Developmental Trajectories of Physical Activity, Sports, and Television Viewing During Childhood to Young Adulthood
Iowa Bone Development Study

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**IMPORTANCE** The diverse developmental patterns of obesogenic behaviors during childhood and adolescence can be better understood by using new analytic approaches to assess the heterogeneity in variation during growth and development and to map the clustering of behavior patterns.

**OBJECTIVES** To identify distinct trajectories of daily time spent in moderate- to vigorous-intensity physical activity (MVPA) from ages 5 to 19 years and to examine the associations of MVPA trajectories with sports participation and television viewing trajectories.

**DESIGN, SETTING, AND PARTICIPANTS** Cohort members in the prospective population-based Iowa Bone Development Study participated in MVPA assessments via accelerometry from September 16, 1998, to December 9, 2013, at ages 5, 8, 11, 13, 15, 17, and 19 years and completed a questionnaire every 6 months on sports participation and daily time spent in television viewing.

**MAIN OUTCOMES AND MEASURES** Trajectories of MVPA (minutes per day), participation in organized sports (yes or no), and television viewing time (hours per day).

**RESULTS** Based on the data from 537 participants (50.1% females; 94.6% white), we identified 4 MVPA trajectories: consistently inactive (14.9%), consistently active (18.1%), decreasing moderate physical activity (52.9%), and substantially decreasing high physical activity (14.1%). All participants in the consistently inactive trajectory also followed a trajectory of no participation in sports. The consistently active trajectory was associated with decreasing an already low television viewing trajectory ($P < .001$).

**CONCLUSIONS AND RELEVANCE** This study provided a nuanced look at the known decrease in MVPA during childhood and adolescence. Sports participation could be a critical way to avoid the consistently inactive pattern. Most important, we identified a subset of participants who maintained a seemingly healthy level of MVPA from childhood to young adulthood. The developmental pathways of physical activity and television viewing behaviors could be related. Additional studies should examine the determinants and health consequences of these specific MVPA trajectories.
Participation in moderate- to vigorous-intensity physical activity (MVPA) during childhood provides numerous physical, psychosocial, and cognitive health benefits. However, most US youth participate in less MVPA than the recommended 60 min/d. Organized sports participation, as a leisure-time activity, has been promoted as an effective strategy to increase physical activity (PA) among youth. Because sports is a subset of PA, it is not surprising to find a strong cross-sectional association between organized sports participation and MVPA among youth. Longitudinal studies have also reported a positive association between organized sports participation and PA during adolescence. These data suggest that consistent participation in organized sports during the growing years is associated with healthy MVPA habits. In reality, of the 84% of US youth who join organized sports, 45% will stop participation at some point during childhood and adolescence. Therefore, it is important to understand whether any participation in organized sports helps youth to develop healthier MVPA habits compared with never participating in sports at all.

Television viewing has been seen as a displacement behavior for PA; that is, youth watch television rather than engage in PA. However, it also has been viewed as an independent health risk behavior that is not necessarily associated with PA levels. In fact, the association between television viewing and PA is mixed: while some studies report an inverse cross-sectional and longitudinal association, other studies report no association, particularly in populations with relatively low levels of PA. A better understanding of the developmental pathways of PA and television viewing behaviors will provide greater insight for improving interventions that target both or each of these behaviors.

Identifying distinct developmental patterns of MVPA, sports, and television viewing behaviors requires an analytic method that effectively uses multiple points of data assessed longitudinally. Traditional analytic approaches generally examine the paths of predefined subgroups using prior analysis and subjective classification rules; that is, groups with an increase, decrease, or no change are classified based on a change between 2 time points. Such predefined subgroup approaches are fraught with statistical dangers, including the dual risks of creating groups that reflect only random variation and failing to identify important but unusual developmental patterns. Group-based trajectory modeling enables the data themselves to divide a study population into subgroups and to fit trajectory models for each of those subgroups. The aims of this study were to use group-based modeling to identify distinct developmental trajectories of MVPA, organized sports participation, and television viewing behaviors from childhood to young adulthood in the Iowa Bone Development Study (IBDS) cohort and to examine associations of the MVPA trajectories with organized sports participation trajectories and television viewing trajectories.

