Changes in Moderate-to-Vigorous Physical Activity Among Older Adolescents

Kaigang Li, PhD, MEd,^a Denise Haynie, PhD, MPH,^b Leah Lipsky, PhD,^b Ronald J. Iannotti, PhD,^c Charlotte Pratt, PhD,^d Bruce Simons-Morton, EdD, MPH^b

abstract

OBJECTIVES: Examined patterns and determinants of objectively measured moderate-to-vigorous physical activity (MVPA) over 4 years in US emerging adults.

METHODS: Waves 1 through 4 (W1 [10th grade] to W4 data of a national cohort starting in 2010 ($N = 561$; 16.19 ± 0.51 years) were used. MVPA was assessed annually from accelerometers; BMI calculated from measured height/weight; and surveys ascertained self-reported physical activity (PA) planning, peer PA, family support, W1 sociodemographics, W4 school status, W4 residence, and W4 employment. Latent growth modeling estimated trajectories in log-transformed duration (minutes/day) of MVPA and associations with covariates.

RESULTS: Less than 9% of participants met the recommended 60+ minutes/day MVPA across W1 through W4. W1 MVPA was greater in males versus females ($B = 0.46$, $P < .001$) and Hispanic versus White ($B = 0.34$, $P < .001$) participants. Increased BMI change (W1 to W4 slope) was associated with decreased MVPA. MVPA was positively associated with PA planning (W1–W3: $B = 0.10$, $B = 0.06$, $B = 0.08$, P s $< .05$), but not with peer PA or family support. Participants attending 4-year college versus not-attending school ($B = 0.52$, $P < .001$), and college students living on campus versus at home ($B = 0.37$, $P < .001$) were more likely to engage in MVPA at W4. Weekend MVPA remained relatively constant from W1 through W4.

CONCLUSIONS: High-school students engaged in little MVPA and maintained this low level through the transition to adulthood. Emerging adults' MVPA engagement may vary according to social contexts. Those with high BMI may benefit most from interventions to promote MVPA.

^aDepartment of Health and Exercise Science, Colorado State University, Fort Collins, Colorado; ^bDivision of Intramural Population Health Research, Eunice Kennedy Shriver National Institute of Child Health & Human Development, Bethesda, Maryland; ^cThe CDM Group, Inc, Bethesda, Maryland; and ^dDivision of Cardiovascular Sciences, National Heart, Lung, and Blood Institute, Bethesda, Maryland

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Address correspondence to Kaigang Li, PhD, MEd, Department of Health and Exercise Science, Colorado State University, B 215E Moby Complex, Fort Collins, CO 80523. E-mail: kaigang.li@colostate.edu.

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WHAT'S KNOWN ON THIS SUBJECT: Habitual physical activity has numerous acute and long-term health benefits. Trajectories of objectively measured moderate-to-vigorous physical activity (MVPA) have been conducted for children but few for adolescents transitioning to adulthood.

WHAT THIS STUDY ADDS: High school students engaged in little MVPA (<9% met the ≥ 60 minutes/day recommendation) and maintained it through the transition to adulthood. Emerging adults' MVPA varies by social context. Those with high BMI may benefit most from interventions to promote MVPA.

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Regular exercise and physical activity (PA) have numerous acute and long-term health benefits, including reduced risk of obesity, metabolic syndrome, and improved mental well-being in children and adolescents.^{1,2} The Centers for Disease Control and Prevention recommend a minimum of 60 minutes of moderate-to-vigorous PA (MVPA) per day for maintenance of general health.³ The literature suggests that a large number of youth fail to meet the physical activity guidelines and engage in less physical activity as they transition through adolescence to early adulthood.^{4–7} However, questions remain about longitudinal patterns and predictors of PA because of study limitations such as cross-sectional design,⁴ self-reported data,⁵ and lack of data in older youth (ie, ≥ 16 years).⁶

