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Factor Analysis Test of an Ecological Model of Physical Activity Correlates

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Abstract

Objectives: The fit of measured variables into a social-ecological model of correlates of physical activity is rarely tested. In this study, we examined the factor structure of correlates of moderate/vigorous physical activity (MVPA) within a hypothesized social-ecological model.

Methods: We measured 46 possible personal, social and environmental correlates of MVPA in 2779 adolescents participating in the Project EAT-2010 study. Confirmatory (CFA) and exploratory factor analyses (EFA) were used to determine the factor structure. Associations of factor scores with self-reported MVPA were calculated with linear regression.

Results: A 6-factor CFA model did not show adequate fit. Eight factors were identified using EFA (Root Mean Square Error [RMSEA] 90% CI: 0.053 to 0.055; CFI = 0.82). A factor representing the mix of personal and social correlates showed the strongest association with MVPA.

Conclusions: The 8-factor model supports independent clustering of possible environmental correlates of MVPA, but indicates that social and personal correlates may not cluster

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Human Subjects Statement

These studies were approved by the University of Minnesota Institutional Review Board Human Subjects Committee. Informed consent was provided by parents and assent was provided by the adolescent participants.

Conflict of Interest Statement

The authors report no conflicts of interest.

independently. The factor most strongly correlated with MVPA represented a mix of personal and social correlates. Future work will be needed to better understand how mechanisms for developing physical activity work within and across levels of the social-ecological framework.

Keywords

adolescents; exercise; factorial validity

Promoting physical activity is a public health priority for preventing a growing list of chronic diseases including obesity, cardiovascular disease and, increasingly, different cancers.[–] The United States Physical Activity Guidelines Advisory Committee has also found strong evidence that physical activity improves measures of wellness like sleep, executive function and symptoms of anxiety or depression. Yet, most modifiable risk factors or correlates of physical activity, risk factors that are possible to change like time spent outdoors, remain poorly understood. To improve understanding and classification of the correlates of physical activity, researchers often organize these correlates using a social-ecological framework.[,] However, most studies organize measured correlates into factors based on social-ecological categories defined in an *a priori* fashion, like personal correlates, social correlates and neighborhood environment correlates under the assumption that these represent independent domains of correlates.[–] We are aware of few previous studies that have tested how well measured correlates cluster into predetermined factors or that have empirically identified clusters of measured correlates related to physical activity.[,]

Better understanding of the modifiable risk factors for activity is needed to improve interventions to increase population levels of physical activity, which continue to show relatively small effects. Large school-based interventions for physical activity in the United States like TAAG and CATCH show intervention effects of less than 15 minutes per week increases in physical activity. Improving intervention effectiveness will require better understanding of the multiple contexts that may support adolescent physical activity.

Although the social ecological model is generally atheoretical, some authors have attempted to bridge the gap between model and theory. Spence and Lee have proposed a hierarchical framework of systems from the microsystem (home environment) to the exosystem (policy environment) that must be in alignment to support physical activity. Each system in the hierarchy proposed by Spence and Lee is a mix of social and environmental factors, and their framework proposes that the effect of these on physical activity is mediated through personal perceptions. In an empirical study, Garcia Bengoechea et al showed that personal characteristics like sex interact with social characteristics like peer or parent influence in their association with physical activity behavior. Theoretical and empirical work such as this implies that variables within the social ecological model interact in complex ways and it may not be appropriate to place them a-priori in personal, social and environmental bins. Yet, we are aware of few studies that have applied a factor analysis approach to empirically assessing latent factors underlying variables associated with physical activity behavior.

The current study aimed first to test how well measured correlates from a cross-sectional study fit an *a priori* hypothesized model based on the social-ecological framework. Next, this study used exploratory modeling to empirically determine how the measured correlates

cluster into unique factors for this study sample. Finally, this study tested the correlations of the empirically derived factors with reported weekly hours of moderate to vigorous physical activity (MVPA) within each sex and whether these correlations differ by ethnicity/race.

METHODS

Sample and Survey Development

Data for this analysis came from 2779 adolescent participants in the Project EAT-2010 (Eating and Activity in Teens) study who reported weekly hours of MVPA, ethnicity/race and sex, and from their parent's responses to the Project F-EAT (Families and Eating and Activity Among Teens) study. These coordinated surveys assessed diet, physical activity, weight status, weight control behaviors and associated factors in adolescents. Participants' friends' responses were linked with nominations of up to 6 friends by each participant. Environmental data were collected from surveys of school administrators and physical education specialists, as well as from Geographic Information Systems (GIS) sources based on the participants' addresses.[,]

For EAT-2010, surveys and anthropometric measures were completed by adolescents from 20 public middle schools and high schools in the Minneapolis/St. Paul metropolitan area of Minnesota during the 2009–2010 academic year. The mean age of the study population was 14.4 years (SD = 2.0) and adolescents were equally divided by sex (46.9% boys, 53.1% girls; Table 1). Research staff measured adolescents' height and weight using standardized procedures and administered surveys during selected health, physical education, and science classes. To ensure consistency of measurement, research staff members completed a one-day study related training and were certified in proving they could accurately complete the measurements. Measurements were completed in a private area and surveys were administered during 2 class periods that were typically 45–50 minutes.

For Project F-EAT, data were collected by surveying up to 2 parents/caregivers of the adolescents in EAT-2010 about their own eating and physical activity behaviors, food-specific parenting practices, the home food environment, the home physical activity environment, the emotional atmosphere at home and the home weight culture. Approximately 30% of participants provided contact information for one parent/guardian and 70% provided information for 2 parents/guardians. In total, 85.3% of adolescent participants in EAT-2010 had at least one parent respond. Most parent respondents were mothers or other female guardians (62.0%), and parents had a mean age of 42.3 years (SD = 8.6). Participating families were ethnically and socioeconomically diverse. The parent sample was 29.7% white, 26.1% African-American, 21.4% Asian, 17.4% Hispanic, and 5.4% mixed or other race/ethnicity. Parent surveys were collected by mail and by phone interviews.

