Multicontextual Correlates of Adolescent Leisure-Time Physical Activity

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Abstract

Background—Adolescent moderate to vigorous physical activity (MVPA) is influenced by many factors. MVPA-promotion interventions would fare better if these multiple determinants were better understood.

Purpose—To simultaneously assess overall and relative contributions of factors from personal, family, friend, school, and neighborhood contexts to adolescent MVPA. It was hypothesized that: (1) key correlates would emerge in each context; (2) factors from more- versus less-proximal contexts would relate more strongly to MVPA.

Methods—Students in grades 6–12 (*n*=2793; mean age=14.4 [SD=2.0] years; 53% girls) were recruited from 20 Minnesota public schools in 2009–2010 to participate in the Eating and Activity in Teens 2010 study. Regression analyses conducted in 2013 examined factors related to weekly MVPA. Data were collected from adolescent participants, their parents and friends, school teachers and administrators, and GIS sources.

Results—Fifty multicontextual factors explained 25% of MVPA variance for boys and 27% for girls. Personal factors (e.g., self-efficacy) were most predictive of MVPA, followed by social factors (e.g., support for PA); environmental factors (e.g., access to PA resources) were least predictive of adolescent PA. Gender differences emerged for several predictors (e.g., in mutually adjusted analyses, MVPA among girls, but not boys, related positively to distance to trails and MVPA among female friends and fathers, and related negatively to perceived barriers).

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Conclusions—Stronger linkages exist between adolescent MVPA and more-proximal (personal, family, and friend) factors compared to more-distal (school and neighborhood) factors, suggesting the importance of working with adolescents, their families, and friends to promote PA.

Introduction

Physical activity (PA) benefits health at all ages.[1–3] PA decreases substantially during adolescence, elevating health risks throughout adulthood.[4] Although the rate of adolescent PA decrease is comparable for boys and girls,[5] this decline occurs earlier for girls (aged 9–12 years) versus boys (aged 13–16 years),[6] girls engage in less PA at all ages,[5] and PA determinants differ by gender.[7] Attempts to prevent or reverse PA decline will be more successful with an understanding of the factors contributing to PA among adolescent girls and boys. Socialecologic models have conceptualized how PA influencers operate in concert[8–10]; however, few studies have simultaneously assessed the contributions to adolescent PA of factors at multiple levels.[11–13]

The present study sought to simultaneously assess overall and relative contributions to adolescent moderate to vigorous PA (MVPA) of factors from personal, family, friend, school, and neighborhood contexts. Based on socialecologic theory and previous research,[13–15] this study was designed around two inter-related premises: (1) factors from multiple contexts will explain a greater proportion of variance in adolescent PA than any single factor or context; and (2) to design interventions to increase PA, one must understand how factors within different contexts relate to each other and to PA.

Some previous research has included, in addition to adolescent self-reports, data supplied by parents and objectively measured environmental data.[12,13] The present study additionally provides data from participants' friends, school administrators, and educators. This study also examines a large, diverse sample of adolescents and assesses both unique and collective contributions to adolescent MVPA by all assessed factors.

Methods

Participants

Data were gathered through two coordinated studies involving adolescents and their parents: Eating and Activity in Teens (EAT) 2010 and Project Families and Eating and Activity among Teens (F-EAT). EAT 2010 participants included 2793 students in grades 6–12 (mean age, 14.4 ± 2.0 years) recruited during 2009–2010 from 20 public middle and high schools serving socioeconomically and racially/ethnically diverse communities in Minneapolis/St. Paul, Minnesota. Parents of all EAT 2010 participants were invited to complete Project F-EAT, with 78% responding.

The sample was diverse in terms of race/ethnicity (18.9% white, 29.0% African American or Black, 19.9% Asian American, 16.9% Hispanic, 3.7% Native American, and 11.6% mixed or other) and SES (71% of participants qualified for free or reduced-price school meals), 53.2% were girls, and 53.9% were enrolled in grades 9–12. As the sample was recruited from urban areas (i.e., city schools), the sample's demographic composition differs from

Minnesota's overall profile, with the study containing a larger proportion of non-white and low-SES individuals. Sampling procedures are described in greater detail elsewhere.[16] EAT 2010 examined factors associated with adolescents' diets, PA, and other weight-related outcomes via surveys, anthropometric measures, and GIS.[16] All procedures were approved by the University of Minnesota's IRB and the participating school districts.

Measures

Measures have been described previously[17–20] and were gathered via adolescent-, parent-, friend-, school personnel-report, and objective measurement; specific variables provided by each source are detailed below and in Table 1.

Adolescent-report—Constructs assessed via adolescent survey included: MVPA (assessed via modified[21] Leisure Time Exercise Questionnaire),[22] PA self-efficacy, perceived PA barriers, PA enjoyment, PA self-management, and sports team participation. Adolescents also reported perceptions of parents' PA, friend and family support for PA, and neighborhood safety (Table 1). Adolescent self-reported demographic information included gender, age, and race/ethnicity. SES was determined via a previously described algorithm based on parental educational level, parental employment status and eligibility for both public assistance and free/reduced-price school meals.[23]

Parent-report—Of the 2793 adolescent participants, 2382 had at least one parent respond to a survey assessing PA resources available at home, their own PA behavior, and their support for the adolescent's PA. Although 1327 participants had both parents complete the survey, for the present analyses, only the primary parent's responses are considered in order to achieve independent data that best describe the usual home environment. Determination of which parent is considered the primary parent is described in greater detail elsewhere[17]; additional details describing the parent-report portion of this study have been previously published.[24]

Friend-report—Friends' data could be linked because participants identified up to six close friends (three of each gender) within their school. For all nominated friends also enrolled in the study, data regarding their participation in total MVPA per week and participation in sports teams were utilized in the present study to assess the relationship between friend PA participation and MVPA behavior by target adolescent. Additional details describing the friend-report portion of this study have been previously published.[20]

School personnel-report—School administrators and physical education (P.E.) teachers provided information on school policies regarding promotion of PA and availability of PA resources.

