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A Cohort-Sequential Latent Growth Model of Physical Activity from Ages 12-17 Years

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Abstract

Background—Despite serious public health implications of decreased physical activity during adolescence, few longitudinal studies have been conducted to determine the trajectory and important correlates of physical activity change during this period.

Purpose—This study examined change in physical activity from ages 12-17 years, and the influences of personal, family, peer, and demographic factors on activity patterns.

Methods—Data were from 371 youth. The sample was 50.1% female; 76% White, 12% African American, 4% Hispanic, 2% Asian, 2% American Indian, and 4% other or mixed races. Mean age was 12.05 years (SD = 1.63) at Time 1. Multivariate latent growth curve modeling (LGM), a cohort-sequential design, and a multiple-group design by gender were employed.

Results—Youth physical activity declined significantly from ages 12-17. Boys had higher initial levels of physical activity than girls. Efficacy to overcome barriers, physically active friends, and friend social support all played roles in reducing the decline in physical activity. Early maturing boys, while more physically active initially, experienced a greater decline in physical activity compared to later-maturing boys.

Conclusions—These findings encourage further research on the etiology and development of youth physical activity using procedures such as LGM, to better understand the risk and protective factors associated with youth physical activity decline.

Introduction

Adolescence is a critical period in the study of physical activity. A review of studies of objectively measured physical activity (heart rate monitors and motion detector) found significant declines in physical activity (heart rate data) over the school-age years (1). Physical activity declined at about 2.7% yearly for males and 7.4% per year for females (1,2). There is a particularly sharp decline through the teenage years (3) with ages 11-12 thought to be a critical age at which physical activity begins to diminish (4). There are serious public health implications of decreased physical activity during adolescence (5). Many of the values and beliefs that influence and regulate health-related behavior are learned during adolescence, and habits are formed which may last a lifetime (6). Despite this, few longitudinal studies on physical activity have been conducted during adolescence. To best determine how to encourage adolescent physical activity, etiological and developmental longitudinal research is needed to understand the changing patterns and determinants of physical activity during this developmental period (7).

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Appropriate statistical techniques for longitudinal data are necessary to best examine change in adolescent physical activity. Few studies of youth physical activity have been conducted using analytic techniques such as latent growth modeling (LGM). LGM is able to capture important group statistics in a way that allows the researcher to study development at the group level while also capturing individual differences in levels and trajectories of physical activity over time (8). Questions and hypotheses concerning the determinants of initial status and growth can be addressed by examining covariates of intercept and slope scores.

Changes in adolescent physical activity do not occur in isolation. Adolescence is embedded in a broader social network of community, society, and culture (9). According to Social Cognitive Theory (SCT) (10,11), behavior is influenced by personal and environmental factors, and the influence is bidirectional. Because of this interaction between person and environment, the most complete studies of adolescent physical activity should incorporate variables from different contexts (9,12). The current study includes covariates of adolescent physical activity from personal, family, peer, and demographic contexts.

Personal Factors Influencing Youth Physical Activity

Physical maturation—Puberty is a major physiologic event in adolescence that likely influences activity patterns (13). Despite the obvious importance of growth and maturation on youth physical activity, research linking the two is extremely limited. Physiological and developmental factors believed to be related to youth physical activity include relative body mass and stage of puberty (4,14). Successful girl athletes tend to be delayed in maturation whereas successful boys tend to be advanced in maturation (15). Overall, few studies have included physical maturation as a covariate of physical activity, and its effects remain unclear (13).

Barriers efficacy—Central to Bandura's (10,11) Social Cognitive Theory is the notion of self-efficacy, that is, the individual's beliefs in his/her capabilities to execute necessary courses of action to satisfy specific situational demands. Efficacy expectations are theorized to influence choice, effort, and persistence (10), and may be related to specific tasks (i.e., task self-efficacy), or to impediments, barriers, or challenges to successful behavior (i.e., barriers self-efficacy). Self-efficacy beliefs in general have been shown to influence adolescent physical activity (16). Barriers self-efficacy reflects youth confidence in their ability to participate in physical activity given various obstacles to physical activity participation (17, 18,19). Some of the most prominent barriers to adolescent physical activity participation are lack of time, school work, time conflicts, other interests, activities with family or friends, too tired, lack of facilities, and the weather (20,21). Recent studies have shown a relationship between barriers self-efficacy and youth physical activity participation (17,18,19). For example, Nigg and Courneya (18) demonstrated that self-efficacy scores increased in a sample of 9th to 12th graders. Trost et al. (17) found that self-efficacy mediated the effect of parental support on youth (grades 7-12) physical activity participation, and Wu et al. (19) found self-efficacy to be the strongest correlate of physical activity among early adolescents. Though clearly an important correlate of youth physical activity in cross-sectional studies, it is unclear how barriers self-efficacy relates to *change* in physical activity throughout adolescence.

Family Factors Influencing Youth Physical Activity

Studies have shown that parents may influence their children's physical activity both directly and indirectly (22,23,24). Mechanisms hypothesized to account for consistencies in family activity include genetics and environmental variables (e.g., modeling, shared activities, social support) (23). Active parents tend to have more active children (25) and physically active parents are likely to be more involved in their child's physical activities (24).