Methods

Participants

The IBDS is an ongoing longitudinal study of bone health during childhood, adolescence, and young adulthood. Participants are a subset of the Iowa Fluoride Study birth cohort that included 1882 families recruited from 8 Iowa hospital postpartum wards between 1993 and 1997. The IBDS used rolling admission to allow Iowa Fluoride Study members to participate in any follow-up examinations. The baseline examinations for the IBDS were conducted between September 16, 1998, and October 5, 2000, in children who were approximately 5 years of age. Participants’ parents self-identified their race among the categories of white, black or African-American, Hispanic or Latino, Asian or Pacific Islander, and other. Of the 630 IBDS participants who completed at least 1 accelerometry assessment wave, 94.0% were white and 72.2% of their mothers had a college degree or higher educational level. Additional information about the IBDS and its participants is available elsewhere. Written informed consent and assent were obtained. The University of Iowa Institutional Review Board approved the IBDS, and the Ann & Robert H. Lurie Children’s Hospital of Chicago Institutional Review Board approved a waiver from review.

Measurements

Accelerometry-Measured PA

Accelerometry assessments were conducted at approximately 5, 8, 11, 13, 15, 17, and 19 years of age (IBDS waves 1 to 7, respectively) from September 16, 1998, to December 9, 2013. When children and their parents visited study sites for onsite examinations, they were given instructions for wearing the accelerometer. Actigraph uniaxial accelerometers (ActiGraph; model 7164 for waves 1-4, GT1M for wave 5, and GT3X+ for waves 6 and 7) were mailed to participants during the autumn (September–November). The detailed procedures for accelerometer data collection are described in previous publications. Briefly, participants were asked to wear the monitors during waking hours for 4 consecutive days (including 1 weekend day) during waves 1 and 2 and for 5 consecutive days (including both weekend days) for all other waves. Accelerometry movement counts were collected in 1-minute epochs during waves 1 to 4 and in 5-second epochs during waves 5 to 7. For analysis, the 5-second epoch raw data were reintegrated into 1-minute epoch data for consistency across the waves. For the accelerometry data reduction process, accelerometers were considered as having not been worn if 60 consecutive minutes of zero accelerometry counts (with an allowance for 2 nonzero interruptions) were encountered in the waves.

At a Glance

- This group-based trajectory approach offers an understanding of the development of obesogenic behaviors in youth.
- Group-based trajectory analysis identified a subset of about 20% of participants who maintained a seemingly healthy level of moderate- to vigorous-intensity physical activity from childhood to young adulthood and watched even less television across time.
- The developmental pathways of healthy behaviors (high physical activity and low television viewing) could be related.
- Sport participation could be a critical way to avoid a consistently inactive pattern.
accelerometry data array. Accelerometry data were used only from participants who wore an accelerometer for at least 8 h/d and at least 3 days during each wave. Daily wear time began at 12:00 AM and ended at 11:59 PM; MVPA (as minutes per day) was defined as 2296 or more accelerometry counts per minute.

Organized Sports Participation and Television Viewing
To define organized sports, we included organized teams and individual sports in any setting (eg, school-based sports teams and sports clubs) that were plausible in the Midwestern United States (as judged by 3 of us: S.K., E.M.L., and K.F.J.). Eligible sports included baseball, softball, basketball, cheerleading, dance (ballet, jazz, or other), football, golf, gymnastics, tumbling, ice hockey, figure skating, martial arts, track and field running, soccer, swimming, tennis, badminton, racquetball, volleyball, lacrosse, and wrestling. To assess organized sports participation and television viewing, 2 versions of a physical activity questionnaire (PAQ) were used. The first version (proxy-PAQ) was designed for a parent to report his or her child’s activities and was used for children younger than 11 years (waves 1 and 2). The proxy-PAQ asked about sports participation: “Did your child participate in any of the following organized sports during the past 6 months?” Responses included baseball, basketball, soccer, gymnastics, dance, swimming, and other. Responses of “other” were reviewed to capture any of the eligible sports listed as “other.” Children who were reported as having participated in at least 1 eligible sport were categorized as participating in organized sports. The proxy-PAQ also asked an open-ended question about the hours per day the child spent watching any type of television (including videotapes of movies and programs).

The second version (self-PAQ), administered when participants were aged 11 years or older, was adapted from the PAQ for older children and PAQ for adolescents. The self-PAQ contained a list of 20 or more sports, and inquired about the frequency of sports participation in the previous 7 days and whether the sport activity was organized, described as a coached sport or lessons. Responses of “other” were also allowed and reviewed by investigators to capture any of the eligible sports listed as “other.” If a respondent reported participating in at least 1 eligible sport and marked it as organized, the respondent was categorized as participating in organized sports. The self-PAQ asked, “How many hours per day did you watch television in the last week? Include the time you spent watching movies or programs on video or DVD. Do not count television or videos watched in school.” The response options of less than 1, 1 to less than 2, 2 to less than 3, 3 to less than 4, and 4 h/d or greater were coded as 0.5, 1.5, 2.5, 3.5, and 4.5, respectively, and were treated as continuous data. All PAQs were administered using a paper form either during clinic visits or via mail every 6 months during the individual-level 14-year follow-up.

