Adolescent Physical Activity and Sedentary Behavior
Patterning and Long-Term Maintenance

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Background: Little is known about physical activity (PA) and sedentary behavior patterning or its impact on long-term PA sustainability, particularly during the critical transition from adolescence to adulthood.

Methods: Nationally representative self-reported data were collected (National Longitudinal Study of Adolescent Health: Wave I, 1994–1995; Wave II, 1996; Wave III, 2001–2002). Cluster analyses identified homogeneous groups of adolescents with similar PA and sedentary behaviors. Logistic regression predicted odds of meeting national activity recommendations in adolescence and young adulthood.

Results: Seven clusters were characterized as follows: C1, high television (TV)/video, video gaming; C2, high skating, video gaming; C3, high sports participation with parents, high overall sports participation; C4, use of neighborhood recreation centers, high sports participation; C5, TV viewing limited by parents, moderate participation in school physical education (PE); C6, low parental TV control, reporting few activities overall; C7, active in school (team/individual sports, academic clubs, and PE). Odds of adolescents meeting PA recommendations were highest in C2 (odds ratio=13.1), C3 (5.8), C4 (4.2), and C7 (4.3) compared to C1. Independent of adolescent PA, absolute odds of meeting recommendations as young adults declined but were still relatively high in these clusters, indicating greater long-term PA sustainability. By young adulthood, however, overall PA declined dramatically in skaters/gamers (C2) and was notably low among those with TV viewing limited by parents (C5).

Conclusions: While odds of meeting PA guidelines in adulthood declined in all clusters, the magnitude of this decline varied by cluster (declining most dramatically in skaters/gamers), providing insights into where to target effective intervention strategies that promote sustainable PA behaviors.

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Introduction

Most Americans fail to meet national physical activity (PA) guidelines.[1–3] PA has many beneficial effects, including weight maintenance and numerous related outcomes.[4–8] With obesity emerging as a major public health crisis,[9,10] PA and sedentary behavior are key targets for altering energy balance in preventing/reducing obesity.[4,11]

The transition from childhood to adulthood marks a striking age-related PA decline.[12–15] Sedentary behaviors (e.g., TV viewing, video gaming) are also notably high during this period.[16,17] Such behavioral trends highlight a need for effective strategies that promote healthful sustainable activity levels, and may be addressed through a better understanding of PA and sedentary behavior patterning and long-term sustainability.[18]

The multidimensional patterning of health behaviors has recently gained recognition, particularly regarding diet[19–21] and other behaviors.[22,23] While PA and sedentary behavior may operate through different behavioral mechanisms,[24] have different determinants,[17] differentially track,[3] and influence disease risk independently, these behaviors are likely correlated within individuals.[25,26] However, specific behaviors may be differentially sustainable (e.g., sedentary behaviors are more easily sustained than PA), and should be explored as **co-occurring behaviors** rather than independent actions.[24]

Cluster analysis is widely used in health research (e.g., Patterson et al.,[19] Wirfalt et al.,[20] and Quatromoni et al.[27]) to identify mutually exclusive, homogeneous groups of individuals sharing numerous characteristics.[28] This data-driven technique detects natural patterns in data, rather than relying on investigator-

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specified patterns. Using nationally representative data, this study uses cluster analysis to (1) identify meaningful patterns of adolescent PA and sedentary behaviors; and (2) of these, identify which patterns are associated with sustainable, healthful activity levels through the transition to adulthood. Analysis took place in 2003 and 2004.

Methods

The National Longitudinal Study of Adolescent Health (Add Health) is a nationally representative school-based survey of youths, grades 7 to 12. Survey procedures described elsewhere[29] were approved by the Institutional Review Board of the University of North Carolina at Chapel Hill. In Wave-I (1994–1995), >90,000 students completed in-school surveys, and 20,745 adolescents (and parents) then completed in-home surveys. Wave II (1996) included 14,738 Wave I adolescents who had not graduated from high school, including dropouts. Wave III (2001–2002, n =14,322) included all located Wave-I respondents, aged 18 to 26 years. Participants who were severely disabled (n =189), pregnant at the time of one or more waves (n =484), and/or Native American (due to small sample size, n =66, after other exclusion criteria) were excluded. In addition, only those with nonmissing in-school and in-home Wave I or II activity data were included (final sample n =11,957). Comparing included and excluded subjects, there were statistically significant differences by age (mean 15.2 and 16.4 years, respectively); gender (50% and 61% female); and race/ethnicity (21% and 24% black, and 7% and 4% Asian).