Variables collected from GIS sources were: distance to the nearest gym, distance to the nearest recreation center, density of parks near the participants' homes, count of busy streets in the participants neighborhood, distance to the nearest trail, number of access points or roads crossing the 1600 meter buffer around participants homes, count of crimes near the participants' homes in 2010 and distance to school. Participants' body mass index (BMI)

was calculated from heights and weights measured by research staff. All other variables were collected by self-report (Table 2).

Initial Theoretical Model

The correlates examined in this study were organized using a social-ecological framework.[9] The UK Government's Foresight Programme is a proposed complex systems model of the development of obesity based on a social-ecological framework. This model was described by Sallis and Owen as "the most relevant and well-known application of complex systems models to chronic disease." Whereas this model was commissioned by the UK Government, the proposed predictors of physical activity behavior in this model – innate levels of childhood activity, degree of physical education, opportunity for team based activity, sociocultural valuation of activity, access to opportunities for exercise, and availability of passive entertainment – have face validity as potential predictors of physical activity across the globe (Figure 1). Variables were chosen for inclusion in this analysis based on their use in Graham's study of the independent correlates of physical activity in Project EAT 2010 participants or their expected relevance to the theoretical model. Measured variables from the Project EAT-2010 surveys were mapped *a priori* onto the constructs from the Foresight model to test this measurement model with confirmatory factor analysis (CFA) (Table 2).

Analysis Variables

Moderate to vigorous physical activity.—Self-Reported Moderate and Vigorous Physical Activity (MVPA) were assessed using a modification of the Godin and Shepard questions. Participants were asked: "In a usual week, how many hours do you spend doing the following activities" for strenuous, moderate and mild exercise. Response options for these questions were: none, less than ½ hour a week, ½ - 2 hours a week, 2 ½ - 4 hours a week, 4 ½ - 6 hours a week, 6+ hours a week. To assess hours per week of physical activity, the response options were coded to: 0 for "none;" 0.3 for "less than ½ hour a week;" 1.3 for "½ −2 hours per week;" 3.3 for "2 ½ −4 hours per week;" 5.3 for" 4 ½ −6 hours per week;" and 8 for "6+ hours a week." The responses from moderate exercise and strenuous exercise were summed to get usual weekly hours of MVPA. In all models MVPA was treated as a continuous variable with a unit of hours per week. The survey questions are available as they were seen by participants at http://www.sphresearch.umn.edu/epi/wp-content/uploads/sites/2/2013/08/EAT-2010-Survey.pdf.

Expected correlates.—Expected personal, social and neighborhood correlates were drawn from adolescent (EAT-2010) and parent surveys (FEAT) as well as surveys of school administrators and physical education specialists and Geographic Information Systems measures derived from the home addresses that participants provided. These variables are grouped by the Project Foresight model construct they are expected to reflect and their distributional characteristics are described in Table 2. The term "correlate" here is used to refer to a risk factor identified in a cross-sectional study as recommended by Atkin et al.

Demographics.—Sex was self-reported by EAT-2010 participants as male or female. Ethnicity/Race was self-reported by EAT-2010 participants as one or more of: white, black or African-American, Hispanic or Latino, Asian American, Hawaiian or Pacific Islander, or

American Indian or Native American. Participants who reported Hispanic or Latino ethnicity were classified as Hispanic or Latino regardless of racial identity. Non-Hispanic participants who reported 2 races with one race being "white" were classified as the non-white race they reported. Because of small sample sizes of Hawaiian or Pacific Islander and American Indian or Native American, these groups were included in the mixed/other race category. Age in years was calculated by subtracting the participants' birthdates from the dates the survey was administered. Parent Education was self-reported by participants' parents with categories ranging from "Did not finish high school" to "Advanced degree." Parent Education was modeled as the maximum education attained by either of the participants' parents. Income was reported by the participants' primary parent by selecting among 7 categories ranging from "Less than $20,000" to "$100,000 or more." Income was modeled as a continuous variable with a unit of $20,000 per year. To create a continuous income variable from the 7 response categories, each participant was assigned the median value or the response category they indicated. For example, participants who reported earning $35,000 – $49,999 per year were assigned the median value of $42,500. To represent income with a unit of $20,000 in regression analyses, the median values were divided by 20,000.

Data Analysis

We used confirmatory factor analysis (CFA) to assess whether the measured variables fit the proposed Project Foresight model of MVPA. The CFA was fixed at 6 factors, one for each expected construct and estimated each factor by the measured variables expected to map to that factor (Table 2). The CFA model was accepted if the upper 90% confidence limit for the RMSEA was less than 0.05 and the Bentler CFI was greater than 0.90. Many variables were measured on the same survey; for example, physical activity self-efficacy and depression and many other variables were measured on the adolescent survey. Variables measured on the same survey may have a common source bias, meaning that they may correlate more highly because of being measured on the same survey than they otherwise would. To test for common source bias, correlation terms for variables measured in the same source were freed for estimation and improvements of fit on RMSEA and CFI were compared (ie, all variables from the student EAT-2010 survey were allowed to co-vary, all variables from the parent F-EAT survey were allowed to co-vary). Where fit indices indicated that the data did not fit the hypothesized CFA model, *post hoc* exploratory factor analyses (EFA) were conducted to determine the clustering of measured variables into factors. Factors with eigenvalues greater than 1 and the inflection of the scree plot were considered when determining the number of latent factors in the EFA. Next, EFA was used to determine which items loaded onto each factor by examining geomin rotated factor loadings for the EFA model with the determined number of latent factors. A sensitivity analysis was conducted with direct oblimin factor rotation to determine if factor loadings differed by rotation method. Each measured variable was assigned to the factor for which it showed the largest absolute value factor loading.

To assess the direct associations of the factors with MVPA, a score for each factor that could be included in mutually adjusted linear regression models was created as follows. All measured variables were coded so that the expected direction of association with MVPA would be positive – meaning that variables that have a negative association with MVPA, like barriers to MVPA, were reverse coded. Next, all measured variables were standardized to

have a mean of zero and a standard deviation of one so that the weight of each variable in the calculation of the factor scores would be equal. To account for the possibility of unit missingness – the possibility that a participant may have responded to most, but not all, of the measurement items for a factor, if a participant responded to more than 75% of the variables for a given factor, the factor score was created as the mean of the standardized measured variables for that factor. Finally, to account for the possibility that some participants may be missing scores for entire factors, a multiple imputation dataset was created with 20 imputations using the Markov Chain Monte Carlo algorithm in SAS Proc MI. Missingness among factor scores and covariates ranged from 0% (N = 0) to 18.9% (N = 526) of the 2779 observations.