Objectively measured neighborhood environment—Neighborhood data were acquired via GIS data sources (e.g., U.S. Census data) and are described in greater detail elsewhere.[23] These data provided information on neighborhood factors that could inhibit or promote PA, including: distance to parks, trails, and fitness centers; percent of nearby area comprised of green/open space; measures of urbanicity (transit stops and street access

points); crime; and demographics (e.g., median household income and proportion of population aged <18 years). Distances used in analyses were street network distances, except in the case of parks, for which straight-line distances were used. Each neighborhood access variable was created uniquely for each participant using buffers centered at the participant's home address. All distance variables were derived using the automobile-accessible road network between a participant's home and the nearest destination. Additional information on GIS methodology has been previously published.[25] Buffer size was 1600 meters, as used in previous work related to adolescent physical activity.[25,26] For Census variables, data were analyzed at the tract level. Police department data were used to determine counts of personal and property crimes committed in 2010. Uniform Crime Report (UCR) crime counts were obtained by neighborhood (ranging from 48 hectares to 387 hectares [mean=170 (SD=77) hectares]) for Minneapolis and by grid zones (ranging from 17 hectares to 381 hectares [mean=68 (SD=37) hectares]) for Saint Paul in 2010. These analyses use continuous crime rates standardized by size of neighborhood (i.e., crimes per hectare).

Analyses

Analyses were conducted in 2013 using SAS version 9.2, 2008 (SAS Institute Inc., Cary NC). In total, 50 predictor variables representing characteristics of adolescents' environments and personal factors were examined for their association with MVPA. Prior to examining associations, it was determined that model fit (i.e., Bayesian information criterion) was not improved by including random effects for clustering at the school or census tract (i.e., neighborhood) level when predicting MVPA, thus ordinary least squares regression assuming independent observations was used for all subsequent analyses. Separate linear regression models were used to examine relationships between each predictor and MVPA. A single regression model simultaneously including all 50 predictors was fit. This mutually adjusted model included variables from multiple contexts. It is likely the case that some variables influenced others in the model. For example, neighborhood green space may influence parents' PA with the adolescent. Thus, the resulting β coefficients from this mutually adjusted model are direct effects unmediated and unconfounded by other variables. A β coefficient for neighborhood green space in the regression model that includes parental PA represents the direct association between green space and MVPA unmediated by parental PA.

Through mutual adjustment, the potentially most salient set of variables independently and directly associated with MVPA could be identified. To summarize the contribution of different contexts (personal, family, friends, school, and neighborhood) to predicting MVPA, adjusted R^2 values (i.e., proportion of variance explained by predictors adjusting for the number of predictors) were obtained from separate regression models including the demographic variables and (1) all 50 predictors; (2) five personal predictors; (3) seven family predictors; 4) five friend predictors; (5) 14 school predictors; or (6) 19 neighborhood predictors.

Owing to the use of multiple data sources, missing data varied by environmental variable as follows: 0%–11% for the EAT 2010 survey, 15%–21% for the parent/caregiver survey,

40%–44% for friendship nominations, 0%–1% for school personnel surveys, and 2%–10% for GIS data. To avoid dropping adolescent participants from the full analytical sample, multiple imputation for missing variables was implemented using Proc MI in SAS.[27,28] Twenty datasets were generated with missing data imputed under a multivariate normality and missing-at-random assumption. All regressions were performed across all imputed datasets and results were combined and summarized using Proc MIANALYZE in SAS, which utilizes Rubin's rule[27] (i.e., combining the average of the SEs with the SD of the β estimates across all imputed datasets) to incorporate uncertainty due to the missing values. Simulation studies show decreased bias and improved efficiency using multiple imputation versus other techniques for handling missing data even when the missing portion for some variables is as large as 50%.[29,30]

Results

Overall, boys engaged in 6.7 (SD=4.9) hours/week of MVPA and girls participated in 5.0 (SD=4.4) hours/week. Regression analyses identified variables from each context (personal, family, friends, school, and neighborhood) related to boys' and/or girls' MVPA. Results are presented first for variables that significantly related to MVPA in individual regression analyses, not adjusting for the effects of other predictors except demographics; next, variables that significantly related to MVPA adjusting for the effects of all other variables are presented (Table 2).

Personal Context

All five personal variables were significant predictors at the $p<0.0001$ level for both boys and girls in the expected direction (i.e., higher self-efficacy, self-management, PA enjoyment, and sport participation, and lower perceived barriers were associated with more MVPA.)

Family Context

Of the seven family variables, five positively correlated with MVPA for both boys and girls: parents' self-reported PA, perception of mom's PA, perception of dad's PA, perception of parent assistance for PA, and perception of family support for PA. Among girls only, access to PA resources in the home/yard positively related to MVPA. Among boys only, amount of time that parents spent being physically active together with them was positively related to MVPA.

Friend Context

Of the five examined friend variables, two were positively correlated with MVPA for both boys and girls: adolescents' perceived friend support for/participation in PA and weekly MVPA reported by female friends. MVPA reported by male friends was also positively associated with MVPA for girls. For boys, having more male friends participate in team sports positively related to their own MVPA.

School Context

Girls and boys currently taking P.E. engaged in more MVPA compared with peers not taking P.E. For girls, having access to outdoor PA facilities at school correlated positively with MVPA and being enrolled at schools where a late bus was available for students staying after school for academic, club, or disciplinary reasons correlated negatively with MVPA.