Measurement of Physical Activity and Sedentary Behavior

Daily PA (in categories such as housework, hobbies, active play, sports, exercise) was assessed using standard 7-day recall questionnaire methodology relevant for epidemiologic studies.[30] Described in detail elsewhere,[17,31,32] the Add Health surveys employed various questions similar to those used and validated in other large-scale studies.[30,33–35] Questions worded, "During the past week, how many times did you. . .," allowed calculation of activity frequency (bouts/week) by metabolic equivalent (MET) value. Moderate or vigorous (MV) PA had an MET of 5 to 8[37] (1 MET is resting metabolic rate).

Adolescents also reported participation in school physical education (PE) (days/week), and school-based sports and academic clubs (number/year). For participants interviewed while school was not in session, PE frequency was imputed from mean values of students in the same grade and school (n =2814). Additionally, adolescents reported using neighborhood recreation centers, watching TV/videos and playing video or computer games (hours/week). Adolescents reported playing a sport with parent(s) in the previous month, and parent-regulated TV viewing. Correlation coefficients describe crude associations between PA and sedentary variables using Bonferroni corrections.

Wave-III questionnaires added questions applicable to young adults (e.g., walking for exercise, weight lifting). Accounting for potential reporting bias and likely artificial increase in reported activities due to inclusion of additional questionnaire items,[37] a scaled MVPA sum corresponding to the number of activities reported in Wave I was used.[3] Overall activity frequency was summed to determine total weekly MVPA or sedentary behavior, as well as whether individuals met national recommendations for PA (five or more weekly bouts of MVPA)[38] and sedentary behavior (≤2 daily hours of "screen time," including TV/video viewing and video/computer gaming),[39,40] at each survey wave.

Measurement of Covariates

A combination of parent and adolescent in-home surveys provided data on household composition, nationality, and race/ethnicity. Race/ethnicity categorized Hispanics, non-Hispanic whites (referred to as "whites" hereafter), non-Hispanic blacks ("blacks"), and Asians. Parental education described the highest education achieved for either parent. Income was reported in $1000 increments and imputed where missing (n =1673), using parental occupation, family structure, and school community (similar to imputation methods of other national surveys).[41,42]

Cluster Development

Cluster analysis was used to identify behavior patterns. Multiple cluster analyses were conducted by partitioning data into different numbers of clusters (4 to 12) by Euclidean distances between observations (SAS FASTCLUS, Research Triangle Institute, Research Triangle Park NC, 2004), weighting for national representation. Cluster procedures run on the full cohort and gender-specific samples yielded similar results; thus only the full cohort results are presented.

Sixteen PA and sedentary behavior–related variables were assessed. To identify patterns representative of adolescence, Waves I and II activity frequencies were averaged. If participants were surveyed in Waves I and II, but were missing activity data in one wave, data from one time point were used. Statistical models adjusted for the number of waves used in estimation; this produced little change in effect estimates. Variables in the cluster analyses were normalized, allowing appropriate weighting of variables with substantially different scales/ranges.[28] TV/video viewing and video/computer gaming were scaled and z-scores computed, ensuring that participants reporting very high (although feasible) values did not overpower the analyses.[20]

To identify optimal specifications for initial cluster centers, 1000 iterations of cluster procedures were conducted. Initial group centers were randomly generated. Iterations with the largest overall r^2 values (identifying relative heterogeneity between clusters, compared to heterogeneity within clusters) were identified. The best fit for the data maximized inter- to intra-variability ratio, resulting in a higher r^2, and indicating that individuals differ more from individuals in **other** clusters than from those in the **same** cluster.