The multiple imputation dataset was used to calculate fully adjusted hierarchical linear regression models of MVPA (standardized with mean of zero and standard deviation of one) on the factor scores. These fully adjusted models included all factor scores and covariates in the model, meaning that the regression coefficients for each factor score are interpreted as direct associations with MVPA adjusted for all other factor scores and covariates. Regression coefficients and standard errors were summarized from the multiple imputations using SAS Proc MIANALYZE using Rubin's rules. These models were also adjusted for age, ethnicity/race, parent education, parent income and included a random intercept for school, and run separately for boys and for girls. Since both the independent variables (factor scores) and the dependent variable (MVPA) were standardized to mean of zero and standard deviation of one, the estimates derived from these models can be interpreted as effect sizes, meaning that the regression coefficients represent the standard deviation increments of MVPA associated with a one standard deviation increment in each factor score. Cohen has proposed that effects sizes of 0.2, 0.5 and 0.8 correspond to small, medium and large effects respectively. Sensitivity analyses were conducted in which variables that lacked face validity within their assigned factor were re moved from the factor scores and fully adjusted correlations with MVPA were calculated using hierarchical linear regression. For example, if a factor was composed entirely of environmental variables with the exception of one personal level variable, the sensitivity analyses were conducted by removing the personal level variable from that factor and running the hierarchical regressions to compare to the regression coefficients from models where the factor included that variable. Additionally, results from multiple imputation analysis were compared to results from complete case analysis.

To test further for heterogeneity of the associations by ethnicity/race, an interaction term for each factor score with ethnicity/race was calculated in hierarchical linear regression models. These tests were conducted in linear mixed models adjusted for age, parent education and parent income with a random effect specified for school. All models used the multiple imputation dataset. As ethnicity/race is a categorical variable, the test-statistics are derived from the ANOVA type-3 f-statistic for the interaction term. To generate correct estimates of p-values from this statistic, the method of Raghunathan and Dong to pool sum of square statistics in multiple imputation datasets was used. To account for the multiple tests run, we calculated the false discovery rate (FDR) for each test. A lower value of FDR indicates lower probability that the discovery of a difference is in fact false. An FDR of 0.10, for example indicates that 1 in every 10 positive tests would be false-positives, or a 10% error in discovery. FDR was calculated from the table of raw p-values for the interactions of each

predictor with ethnicity/race. Interaction terms with an FDR of 10% or less were considered strong evidence of an interaction. Interaction terms with an FDR of 10–20% were considered moderate evidence of an interaction. All analyses were conducted using SAS version 9.4 (2013, SAS Institute, Cary, NC) and MPlus version 7.4 (2015, Los Angeles, CA).

RESULTS

CFA and EFA

The 6 factor CFA model did not fit the data well (Model χ^2 = 17328.9, df = 974, p < .001; RMSEA 90% CI: 0.072 to 0.074; CFI = 0.57; WRMR = 4.60). The factor loadings for individual items showed that only 2 variables did not fit well on their factor: count of indoor physical education facilities at school and distance to the nearest trail did not fit well on the "Opportunities for Exercise" factor (Supplemental Table 1). Because the factor loadings did not allow much insight into the misfit of the CFA model, we turned to EFA to determine if the variables were more consistent with a different number of factors.

The eigenvalue test and the scree-plot in EFA were not consistent in the number of factors predicted. Although the eigenvalue test in EFA showed 16 factors with eigenvalues greater than 1, the scree-plot showed an inflection, or the last sharp drop in the eigenvalues, from 8 to 9 factors (Figure 2). As the scree plot showed small additional explanatory power for each factor beyond 9, the factor loadings for 8- and 9-factor solutions were examined. When factor loadings were examined for a 9-factor solution, one factor only had one measured variable loading onto it. Therefore, the 8-factor solution EFA was chosen as the best fit. This solution showed fair global fit for the model (RMSEA 90% CI: 0.053 to 0.055; CFI = 0.82).

Two of the 8 factors seemed to represent general environment characteristics. Two factors represented school characteristics. One school factor seemed to reflect physical education offerings and the other school factor reflected the school environment more generally. One factor captured parent physical activity behavior, and another factor captured the participants' sedentary behaviors. One factor reflected personal level characteristics. One factor reflected a mix of personal and social characteristics (Table 3). In sensitivity analysis with direct oblimin rotation for the factor loadings, a few variables loaded onto different factors (Supplemental Table 2). These were variables like Physical Activity Barriers that showed similar loadings onto 2 different factors in both the geomin and oblimin rotations. The interpretations of the factors were not subjectively different between the geomin and oblimin solutions (Supplemental Table 2).

Associations of Factor Scores with MVPA

The model fit for the mutually adjusted regression model showed a Bayesian Information Criterion (BIC) of 7262.4 for the maximum likelihood solution; using a fixed-effects model with ordinary least squares estimation, this corresponds to an overall r-squared of 0.22. In the regression models mutually adjusted for all the factor scores, the *Personal/Social* factor showed the strongest association with MVPA among both boys and girls (Table 4). One standard deviation greater score on the *Personal/Social* factor was associated with 0.86

standard deviations greater MVPA among boys (95% CI: 0.75 to 0.97) and 0.76 standard deviations greater MVPA among girls (95% CI: 0.67 to 0.85) after adjusting for the other factor scores and age, ethnicity/race, household income and parent education level.

All other factors showed weak or non-statistically significant associations with MVPA (Table 4). The factor score associations did not change substantially when BMI, substance use and distance to trails – all of which loaded onto unexpected factors – were removed from the models in sensitivity analyses. Factor score associations were not substantially different under complete case analysis compared to multiple imputation analysis. None of the factor scores showed even moderate evidence of differing by ethnicity/race (all FDR for the interaction terms were greater than 0.20).