Although a number of studies have reported the prevalence of adolescents who met the 60 minutes per day PA recommendation using self-reported measures,^{7–10} few studies have reported the prevalence based on objectively measured PA or examined the change in objectively measured PA during late adolescence. In a rare longitudinal study using accelerometers, Nader and colleagues⁶ reported MVPA from children (age 9 years) to early adolescence (age 15 years) using a US national sample from 10 geographic locations. In this study, the researchers reported a significant negative trajectory for children's MVPA between ages 9 to 15. The percentages of children who did not meet the 60 minutes per day recommended MVPA increased sharply on both weekday (0.4% at age 9 to 69.4% at age 15) and weekend (2.3% at age 9 to 83.2% at age 15). However, no similar studies have been conducted on trajectories in emerging adults (subjects transitioning from adolescence to adulthood).

Some evidence suggests that certain psychosocial and social-contextual variables, such as peer influence, family support, and action planning^{10–12} are positively associated with levels of PA in high school. Only a few studies have examined the association of longitudinal changes¹³ and trajectories¹⁴ of PA with their temporal and prospective predictors. In addition, to our knowledge, no studies have investigated the association between MVPA and environmental status after transitioning out of high school.

Overall, the purposes of this study were to examine the patterns and determinants of objectively measured MVPA of a national cohort US youth over 4 years from 10th grade to post-high school and estimate the association between post-high school MVPA and school attendance, employment and residence (ie, parental home, college campus, or on their own).

METHODS

Sampling

The NEXT Generation Health Study recruited a nationally representative cohort of 10th-grade students at wave 1 (W1) from 81 public, private, and parochial schools in the United States using a multistage sampling design stratified by nine census divisions. Systematic sampling was used to identify a subsample ("NEXT Plus") of approximately equal number of normal-weight (5th–85th percentile, $N = 289$) and overweight (≥ 85 th percentile, $N = 272$) participants in 44 schools representing urban, suburban, and rural communities in each census division at W1 to participate in additional assessments and comprise the sample for the current study. Weight status was determined from measured height and weight using age- and sex-adjusted BMI percentiles.¹⁵ Parental consent and

adolescent assent to participate were obtained for participation in NEXT and separately for NEXT Plus. Participants provided consent upon turning 18 years of age. Incentives (\$40 gift card at each wave) were provided for participation in assessment procedures. The study protocol was reviewed and approved by the Institutional Review Board of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development.

Assessments of Physical Activity (Outcome Variable)

Participants wore an ActiGraph GT3 X accelerometer on their right hip during waking hours to provide an objective measure of duration and intensity of PA. Participants were asked to wear the devices for 7 consecutive days for ≥ 10 hours per day. Because accelerometers were not waterproof, participants were instructed to remove the devices while swimming or bathing. Participants were asked to repeat the protocol if the devices were damaged or failed to collect or download data, had <5 days of data, or did not include a weekend day. Wear time was determined by subtracting nonwear time (≥ 60 consecutive minutes of zero counts) from 24 hours. Participants with ≥ 4 days (including at least 1 weekend day) of monitoring data, for ≥ 500 minutes per day, were considered compliant and included in analyses.

Using the standard ActiLife analysis software,¹⁶ vertical acceleration, recorded as counts per 30-second epoch, was converted into MVPA using age-appropriate cut points (MVPA: ≥ 2296) developed by Evenson et al¹⁷ and recommended as an accurate estimation of PA among youth in a methods trial.¹⁸ To be included in analyses, minimum bout length was set at 10 minutes for MVPA.³

Time Varying Covariates

PA planning (W1–W4) was measured by using 3 previously validated items.¹⁹ Participants were asked how often in the past 7 days they planned for when, how often, and where they would exercise (from 1 = not at all to 5 = very often). The mean score of the 3 items was calculated at each wave. Cronbach's α internal consistency coefficients of this scale were 0.90, 0.93, 0.94, and 0.94 for W1 to W4, respectively.