Neighborhood Context

After adjusting for sociodemographic variables, girls with homes located amidst a higher-than-median level of green space reported approximately 30 minutes more weekly MVPA than those with homes located in areas with below-median level of green space. Girls' MVPA was lower if they lived on/near busy streets (as reflected by a high density of transit stops and access points), if they lived in an impoverished neighborhood, and if they had high population density within a mile of home. There were no significant neighborhood-level correlates of MVPA for boys after adjusting for sociodemographics.

When mutually adjusted for all other predictor variables, associations between both neighborhood– and school–context variables and adolescent MVPA were no longer significant (Table 3). Within the friend context, perceived friend support for PA remained positively associated with boys' and girls' MVPA in the mutually adjusted model, as did perceived parental support for PA within the family context. All other statistically significant predictors of both boys' and girls' MVPA in the mutually adjusted model were personal variables: self-efficacy, PA enjoyment, PA self-management, and sport participation.

Girls with higher levels of friend MVPA reported higher MVPA themselves, as did girls whose fathers reported more PA. Girls with fewer perceived barriers to being active were more active than girls with more perceived barriers. In addition, girls whose homes were farther from bike/walking trails reported higher levels of MVPA than did those who lived nearer to trails. There were no predictor variables in the mutually adjusted model that were related to MVPA among boys only. Taken together, all 50 variables included in the mutually adjusted models explained 25% and 27% of the variance in MVPA among boys and girls, respectively. Considering the variables within each level as a unique block of predictors, the total proportions of variance explained by each block were as follows: personal, 22.3% for boys and 22.1% for girls; family, 9.0% for boys and 9.8% for girls; friends, 10.7% for boys and 10.6% for girls; school, 4.1% for boys and 5.9% for girls; and neighborhood, 2.4% for boys and 4.5% for girls.

Discussion

This study assessed the influence of many personal, social, and environmental factors on adolescent MVPA. Consistent with the stated hypotheses, in both separate and mutually adjusted analyses, a smaller proportion of the neighborhood and school factors were related to MVPA compared with friend and family variables. Similarly, a smaller proportion of friend and family variables displayed significant relationships with MVPA compared with

personal variables, all of which were related to adolescent MVPA in both the separate and mutually adjusted analyses.

Most of the relationships between MVPA and examined correlates were similar for boys and girls, but some gender differences did emerge, consistent with previous research[10,31]; gender differences were particularly pronounced for neighborhood and school contextual factors. Some of the variables that predicted girls', but not boys', PA (e.g., dad's perceived PA and female friends' MVPA) may be explained by communal characteristics more commonly displayed by girls than by boys.[32,33]

Boys and girls enrolled in P.E. were more active. Consistent with previous research,[34] the results of the present study demonstrate a strong relationship between P.E. and adolescent PA. As the only consistent school- or neighborhood-level predictor of MVPA among both boys and girls in this study, P.E. provides a unique high-leverage opportunity for promoting health among adolescents. The present results add to a growing body of literature indicating that reductions in adolescents' P.E. time are likely to have deleterious consequences on both activity and academic performance.[35] Further, increasing P.E. time and decreasing curricular time positively affects students' fitness and does not negatively impact academic performance.[36,37]

A recent review[38] notes, "Living close to parks, trails, and recreation facilities is related to greater use of facilities and more recreational physical activity." In the present study, counterintuitively, girls living nearer to trails reported less MVPA than those living farther. This finding may owe to the focus on MVPA, rather than total PA or specific characteristics of neighborhood environments in the Minneapolis/St. Paul area (e.g., abundant trails). The MVPA measure may not capture all trail-use activities, particularly walking for transportation or leisure. As the most common form of PA,[39] walking is a common trail use[40] and may have been classified at a light, rather than moderate, intensity, possibly contributing to this unexpected result.

This study contributes to adolescent PA research by incorporating multiple data sources (self-report, objective measurement, friend-report, parent-report, and teacher/administrator-report) to investigate a robust set of theoretically implicated influences on MVPA. In addition, the methodology enabled identification of the relative strength of factors within multiple contexts both in the absence and presence of other MVPA correlates. This study provided support for several tenets of socialecologic theory[8,41]; specifically, factors within multiple contexts were related to adolescent MVPA, and those more proximal to the individual were most predictive. In addition, it should be noted that the effects of more-distal factors (e.g., neighborhood variables) might impact adolescent PA indirectly through more-proximal factors (e.g., personal variables), in which case the estimates obtained in a mutually adjusted model could underestimate the total impact of more-distal variables. This possibility was assessed in the present study by calculating the proportion of variance in MVPA collectively explained by all variables within each context. These proportions included both direct effects and any mediated effects that might occur through variables in other contexts, and indicated that the relation with MVPA became increasingly strong at increasingly proximal contexts.

As in previous research,[13] the proportion of variance in adolescent MVPA explained by the entire group of variables was relatively small (i.e., 25% for boys and 27% for girls) and the variables with the most explanatory power were located at the most-proximal levels. The relatively low explanatory power of the tested set of variables, particularly the environmental variables, may owe, in part, to the outcome measure of **leisure** PA. It is possible that, as with adults,[42] the physical environment would relate more strongly to an outcome that includes utilitarian PA (e.g., active transportation). Additionally, although many factors across multiple contexts were measured, there are other influences on adolescent MVPA. In the personal context, the present research assessed behavioral and psychologic constructs; there are also biological factors (e.g., genes, specific neural systems and structures) that relate to preference for and participation in PA that could help explain additional variance.[43] Physical health and time commitments outside of school (e.g., employment, home/family responsibilities, volunteering, non-sport afterschool activities) could also explain further variance. It is possible that the influence that friends have on adolescents' MVPA could have been underestimated, as just over half of participants' nominated friends were included in the study. In addition, although the Census data used in the present analyses are frequently used to objectively describe neighborhood environments, these data may not perfectly reflect each participant's **perceived** neighborhood; indeed, the manner in which environmental factors are assessed can relate to the environment–PA relationships uncovered[44]; thus, future research may benefit from including both objective and subjective environmental measures.