The family is an important source of social support for youth (7,26). Support might take a variety of forms: informational and emotional (e.g., providing information, viewing practices, discussing physical activity), and instrumental/tangible aid (e.g., offering to take part in the activity with the child, and assisting with fees, equipment, and transportation) (7,23,26).

Peer Factors Influencing Youth Physical Activity

As children age, they spend more time with friends compared to family, enhancing the potential for peer influences in a number of domains (27,28). In adolescence, peers represent increasingly important role models and sources of social support for physical activity and for efficacy beliefs regarding activity. Despite the apparent importance of peers in influencing adolescent physical activity, few studies have studied this influence or have included peers as part of the physical activity support network for youth (26,29).

Wold and Anderssen (30) found the sport participation of best friends to be more strongly associated with 11- to 15-year-olds' sport activity than the participation of family members. More recently, Duncan et al. (26) found that friend support was a stronger influence of 10- to 14-year-olds' physical activity than parent or sibling support. As with parents, peer support may serve a number of functions: social integration or companionship; emotional support; informational support; instrumental support; and reassurance of worth.

Demographic Factors Influencing Youth Physical Activity

When studying youth physical activity, the influence of demographic factors must be considered. Prior research demonstrates that younger children are more active than older children (31,32). There is a decline in physical activity during adolescence, with adolescent girls at particularly high risk for inactivity (33). Factors influencing physical activity also may differ by gender. Zakarian et al. (34) found both common predictors of physical activity among males and females (e.g., self-efficacy) and marked differences (e.g., body mass index [BMI] and family support correlated with vigorous exercise for females but not males). More physical activity and less sedentary behavior is reported in White compared to minority populations (4,13) and children in higher-income families tend to be more active than other children (13, 35).

The purpose of the current study was to examine the developmental nature of physical activity (increase, decrease) among boys and girls from ages 12-17. Using LGM, the aim was to determine the developmental trajectory of physical activity as well as the determinants of initial physical activity and growth of physical activity. The determinants included demographic, personal, family, and peer variables, and were selected based on prior research and hypotheses regarding expected influences. More malleable variables (e.g., efficacy, family and friend activity and social support) may have potential importance in future interventions.

A cohort-sequential design was employed within the LGM to allow assessment of the developmental trajectory of physical activity from ages 12-17 years using only 4 years of data. In addition, based on literature indicating a need to understand how the context of physical activity may differ for boys and girls (4,36), a multiple-group analysis by gender was included. Several hypotheses were formed and tested: (a) Average levels (group means) of physical activity decrease throughout this period for boys and girls; (b) Individual physical activity participation varies significantly around group means; (c) Compared to girls, boys participate in more physical activity and have less decrease in physical activity; (d) Youth in higher-income families are more active; (e) Physical maturation and BMI are negatively related to physical activity; (f) Self-efficacy to overcome barriers is positively related to activity; (g) Family and peer physical activity and social support are positively related to physical activity.

Method

Participants and Procedures

Data for this study were collected from youth residing in a metropolitan area in the Pacific Northwest. As part of a longitudinal cohort-sequential study design, data were collected from three age cohorts (ages 10, 12, and 14). Families having eligible children were randomly recruited from 58 neighborhoods, primarily using a computer-aided telephone interviewing (CATI) system. Recruitment was balanced across seasons. Of eligible families, approximately 68% agreed to participate (37). Compared to 2000 Census data, families in this study were representative of the county from which they were recruited in terms of race (76% vs. 79%) and family structure (23% vs. 20.3% single-parent families). In addition, youth in this study were similar to same-age children in the 1999 Youth Risk Behavior Surveillance Survey on vigorous physical activity (69% vs. 72%), enrollment in physical education (79% vs. 79%), and sport team membership (58% vs. 59%).

Participants were assessed annually for 4 years at the participants' homes. The youth and a parent completed surveys in the presence of trained research assistants. Children aged 11 years or younger were administered the survey as an interview. Participants completed individual surveys in private, away from other family members, to enhance confidentiality. For 7 days prior to the survey, youth completed a daily record of physical activities and wore a pedometer to record the number of steps taken each day. In Year 1, youth were paid $25 for completing the assessments with a bonus of $5 if all aspects of the assessment were completed. Parents were paid $15. The payment was increased by $5 each year. Appropriate Institutional Review Board approval for research with human subjects was obtained; informed consent (adult) and assent (youth) was obtained for all participants.

Data included 371 youth. The sample was 50.1% female; and 76% White, 12% African American, 4% Hispanic, 2% Asian, 2% American Indian, and 4% other or mixed races. Mean age at Time 1 was 12.05 years (SD = 1.63). The annual household income for the sample was: 19% under $30,000, 30% $30,000-$49,999, 26% $50,000-$69,999, 13% $70,000-$89,999, and 12% $90,000 and above. Attrition from Times 1-4 was 4.3%.

Measures

Youth Physical Activity—Since physical activity is a complex multidimensional behavior, researchers emphasize collecting data from multiple sources (38,39). The suitability of each methodology depends on the type of research, the age and number of research participants, and pragmatic considerations such as the resources available to the researcher (40). The measures of youth physical activity used in this study included survey items and data from electronic motion sensors (pedometers).