DISCUSSION

In this study, we tested an *a priori* factor model of correlates of physical activity using confirmatory factor analysis, and explored other possible factor models using exploratory factor analysis. We found that an 8 factor EFA model supported independent environmental clusters of possible predictors of MVPA, but showed that personal and social correlates may cluster together. Indeed, the factor with the strongest predictive association with MVPA represented a mix of personal and social measured variables. The associations of the factor scores with MVPA showed similar patterns among boys and girls and across the ethnicities/races, with the *Personal/Social* factor score most strongly associated with MVPA.

Previous analyses that have been undertaken of individual correlates of MVPA in the Project EAT-2010 study and other samples were organized *a priori* using a social-ecological framework.[9] The present study expands on this previous work by testing whether measured variables fit into categories defined by a social-ecological framework, and considering how empirically derived clusters of measured variables perform in predicting MVPA. Unlike previous analyses, the current analysis provides evidence that there may be more subtle distinctions within levels of the social-ecological framework and that some mechanisms may act across levels. Whereas Graham et al analysis found that *a priori* classified personal level correlates of MVPA had the strongest direct association with MVPA, the factor we found having the strongest association with MVPA was composed of a mix of personal and social correlates.

The *Personal/Social* factor included psychological items like physical activity self-efficacy, behavioral items like participation on sports teams and social context items like perceived parent physical activity and friends' self-reported physical activity. This may reflect some level of self-sorting at adolescence into groups defined by higher or lower levels of activity and reflecting some socially and personally constructed *identity* as active or non-active. This hypothesis of a constructed identity that is based on physical activity behavior could help explain unique findings in previous studies. For example, Garcia Bengoechea et al found that parental or peer apathy or disinterest towards physical activity was a stronger barrier to physical activity in adolescents than parents or peers actively discouraging physical activity. This may be consistent with a constructed identity hypothesis of physical activity – where an adolescent who already identifies as active may be discouraged from excess activity to

balance other pursuits, while adolescents whose social groups are apathetic towards activity do not form an identity as being active.

It is possible also that within social-ecological levels there are multiple mechanisms acting at once. Ommundsen et al, using EFA, found that Norwegian children primarily engaged in activity in commuting to school, in community sports and in unstructured play at school, and that the correlates of these behaviors differed. Also using EFA, Olvera et al, found that activity among white and Hispanic children was divided between free-play, sports, and exercise. These contexts may have different predictors of physical activity. Our study found that the environmental context and the school context were each captured by 2 factors in the EFA. Building from the theory of Spence and Lee, it will be useful in future work to determine the extent to which the associations of environmental factors with MVPA are mediated by personal/social factors, or whether the associations of personal/social factors with MVPA differ by environmental context.

Alternative Approaches, Limitations and Strengths

Latent variable approaches attempt to find clustering either of variables, or of people within categories. We chose a variable centered approach – confirmatory and exploratory factor analysis (CFA and EFA) – as opposed to a person-centered approach – latent class analysis (LCA), as factor analysis is more suited to an examination of a large number of predominantly continuous variables. An LCA approach would require categorization of variables to interpret the resulting latent classes. With a large number of variables examined, categorization presents the possibility of unstable model estimation. We recognize that an LCA approach to this problem would be useful. However, we also recognize that many of the inferences we make from the EFA approach will be similar to those we would expect to obtain from an LCA approach. Additionally, the factors described in this study, particularly the *Personal/Social* factor could form the basis for future person-centered analyses to better examine the hypothesis that an identity is constructed around physical activity that is both personally and socially constructed.

Inferences from this study are limited by the cross-sectional nature of the data and the self-report measurement of MVPA. Temporality cannot be established between dependent and independent variables in regression analyses; therefore, reverse causation is likely. MVPA was assessed with self-report in this study. Whereas self-report captures some modes of activity like swimming and contact sports that are not usually captured with accelerometers, self-report is also subject to social desirability bias. Future studies will need to examine longitudinal data and examine other measures of MVPA like accelerometers. Additionally, the factors identified in this study may be specific to this sample. Future work with different samples will be needed to assess the generalizability and validity of these factors.

Although the factors we identified seem to roughly fit the headings we assigned them, these headings are subjective and open to different interpretations, especially given that there are many items that load onto unexpected factors. For example, substance use loaded onto a factor with environmental correlates. Furthermore, although we tested for residual correlation due to same source, it is possible that the factors loaded as they did in part due to questions coming from the same source. For example, the *parent* factor consisted of items

only from the parent survey – including 4 physical activity items, but also one unexpected screen-time item. Encouragingly, though, some factors seemed particularly clear – like the *sedentary behavior* factor, which consisted only of home media and screen-time items and included items measured from both the adolescent surveys and the parent surveys. The personal/social factor included responses from the individual participants as well as linked responses from their nominated friends. These factors will likely need to be refined through future work.

The strengths of this study are its breadth of measured variables and its large and diverse sample. Although the data were collected 10 years ago, we are unaware of any studies that include such a large number of possible predictors of physical activity in a sample of United States adolescents. The Project EAT-2010 sample includes measured variables at the personal, social and environmental levels of the social-ecological framework. These variables come from multiple sources, including adolescent report, parent report, surveys of school staff and neighborhood GIS measures. The breadth of variables and data sources, as well as the large sample size, allows a relatively robust testing of the Project Foresight Theoretical Measurement model. Additionally, the diversity of the sample, as well as its size allowed us to perform subgroup analyses to determine if the associations of the factor scores with MVPA differed by ethnicity/race as well as by sex.

Conclusion and Implications for Practice

The social-ecological framework is useful for organizing modifiable correlates of physical activity by level of influence. However more specific mechanisms acting within each level of influence may cause correlates to further cluster within levels. And further complicating the organization of correlates is the possibility of clustering of correlates *across* social-ecological levels. Our study is unique in using factor analysis to show that correlates of MVPA may load onto the same factor across levels of the social ecological model. The factor that captured personal and social influences around physical activity had the strongest correlation with MVPA, which leads us to hypothesize that there may be a mechanism of identity creation that is driven by both personal and social characteristics that is critical to predicting physical activity in adolescents. This hypothesis points to directions for future work, like person centered approaches to describing identity classes that may be more or less associated with physical activity and may inform interventions to increase physical activity.