Conclusion

PA is lower than recommended and declines during adolescence. The ability to successfully intervene to increase PA depends on understanding the factors that contribute to PA. This study identified factors from multiple contexts that represent opportunities for intervention. Identified factors overlapped substantially for boys and girls, although some gender-specific correlates were also identified. The highest-leverage factors may be personal- and social-context variables and P.E. at school. Intervention efforts may enhance effectiveness by targeting boys and girls separately and incorporating members of adolescents' social networks.

Acknowledgments

References

1. Fletcher GF, Balady G, Blair SN, et al. Statement on exercise: benefits and recommendations for physical activity programs for all Americans a statement for health professionals by the committee on exercise and cardiac rehabilitation of the council on clinical cardiology, American Heart Association. Circulation. 1996; 94(4):857–62. [PubMed: 8772712]

2. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. J Pediatr. 2005; 146(6):732–7. [PubMed: 15973308]

3. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. Can Med Assoc J. 2006; 174(6):801–9. [PubMed: 16534088]

4. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the U.S. measured by accelerometer. Med Sci Sports Exerc. 2008; 40(1):181–8. [PubMed: 18091006]

5. Nader PR, Bradley RH, Houts RM, McRitchie SL, O'Brien M. Moderate-to-vigorous physical activity from ages 9 to 15 years. J Am Med Assoc. 2008; 300(3):295–305.

6. Dumith SC, Gigante DP, Domingues MR, Kohl HW. Physical activity change during adolescence: a systematic review and a pooled analysis. Int J Epidemiol. 2011; 40(3):685–98. [PubMed: 21245072]

7. Wenthe PJ, Janz KF, Levy SM. Gender similarities and differences in factors associated with adolescent moderate-vigorous physical activity. Pediatr Exerc Sci. 2009; 21(3):291–304. [PubMed: 19827453]

8. Sallis, J.; Owen, N.; Fisher, EB. Ecological models of health behavior. In: Glanz, K.; Rimer, BK.; Viswanath, K., editors. Health behavior and health education. 4th ed. Jossey–Bass; San Francisco CA: 2008.

9. Sallis J, Prochaska JJ, Taylor WC, Hill JO, Geraci JC. Correlates of physical activity in a national sample of girls and boys in grades 4 through 12. Health Psychol. 1999; 18(4):410–5. [PubMed: 10431943]

10. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000; 32(5):963–75. [PubMed: 10795788]

11. Deforche B, Dyck Dv, Verloigne M, et al. Perceived social and physical environmental correlates of physical activity in older adolescents and the moderating effect of self-efficacy. Prev Med. 2010; 50(S1):S24–S29. [PubMed: 19818363]

12. Graham DJ, Schneider M, Dickerson SS. Environmental resources moderate the relationship between social support and school sports participation among adolescents: a cross-sectional analysis. Int J Behav Nutr Phys Act. 2011; 8:34. [PubMed: 21501504]

13. 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. [PubMed: 21047429]

14. Sallis, JF.; Owen, N. Physical activity & behavioral medicine. Vol. Vol 3. Sage; Thousand Oaks CA: 1999.

15. Spence JC, Lee RE. Toward a comprehensive model of physical activity. Psychol Sport Exerc. 2003; 4(1):7–24.

16. Neumark-Sztainer D, Wall MM, Larson N, et al. Secular trends in weight status and weight-related attitudes and behaviors in adolescents from 1999 to 2010. Prev Med. 2012; 54(1):77–81. [PubMed: 22024221]

17. Larson N, Wall M, Story M, Neumark Sztainer D. Home/family, peer, school, and neighborhood correlates of obesity in adolescents. Obesity. 2013; 21(9):1858–69. [PubMed: 23512596]

18. McGuire M, Neumark-Sztainer D, Story M. Correlates of time spent in physical activity and television viewing in a multi-racial sample of adolescents. Pediatr Exerc Sci. 2002; 14(1):75–86.

19. Mcguire MT, Hannan PJ, Neumark-Sztainer D, Cossrow NHF, Story M. Parental correlates of physical activity in a racially/ethnically diverse adolescent sample. J Adolescent Health. 2002; 30(4):253–61.

20. Sirard JR, Bruening M, Wall MM, Eisenberg ME, Kim SK, Neumark-Sztainer D. Physical activity and screen time in adolescents and their friends. Am J Prev Med. 2013; 44(1):48–55. [PubMed: 23253649]

21. Neumark-Sztainer D, Goeden C, Story M, Wall M. Associations between body satisfaction and physical activity in adolescents: implications for programs aimed at preventing a broad spectrum of weight-related disorders. Eat Disord. 2004; 12(2):125–37. [PubMed: 16864312]

22. Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. Can J Appl Sport Sci. 1985; 10(3):141–6. [PubMed: 4053261]

23. Wall MM, Larson NI, Forsyth A, et al. Patterns of obesogenic neighborhood features and adolescent weight: a comparison of statistical approaches. Am J Prev Med. 2012; 42(5):e65–75. [PubMed: 22516505]

24. Neumark-Sztainer D, MacLehose R, Loth K, Fulkerson JA, Eisenberg ME, Berge J. What's for dinner? Types of food served at family dinner differ across parent and family characteristics. Public Health Nutr. 2012; 19:1–11.

25. Forsyth A, Van Riper D, Larson N, Wall M, Neumark-Sztainer D. Creating a replicable, valid cross-platform buffering technique: the sausage network buffer for measuring food and physical activity built environments. Int J Health Geographics. 2012; 11(1):14.