Cluster robustness was examined in numerous exploratory analyses, grouping individual variables before cluster analyses and removing variables in stepwise procedures. Variables representing activities sharing similar themes were grouped together, such as physical (in-school, home, or neighborhood activities) and/or social (team vs individual activities) setting. The results of these numerous analyses were assessed to

identify common patterns appearing across various procedures. The final cluster solution represented the most robust patterns and maximized variability between clusters.

Descriptive Analyses of Clusters

Within each cluster, the prevalence of each of the 16 activity variables was determined. Between-cluster differences were tested ($p<0.05$, with Bonferroni correction). To further describe activity patterning, logistic regression used clusters to predict the likelihood of currently meeting national activity recommendations during adolescence (Waves I and II). Models controlled for covariates (gender, age, parental education, race/ethnicity, and household income).

Analyses to Test Cluster Validity

To demonstrate meaningful variability between clusters (using data that were not used to generate clusters), logistic regression used adolescent activity clusters to predict the likelihood of meeting national activity recommendations 5 to 6 years later in adulthood (Wave III) (controlling for influential covariates). While methods of validating cluster analyses are limited,[26] similar techniques are often used to "test" cluster validity (e.g., e.g., Patterson et al.[19] and Wirfalt et al.,[20]). Although not presented here, clusters were used to predict overweight to illustrate other meaningful variability. The basic cluster analysis procedure will detect underlying patterns in data, regardless of utility or substantive merit. Thus, this final step of pattern identification and development is critical to uncovering meaningful patterns in the data.

Likelihood of Meeting Activity Recommendations Over Time

Descriptive analyses (using Waves I and II) were combined with those testing cluster validity (Wave III) to describe longitudinal trends in activity patterns. Logistic regression and predicted probabilities of meeting recommendations for each activity pattern were calculated using STATA post-estimation commands (STATA Corp, College Station TX, 2004) and graphed.

Descriptive analyses used post-stratification sample weights to allow results to be nationally representative. Survey design effects of multiple stage cluster sampling were controlled in all analyses.

Results

Descriptive Statistics of Sample and Final Cluster Solution

The final analysis sample (male: $n=5978$, female: $n=5979$) comprised 70.8% white, 13.9% black, 11.1% Hispanic, and 4.3% Asian adolescents. Approximately 12.9% of participants' parents had less than a high school education, 32.0% graduated from high school, 28.4% had some college, and 26.6% had a college degree or higher. Mean household income was $45,000 per year. Mean age at Wave I was 14.9 (±0.12) years. Among the 16 PA and sedentary behavior variables assessed, 74 of 120 possible pairwise correlation coefficients were statistically significant. Coefficients ranged from −0.07 to 0.40. Many activities of similar intensity were positively correlated (i.e., active behaviors were positively correlated with each other, as were sedentary behaviors).

Table 1 includes activity frequency by cluster. The final cluster solution identified seven robust patterns observed across numerous iterations of analyses, representing nonoverlapping groups of adolescents sharing PA and sedentary behaviors, and primarily characterized as follows:

Cluster 1: Adolescents have high frequency of TV/video viewing and video gaming; adolescents make their own decisions regarding TV viewing.

Cluster 2: Adolescents have high frequency of skating, skateboarding, bicycling, and video gaming.

Cluster 3: Adolescents play sports with parent(s); have high frequency of overall sports participation.

Cluster 4: Adolescents use neighborhood recreation centers; have high frequency of overall sport participation.

Cluster 5: Adolescents' TV viewing is limited by parents; participate in moderate amount of school PE.

Cluster 6: Adolescents have control over TV viewing, but choose to watch very little; report few activities overall.

Cluster 7: Adolescents have high participation in school activities, including team and individual sports, academic clubs, and PE.

These clusters varied by sociodemographic characteristics (Table 2). High TV viewers (Cluster 1) had a higher proportion of lower socioeconomic status (SES) blacks or Hispanics. Conversely, skaters/gamers (Cluster 2) had a larger proportion of high SES white males with a father in the household. Adolescents playing sports with parents (Cluster 3) were more likely to be younger, white, and higher SES. Those using recreation centers (Cluster 4) were higher-income blacks with no father in the household and larger household size, whereas adolescents with limited TV decisions (cluster 5) were younger, lower SES, foreign-born minorities who also lived in large households. Those reporting few activities (Cluster 6) had a higher proportion of older girls. Finally, individuals active in school (Cluster 7) were more likely high SES, young adolescents living in larger households.