Survey items—Three survey items were used based on prior measures (41,42). The first two items were based on questions from the Youth Risk Behavior Survey (YRBS) (42,43,44). Youth were asked: (a) “On how many of the past 7 days did you exercise or take part in hard physical activities that made you sweat and breathe hard for at least 20 minutes without stopping (such as basketball, jogging, swimming laps, fast bicycling, or similar aerobic activities)?” and (b) “In a typical week, how many days do you take part in any regular physical activity long enough to work up a sweat (heart beats rapidly)?” For both items, responses ranged from 0 to 7 days. Reports in this study compare favorably to those from the 1999 YRBS; for example, hard physical activity at equal to or greater than 3 days a week is 69% in this sample vs. 72% in the YRBS data. The third survey item asked, “Compared to others the same age and sex, how much physical activity do you get?” (1 = “much less than others” to 5 = “much more than others”). This item was taken from a study of physical activity self-reports among children

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aged 10-16 years (41), in which it was found to be valid and reliable (test-retest *r* = .93) in this age group. Distributions for the self-report questionnaire items were normal with skewness scores ranging from -.351 to .187 for the three items across all 4 years.

Pedometer—The fourth physical activity measure was a pedometer. Pedometers have been shown to be valid and reliable tools for measuring youth physical activity (45,46). At the assessment visit, youth were instructed in how to wear a pedometer and record the number of steps taken each day for 7 days. The Yamax Digiwalker SW-701 (Optimal Health Products and Services, San Antonio, TX; $20.00 U.S.) was used in this study.

Compliance in filling out the 7-day physical activity record was generally very good, with 99% of participants recording the daily pedometer total for at least 4 of the 7 days (70.3% completed all 7 days). The study protocol was designed to maximize use of the pedometer and recording of the data on a daily record. Along with a pedometer, target youth received two project-logo magnets and were instructed to put the form on the refrigerator or in some other prominent place. Parents were encouraged to help remind children, and reminder phone calls were made to the family 2 days after the first visit. An average steps/day variable was computed by summing the number of steps for the week and dividing by the number of days. The average daily number of steps was then divided by 10,000 to rescale the values to reduce problems related to variance discrepancies across measures in the structural equation model (47). Skewness scores for the pedometer were acceptable, ranging from .830 to 1.328. The survey items and pedometer data were used as indicators of the youth physical activity latent factor.

Covariates—Covariates included personal or individual factors (BMI, physical maturation, barriers self-efficacy), family influences (parent physical activity, parent social support), peer influences (friends' physical activity, friends' social support), and demographic factors (race, parent marital status, household income). All variables were measured at the first assessment (Time 1) and were included as covariates of the physical activity intercept and slope factors. Change scores from Time 1 to Time 4 (calculated as Time 4 minus Time 1) also were included as covariates of the slope, or trajectory, of youth physical activity. Although measures were available for the covariates at all time points, the use of each individual covariate across time would have resulted in extremely complex and likely infeasible models. An acceptable alternative is to include a change score as a predictor (see (48) for more information relating to change scores).

Body Mass Index—Trained assessors measured height (m) and weight (kg) of participants using calibrated, sensitive scales. BMI was calculated as weight (kg) divided by height (m) squared (kg/m^2).

Physical Maturation—Physical maturation was assessed via self-report items using shortened versions of the boys' and girls' Pubertal Development scales (49,50). For this study, there were four items for girls and five items for boys. This measure provides an assessment of the child's level of maturation with regard to changes in body proportions (e.g., “growth in height” and “growth in breasts” for girls), facial features (e.g., “growth in body hair,” “skin changes, especially pimples,” and “hair growth on your face” for boys), and, for boys only, “deepening of your voice.” Youth responded on a 4-point scale from (1) “Not yet begun to change” to (4) “This change seems completed.” Internal consistency in this study was $\alpha = .80$ for girls and $\alpha = .79$ for boys.

Barriers Self-Efficacy—When the study started, there were no youth barriers self-efficacy measures available; thus, a measure of barriers self-efficacy was developed specifically for this study. The scale consists of 18 items with a common stem: “How confident are you that you can do exercise, sports, or other physical activities even when faced with any of the following obstacles?” Examples of obstacles include “The weather is bad,” “It is hard to get transportation to the activity location,” and “My schoolwork/homework schedule conflicts with the activity.” Responses were on a 5-point scale ranging from (1) “Not confident at all” to (5) “Completely confident.” Internal consistency of this scale was α = .92. This scale is similar to other scales used in recent studies of youth physical activity (17,18,19) which also demonstrated good reliability. The barriers self-efficacy variable correlated significantly ($p < .05$) with each of the physical activity measures at Time 1, hard physical activity, $r = .28$, typical physical activity, $r = .35$, activity compared to others, $r = .47$, and pedometer, $r = .14$.

Parent Physical Activity—One parent per family reported on their own, and their partner's (if applicable), physical activity. Parents were asked, “In a typical week, how many days do you take part in any regular physical activity long enough to work up a sweat (heart beats rapidly)?” Responses ranged from 0 to 7 days. Where appropriate, a mean score of own and spouse/partner's activity was computed.