26. McDonald K, Hearst M, Farbakhsh K, et al. Adolescent physical activity and the built environment: a latent class analysis approach. Health Place. 2012; 18(2):191–8. [PubMed: 21975286]

27. Rubin, D. Multiple imputation for nonresponse in surveys. John Wiley and Sons, Inc; New York: 1987.

28. Yuan, Y. Multiple imputation for missing data: concepts and development. version 9.0. SAS Institute; Rockville MD: support.sas.com/rnd/app/papers/multipleimputation.pdf

29. Fichman M, Cummings JN. Multiple imputation for missing data: making the most of what you know. Organ Res Meth. 2003; 6(3):282–308.

30. Little, RJ.; Rubin, DB. Statistical analysis with missing data. Wiley; New York: 2002.

31. Plotnikoff RC, Mayhew A, Birkett N, Loucaides CA, Fodor G. Age, gender, and urban– rural differences in the correlates of physical activity. Prev Med. 2004; 39(6):1115–25. [PubMed: 15539045]

32. Eagly AH, Wood W. The origins of sex differences in human behavior: evolved dispositions versus social roles. Am Psychol. 1999; 54(6):408–23.

33. Moskowitz DS, Suh EJ, Desaulniers J. Situational influences on gender differences in agency and communion. J Pers Soc Psychol. 1994; 66(4):753–61. [PubMed: 8189350]

34. Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. Pediatrics. 2000; 105(6):e83–90. [PubMed: 10835096]

35. Trost SG, van der Mars H. Why we should not cut PE. Health Learn. 2010; 67(4):60–5.

36. Sibley BA, Etnier JL. The relationship between physical activity and cognition in children: a meta-analysis. Pediatr Exerc Sci. 2003; 15(3):243–56.

37. Trudeau F, Shephard RJ. Physical education, school physical activity, school sports and academic performance. Int J Behav Nutr Phys Act. 2008; 5(1):10. [PubMed: 18298849]

38. Sallis, JF.; Millstein, RA.; Carlson, JA. Making healthy places. Springer; New York: 2011. Community design for physical activity.

39. U.S. Public Health Service. Office of the Surgeon General. National Center for Chronic Disease Prevention. Health Promotion (U.S.). President's Council on Physical Fitness. Sports (U.S.). Physical activity and health: a report of the Surgeon General. Jones & Bartlett Learning; Sudbury MA: 1996.

40. Brownson RC, Housemann RA, Brown DR, et al. Promoting physical activity in rural communities: walking trail access, use, and effects. Am J Prev Med. 2000; 18(3):235–41. [PubMed: 10722990]

41. Stokols D. Establishing and maintaining healthy environments. Am Psychol. 1992; 47(1):6–22. [PubMed: 1539925]

42. Troped PJ, Saunders RP, Pate RR, Reininger B, Addy CL. Correlates of recreational and transportation physical activity among adults in a New England community. Prev Med. 2003; 37(4):304–10. [PubMed: 14507486]

43. Lenard NR, Berthoud HR. Central and peripheral regulation of food intake and physical activity: pathways and genes. Obesity. 2008; 16(S3):S11–S22. [PubMed: 19190620]

44. Pate RR, Pfeiffer KA, Trost SG, Ziegler P, Dowda M. Physical activity among children attending preschools. Pediatrics. 2004; 114(5):1258–63. [PubMed: 15520105]

45. Barr-Anderson DJ, Neumark-Sztainer D, Lytle L, 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]

46. 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(5):584–94. [PubMed: 11071840]

47. Dishman RK, Motl RW, Sallis JF, et al. Self-management strategies mediate self-efficacy and physical activity. Am J Prev Med. 2005; 29(1):10–8. [PubMed: 15958246]

48. van den Berg, P. Body image concerns as barriers to physical activity [unpublished Master's thesis]. University of Minnesota; Minneapolis, MN: 2008.

49. 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(2):110–7. [PubMed: 11457630]

50. Davison K. Activity-related support from parents, peers, and siblings and adolescents' physical activity: are there gender differences? J Phys Act Health. 2004; 1:363–376.

51. Saelens B, Sallis J, Black J, Chen D. Measuring perceived neighborhood environment factors related to walking/cycling. Ann Behav Med. 2002; 24:139.

52. Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. Am J Public Health. 2003; 93(9):1552–8. [PubMed: 12948979]

Table 1

Personal, family, friend, school, and neighborhood predictors of adolescent physical activity

Personal	Measure description
PA self-efficacy	3-item PA self-efficacy scale[45,46]
PA barriers	4 items, barriers to PA: *weather, time, school work, embarrassed about how I look when I'm active*[47,48]
PA enjoyment	3-item PA enjoyment scale: *I feel bored, I dislike it, it frustrates me*[49]
PA self-management	3-item PA self-management scale: *set goals, backup plan, I can get back on track*[47]
Sport participation	*During the past 12 months, on how many sports teams did you play? (0 teams, 1 team, 2 teams, 3 teams)*
Family	
Home PA resources	*Count of PA resources available to your child in your home, yard, or apartment complex (stationary aerobic equipment [bicycle, treadmill, etc.], bicycle, skateboard, scooter, rollerskates/blades, basketball hoop, weight-lifting equipment [free weights, Nautilus, Universal, etc.], interactive video games [Wii Sport/Fit, Dance Dance Revolution]).*
Parent-reported weekly PA	Parent self-reported total weekly hours of PA[22]
Perceived mom's PA	*My mother is physically active in her free time. (never, rarely, sometimes, on a regular basis)*
Perceived dad's PA	*My father is physically active in his free time. (never, rarely, sometimes, on a regular basis)*
Parent active with child	*In a typical week, how many hours do you spend being physically active with your child (e.g., throwing a ball around, taking a walk or bike ride together)? (none, <0.5 hours, 0.5–2 hours, 2.5–4 hours, 4.5–6 hours, 6 hours)*
Parent helps child be active	*In a typical week, how many hours do you spend helping your child to be physically active (e.g., driving them to the gym or sport practice, watching them play a sport)? (none, <0.5 hours, 0.5–2 hours, 2.5–4 hours, 4.5–6 hours, 6 hours)*
Family support for PA	Composite of 2 items: (1) *My family (including parents and siblings) and I do active things together (e.g., bike rides, walks)*; and (2) *My family supports me in being physically active (e.g., enrolling me in sports, watching me perform, providing transportation to places to be active). (strongly disagree, somewhat disagree, somewhat agree, strongly agree)*
Friends	
Friend support for PA	Composite variable: 3 items asking about perceptions of friends' participation in PA, sports, and support for PA[50]
Male friends' MVPA	MVPA hours per week reported by male friends
Female friends' MVPA	MVPA hours per week reported by female friends