Likelihood of Meeting National Recommendations

Adolescence. Clusters predicted the odds of meeting national PA recommendations during adolescence and adulthood (Table 3). The odds of meeting recommendations were highest among individuals in Clusters 2 (skaters/gamers, odds ratio [OR]=13.1); 3 (sports with parent, OR=5.8); 4 (uses recreation center, OR=4.2); and 7 (active in school, OR=4.3), compared to 1

Table 1. Mean frequency of specific activities by activity cluster, National Longitudinal Study of Adolescent Health, mean (Z score)

	Cluster 1 (*n*=2494) TV/video and gaming	**Cluster 2 (*n*=1119) Skaters and gamers**	**Cluster 3 (*n*=1681) Sports with parents**	**Cluster 4 (*n*=1309) Uses recreation center**	**Cluster 5 (*n*=1522) Limited TV decisions**	**Cluster 6 (*n*=2897) Reports few activities**	**Cluster 7 (*n*=935) Active in school**	**Total (*n*=11,957)**
TV viewing, hrs/wk	**23.8** (0.78)	16.1[a] (0.11)	13.2[b] (−0.08)	15.2[a,b] (0.00)	12.6[b] (−0.18)	**8.9** (−0.54)	13.8[a,b] (−0.05)	15.1
Video viewing, hrs/wk	**7.4** (0.70)	5.0[a] (0.24)	3.7[b] (0.00)	4.7[a,c] (0.12)	3.0[d] (−0.28)	**2.1** (−0.53)	3.7[b,c,d] (−0.03)	4.3
Video game playing, hrs/wk	**5.0**[a] (0.57)	**4.7**[a] (0.67)	2.8[b] (0.22)	2.9[b,c] (0.16)	1.7[d] (−0.12)	**0.6** (−0.59)	1.9[c,d] (−0.02)	2.7
Housework, bouts/wk	**3.4**[a] (−0.12)	**3.9**[b] (0.21)	**3.9**[b] (0.19)	**3.7**[a,b] (0.01)	**3.8**[b] (0.11)	**3.4**[a] (−0.10)	**3.8**[b] (0.11)	3.7
Hobbies, bouts/wk	2.4[a] (−0.12)	**3.5**[b] (0.51)	**3.3**[b,c] (0.40)	2.9[d] (0.23)	2.4[a] (−0.04)	**2.2** (−0.19)	3.0[c,d] (0.28)	2.7
Skating, bouts/wk	0.6 (−0.28)	**3.9** (2.00)	1.2[a] (0.10)	1.0[b] (−0.07)	1.0[b] (−0.08)	**0.5** (−0.34)	1.2[a,b] (0.10)	1.1
Sports, bouts/wk	2.0[a] (−0.18)	3.6[b] (0.64)	**4.0** (0.85)	3.5[b] (0.63)	2.2[a] (−0.11)	**1.3** (−0.59)	3.5[b] (0.59)	2.5
Exercise, bouts/wk	**2.3**[b] (−0.26)	**3.4**[a] (0.36)	**3.4**[a] (0.36)	**3.4**[a] (0.38)	2.8 (−0.04)	**2.3**[b] (−0.29)	**3.6**[a] (0.50)	2.8
Hang out, bouts/wk	3.6[a,b] (0.01)	**4.3** (0.38)	3.6[a,b,d] (0.05)	3.8[a,d] (0.16)	**3.1** (−0.33)	3.5[b] (−0.08)	3.9[d] (0.20)	3.6
School academic clubs, number/year	**0.6**[a] (−0.15)	**0.8**[a,b] (−0.08)	0.9[b,c] (0.03)	**0.9**[a,c] (−0.05)	**0.8**[a,c] (−0.07)	0.9[b,c] (0.01)	**3.2** (1.63)	1.0
School team sports, number/year	**0.6**[a] (−0.22)	1.0[b] (0.09)	1.4 (0.52)	1.1[b] (0.26)	**0.6**[a] (−0.20)	**0.5**[a] (−0.30)	**2.7** (1.63)	0.9
School individual sports, number/year	**0.1**[a] (−0.22)	**0.2**[a,b,c] (−0.07)	0.2[b] (0.03)	0.2[b,c] (−0.01)	**0.1**[a,c] (−0.16)	**0.1**[a] (−0.19)	**1.5** (2.5)	0.2
Likelihood of making own TV decisions	**0.95**[a] (0.33)	0.83[b] (0.00)	0.84[b] (0.05)	0.87[b] (0.11)	**0.27** (−1.76)	**0.96**[a] (0.38)	0.87[b] (0.10)	0.83
School physical education, days/wk	2.2[a](−0.07)	3.1[b](0.37)	2.9[b](0.28)	2.4[a,d] (0.03)	2.8[b,d](0.20)	**1.4** (−0.47)	**3.4** (0.55)	2.4
Likelihood of playing sport with a parent	0.07 (−0.23)	0.20 (0.27)	**0.62** (1.96)	0.12[a] (−0.05)	0.11[a] (−0.07)	**0.04** (−0.31)	0.13[a] (0.00)	0.17
Likelihood of using a recreation center	**0.08**[a] (−0.33)	0.18[b] (−0.07)	0.16[b] (−0.08)	**0.86** (1.85)	**0.11**[a] (−0.22)	**0.10**[a] (−0.27)	0.18[b] (−0.04)	0.20