Peer physical activity (W1–W4) was measured with 1 item, which asked participants how often their 5 closest friends engaged in vigorous PA at least 3 times per week (from 1 = never to 5 = almost always). The question was developed for this study.

Parental support of daily PA (W1–W4) was derived from the National Survey on Drug Use and Health²⁰ and asked participants how important it was to their parents/guardians that he or she get daily PA and/or exercise (from 1 = not at all to 7 = extremely).

Time-Invariant Covariates

BMI difference was calculated as W4 – W1 BMI. Positive difference indicates weight gain, whereas negative difference indicates weight loss.

Participants reported residential status (parent/guardian's home, own place, and on campus), school attendance (not in school, attending technical/community college, and attending university/college) and employment (not working, part-time work <30 hours/week, and full-time work $\geq$ 30 hours/week).

The sociodemographic variables included sex, race/ethnicity, family socioeconomic status, urbanicity, and parent education. Family socioeconomic status was estimated by using the Family Affluence Scale²¹ and categorized as low, moderate,

or high affluence.²² Urbanicity was categorized into 2 groups based on location of their school at W1 in an urban or rural neighborhood community.²³ Parents reported educational attainment during the consent process (less than high school diploma, high school diploma/GED, some college/technical school/advanced degree, or a bachelors/graduate degree).

Statistical Analysis

This longitudinal analysis examined data from W1 (10th grade) through W4 (first year after high school). Thirty-nine participants (8% of 561 participants) with incomplete or missing data for PA were excluded from analyses. The final analytic sample included 522 participants at W1. A linear growth model (LGM) for a continuous outcome with time-invariant and time-varying covariates was conducted by using Mplus 7.31 and all other statistical analyses were conducted by using SAS version 9.4 (SAS Institute Inc, Cary, North Carolina). Log-transformed duration (minutes/day) of MVPA was used.

In statistical terms, the 2-level hierarchical linear models are represented by a level 1 (repeated measures [waves] level) and a level 2 (personal level) regression model as follows:

Level 1 model:

$$Y = \pi_{0i} + \pi_{1i} \times \text{TIME}_{ij} + \pi_{2i} \times \text{TIME}_{ij}^2 + \varepsilon_{ij} \quad (1)$$

where Y is the MVPA; π_{0i} is the MVPA for participant i at W1; π_{1i} and π_{2i} are the growth rates of MVPA as a function of Time (linear) and Time $\times$ Time (quadratic) for person i over the 4 waves, respectively; and the ε_{ij} is the level 1 residuals.

Level 2 model:

$$\pi_{0i} = \gamma_{00} + \gamma_{01} \times \text{time-invariant covariates} + \zeta_{0i} \quad (2)$$

$$\pi_{1i} = \gamma_{10} + \gamma_{11} \times \text{time-invariant covariates} + \zeta_{1i} \quad (3)$$

$$\pi_{2i} = \gamma_{20} + \gamma_{21} \times \text{time-invariant covariates} + \zeta_{2i} \quad (4)$$

where γ_{00} is the mean value of the level 1 dependent variable; γ_{10} and γ_{20} are the mean slope of Time and Time $\times$ Time, respectively; γ_{01} , γ_{11} , and γ_{21} are the fixed effects; and ζ_{0i} , ζ_{1i} , and ζ_{2i} are the random effects.

Hox procedure²⁴ and Singer and Willett's taxonomy²⁵ were used for a multilevel analysis of longitudinal data. First, the null or unconditional means model was estimated containing the intercept term only. Second, the unconditional linear growth model (the predictor Time was included) was tested; and then the unconditional quadratic growth model was examined by adding the Time $\times$ Time term. Then time-invariant covariates were entered into the growth models (intercept and slopes submodels). Finally, time-varying covariates were included in the models.