Personal	Measure description
Male friends play sports	Percentage of male friends reporting that they play team sports
Female friends play sports	Percentage of female friends reporting that they play team sports
School	
Currently taking P.E.	*Are you currently taking a physical education or gym class at school? (yes/no)*
Total indoor PA facilities	Facilities school has access to for indoor physical education *(Mark all that apply: gymnasium, pool, weight room, cardio center, wrestling room, dance studio, P.E. classrooms, P.E. multipurpose area, other indoor P.E. facility)*
Total outdoor PA facilities	Facilities school has access to for outdoor physical education *(Mark all that apply: track, volleyball court, basketball court, tennis court, baseball field, football field, black top, other outdoor P.E. facility.)*
P.E. facilities well maintained	*Are your school's physical education facilities well maintained and usable? (not at all, somewhat, mostly, very well)*
Activity fee	*Must students pay an activity fee to participate in any sports, intramural activities, or physical activity clubs? (yes, no)*
Late bus	*Does school have "late bus" home for students staying after school for academic, club, or discipline reasons? (no, yes)*
Sport bus	*Does this school provide transportation home for students who participate in after-school sports, intramural activities, or physical activity clubs that is separate from the "late bus" in the previous question? (no, yes)*
School promoting PA	*Are there activities currently underway at your school to promote increased physical activity among students?*
School effort promoting PA	*In your opinion, to what extent has your school made a serious/real effort to promote increased physical activity among students? (not at all, to a little extent, to some extent, to a great extent, to a very great extent)*
District effort promoting PA	*In your opinion, to what extent has your school district made a serious/real effort to promote increased physical activity among students? (not at all, to a little extent, to some extent, to a great extent, to a very great extent)*
Student campaign involvement	*In the past year, have students been involved in school assemblies, events, or campaigns promoting physical activity?*
Groups use school PA facilities	*Outside of school hours or when school is not in session, do outside groups conduct physical activity or sports programs on school grounds or in school facilities? (yes, no)*
Teams use school PA facilities	*Outside of school hours or when school is not in session, do students use any of this school's physical activity or athletic facilities for community sponsored sports teams? (yes, no)*

Personal	Measure description
Open gym in school PA facilities	*Outside of school hours or when school is not in session, do students use any of this school's physical activity or athletic facilities for community-sponsored supervised "open-gym" or "free-play?" (yes, no)*
Neighborhood	
Neighborhood safety	Composite of two items regarding safety in the neighborhood where participant lived for the majority of the past year. 0 indicates always safe, 1 indicates unsafe only at night, 2 indicates unsafe day and night[51,52]
Crime (density)	Total number of crimes in 2010 within crime grid zone or neighborhood
Green space (distance)	Straight-line distance in meters to nearest park/recreation space
Green space (%)	1600-meter straight-line buffer percent park/recreation space
Recreation center (distance)	Road network distance in meters to nearest recreation center
Recreation center (density)	1600-meter straight-line buffer count of recreation centers
Gym (distance)	Road network distance in meters to nearest gym/fitness center
Gym (density)	1600-meter road network buffer density of gyms/fitness centers (count per hectare, excluding water)
Trail (distance)	Straight-line distance in meters to nearest bike or walking trail
Transit stops (density)	1600-meter network buffer count of transit stops
Busy streets (density)	1600-meter road network buffer percent busy streets
Access points (density)	1600-meter straight line buffer count of access points
School (distance)	Road network distance in meters to school attended
Woman-headed households (%)	Proportion of households headed by women within Census tract
High school graduates (%)	Proportion of residents with high school degree within Census tract
Median household income	Median household income in the past year (in 2009 inflation-adjusted dollars) within Census tract

Personal	Measure description
Below poverty (%)	Proportion of households in census tract with incomes below 100% of the poverty threshold
Age <18 years (%)	Proportion of population aged 17 years within Census tract
Population (density)	1600-meter straight-line buffer 2010 population count per hectare, excluding water

Table 2

Independent regression equations predicting weekly MVPA (hours) based on neighborhood, school, friends, family, personal factors[a]