[a,b,c,d]In each row, means with the same letter are not significantly different from each other ($p \geq 0.05$ with Bonferoni correction); means that are **underlined and boldface** are significantly **highest;** means that are **in boldface only** are significantly **lowest.**

Table 2. Mean frequency of sociodemographic characteristics by activity cluster, National Longitudinal Study of Adolescent Health, mean (standard error)

	Cluster 1 TV/video and gaming	Cluster 2 Skaters and gamers	Cluster 3 Sports with parents	Cluster 4 Uses recreational center	Cluster 5 Limited TV decisions	Cluster 6 Reports few activities	Cluster 7 Active in school	Total
Age, years	15.0 (0.1)	**14.2** (0.1)	**14.4** (0.1)	15.1 (0.1)	**14.5** (0.1)	**<u>15.6</u>** (0.1)	**14.5** (0.1)	15.0
Proportion black	**<u>0.20</u>** (0.03)	**0.07** (0.01)	0.08 (0.01)	**<u>0.21</u>** (0.04)	**<u>0.15</u>** (0.02)	0.11 (0.02)	**<u>0.13</u>** (0.02)	0.14
Proportion Hispanic	**<u>0.12</u>** (0.02)	0.08 (0.01)	0.07 (0.02)	0.07 (0.02)	**<u>0.20</u>** (0.03)	0.11 (0.02)	0.09 (0.02)	0.11
Proportion Asian	**<u>0.05</u>** (0.01)	**0.03** (0.01)	**0.02** (0.01)	0.04 (0.01)	**<u>0.08</u>** (0.02)	0.04 (0.01)	**0.04** (0.01)	0.04
Household income ($)	**37,400** (1,300)	**<u>48,000</u>** (2,200)	**<u>51,200</u>** (1,800)	**<u>46,400</u>** (3,100)	**42,800** (2,200)	44,700 (2,000)	**<u>48,400</u>** (1,900)	44,800
Proportion of parent education <high school	**<u>0.14</u>** (0.01)	0.10 (0.01)	0.09 (0.01)	0.11 (0.02)	**<u>0.20</u>** (0.03)	**<u>0.15</u>** (0.02)	0.09 (0.02)	0.13
Proportion of parent education ≥college	**0.21** (0.02)	0.29 (0.03)	**<u>0.32</u>** (0.02)	0.26 (0.03)	0.27 (0.03)	0.26 (0.02)	**<u>0.31</u>** (0.03)	0.27
Proportion female	0.46 (0.02)	**0.25** (0.02)	0.44 (0.02)	0.41 (0.02)	0.58 (0.02)	**<u>0.71</u>** (0.02)	0.55 (0.03)	0.51
Proportion with father present in household	**0.78** (0.02)	**<u>0.85</u>** (0.02)	**<u>0.89</u>** (0.01)	0.77 (0.02)	0.82 (0.02)	**0.80** (0.01)	0.82 (0.02)	0.82
Household size	**4.50** (0.07)	**4.44** (0.06)	**4.48** (0.05)	**<u>4.63</u>** (0.08)	**<u>4.80</u>** (0.08)	**4.45** (0.06)	**4.49** (0.09)	4.53
Proportion born in United States	0.95 (0.01)	**<u>0.97</u>** (0.01)	**<u>0.97</u>** (0.01)	**<u>0.96</u>** (0.01)	**0.88** (0.02)	0.94 (0.01)	**<u>0.97</u>** (0.01)	0.95