Parent Social Support—Similar to items used in other studies (25,26), youth were asked the extent to which their parents provided different types of support. These included informational and emotional support (“Encourage you to do physical activities,” “Watch you take part in physical activities,” and “Talk with you about your physical activity”) and instrumental support/tangible aid (“Do a physical activity with you” and “Provide transportation so you can go to a place where you can do physical activities”). Questions asked how often during a typical week each parent did these things. Responses were on a 5-point scale ranging from (1) “Never” to (5) “Very often.” The internal consistency of the parent's social support scale was α =.78.

Friend Physical Activity—Youth reported on the physical activity of their friends. Children were asked, “In a typical week, how many days do your friends take part in any regular physical activity long enough to work up a sweat (heart beats rapidly)?” Responses ranged from 0 to 7 days.

Friend Social Support—Similar to parent social support, youth were asked the extent to which their friends provided different types of support. The informational and emotional support items were the same as for parents except the questions asked how often friends did these things. Given the age of the youth, the transportation item for friends asked whether friends or parents of friends provided transportation. Responses were on a 5-point scale ranging from (1) “Never” to (5) “Very often.” Internal consistency for the friends' social support scale in this study was α = .80.

Demographic Variables—Demographic variables of youth race, parent marital status, and family income were included in the model to control for their possible effects on youth physical activity over time. Because the majority of the participants were White, race (self-report) was coded 1 = White and 0 = other races. Parent-reported marital status was coded 0 = single-parent family and 1 = two-parent family. Parents also reported annual household income, which was divided into 11 categories, the lowest being “under $5,000” and the highest “more than $90,000.” Youth age and gender were included in the model as part of the multiple-group cohort-sequential design.

Analyses

LGM was used in this study to model developmental change (the trajectory) of physical activity among youth ages 12-17 years. LGM has numerous advantages over traditional methods for constructing complex and dynamic models that assess change (8,52). This strategy can describe a single individual's developmental trajectory and capture important group statistics in a way

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that allows the researcher to study development at the group level. LGMs are able to test both linear and nonlinear growth functions, and to determine which predictor variables affect the rate of development. Multivariate or higher-order LGMs allow examination of the degree to which relations among growth factors can be described by common higher-order constructs, and, similar to other structural equation models, permit testing of multiple samples in the same model. Accelerated or cohort-sequential designs also can be incorporated into LGMs.

Cohort-Sequential LGM—Given time constraints, concerns about attrition, and the cost of multiple assessments, researchers have long sought ways to maintain the advantages and minimize the disadvantages of the longitudinal design (8). In 1953, Bell introduced the idea of "convergence." This method calls for limited repeated measurements of independent age cohorts, resulting in temporally overlapping measurements of the various groups. This technique, which has gained popularity as the "cohort-sequential" (53) or accelerated design, provides a way to link adjacent segments of limited longitudinal data from different age cohorts to determine the existence of a common developmental trend, or growth curve. The analyses in this study incorporated a cohort-sequential specification (see (8) for a complete discussion), combining information from three different age cohorts simultaneously to approximate a long-term longitudinal study from ages 12-17 years.

Because of the overlap between ages, it was possible to test the hypothesis that a common developmental trajectory existed for physical activity from ages 12-17. Each age cohort contributes a different section of the overall curve. Because each cohort represents a different pattern of "missingness" in the overall developmental curve, it is possible to build the complete curve using information from all cohorts simultaneously. The same developmental model is assumed in each cohort, permitting tests of convergence across groups and the feasibility of specifying a common growth trajectory across 6 years.

Figure 1 depicts the model tested in this study. As shown in the bottom rows, data were collected in the 12- and 14-year-old cohorts, each measured at four approximately equal yearly intervals. Due to mean and variance issues with the 10-year-olds' data at the first two assessments (ages 10 and 11 years), data for this cohort were used at only two yearly intervals (ages 12 and 13 years). Specifically, data for the 10-year-old cohort at ages 10 and 11 years showed no significant variance in the model, which led to negative error variance estimates for the first two time points and an inadmissable solution for the model. This variance restriction could not be overcome because no other cohort contributed data for these two ages. The same model was assumed in each cohort (using cross-group constraints), allowing for tests of hypotheses concerning convergence across separate groups and the feasibility of specifying a common developmental trajectory.

Higher-Order Curve-of-Factors LGM—LGMs often are used to model growth as a factor of repeated observations of a single variable. In this study, youth physical activity was not represented by a single variable, but as a latent factor reflecting four variables. Therefore, it was necessary to use a multivariate or higher-order LGM to adequately represent change over time in the latent youth physical activity factor.

A curve-of-factors multivariate LGM was used to determine the trajectory of youth physical activity from ages 12-17 years. Within the model, a growth curve was fitted to factor scores representing what the four physical activity measures had in common at each age. That is, within the model the observed variables at each age were factor-analyzed to produce youth physical activity factor scores, which were then used for modeling the physical activity growth curve (54). Based on prior research, a linear growth model was used to capture the trajectory of physical activity from age 12-17 years.