				Boys		Girls
	β [b]	SE	p	β [b]	SE	p
Personal						
PA self-efficacy	0.700	0.053	**<0.0001** [*]	0.575	0.047	**<0.0001** [*]
PA barriers	−0.220	0.044	**<0.0001** [*]	−0.269	0.034	**<0.0001** [*]
PA enjoyment	−0.594	0.063	**<0.0001** [*]	−0.474	0.047	**<0.0001** [*]
PA self-management	0.499	0.040	**<0.0001** [*]	0.496	0.035	**<0.0001** [*]
Sport participation	2.319	0.284	**<0.0001** [*]	1.906	0.232	**<0.0001** [*]
Family						
Home PA resources	0.225	0.116	0.052	0.265	0.090	**0.003** [*]
Parent-reported weekly PA	0.084	0.026	**0.001** [*]	0.042	0.021	**0.046** [*]
Perceived mom's PA	0.380	0.148	**0.011** [*]	0.488	0.114	**<0.0001** [*]
Perceived dad's PA	0.589	0.135	**<0.0001** [*]	0.565	0.109	**<0.0001** [*]
Parent active with child	0.186	0.083	**0.025** [*]	0.051	0.067	0.442
Parent helps child be active	0.381	0.064	**<0.0001** [*]	0.346	0.054	**<0.0001** [*]
Family support for PA	0.605	0.088	**<0.0001** [*]	0.466	0.069	**<0.0001** [*]
Friends						
Friend support for PA	0.597	0.063	**<0.0001** [*]	0.498	0.055	**<0.0001** [*]
Male friends' MVPA[c]	0.058	0.040	0.141	0.118	0.037	0.001[*]
Female friends' MVPA[c]	0.115	0.047	**0.013** [*]	0.173	0.037	**<0.0001** [*]
Male friends play sports[c]	1.544	0.413	**0.000** [*]	0.619	0.409	0.130
Female friends play sports[c]	0.727	0.439	0.098	0.153	0.333	0.647
School						
Currently taking P.E.	0.563	0.274	**0.040** [*]	0.581	0.232	**0.012** [*]
Total indoor PA facilities	0.183	0.094	0.052	0.130	0.101	0.198
Total outdoor PA facilities	0.013	0.146	0.929	0.285	0.131	**0.030** [*]
P.E. facilities well maintained	−0.121	0.314	0.700	−0.174	0.316	0.583
Activity fee	1.208	0.721	0.094	−0.163	0.707	0.818
Activity fee waiver	0.448	0.471	0.342	−0.200	0.609	0.743
Late bus	−0.276	0.472	0.559	−1.142	0.408	**0.005** [*]
Sport bus	−0.247	0.596	0.679	0.544	0.599	0.364
School promoting PA	−0.719	0.374	0.055	−0.546	0.433	0.207
School effort promoting PA	0.099	0.228	0.665	0.083	0.232	0.719

	Boys					Girls
	β [b]	SE	p	β [b]	SE	p
District effort promoting PA	−0.174	0.229	0.446	0.027	0.232	0.908
Student campaign involvement	0.319	0.460	0.488	−0.209	0.465	0.653
Groups use school PA facilities	0.194	0.520	0.709	0.391	0.508	0.441
Teams use school PA facilities	0.261	0.453	0.565	0.155	0.457	0.735
Open gym in school PA facilities	0.226	0.440	0.607	−0.103	0.464	0.824
Neighborhood [d]						
Neighborhood safety	−0.250	0.173	0.148	−0.128	0.140	0.362
Crime (density)	−0.483	0.284	0.089	−0.001	0.238	0.997
Green space (distance)	0.013	0.272	0.962	−0.077	0.231	0.740
Green space (%)	0.433	0.277	0.118	0.485	0.232	**0.036** [*]
Recreation center (distance)	−0.067	0.271	0.805	−0.225	0.228	0.324
Recreation center (density)	−0.018	0.272	0.948	0.036	0.229	0.875
Gym (distance)	−0.227	0.274	0.407	0.298	0.230	0.195
Gym (density)	0.012	0.275	0.966	−0.243	0.230	0.291
Trail (distance)	0.153	0.270	0.572	0.425	0.231	0.066
Transit stops (density)	−0.389	0.276	0.159	−0.571	0.234	**0.014** [*]
Busy streets (density)	−0.028	0.274	0.918	0.208	0.229	0.363
Access points (density)	−0.033	0.275	0.906	−0.581	0.231	**0.012** [*]
School (distance)	−0.182	0.269	0.500	0.095	0.230	0.680
Woman-headed households (%)	−0.178	0.287	0.536	−0.180	0.240	0.453
High school graduates (%)	0.111	0.287	0.698	0.236	0.240	0.326
Median household income	0.167	0.294	0.571	0.109	0.241	0.651
Below poverty (%)	0.000	0.293	1.000	−0.502	0.240	**0.037** [*]
Age <18 years (%)	−0.324	0.286	0.257	−0.002	0.236	0.994
Population (density)	−0.075	0.274	0.786	−0.652	0.230	**0.005** [*]

[*] *Note:* and boldface indicates $p<0.05$.

[a] All regression models were stratified by gender and controlled for adolescent age, SES, and race/ethnicity.

[b] The units for all β coefficients are in MVPA hours per the unit of the predictor; if the predictor is dichotomous, then β represents the difference in MVPA hours between an adolescent with the predictor equal to one compared to an adolescent with the predictor equal to zero.

[c] Friend variables representing nominated friend data were adjusted for the number of male and female friends nominated and present in the sample.

[d] All neighborhood variables were initially measured on continuous scales but were dichotomized at their median for analysis to facilitate interpretation and to avoid influence of outlying values arising from the right skew inherent in these measures.