Statistical Analysis
Participants who completed at least 3 of the 7 accelerometry assessments were included in the data analyses. This approach allowed us to consider the possibility of quadratic models. Descriptive analyses for the main variables were performed by waves (at approximately 5, 8, 11, 13, 15, 17, and 19 years of age). To identify distinct MVPA trajectory patterns (groups), we conducted group-based trajectory analysis with STATA TRAJ (StataCorp LP). In the process of determining the number of groups, a quadratic model was initially used for all groups. The final number of groups was determined based on the Bayesian Information Criterion, trajectory shapes for similarity, and the proportion of cohort members in each class. After identifying the optimal number of groups, the level of polynomial functions for each group (ie, quadratic, linear, and constant) was reduced until a parameter estimate in the highest function had a significance of P < .01 (eTable 1 in the Supplement). As suggested by Nagin, we evaluated model adequacy using the following 4 diagnostic measures: average posterior probability of assignment for each group is 0.7 or higher, odds of correct classification are 5.0 or higher, the proportion of a sample assigned to a certain group is close to the proportion estimated from the model, and 99% CIs of the estimated proportion are reasonably narrow. This modeling process was repeated for organized sports participation (yes or no) and television viewing (hours per day). We then used dual trajectory models of MVPA and organized sports participation, as well as MVPA and television viewing, to understand the interrelationship between the development of MVPA and television viewing behaviors because the dual trajectory model offers probabilities that link membership in trajectory groups across 2 behaviors. Each participant was assigned to one of the trajectory based on the individual’s maximum posterior probability from the final models. The difference in the sex distribution between the groups was tested via χ² tests. P < .05 was considered significant.

Results
Of 690 participants who completed at least 1 accelerometer assessment wave, 537 participants (50.1% females) who had at least 3 valid accelerometer assessment waves were included in the data analysis. Those who were excluded (n = 93) had similar levels of family income and mother’s education as those who were included (eTable 2 in the Supplement). Of the 537 participants, 31.3% completed all 7 MVPA assessments, 29.0% completed 6 assessments, 16.4% completed 5 assessments, 14.0% completed 4 assessments, and 9.3% completed 3 assessments. The number of accelerometer assessments completed at each wave is presented in Table 1. The mean accelerometer wear time at each wave was 12 hours or more (range, 12.0-12.7 hours across waves). The median of accelerometer wear days was 5 in all waves. On average, each participant completed the PAQ 23 times during the study years (range, 3-35 times). In general, more participants completed the PAQ than the accelerometer assessment at each wave (Table 1).

We identified 4 distinct MVPA trajectories (Figure 1 and eTable 3 in the Supplement): consistently inactive (MVPA group 1; 14.9%), consistently active (MVPA group 2; 18.1%), decreasing moderate PA (MVPA group 3; 52.9%), and substantially decreasing high PA (MVPA group 4; 14.1%). Compared with males,
more females followed the consistently inactive pattern ($P < .001$), but fewer females followed the consistently active pattern ($P < .001$). The percentages of females were 84.8% in MVPA group 1, 28.6% in MVPA group 2, 57.8% in MVPA group 3, and 11.8% in MVPA group 4.

We identified 3 organized sports participation trajectories (Figure 2): no sport participation (sport group 1; 13.6%), dropout from sports participation (sport group 2; 40.2%), and consistent sports participation (sport group 3; 46.2%). The sex distributions were not significantly different by groups ($P = .88$): the percentages of females were 52.9% in sport group 1, 49.5% in sport group 2, and 49.8% in sport group 3.