In line with structural modeling conventions, squares in Figure 1 denote observed variables and circles denote latent variables. In the figure, the first common, or second-order, factor is labeled Youth Physical Activity Intercept and is a constant for any individual across time. The intercept represents information concerning the mean, represented by M_i, and variance, represented by D_i, of the collection of individual intercepts that characterize each individual's growth curve. The second factor, labeled Youth Physical Activity Slope, represents the trend of an individual's trajectory determined by the repeated measures. The second-order slope factor has a mean, M_s, and variance, D_s, across the whole sample. The basis terms (factor loadings) of the intercept are fixed at 1. The basis terms of the slope are fixed (0 to 5) to represent a linear growth trend in physical activity from ages 12-17 years. The slope and intercept are allowed to covary, R_{is}, shown by the double-headed arrow between the two factors.

In fitting the curve-of-factors LGM, unique covariances for each variable over time are allowed to covary. The curve-of-factors LGM requires a condition of factor pattern invariance where common factor pattern elements must be equal over time. In Figure 1, the variable “Hard Physical Activity” is used as the scaling reference for the first-order common factors (PA Age 12, 13, etc.), and the loadings for “Typical Physical Activity,” “Compared to Others,” and the pedometer data are constrained to be equal across time, as represented by the factor loadings *a*, *b*, and *c*, respectively. These first-order factors are then used as time-varying indicators for the second-order youth physical activity LGM. Detailed rationales for the metric invariance assumptions are provided by Nesselroade (55). Additional information on the specification of the curve-of-factors LGM can be found in McArdle (54) and Duncan et al. (8).

Gender Comparisons—A multiple-sample framework was used in the LGM analyses to make gender comparisons. Such multiple-sample analyses permit simultaneous evaluation of developmental hypotheses on multiple populations (e.g., males and females) (8,56). In this study, the analyses tested for significant differences by gender in initial levels of physical activity, the development of physical activity, and/or in those variables believed to exert effects on the growth parameters. LGM analyses were conducted using Mplus structural equation modeling software, version 3.11 (57). Program code for the LGM cohort-sequential curve-of-factors model is available from the authors upon request.

Results

Missing Data Analyses

In the present study, the percent of missing data across all variables ranged from 0% to 13%, with the majority of variables having 5% or less missing data. Thus, to make use of all possible data and reduce the likelihood of biased estimates, imputation of missing data was conducted using an EM-based procedure. The imputed data were then used in the LGM analyses. Means and variances for each of the variables in the model are shown in Table 1.

LGM Analyses

Unconditional Model—A series of LGM models was tested. Analyzed first was a linear unconditional or measurement model (e.g., a model containing no covariates) to determine the viability of the multiple-sample cohort-sequential curve-of-factors LGM. Constraints were placed across ages to determine the viability of the cohort-sequential model, and across genders. The model fit for the linear unconditional model was $\chi^2(334, N = 371) = 512.02$, $p < .05$, Comparative Fit Index (CFI) = .92, and Root Mean Square Error of Approximation (RMSEA) = .05. Values of .90 or greater on the CFI and .05 or less on the RMSEA suggest a model which adequately fits the relationships among the observed data. The observed physical activity variables all loaded significantly on the first-order physical activity age factors. As indicated earlier and shown in Figure 1, the variable “Hard Physical Activity” was used as the scaling reference for the first-order common factors (PA Age 12, 13, etc.) and thus set at "1." The loadings for the other variables on the first-order age factors were λ = .99, t = 22.20 for "Typical Physical Activity," λ = .42, t = 15.62 for "Compared to Others," and λ = .09, t = 8.33 for the pedometer data. Loadings for "Typical Physical Activity," "Compared to Others," and the pedometer data were constrained to be equal across time. The pedometer variable loaded less significantly than the other variables on the physical activity (PA) factor, but its contribution was a significant one, suggesting it shares significant variance with the other measures. Variance accounted for in the pedometer measure by the latent factor ranged from 10-17%.

Significant mean levels existed for the higher-order common factors of the youth physical activity intercept (age 12), M_i = 3.73, t = 35.46, and slope (growth from ages 12-17 years), M_s = -.234, t = -6.102. Individual differences in the higher-order intercept and slope factors also were significant, with variances of D_i = 1.78, t = 6.84, and D_s = .12, t = 3.73, respectively. These findings indicate that, at the group level, on average, there was a significant decline (negative linear slope) in physical activity from ages 12-17 years, with significant variation among youth in their initial physical activity at age 12 (intercept) and in their trajectory (slope) from ages 12-17. The correlation between the intercept and slope, R_{is}, also was significant, -.43, t = -2.46, indicating that higher levels of activity at age 12 were associated with greater decreases from ages 12-17.