MVPA, moderate to vigorous physical activity; PA, physical activity; P.E., physical education

Table 3

Mutually adjusted regression equations[a] predicting weekly MVPA (hours) based on neighborhood, school, friend, family, personal factors

	Boys (*n*=1307)			Girls (*n*=1486)		
	β[b]	SE	*p*	β[b]	SE	*p*
Personal						
PA self-efficacy	0.377	0.059	**<0.001** [*]	0.213	0.051	**<0.001** [*]
PA barriers	−0.071	0.044	0.105	−0.127	0.033	**<0.001** [*]
PA enjoyment	−0.231	0.066	**<0.001** [*]	−0.181	0.047	**<0.001** [*]
PA self-management	0.255	0.044	**<0.001** [*]	0.295	0.039	**<0.001** [*]
Sport participation	0.839	0.293	**0.004** [*]	0.620	0.236	**0.009** [*]
Adjusted R² (5 personal factors) [c]	**0.223**			**0.221**		
Family						
Home PA resources	−0.060	0.108	0.577	0.094	0.083	0.258
Parent-reported weekly PA	0.045	0.025	0.073	0.021	0.022	0.340
Perceived mom's PA	−0.125	0.150	0.405	−0.125	0.117	0.285
Perceived dad's PA	0.139	0.132	0.294	0.216	0.109	**0.048** [*]
Parent active with child	0.062	0.090	0.495	−0.118	0.071	0.097
Parent helps child be active	0.155	0.069	**0.026** [*]	0.205	0.059	**0.001** [*]
Family support for PA	0.053	0.094	0.573	0.026	0.074	0.727
Adjusted R² (7 family factors) [c]	**0.090**			**0.098**		
Friends						
Friend support for PA	0.189	0.067	**0.005** [*]	0.127	0.057	**0.025** [*]
Male friends' MVPA[d]	0.024	0.038	0.525	0.065	0.034	0.060
Female friends' MVPA[d]	0.083	0.045	0.070	0.104	0.035	**0.004** [*]
Male friends play sports[d]	0.536	0.347	0.122	0.330	0.350	0.347
Female friends play sports[d]	0.000	0.382	1.000	−0.317	0.290	0.276
Adjusted R² (5 friend factors) [c]	**0.107**			**0.106**		
School						
Currently taking P.E.	0.476	0.279	0.088	0.433	0.241	0.072
Total indoor PA facilities	−0.095	0.203	0.642	0.175	0.168	0.298
Total outdoor PA facilities	−0.484	0.406	0.233	0.160	0.315	0.611
P.E. facilities well maintained	−0.164	0.414	0.692	−0.432	0.323	0.182
Activity fee	2.520	1.623	0.121	−0.348	1.300	0.789
Late bus	−1.889	1.359	0.165	−0.664	1.052	0.528
Sport bus	0.796	1.142	0.486	0.515	0.901	0.567
School promoting PA	0.067	0.656	0.919	−0.678	0.519	0.191

	Boys (*n*=1307)			Girls (*n*=1486)		
	β [b]	SE	*p*	β [b]	SE	*p*
School effort promoting PA	0.742	0.828	0.370	0.012	0.652	0.986
District effort promoting PA	−0.463	0.468	0.322	0.239	0.380	0.529
Student campaign involvement	0.846	0.560	0.130	−0.645	0.476	0.176
Groups use school PA facilities	−0.857	0.715	0.231	0.274	0.586	0.641
Teams use school PA facilities	0.595	0.998	0.551	−0.638	0.815	0.434
Open gym in school PA facilities	−0.960	1.056	0.364	−0.148	0.826	0.858
Adjusted R² (14 school factors) [c]	**0.041**			**0.059**		
Neighborhood [e]						
Neighborhood safety	−0.049	0.163	0.764	0.017	0.133	0.901
Crime (density)	−0.370	0.321	0.250	0.451	0.254	0.076
Green space (distance)	−0.061	0.266	0.819	−0.232	0.224	0.302
Green space (%)	0.278	0.305	0.362	0.476	0.263	0.071
Recreation center (distance)	0.031	0.266	0.907	−0.084	0.218	0.699
Recreation center (density)	0.076	0.300	0.801	0.133	0.251	0.595
Gym (distance)	−0.409	0.421	0.332	0.101	0.360	0.780
Gym (density)	−0.399	0.408	0.329	−0.102	0.362	0.778
Trail (distance)	0.258	0.264	0.329	0.681	0.230	**0.003** *
Transit stops (density)	−0.255	0.292	0.382	−0.101	0.262	0.699
Busy streets (density)	−0.224	0.272	0.410	0.324	0.225	0.150
Access points (density)	0.239	0.324	0.461	−0.157	0.271	0.562
School (distance)	−0.124	0.268	0.643	−0.238	0.228	0.296
Woman-headed households (%)	0.144	0.334	0.666	−0.112	0.290	0.700
High school graduates (%)	−0.317	0.356	0.374	0.040	0.310	0.899
Median household income	−0.022	0.419	0.958	−0.535	0.329	0.104
Below poverty (%)	0.306	0.431	0.478	−0.470	0.345	0.173
Age <18 years (%)	−0.590	0.340	0.083	0.272	0.294	0.355
Population (density)	−0.298	0.328	0.364	−0.247	0.285	0.387
Adjusted R² (19 neighborhood factors) [c]	**0.024**			**0.045**		
Adjusted R² (50 variables + demographics) [c]	**0.250**			**0.268**		

*
Note: and boldface indicates *p*<0.05.

[a] All predictor variables included simultaneously in models predicting MVPA for boys and girls; all regression models were stratified by gender and controlled for adolescent age, SES, and race/ethnicity.

[b] The units for all β coefficients are in MVPA hours per the unit of the predictor; if the predictor is dichotomous, then the β represents the difference in MVPA hours between an adolescent with the predictor equal to one compared to an adolescent with the predictor equal to zero.

[c] Adjusted R^2 values were examined for the full mutually adjusted models (all 50 factors) to determine the total variance explained by all variables. Additional models were fit including only the variables from one level of potential influence (i.e., personal, family, friend, school, and neighborhood) at a time in order to obtain the variance explained by each block of variables.

*d*Friend variables representing nominated friend data were adjusted for the number of male and female friends nominated and present in the sample.

*e*All neighborhood variables were initially measured on continuous scales but were dichotomized at their median for analysis to facilitate interpretation and to avoid influence of outlying values arising from the right skew inherent in these measures.

MVPA, moderate to vigorous physical activity; PA, physical activity; P.E., physical education