Means that are **<u>underlined and boldface</u>** are significantly **<u>highest;</u>** means that are **in boldface only** are significantly **lowest** ($p < 0.05$ with Bonferoni correction).

(TV/video and video gaming). Clusters also predicted total weekly MVPA. Adolescents in Cluster 2 (skaters/gamers) had 2.8 more bouts of weekly activity (95% confidence interval [CI]=2.6–2.9); Cluster 3 (sports with parent) had 1.8 more bouts (95% CI=1.7–1.9); Cluster 4 (uses recreation center) had 1.4 more bouts (95% CI=1.3–1.6); Cluster 5 (limited TV decisions) had 0.4 more bouts (95% CI=0.3–0.5); and Cluster 7 (active in school) had 1.6 more bouts (95% CI=1.4–1.7) than those in Cluster 1. Individuals in Cluster 6 (reporting few activities) had 0.5 fewer bouts (95% CI=−0.6–−0.4) than those in Cluster 1.

Young adulthood. To test the validity of these activity patterns, clusters predicted total activity levels in young adulthood (using Wave-III data not used to generate clusters). Independent of adolescent PA level, clusters significantly predicted differential sustainability of activity over time. Weekly activity bouts were greater in all other clusters compared to Cluster 1. While absolute odds of meeting PA recommendations in early adulthood declined, they remained relatively high in Cluster 2 (skaters/gamers, OR=1.8); 3 (sports with parent, OR=2.6); 4 (uses recreation center, OR=2.3); and 7 (active in school, OR=2.4) compared to 1 (TV) (Table 3), indicating greater PA sustainability among these clusters.

Predicted probabilities of meeting national recommendations. Adjusted predicted probabilities illustrate different trends over time for seven activity patterns (Figure 1). Likelihood of meeting PA recommendations declined substantially with age/time, although the magnitude of decline varied by cluster. For example, predicted probabilities of adolescent skaters/gamers (Cluster 2) meeting this recommendation was high (Wave I: 0.80; Wave II: 0.73), but dropped 88% by adulthood. The likelihood of meeting recommendations for levels of sedentary behaviors followed different trends (Figure 2). Most clusters increased in likelihood during adolescence (Waves I to II), and decreased in early adulthood.

Discussion

Cluster analyses identified seven groups of adolescents sharing specific PA and sedentary behavior patterns. In descriptive analyses, odds of adolescents meeting national PA recommendations differed by cluster and were highest in Clusters 2 (skaters/gamers); 3 (sports with parent); 4 (uses neighborhood recreation center); and 7 (active in school). By young adulthood, weekly PA bouts declined in all clusters. While the magnitude of decline varied, the results demonstrate meaningful variability between clusters and provide validation of identified patterning.

Sedentary behaviors followed different trends. Across all clusters, likelihood of meeting national

Table 3. Logistic regression using activity clusters to predict likelihood of meeting national physical activity guidelines at multiple points in time