Interventions to increase adolescent physical activity have traditionally been targeted at schools, yet have often shown limited effects.[9] There is a present trend towards leveraging technology to engage youth in physical activity, for example through exergaming or activity based videogames or through self-monitoring using devices like pedometers. However, the results from the present study suggest that it may be advantageous to pursue interventions that aim to increase physical activity within social networks consisting of parents and peers. Social network approaches may be considered as novel interventions on their own but could also be leveraged to possibly improve existing approaches such as those based in schools or on self-monitoring.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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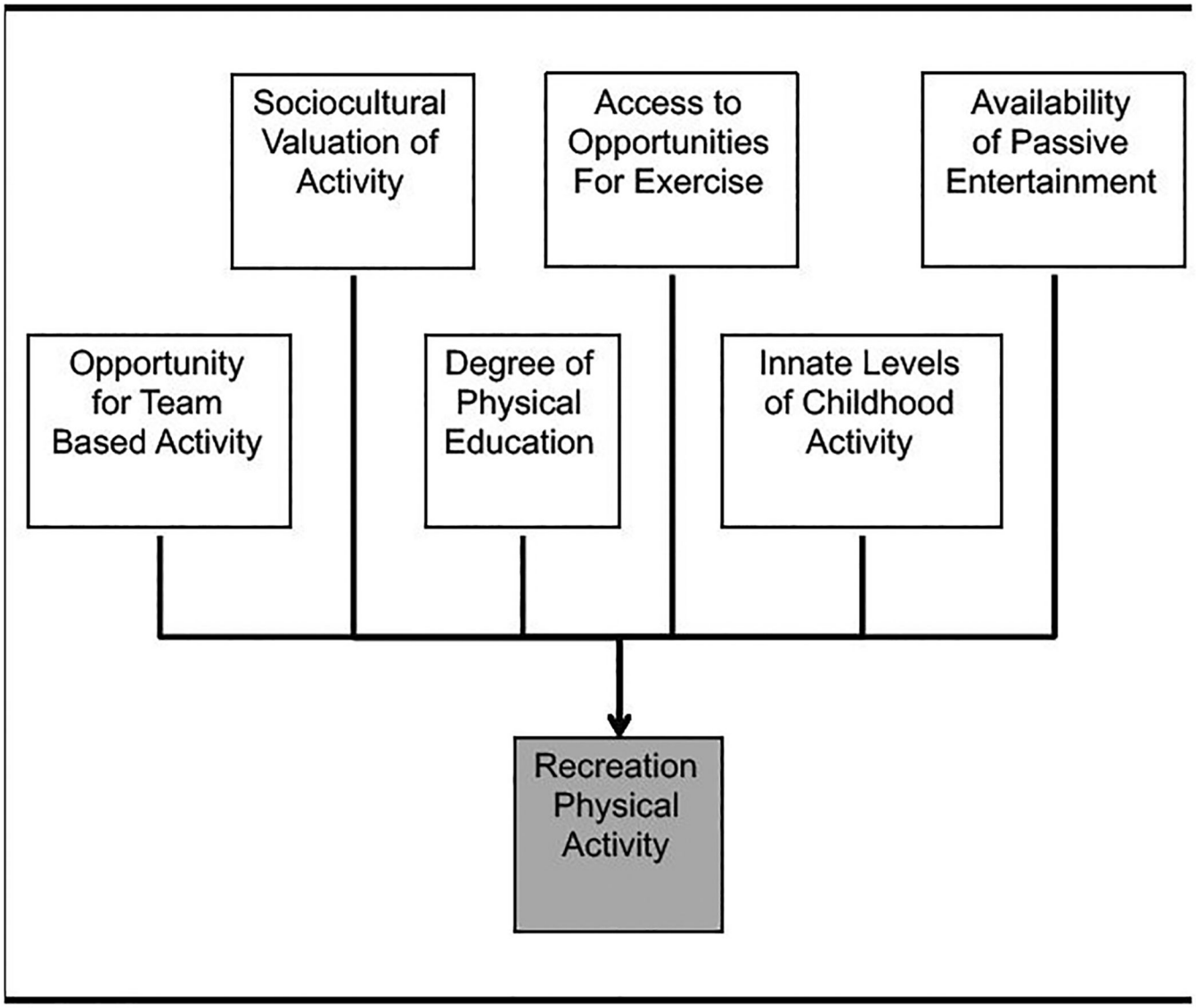

Figure 1.
Theoretical Model of the Determinants of Recreation Physical Activity Behavior