Results of the linear unconditional model pointed to a significant gender difference in the intercept (Time 1) mean. Results suggested that a significant chi-square decrease would occur if this gender constraint were relaxed. Thus, a second unconditional model was analyzed with the gender constraint relaxed on the intercept mean. The fit for this model was χ^2 (333, N = 371) = 482.00, p < .05, CFI = .94, and RMSEA = .05. With this constraint relaxed, mean levels of physical activity on the intercept were significant for both boys and girls, but boys had significantly higher mean levels of physical activity at age 12, M_i = 4.22, t = 31.48, compared to girls, M_i = 3.35, t = 27.40. No other significant gender differences were indicated. Thus, this model represents the final linear unconditional model, with a significant youth physical activity slope mean, M_s = -.25, t = -6.69, and significant variances on the intercept (age 12), D_i = 1.63, t = 6.71, and slope (growth from ages 12-17), D_s = .12, t = 3.83. The mean slope score represents an average decrease in physical activity of approximately 18% from ages 12-17 years. In this model, the loadings for the physical activity variables on the first-order age factors remained significant, λ = 1.02, t = 21.56 for "Typical Physical Activity," λ = .42, t = 15.44 for "Compared to Others," and λ = .09, t = 8.27 for the pedometer data. The correlation between the intercept and slope, R_{is}, remained significant, -.46, t = -2.62.

In sum, the results of the linear unconditional model indicated the appropriateness of the curve-of-factors and cohort-sequential model for describing these physical activity data and the nature of youth physical activity from ages 12-17 years.

A nonlinear unconditional model also was tested. A comparison of the linear and nonlinear unconditional models resulted in a nonsignificant chi-square difference test, χ^2 difference(4) = 7.478, p > .05, indicating that the nonlinear model was not a better fit than the linear model. The more parsimonious linear model, which adequately represented the underlying trajectory, was used for subsequent analyses.

Conditional model—The next model tested was a linear conditional model with all the predictors included. Not surprisingly, given the number of covariates, the model fit with all predictors was not good, χ^2 (1037, N = 371) = 1573.71, p < .05, CFI = .82, and RMSEA = .05. Backwards elimination (58) of covariates was used (at a significance level of p < .05) to derive the most parsimonious model among the pool of predictors. With this method, all independent variables are initially included in the model, each variable is treated as if it were entered last in the equation, and variables that do not significantly add to the equation are deleted one at a time until all remaining variables are significant. The final conditional model resulted in the following acceptable fit indices, $\chi^2(607, N = 371) = 862.29$, $p < .05$, CFI = .90, and RMSEA = .048. The significant covariate effects for boys and girls are shown in Table 2.

There was only one significant effect (barriers efficacy change on the slope) that was identical for boys and girls. For boys, greater physical maturation, barriers efficacy, and perceived friend support were related to higher physical activity at age 12. Girls with higher barriers efficacy and more physically active friends also had higher initial physical activity. With regard to the slope (negative growth from ages 12-17), boys who were initially more physically mature experienced greater declines in physical activity from ages 12-17 than boys who were less physically mature, whereas those with more physically active friends and more positive change in barriers efficacy over time had less of a decline in physical activity from ages 12-17. Girls with more positive change over time in barriers efficacy and physically active friends had less of a decline in physical activity from ages 12-17 than girls with less positive change in barriers efficacy and less active friends. For girls, there was also an effect of Time 1 friend physical activity on the slope such that girls with initially more physically active friends had a greater decline in physical activity from ages 12-17. This result most likely represents a change score effect; that is, simultaneous estimation of change in the variable “physically active friends” would indicate a decline in this covariate over time. The initially higher level of physically active friends, followed by a decline in their activity, paralleled the relationship between the girl's own initial level of physical activity (e.g., intercept) and physical activity from ages 12-17 (e.g., slope) in that female youth who had higher levels of physical activity at age 12 experienced more decline in activity from ages 12-17 than girls who had lower levels of physical activity at age 12.

For boys, 36% and 27% of the variance in the intercept and slope, respectively, was accounted for by the final model's covariates. For girls, 42% and 36% of the variance in the intercept and slope, respectively, was accounted for by the final model's covariates.

Discussion

This study represents one of few longitudinal panel studies of adolescent physical activity examining change in youth physical activity. Personal, family, peer, and demographic covariates of initial status and change in physical activity were included, and the model was tested across boys and girls. As hypothesized, the results of the study provide evidence of a significant decline in physical activity from ages 12-17 years. Significant variation around the group means also was evident.

In line with previous research, boys were significantly more physically active at age 12 than girls, but both boys and girls became significantly less physically active from ages 12-17 years. Significant covariates included physical maturation, barriers efficacy, friend physical activity, and friend social support.

Barriers efficacy was found to be a significant influence on the intercept (age 12) and slope (ages 12-17) of physical activity for both boys and girls, supporting prior research indicating the importance of self-efficacy beliefs (4,16), and in particular, barriers efficacy beliefs on youth physical activity (17,18,19). Boys and girls with higher efficacy to overcome barriers were initially more active and those with a more positive change in barriers efficacy from Times 1-4 declined less in physical activity from ages 12-17 years, suggesting that efficacy to overcome barriers may not only promote current physical activity but also might protect against future activity declines.

Physical maturation emerged as a significant predictor of physical activity for boys only. Armstrong and Welsman (15) suggested that boys who are successful in youth sports tend to be more mature. In this study, early maturing boys had higher levels of physical activity at age 12, but experienced a greater decrease in physical activity during adolescence than later-maturing boys. Thus, early maturing boys may have higher levels of physical activity early on may be at greater risk for physical activity declines during adolescence and may require special attention. More research is needed to determine how physical maturation affects physical activity in boys and girls.