	OR of meeting PA guidelines in adolescence (Wave II) AOR[a] (95% CI)	OR[b] of meeting PA guidelines in early adulthood (Wave III) AOR[a] (95% CI)
Cluster 1: High TV	1.00	1.00
Cluster 2: Skaters and gamers	13.13 (10.83, 15.92)	1.77 (1.33, 2.36)
Cluster 3: Sports with parents	5.84 (5.02, 6.80)	2.58 (2.00, 3.33)
Cluster 4: Uses recreation center	4.19 (3.47, 5.05)	2.26 (1.70, 3.01)
Cluster 5: Limited TV decisions	1.60 (1.29, 1.97)	1.21 (0.92, 1.60)
Cluster 6: Reports few activities	0.53 (0.45, 0.64)	1.13 (0.87, 1.47)
Cluster 7: Active in school	4.34 (3.42, 5.52)	2.35 (1.80, 3.08)

[a]Adjusted for household income; parental education, race/ethnicity, age, and gender.
[b]Adjusted for likelihood of meeting PA guidelines in adolescence (wave II), as well as household income, parental education, race/ethnicity, age, and gender.
CI, confidence interval; OR, odds ratio; PA, physical activity.

guidelines for levels of sedentary behavior generally increased through adolescence and decreased in adulthood. These declines are notably less than observed PA declines. However, likelihood of meeting recommendations for sedentary behaviors increased by young adulthood in Clusters 1 (high TV) and 2 (skaters/gamers). While previous literature has used pattern analyses to examine the co-occurrence of multiple health behaviors (e.g., PA, smoking, diet),[23,43] few analyses have specifically explored the co-occurrence of PA- and sedentary-related factors.[25,26] To our knowledge, these are the first analyses using cluster analyses to specifically examine these adolescent behaviors in a large, nationally representative cohort.

In this cohort, the overall likelihood of being physically active is low in all young adults,[3] reflecting national PA levels[2] and documented age-related PA declines.[14] However, the likelihood of being physically active among certain clusters (skating/gaming, sports with parent, using recreation centers, active in school) is relatively higher, indicating that these activity patterns may be more sustainable over time. During the transition from adolescence to young adulthood, however, the **magnitude** of decline in likelihood of meeting national recommendations also varies widely by cluster. While most adolescent skaters/gamers met PA recommendations, this group had the greatest PA decline once reaching adulthood. This may be partially a function of their high baseline value, as it is not possible for clusters with very low overall PA to decline as much as other clusters with higher overall PA.

However, these results may have important implications for targeting health promotion efforts. Skaters/gamers, for example, represent the most active adolescents in this cohort and would not likely be targeted in health promotion strategies. However, over time this group experiences the greatest PA decline compared to all other groups. Therefore, effective intervention strategies might target these individuals during the transition to adulthood. These adolescents have the desire and ability to be highly active on their own accord, presumably engaging in enjoyable activities. As they become adults, however, social or physical barriers may override this desire, and thus their PA levels drop dramatically.

In addition to these differences in PA decline by clusters, these results may provide other interesting insights into PA promotion strategies. Reducing sedentary behaviors (e.g., TV) has been proposed as a means of increasing PA to prevent obesity,[44,45] and recent national recommendations have included limiting children's TV viewing.[39,40,46] However, TV viewing has not been a strong PA predictor in observational cohort studies,[26,47–49] and reducing healthy children's sedentary behaviors has not resulted in PA increases,[45] although it has reduced adiposity (possibly by reducing meals eaten while watching TV).[44,50] In treating obesity, controlled trials illustrate that limiting sedentary behaviors may increase PA.[51] However, our results indicate that while adolescents whose parents limited their TV viewing (Cluster 5) were moderately likely to meet adolescent PA guidelines, they were among the

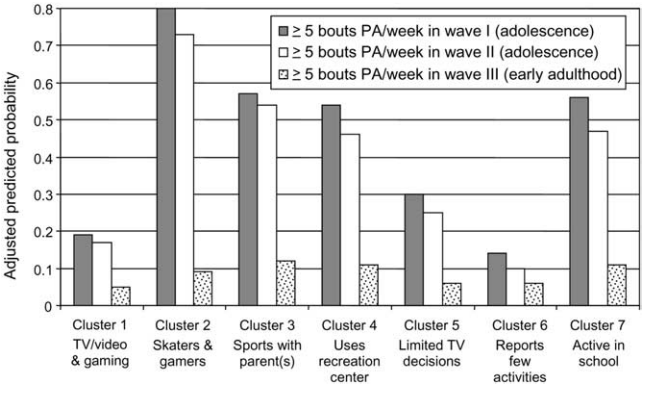

Figure 1. Adjusted predicted probabilities of meeting national recommendations for moderate vigorous physical activity, in adolescence (Waves I and II) and early adulthood (Wave III). Adjusted for gender, age, parent education, race/ethnicity, and household income.