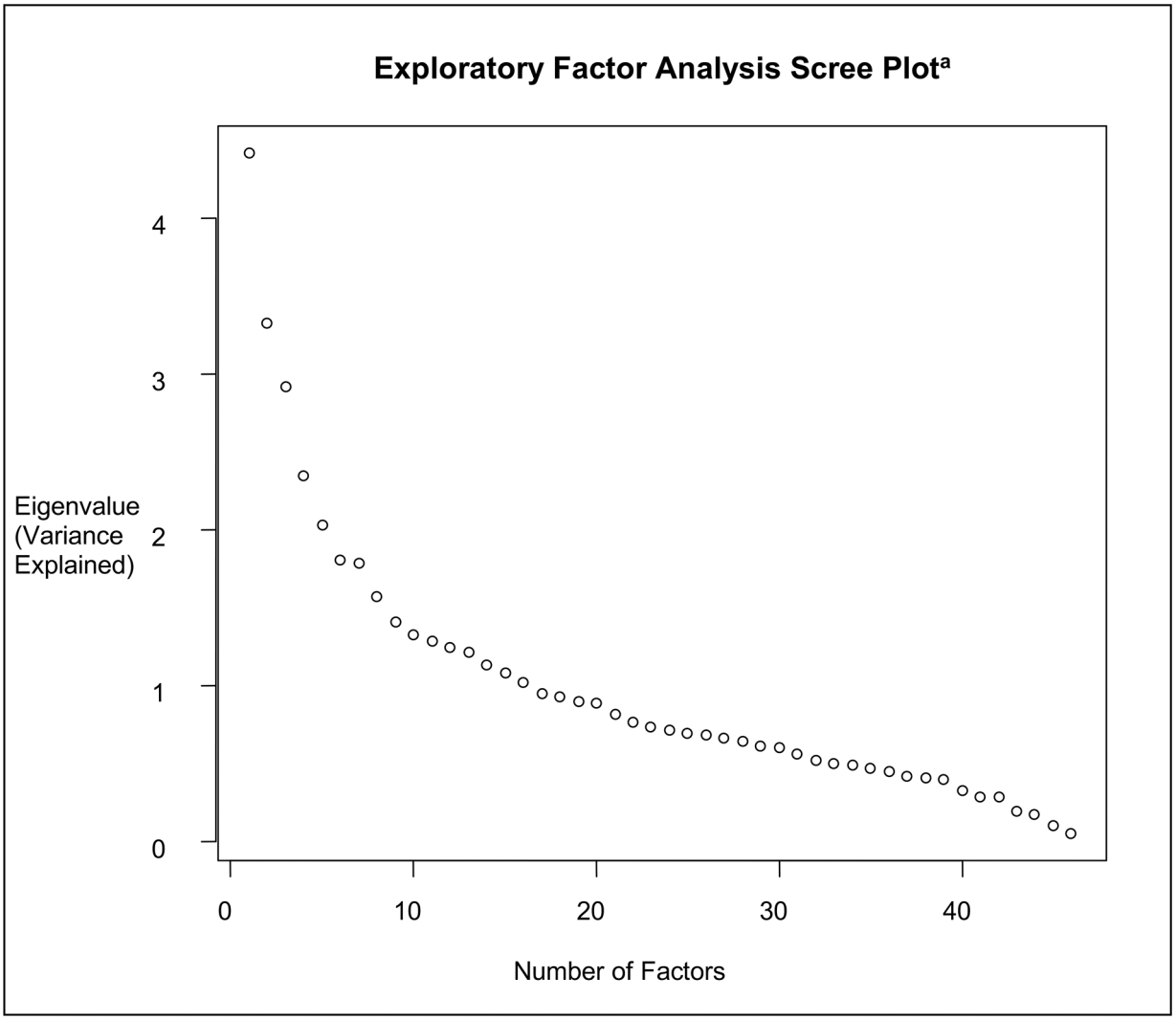

Figure 2. EFA Screeplot

Note. a:The Scree Plot is a visual test to determine the number of meaningful factors in an Exploratory Factor Analysis. The point where the plot flattens indicates that additional factors explain less of the covariance among the measured variables.

Table 1

Sample Demographics

	Analysis Sample (N = 2779)
Age: Mean (SD)	**14.4 (2.0)**
MVPA: Mean (SD)	**5.8 (4.7)**
Race-Sex Groups: N (%)	
Boys	1302 (46.9%)
White	277 (10.0%)
African American	378 (13.6%)
Hispanic	252 (9.1%)
Asian	260 (9.4%)
Mixed or Other	135 (4.9%)
Girls	1477 (53.1%)
White	248 (8.9%)
African American	428 (15.4%)
Hispanic	311 (11.2%)
Asian	293 (10.5%)
Mixed or Other	197 (7.1%)
Parent Education: N (%)	
Less than High School	616 (23.4%)
High School	556 (21.1%)
Some College	748 (28.4%)
Bachelor's Degree	476 (18.1%)
Advanced Degree	239 (9.1%)
Parent Income: N (%)	
Less than $20,000	846 (37.6%)
$20,000 – $34,999	516 (22.9%)
$35,000 – $49,999	351 (15.6%)
$50,000 – $74,999	266 (11.8%)
$75,000 – $99,999	137 (6.1%)
$100,000 or more	137 (6.1%)

Table 2

Correlates of MVPA by Project Foresight Model Construct

Variable (Unit)	Source	Mean (SD)	Description[a]
Inclination to Activity			
Physical Activity Enjoyment (Range: 3–12)	Adolescent Report	5.26 (2.25)	3 item scale (Cronbach's alpha = 0.82); Higher score indicates lower enjoyment.
Physical Activity Barriers (Range: 4–20)	Adolescent Report	9.73 (3.22)	4 item scale (Cronbach's alpha = 0.49); Higher score indicates greater barriers.
Physical Activity Self-Efficacy (Range: 3–12)	Adolescent Report	7.86 (2.38)	3 item scale (Cronbach's alpha = 0.76); Higher score indicates greater self-efficacy.
Physical Activity Self-Management (Range: 5–15)	Adolescent Report	8.82 (3.14)	3 item scale (Cronbach's alpha = 0.82); Higher score indicates greater self-management.
BMI (z-score)	Measured by Research Staff	0.71 (1.07)	Z-score of BMI measured as kg/m2
Past Year Substance Use Frequency Score (Range: 3–15)	Adolescent Report	3.85 (1.88)	Participant Use of Alcohol, Cigarettes or Marijuana in the past year (test-retest reliability: r = 0.83). Higher score indicates greater frequency.
Depression (Range: 6–18)	Adolescent Report	10.21 (3.01)	6 item scale (Cronbach's alpha = 0.83); Higher score indicates greater depressive symptoms
Opportunities for Team Based Activity			
Activity Fee (No Fee/Waiver Available/Fee with No Waiver)	PE Specialist Survey	2.23 (0.52)	Students must pay an activity fee to participate in any sport, intramural or physical activity clubs?
Availability of a Sport Bus (yes/no)	PE Specialist Survey	61% Yes	School has an afterschool bus for sports, academic, club, or discipline reasons (yes/no)
Distance to the Nearest Gym (kilometers)	GIS	1.26 (0.73)	Distance (km) to nearest gym
Distance to the nearest Rec Center (kilometers)	GIS	0.52 (0.37)	Distance (km) to nearest Rec Center
Participation on Sports Teams (count)	Adolescent Report	2.03 (1.06)	"During the past 12 months, on how many sports teams did you play?" (test-retest reliability: r = 0.86)
Opportunities for Exercise			
Density of Parks near Home (%)	GIS	9.5 (7.4)	Percent of 1600m Buffer around home that is Greenspace
Indoor Physical Education Facilities at School (count)	PE Specialist Survey	4.55 (1.96)	Count of Indoor Activity facilities reported by PE Specialist
Outdoor Physical Education Facilities at School (count)	PE Specialist Survey	3.74 (1.36)	Count of Outdoor Activity facilities reported by PE Specialist
Perceived Neighborhood daytime safety (Range: 1–4)	Adolescent Report	1.72 (0.9)	"The crime rate in my neighborhood makes it unsafe to go on walks during the day." (test-retest reliability: r = 0.57); Higher score indicates lower feeling of safety.
Perceived Neighborhood nighttime safety (Range: 1–4)	Adolescent Report	2.29 (1.14)	"The crime rate in my neighborhood makes it unsafe to go on walks during at night." (test-retest reliability: r = 0.65); Higher score indicates lower feeling of safety.
Busy Streets in Neighborhood (count)	GIS	1.96 (0.95)	Percent of streets in 1600m Buffer around home that are busy
Distance to the nearest Trail (kilometers)	GIS	0.64 (0.47)	Street network distance (km) to nearest bike or walking trail
Access Points (count)	GIS	6.62 (1.67)	Count of streets crossing into 1600m buffer around home (unit= 10 crossings)
Reported Neighborhood Crime (count)	GIS	1.72 (0.97)	Count of total crimes per hectare near home in 2010

