD only		11th grade 2009 MD only	
	Parameter (SE)	***P***	**Parameter (SE)**	***P***	**Parameter (SE)**	***P***	**Parameter (SE)**	***P***
Number of weeks per year physical education is required	0.01 (0.08)	.89	0.15 (0.08)	.06	−0.41 (0.22)	.06	–	
Bike rack availability at school	0.92 (2.05)	.65	−0.09 (2.23)	.97	–		5.63 (4.28)	.19
Interscholastic programs at school	−0.02 (1.57)	.99	0.27 (2.50)	.91	–		3.13 (3.99)	.43
Intramural programs at school	−0.18 (1.34)	.89	−0.59 (1.36)	.66	–		7.35 (2.99)	.01
School grounds changes in past year	−1.14 (1.24)	.36	0.50 (1.20)	.68	16.76 (4.38)	<.001	3.08 (2.13)	.15
School policy changes encouraging physical activity	−1.09 (1.61)	.50	−0.99 (1.77)	.57	−2.93 (2.34)	.21	–	–
Unstructured free play before school	−0.97 (1.39)	.49	0.99 (1.22)	.41	–		−5.79 (3.16)	.07
Unstructured free play during school	3.08 (1.33)	.02	3.33 (1.29)	.01	–		–	
Unstructured free play after school	0.29 (1.29)	.82	−2.62 (1.49)	.08	–		–	
Number of programs in school	0.08 (0.17)	.63	0.04 (0.08)	.61	–		–	
Neighborhood level								
Perceived access to recreational facilities	0.21 (0.10)	.03	0.02 (0.07)	.81	−0.03 (0.16)	.86	−0.04 (0.21)	.86
Perceived places within walking distance of home	−0.07 (0.24)	.77	0.11 (0.17)	.51	0.39 (0.35)	.27	−0.15 (0.42)	.72
Perceived sidewalks in neighborhood	0.06 (0.21)	.77	−0.05 (0.15)	.76	−0.10 (0.34)	.76	−1.40 (0.42)	<.001
Perceived safety to walk in neighborhood	0.22 (0.26)	.39	0.41 (0.18)	.03	0.78 (0.39)	.05	0.80 (0.46)	.08
African American households	−3.38 (2.50)	.18	−2.02 (2.05)	.32	4.17 (3.03)	.17	−3.17 (4.02)	.43
Hispanic households	−6.81 (9.04)	.45	2.39 (7.64)	.75	5.92 (6.98)	.40	−5.35 (8.38)	.52
Households below poverty	8.26 (6.91)	.23	−0.27 (6.70)	.97	−0.01 (0.01)	.06	0.00 (0.01)	.67
Population density	0.00 (0.00)	.65	−0.00 (0.00)	.39	−0.00 (0.00)	.51	0.00 (0.00)	.36
Street connectivity index	−2.97 (4.99)	.55	−2.04 (2.42)	.40	0.69 (6.66)	.92	−7.25 (9.58)	.45
Distance to girl’s school	−0.34 (0.17)	.05	0.00 (0.11)	.97	−0.26 (0.26)	.32	−0.38 (0.26)	.15
Number of parks 1 mile of girl’s residence	0.19 (0.12)	.13	0.37 (0.09)	<.001	0.08 (0.80)	.92	0.15 (0.85)	.86
Closest distance to any school	0.09 (0.50)	.85	0.32 (0.47)	.50	0.04 (1.02)	.97	2.38 (1.17)	.04

[a]Data are expressed as regression coefficient (standard error).

Abbreviations: N/A, not assessed at this grade level; –, variable not included in model because of nonpositive Hessian matrix.