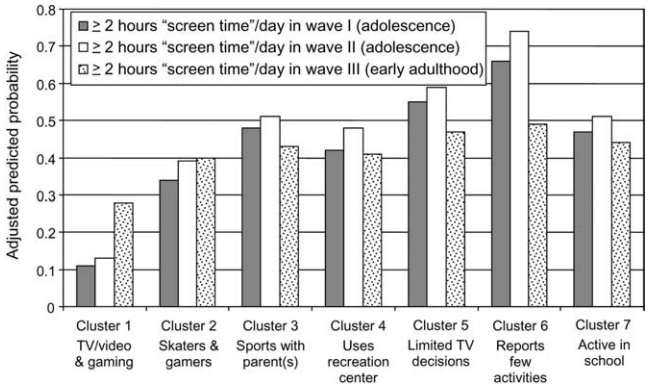

Figure 2. Adjusted predicted probabilities of meeting national recommendations for moderate TV/video viewing and video/computer gaming ("screen time"), in adolescence (Waves I and II) and early adulthood (Wave III). Adjusted for gender, age, parent education, race/ethnicity, and household income.

What This Study Adds . . .

Despite age-related physical activity (PA) declines, little is known about adolescent PA and sedentary behavior patterning and long-term activity sustainability.

Using cluster analysis, this study identified seven activity patterns.

PA decline through adolescence varies by pattern.

Adolescents characterized by both active and sedentary behaviors (skaters/gamers) decline most dramatically.

Adolescents with parent-restricted television are among the least likely to have adequate adult PA.

These findings identify important targets for effective future PA promotion strategies.

least likely to meet these guidelines during young adulthood. While these analyses cannot address **how** parents regulated TV and PA, declines also may be attributed to other factors (e.g., adolescent PE in school). These and other results illustrate that PA and sedentary behaviors are regulated through a complex series of decision-making mechanisms,[51] and simply restricting adolescent TV viewing may not be effective in increasing PA. The manner in which TV is restricted may dramatically affect subsequent changes in PA; to be effective in preventing obesity by increasing PA, TV restriction may need to be implemented in combination with other PA promotion efforts.

To promote healthful, sustainable activity patterns during this critical age, several possibilities arise from these results. First, promoting more sustainable activity patterns in less-active adolescents may lead to overall increases in long-term PA. Second, identifying and addressing specific barriers to continued PA among clusters with the most substantial declines in overall activity will be critical to enhancing successful activity-promotion efforts. For example, PA decline in skaters/gamers may be buffered by altering the physical environment (e.g., via skating parks, bicycle lanes) to support continuation of these activities, coupled with efforts to increase social acceptability of such activities among young adults.

Our conclusions, however, are limited by several factors: the use of only self-report measures in our analyses, potential for selection bias due to our sampling and exclusion criteria, and the somewhat limited data we have to characterize types of PA and sedentary behaviors. More in-depth analyses of individuals maintaining recommended PA are needed to understand how to successfully promote sustainable activities. Qualitative methods will be helpful in addressing motivation and coping mechanisms of individuals engaging in long-term, regular PA. For example, while different types of activity patterns may be differentially sustainable, sustainability also may rely heavily on how individuals feel about the activities in which they engage and their ability to adapt to changing environments.

This work provides important insights into targeting intervention strategies for sustainable PA behaviors. While little research has examined patterns of activity-related behaviors, this issue is critical in assessing overall lifestyle effects. Individuals perform **various** behaviors that are interwoven into overall activity patterns. Effective activity promotion strategies may focus on determinants initiating shifts toward more healthful, sustainable **overall** behavior patterns, rather than shifts focused on any single aspect of these patterns. Therefore, research informing promotion efforts should reflect this by evaluating multiple dimensions of activity-related behaviors simultaneously to identify behavior patterning.

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