RESULTS

Descriptive Information

Figure 1 and Table 1 show the distribution of mean duration (minutes) of monitored MVPA on weekdays and weekends, which indicates that <9% of the participants met the recommended $\geq$ 60 minutes/day at all waves on weekdays and weekends. Descriptive information of sociodemographic variables is presented in Supplemental Table 4. Those variables were included in the multilevel models as control variables and the interactions between sociodemographic variables and linear (Time) and quadratic (Time $\times$ Time) slopes were tested.

Across all years, participants consistently engaged in significantly more daily MVPA on weekdays (27–29 minutes/day, Table 2) than on weekends (19–21 minutes/day; all P s < .001, Table 2). Male participants (25–36 minutes/per day) were more active than their female counterparts (13–23 minutes/day) on both weekdays and weekends (all

FIGURE 1
 Distribution of moderate-to-vigorous physical activity (MVPA) minutes by wave on weekday and weekend. The vertical line indicates the recommended 60 minutes per day of MVPA for adolescents.

TABLE 2 Mean Minutes per Day of MVPA

Wave and Grade	Weekday												Weekend											
	Overall						Sex						Overall						Sex					
							Weight Status												Weight Status					
	F			M			NW			OW			F			M			NW			OW		
M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	
W1, 10th	27.44	21.45	23.13	19.52	32.75 ^a	22.54	28.74	22.27	26.16	20.56	19.76 ^b	21.33	15.37	17.45	25.35 ^a	24.35	21.90	22.29	17.62 ^c	20.14				
W2, 11th	28.63	21.44	22.67	17.08	36.30 ^a	23.94	30.34	23.40	26.81	19.03	19.86 ^b	27.76	15.23	19.84	25.70 ^a	34.48	20.95	27.64	18.68	27.90				
W3, 12th	28.44	21.00	22.57	18.21	35.97 ^a	21.96	29.45	22.01	27.51	19.97	20.80 ^b	24.24	15.14	18.00	28.48 ^a	29.07	22.13	23.91	19.55	24.59				
W4, first y post-HS	27.71	22.78	22.33	19.23	35.57 ^a	25.21	30.60	23.89	24.84 ^c	21.29	19.57 ^b	21.56	13.33	15.08	28.39	25.89	20.63	22.72	18.50	20.33				
4 y average	28.14	16.99	22.63	14.20	34.83 ^a	17.71	29.78	18.11	26.49 ^c	15.61	19.94	17.71	14.76	13.53	26.42 ^a	20.06	21.46	18.61	18.45 ^c	18.63				

F, female; HS, high school; M, male; NW, normal weight; OW, overweight.

a Male MVPA was significantly different from female MVPA on weekday and weekend, respectively, by wave at $P = .001$ level.

Overall MVPA on weekdays was significantly different from weekends at $P = .001$ level.

c. MVPA was significantly different between overweight and normal weight participants on weekday and weekend respectively by wave at $P = .05$ level.

On weekends, a dynamic pattern of MVPA in terms of significant LGM time slopes was not identified, indicating that weekend W1 to W4 MVPA remained relatively constant.

In this study of a contemporary, national cohort of US adolescents followed from 10th grade for 4 years, duration of MVPA increased over the first year, but then steeply declined over the next 2 years. Longer duration of MVPA was observed on weekdays than on weekends and was inversely associated with BMI change over follow-up. Additionally, MVPA was greater among 4-year college students than those not attending school and among students living on campus as compared with those living on their own or at home.