Results also highlight the importance of friends. Boys and girls with physically active friends were more physically active at age 12. For girls, having physically active friends also played a protective role in that those with increases in physically active friends over time also had less of a decline in physical activity from ages 12-17. While there was also an effect of Time 1 friend physical activity on the slope (girls who had more physically active friends had a greater decline in physical activity over time), this result is most likely attributed to a change score effect, as explained earlier. For boys, social support of friends also was a significant covariate of physical activity at age 12.

In pre-adolescence and adolescence, youth increasingly value and spend time with peers, including such contexts as organized sport, physical education, and neighborhood games (28). Friends who presumably are similar to each other in many respects might act as powerful models with regard to physical activity participation (30). Findings on the importance of friends' activity and support imply that health promotion programs aimed at increasing youth physical activity might be most effective if they included efforts targeting friends or significant others.

This study has limitations and strengths. The research was conducted in one metropolitan area with a predominantly White sample, restricting the ability to make comparisons by race. The physical activity measures have limitations. Measurement of youth physical activity is difficult, with no measure being perfect for every situation. The physical activity measures selected for this study were based on many factors, including the epidemiological nature of the study, the availability of measures at the time the study started, prior findings, study aims, and practicality and simplicity. Since results of the study are affected by the physical activity measures, it must be noted that other studies with different measures may yield different results.

The covariates included in the study represent only a small number of possible potential influences on adolescent physical activity. Other contextual influences (e.g., school, neighborhood, the media) may be important in explaining adolescent physical activity. In particular, neighborhood factors have been found to play a significant role in physical activity and other health behaviors (40,59); thus, future studies should include analyses of data nested within neighborhoods. The current study demonstrated the importance of physical maturation in explaining physical activity trends, and the authors encourage researchers to pursue studies that include potential physiological and biological as well as social and contextual variables.

Only a handful of covariates were found to be significantly related to youth physical activity when included in this model along with the other covariates. These results could be due to the combination of covariates used or to the measures or calculation of measures. For example, there are numerous ways to calculate parent physical activity—a mean as in this study, a maximum, or sum—and all represent slightly different approaches. Future studies could examine how children are influenced differently by combinations of parent activity patterns.

Another limitation of this study is the lack of variance in physical activity at age 10 and 11, which necessitated the omission of these data from the LGM model. The cause may be related to the measures, to the specific cohort, or to the age of the participants. Because no other cohort contributed data for these two ages, cohort and age effects can not be disentangled and, as a result, neither can be ruled out. Future studies with different samples are needed to determine whether trajectories of physical activity can be modeled for younger age groups.

Major strengths of the study are the longitudinal nature of the data and design, the use of LGM and cohort-sequential modeling to test the trajectory of physical activity from ages 12-17 with only four annual assessments, and a multiple-group model specification to determine gender effects. The inclusion of individual, family, peer, and demographic covariates also is a strength of the study. The longitudinal nature of the study addresses a critical need for data on patterns of youth physical activity and how it changes over time. By following participants through pre-adolescence and adolescence, it is possible to document changes in physical activity during crucial times when participation declines and to examine influential factors of such change. Other strengths of the study include the randomly recruited sample, self- and parent-report data, and the use of different data methods (survey items and pedometer data) to document physical activity.

The latent variable approach is a powerful technique for the operationalization of physical activity, as it offers an efficient and appropriate way to combine several physical activity variables into one factor for analysis. This approach can be used successfully not only with cross-sectional data but also in longitudinal analyses, as demonstrated in the current study with the use of the cohort-sequential curve-of-factors LGM. There are many advantages of LGM, including its flexibility, practicality, and value for modeling developmental processes, and its ability to identify important predictors and outcomes of change. Unfortunately, to date LGM has been vastly underutilized in the study of physical activity. Future studies are encouraged to use procedures such as LGM to examine the etiology and development of youth physical activity from childhood through adolescence so that we can better understand the risk and protective factors associated with physical activity decline, and thus devise effective interventions for maintaining physical activity throughout childhood, adolescence, and the life span.