Variable (Unit)	Source	Mean (SD)	Description[a]
Distance to School (kilometers)	GIS	5.92 (4.58)	Street network distance (km) to school
Home Physical Activity Equipment (count)	Parent Report	2.28 (1.37)	Parent reported count of exercise equipment available at home. (test-retest reliability: % concordance = 80% to 89%)
Social Norms			
Perceived Mother's PA (Range: 1–4)	Adolescent Report	2.48 (0.99)	"My mother is physically active in her free time." (test-retest reliability: r= 0.70); Higher score indicates greater perceived mother activity.
Perceived Father's PA (Range: 1–4)	Adolescent Report	2.54 (1.08)	"My father is physically active in his free time." (test-retest reliability: r= 0.69); Higher score indicates greater perceived father activity.
Parent Self-Reported PA (hours/week)	Parent Report	4.08 (3.7)	Parent reported moderate and vigorous physical activity (Godin-Shepard, test-retest reliability: r = 0.56 to 0.75)
Parent Active with Child (hours/week)	Parent Report	1.22 (1.53)	Hours per week parent is active with their adolescent (test-retest reliability: r = 0.58)
Family does Active Things (Range: 1–4)	Adolescent Report	2.59 (0.98)	"My family and I do active things together." (test-retest reliability: r = 0.73); Higher score indicates more family activity.
Family Support for Physical Activity (Range: 1–4)	Adolescent Report	3.14 (0.92)	"My family supports me in being physically active." (test-retest reliability: r = 0.60); Higher score indicates more family support for activity.
Parent helps Child be Active (hours/week)	Parent Report	1.52 (1.86)	Hours per week parent helps their adolescent be physically active (test-retest reliability: r = 0.62)
Parent Talks to Child about being Active (Range: 1–5)	Parent Report	2.97 (1.2)	"Have you had a conversation with your child about being physically active?" (test-retest reliability: r = 0.64); Higher score indicates more frequent conversations about being physically active.
Friends Play Sports (Range: 1–4)	Adolescent Report	3.18 (0.81)	"My friends often play sports or do something active." (test-retest reliability: r = 0.54); Higher score indicates more friend activity.
Friends think it is Important to be Active (Range: 1–4)	Adolescent Report	2.91 (0.83)	"My friends think it is important to be physically active." (test-retest reliability: r = 0.43); Higher score indicates greater importance to friends of activity.
Friends are Active Together (Range: 1–4)	Adolescent Report	3.1 (0.87)	"My friends and I like to do active things together." (test-retest reliability: r= 0.49); Higher score indicates greater activity with friends.
Friend Self-Reported Physical Activity (hours/week)	Adolescent Report	6.19 (3.61)	Mean of Godin Shepard self-reported MVPA among nominated friends.
School Physical Activity Promotion (Range: 1–5)	School Administrator Survey	3.49 (0.77)	"To what extent has your school made a serious effort to promote increased physical activity among students?"; Higher score indicates greater efforts to promote physical activity.
Average Physical Activity of Students in School (hours/week)	Adolescent Report	5.78 (0.72)	Mean of Godin Shepard self-reported MVPA among students within the school.
Degree of PE			
Time spent in PA in an average week (hours/week)	PE Specialist Survey	3.91 (1.5)	"On average, how many minutes per week do students at your school participate in physical education?"
School's Required Physical Education Credits (credits/year)	PE Specialist Survey	0.65 (0.58)	"What is the minimum physical education requirement for students at your school?"
Had gym class in the last year (yes/no)	Adolescent Report	47% Yes	Adolescent participated in gym class in the past year.

Variable (Unit)	Source	Mean (SD)	Description[a]
Passive Entertainment			
Video Games in Bedroom (yes/no)	Adolescent Report	64% Yes	In the room where you sleep, do you have an electronic games console?" (test-retest reliability: % concordance = 94%)
TV in Bedroom (yes/no)	Adolescent Report	39% Yes	In the room where you sleep, do you have a television?" (test-retest reliability: % concordance = 97%)
Screen Time (hours/day)	Adolescent Report	5.74 (3.82)	Hours per day watching TV, using a computer, or playing video-games. (test-retest reliability: r = 0.86)
Parent watches TV with Child (hours/week)	Parent Report	2.38 (1.92)	Hours per week parent watches TV with their adolescent (test-retest reliability: r = 0.53)
Parent TV hours (hours/week)	Parent Report	14.35 (9.14)	"On an average day, how many hours do you spend watching TV, DVD's, or videos?" (test-retest reliability: r = 0.78)
Home Media Equipment (count)	Parent Report	7.75 (3.33)	Parent reported count of media equipment available at home. (test-retest reliability: r = 0.73 to 0.90)

Note.

[a]: Internal reliability for score measures is represented with Cronbach's alpha. Higher alpha values indicate better internal reliability.