Cross-sectional and longitudinal studies have documented that body weight status may be associated with engagement in PA among children and adolescents.^{1,26,27} Therefore, we examined whether baseline weight status influenced the pattern of MVPA and whether changes in BMI influenced the pattern of MVPA among emerging adults. In our sample, weight status at W1 was not associated with the pattern of MVPA over the 4 waves, although increased BMI between W1 and W4 was associated with decreased MVPA. Our findings echo a recently published longitudinal study that showed that a greater decrease in sport participation was associated with a greater increase in BMI during the transition to higher education, indicating the transition is a risk period for weight gain and decreased PA engagement.²⁸ Moreover, Deforche and colleagues²⁸ recommended that intervention programs should consider individual, psychosocial, and environmental factors. In the current study, we

investigated the longitudinal association of PA engagement with individual covariates and cross-sectional association of PA engagement with covariates in the year after high school. Our findings are consistent with Deforche et al with respect to the importance of individual PA planning and the environment. That PA engagement decreased less among those who were attending 4-year college and living on campus compared with those not attending school and those living at home suggests that access to and proximity of PA facilities may influence college students' engagement in PA.^{29,30}

Previous studies have reported differences in PA engagement according to sex and race/ethnicity,^{1,2} such as a greater decline of PA in girls than in boys.^{4,6,10} In our research, without including time-varying covariates, sex was significantly associated with the linear slope of the trajectory of log MVPA (ie, MVPA over time increased for males compared with females). However, when controlling for time-varying covariates, such as PA planning and parent influences, our data indicate that male adolescents engaged in more MVPA compared with female adolescents in 10th grade (baseline) only, but sex did not influence the longitudinal curve. Thus, factors reflecting self-regulation or environment may influence MVPA engagement more than sex.

Consistent with previous findings among adolescents,³¹ MVPA was higher on weekdays than weekends in our sample. Also, the LGM modeling did not show a change across time in MVPA engagement on weekends, whereas change was found on weekdays. These findings may indicate that as adolescents transition into the first year after high school, their weekday schedules change in ways that reduce MVPA, such as increased school/work demands, whereas their weekends

TABLE 3 Latent Growth Models Examining the Change in Youth Weekday MVPA^a From 10th Grade Over 4 Years

	β	<i>P</i>	Random Effect	<i>P</i>
Intercept	3.06	<.001	0.41	<.001
Intercept on overweight (ref: normal wt)	−0.07	.26		
Intercept on male (ref: female)	0.47	<.001		
Intercept on race/ethnicity				
Hispanic	0.34	<.001		
Black	−0.01	.83		
Other	−0.03	.83		
White	Ref			
Time (linear slope)	0.46	<.001	0.23	<.05
Time on male (ref: female)	0.15	.17		
Time on parental education				
Less than high school	−0.14	.35		
High school	−0.17	.25		
Some college	−0.08	.60		
On college	Ref			
Time on W4–W1 BMI difference	−0.02	<.01		
Time * time (quadratic slope)	−0.20	<.001	0.05	.08
Time * time on male (ref: female)	−0.05	.16		
Time * time on parental education				
Less than high school	0.07	.17		
High school	0.07	.16		
Some college	0.07	.21		
On college	Ref			
Time varying covariates				
W1 MVPA				
On W1 peer PA	0.02	.21		
On W1 PA planning	0.10	<.001		
On W1 family support of PA	0.02	.11		
Wave 2 MVPA				
On W2 peer PA	0.02	.21		
On W2 PA planning	0.06	<.01		
On W2 family support of PA	0.02	.11		
Wave 3 MVPA				
On W3 peer PA	0.02	.21		
On W3 PA planning	0.08	<.001		
On W3 family support of PA	0.02	.11		
W4 MVPA				
On W4 peer PA	0.02	.21		
On W4 PA planning	0.02	.46		
On W4 family support of PA	NA			
On school status				
Technical school/community college	0.06	.67		
4-year college/university	0.52	<.001		
Not attending school	Ref			
On residential status				
Living on own	0.10	.54		
Living on campus	0.37	<.001		
Living at parents' home	Ref			

Mean age = 16.2 ± 0.51 y. NA, not available; ref, reference.

^a Log-transformed min/day.

remain more consistent. Possibly, there may be more autonomy in arranging their weekday activities at adolescents' age.