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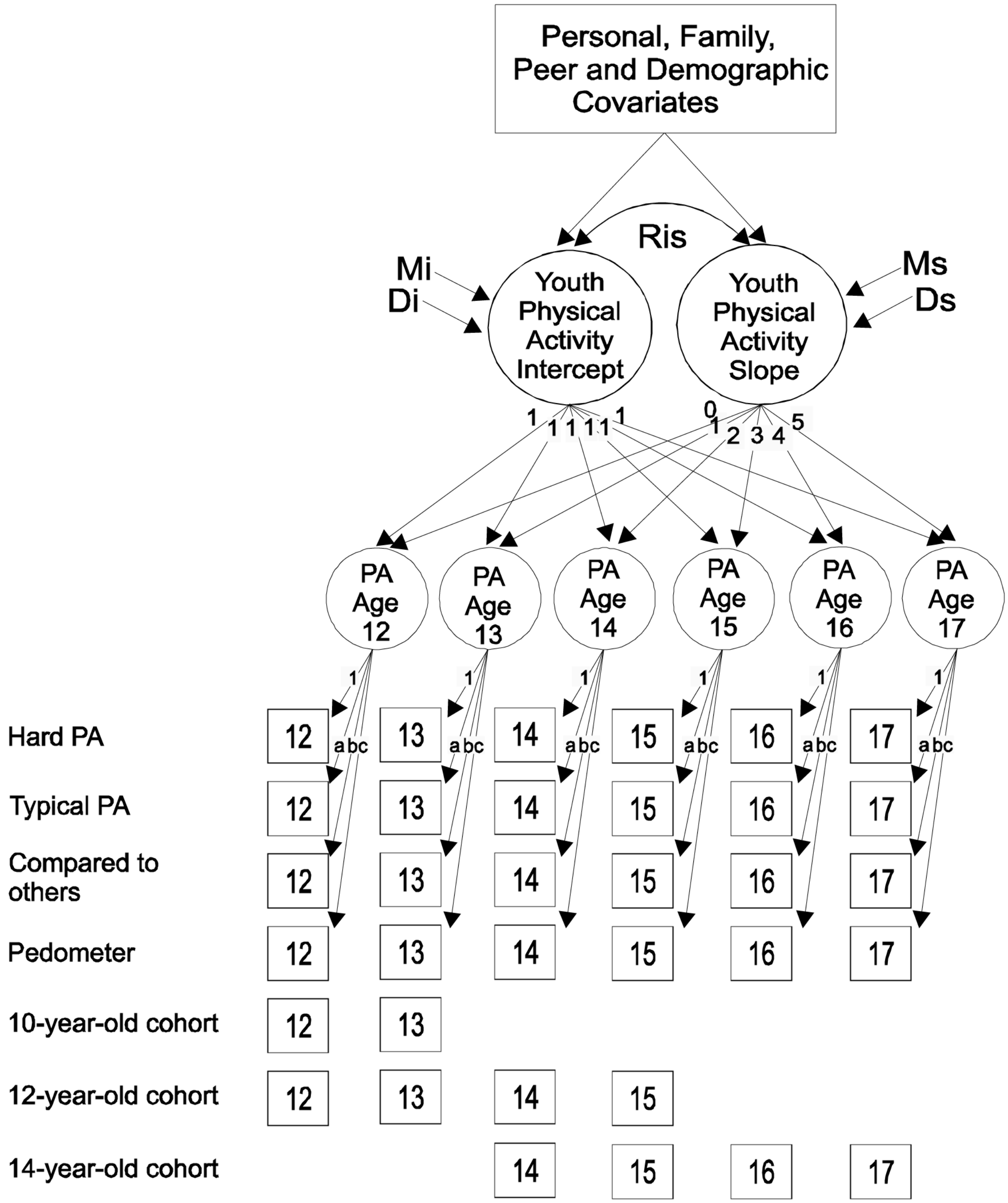

Figure 1.
Representation of the cohort-sequential curve-of-factors latent growth model.

Table 1

Means and Standard Deviations of the Variables in the Model

	Mean	SD
Physical Activity Variables		
Time 1 Hard PA	3.50	1.94
Time 2 Hard PA	3.35	2.01
Time 3 Hard PA	3.26	1.99
Time 4 Hard PA	2.95	2.03
Time 1 Typical PA	3.99	1.88
Time 2 Typical PA	3.84	1.84
Time 3 Typical PA	3.73	1.81
Time 4 Typical PA	3.64	1.83
Time 1 Compared to Others	3.54	0.91
Time 2 Compared to Others	3.52	0.96
Time 3 Compared to Others	3.43	0.98
Time 4 Compared to Others	3.37	1.02
Time 1 Pedometer	1.04	0.42
Time 2 Pedometer	1.02	0.45
Time 3 Pedometer	0.99	0.42
Time 4 Pedometer	0.98	0.44
Covariates at Time 1		
Parent Marital Status (% two-parent)	77%	
Race (% White)	76%	
Household Income	6.74	2.51
BMI	22.4	5.36
Physical Maturation	2.32	0.76
Barriers Efficacy	3.32	0.75
Parent PA	2.49	1.63
Friend PA	3.37	1.86
Parent Social Support	3.44	0.86
Friend Social Support	2.89	.92
Covariates - Change Scores (Time 4 minusTime 1)		
BMI Change	2.03	3.26
Barriers Efficacy Change	-0.63	0.77
Parent PA Change	-0.15	1.09
Friend PA Change	-0.43	0.98
Parent Social Support Change	0.54	1.56
Friend Social Support Change	-0.28	2.52

Table 2

Standardized Regression Coefficients and *t*-values for Covariates in the Final Conditional Model

	Intercept (Age 12)		Slope (Growth 12-17 years)	
	Estimate	***t* value**	**Estimate**	***t* value**
Boys				
Time 1 Physical Maturation	0.21	2.60	-0.33	-3.99
Time 1 Barriers Efficacy	0.35	4.78		
Time 1 Friend Social Support	0.32	4.64		
Time 1 Friend Physical Activity			0.20	2.20
Barriers Efficacy Change			0.43	4.36
Girls				
Time 1 Barriers Efficacy	0.55	8.38		
Time 1 Friend Physical Activity	0.26	3.21	-0.25	-2.38
Barriers Efficacy Change			0.33	4.36
Friend Physical Activity Change			0.30	2.54

Note. *t* values equal to or greater than 1.96 are significant at $p < .05$.