Table 3

Factor Loadings from the 8 Factor EFA Solution

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Personal/Social								
Physical Activity Enjoyment	−0.375	0.183	−0.003	−0.026	−0.026	−0.025	0.049	0.003
Physical Activity Barriers	−0.239	0.236	−0.016	0.099	0.045	0.031	0.077	0.001
Physical Activity Self-Efficacy	0.434	0.001	0.012	0.004	0.016	−0.005	−0.009	0.087
Physical Activity Self-Management	0.458	0.104	0.019	0.038	0.048	−0.02	−0.018	0.021
Participation on Sports Teams	0.375	−0.058	0.032	−0.097	0.053	0.071	−0.012	0.024
Perceived Mother's PA	0.317	−0.134	0.197	0.136	−0.023	0.029	0.073	0.05
Perceived Father's PA	0.309	−0.07	0.156	0.142	0.004	0.103	0.083	−0.005
Family does Active Things	0.421	−0.14	0.158	0.19	−0.12	−0.011	0.01	−0.083
Family Support for Physical Activity	0.535	−0.154	0.116	0.051	−0.032	0.088	−0.02	0.009
Friends Play Sports	0.84	0.034	−0.343	−0.11	0.015	−0.021	0.002	−0.001
Friends think it is Important to be Active	0.804	0.049	−0.34	−0.003	0.03	−0.027	−0.005	−0.044
Friends are Active Together	0.737	0.014	−0.211	−0.023	−0.033	−0.033	0.034	0.023
Friend Self-Reported Physical Activity	0.136	−0.014	−0.091	−0.095	0.117	0.094	0.037	0.103
Personal 2								
BMI Percentile	−0.038	0.139	0.104	−0.078	0.016	−0.049	0.011	−0.027
Depression	−0.236	0.295	−0.014	0.023	0.115	0.004	0.029	0.076
Perceived Neighborhood daytime safety	−0.008	0.867	−0.005	0.006	−0.039	−0.003	−0.03	−0.026
Perceived Neighborhood nighttime safety	0.014	0.885	0.015	−0.018	−0.019	0.018	−0.009	−0.01
Parent								
Parent Self-Reported PA	0.013	−0.021	0.487	−0.032	0.048	−0.008	−0.018	0.055
Parent Active with Child	−0.01	0.038	0.625	−0.039	−0.009	−0.111	−0.011	−0.075
Parent helps Child be Active	0.173	0.03	0.53	−0.101	0.059	0.035	−0.017	0.05
Parent Talks to Child about being Active	0	0.094	0.267	0.007	−0.056	−0.059	0.043	−0.089
Parent watches TV with Child	−0.049	0.051	0.319	−0.181	−0.016	−0.053	0.028	−0.029
Sedentary Behavior								
Video Games in Bedroom	−0.086	0.075	−0.009	0.786	0.061	0.016	−0.023	0.042
TV in Bedroom	−0.005	0.017	−0.031	0.899	−0.001	−0.002	0.04	0.007

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8
Screen Time	−0.089	0.074	−0.042	−0.336	−0.01	0.015	0.031	−0.018
Parent TV hours	−0.029	0.058	0.069	−0.358	−0.039	−0.044	−0.012	0.021
Home Media Equipment	0.03	0.08	0.059	−0.328	0.013	0.088	0.059	0.259
School 1								
Sport Bus	0.036	0.066	0.034	0.076	−0.9	0.015	0.457	0.023
Indoor Physical Education Facilities at School	−0.008	0.011	0.021	0.068	0.603	0.468	−0.099	0.124
Outdoor Physical Education Facilities at School	0.041	0.029	0.054	0.109	0.708	−0.008	0.254	−0.039
Distance to the nearest Trail	−0.038	−0.01	−0.081	−0.078	−0.269	0.256	−0.014	0.044
Average Physical Activity of Students in School	0.061	0.008	0.005	0.049	0.392	0.145	0.046	0.318
Time spent in PE in an average week	−0.002	0.005	−0.016	−0.03	0.403	−0.07	−0.383	0.111
School 2								
School's Required Physical Education Credits	−0.002	−0.002	−0.015	0.066	0.186	−0.797	0.022	0.041
Had gym class in the last year	0.031	0	0.107	−0.073	−0.023	−0.211	−0.2	0.023
Activity Fee	0.005	0.021	−0.005	0.022	0.439	0.552	0.025	−0.345
Environment 1								
Substance Use	−0.068	0.02	−0.025	−0.074	0.028	0.057	−0.142	0.141
Distance to the nearest Rec Center	−0.059	−0.118	−0.06	−0.093	−0.009	0.171	0.54	0.009
Busy Streets in Neighborhood	0	−0.013	−0.004	−0.085	0.27	−0.031	0.559	−0.539
Road Intersection Density	0.031	0.114	0.04	0.046	−0.018	0.044	−0.571	−0.404
Distance to School	0.019	0.031	−0.014	0.032	−0.018	0.102	0.451	0.138
School Physical Activity Promotion	0.042	0.052	0.056	0.116	−0.195	−0.126	0.478	0.245
Environment 2								
Distance to the Nearest Gym	−0.007	0.034	−0.044	0.011	0	−0.127	−0.041	0.442
Density of Parks near Home	−0.025	−0.091	0.022	−0.03	−0.009	−0.027	0.251	0.317
Reported Neighborhood Crime	0.024	0.153	0.003	0.014	−0.035	0.015	−0.145	−0.577
Home Physical Activity Equipment	0.144	−0.006	0.156	−0.129	0.01	0.104	0.066	0.217

Table 4

Associations of Factor Scores with MVPA[a]

Factor	Girls: β [95% CI][b]	Boys: β [95% CI][b]
Personal/Social	0.76 [0.67 to 0.85]	0.85 [0.74 to 0.97]
Personal 2	−0.10 [−0.17 to −0.03]	−0.04 [−0.13 to 0.05]
Parent	0.04 [−0.04 to 0.13]	0.11 [−0.0002 to 0.22]
Sedentary	−0.06 [−0.15 to 0.03]	−0.05 [−0.14 to 0.04]
School 1	0.16 [0.06 to 0.27]	0.05 [−0.07 to 0.17]
School 2	0.12 [0.04 to 0.19]	0.001 [−0.08 to 0.08]
Environment 1	−0.12 [−0.25 to 0.01]	0.02 [−0.13 to 0.16]
Environment 2	0.04 [−0.05 to 0.13]	0.11 [0.01 to 0.21]

Note.

[a]: Models mutually adjusted for all factor scores as well as age, race, parent education and parent income

[b]: Beta coefficients represent the standard deviation change in reported MVPA with a 1 standard deviation change in the factor score