This study has several notable strengths, including objectively measured physical activity in a

large, national, ethnically/racially diverse sample. Accelerometers are among the most valid and reliable assessment method of structured and unstructured movements. Another key strength is that this study included participants who take a range

of pathways after leaving school rather than the pathway only to higher education. In addition, this prospective research design enables investigation of the trajectory of MVPA and factors associated with variability of MVPA over time. Despite the strengths of the study several limitations should be considered. First, the sample is not strictly nationally representative, which may limit the generalization of the findings to some extent. However, the sample was systematically drawn from a nationally representative sample and included participants from urban, suburban, and rural areas from each US Census division. Second, covariates were self-reported, which are susceptible to response bias (including social desirability) and estimation errors. Third, although we observed a statistically significant association among this young and healthy population, the actual difference in minutes of MVPA was small. It is unknown what magnitude of difference would affect health status. Given the limited amount of MVPA young adults reported, any increase in regular MVPA should be encouraged, although more evidence is needed to justify the link between small increases in PA and health outcomes. Finally, although this study is prospective, the observational study design nonetheless limits inferences regarding causality based on the observed associations.

In addition, we would like to point out the potential influence of the parameter settings when processing the accelerometer data. For example, we applied a minimum bout length of 10 minutes for MVPA in the current study. It may lead to a smaller amount of MVPA duration compared with using a shorter bout.³² However, we tried to follow the 10-minute bout recommended by the Physical

FIGURE 2

Average minutes of weekday MVPA by BMI difference (Wave 4 BMI – Wave 1 BMI) at 25th and 75th percentile and environmental variables (school status and residence) at Wave 4. BMI Diff 75 PCT, given the value of W4 to W1 BMI difference at the 75th percentile; BMI Diff 25 PCT, given the value of W4 to W1 BMI difference at the 25th percentile.

Activity Guidelines for Americans³ to ensure that our results are comparable to the results based on the recommendations.

The findings should also be considered in relation to those in our parallel analyses of self-reported PA included in a separate manuscript.³³ The analyses of the association of self-reported MVPA with environmental variables and time-varying covariates in the NEXT full sample found that compared with those attending 4-year colleges or living on campus, participants not attending school or attending community-college level schools, and living at home or in own place were more likely to meet MVPA recommendations (at least 60 minutes per day over the past 7 days). The inconsistencies between the 2 studies are likely attributable to the use of self-reported versus objectively measured physical activity. Differences between self-reported and objectively measured PA,^{34,35} as well as self-reported

and objectively measured sedentary activities,³⁶ have been previously reported. Similarly, the proportion of engagement in MVPA for 60 minutes per day on at least 5 days a week was substantially higher in the NEXT full sample based on self-report (>34% at any wave) compared with objective measurement (<10% in the current study), indicating gross overestimation of PA that would be expected to introduce biased estimates of associations with covariates. The different proportions may also be due to the varying sampling strategies (random sampling for NEXT full sample and predefined normal weight and overweight participants for NEXT Plus sample). Supplemental Table 4 shows the sociodemographic difference between the full and the subsamples who wore the accelerometer. It is noted that the weighted percent (complex survey variables were applied in the full sample analysis)

and nonweighted percent are visually different, although not dramatically. The latter might not fully generalize to the full sample because of its nonrandom sampling design as mentioned in the first limitation. We believe that useful, but different, types of information can be obtained from each method. Nevertheless, more studies are needed to understand the discrepancies between

self-reported and objectively measured PA.

CONCLUSIONS

High school students engaged in little MVPA and maintained this low level through the transition to adulthood. Emerging adults' MVPA engagement varies by social contexts. Those with high BMI may benefit most from interventions to promote MVPA.

ABBREVIATIONS

CI: confidence interval
LGM: linear growth model
MVPA: moderate-to-vigorous physical activity
PA: physical activity
W1: Wave 1 (10th grade)
W2: Wave 2 (11th grade)
W3: Wave 3 (12th grade)
W4: Wave 4 (1 year after high school)

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