We identified 4 television viewing trajectories (Figure 3): decreasing low television viewing (television group 1; 25.4%), increasing low television viewing (television group 2; 26.4%), decreasing high television viewing (television group 3; 27.6%), and maintaining high television viewing (television group 4; 20.5%). For labeling purposes, we defined low television viewing as less than 2 h/d and high television viewing as 2 h/d or greater. The sex distributions were not different by groups ($P = .37$); the proportion of females was 53.3% in television

### Table 1. Descriptive Analysis of Physical Activity Measures Across 7 Examinations of the Iowa Bone Development Study

<table>
<thead>
<tr>
<th>Wave</th>
<th>Participants, No.</th>
<th>Accelerometry</th>
<th>PAQ</th>
<th>Probability of Organized Sports Participation, Mean (SD), %</th>
<th>Television Viewing, Mean (SD), h/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>406</td>
<td>MVPA, Mean (SD), min/d</td>
<td>Participants, No.</td>
<td>PAQ Completed, No.*</td>
<td>Probability of Organized Sports Participation, Mean (SD), %</td>
</tr>
<tr>
<td>2</td>
<td>509</td>
<td>43 (19)</td>
<td>426</td>
<td>2495</td>
<td>62 (36)</td>
</tr>
<tr>
<td>3</td>
<td>512</td>
<td>47 (23)</td>
<td>505</td>
<td>1969</td>
<td>79 (31)</td>
</tr>
<tr>
<td>4</td>
<td>467</td>
<td>45 (24)</td>
<td>523</td>
<td>1963</td>
<td>53 (38)</td>
</tr>
<tr>
<td>5</td>
<td>405</td>
<td>37 (21)</td>
<td>517</td>
<td>1870</td>
<td>49 (39)</td>
</tr>
<tr>
<td>6</td>
<td>378</td>
<td>28 (17)</td>
<td>492</td>
<td>1812</td>
<td>37 (40)</td>
</tr>
<tr>
<td>7</td>
<td>324</td>
<td>27 (17)</td>
<td>470</td>
<td>1812</td>
<td>37 (40)</td>
</tr>
</tbody>
</table>

Abbreviations: MVPA, moderate- to vigorous-intensity physical activity; PAQ, physical activity questionnaire.

* The number of completed PAQ responses at ages 4 to less than 7 years for wave 1, ages 7 to less than 10 years for wave 2, ages 10 to less than 12 years for wave 3, ages 12 to less than 14 years for wave 4, ages 14 to less than 16 years for wave 5, ages 16 to less than 18 years for wave 6, and ages 18 to less than 20 years for wave 7.
Table 2. Distribution of MVPA Trajectory Groups Conditional on Organized Sports Participation Trajectory Groups and on Television Viewing

<table>
<thead>
<tr>
<th>Group</th>
<th>MVPA, No. (%)</th>
<th>Television Groups</th>
<th>P Value for ( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2 (Healthiest)</td>
<td>Group 3</td>
</tr>
<tr>
<td>Sports Groups*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>35 (6.5)</td>
<td>85 (15.8)</td>
<td>343 (63.9)</td>
</tr>
<tr>
<td>Group 1</td>
<td>35 (49.3)</td>
<td>0</td>
<td>32 (45.1)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0</td>
<td>82 (36.3)</td>
<td>131 (58.0)</td>
</tr>
<tr>
<td>Group 3 (Healthiest)</td>
<td>0</td>
<td>3 (1.3)</td>
<td>180 (75.0)</td>
</tr>
<tr>
<td>Television Groups*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>70 (13.0)</td>
<td>79 (14.7)</td>
<td>312 (58.1)</td>
</tr>
<tr>
<td>Group 1 (Healthiest)</td>
<td>9 (6.7)</td>
<td>42 (31.1)</td>
<td>65 (48.1)</td>
</tr>
<tr>
<td>Group 2</td>
<td>16 (11.7)</td>
<td>17 (12.4)</td>
<td>71 (51.8)</td>
</tr>
<tr>
<td>Group 3</td>
<td>34 (22.1)</td>
<td>17 (11.0)</td>
<td>85 (55.2)</td>
</tr>
<tr>
<td>Group 4</td>
<td>11 (9.9)</td>
<td>3 (2.7)</td>
<td>91 (82.0)</td>
</tr>
</tbody>
</table>

Abbreviations: MVPA, moderate- to vigorous-intensity physical activity; NA, not applicable.

* MVPA group labels: 1 = consistently inactive; 2 = consistently active; 3 = decreasing moderate physical activity; and 4 = substantially decreasing high physical activity.

b \( \chi^2 \) test of whether the proportion of MVPA group 2 was different between television group 1 (reference group) and other television groups.

c Sport groups labels: 1 = no sports participation; 2 = dropout from sports participation; and 3 = consistent sports participation.

d Not applicable because \( \chi^2 \) tests could not be performed with zero cells.

e Television groups labels: 1 = decreasing low television viewing; 2 = increasing low television viewing; 3 = substantially decreasing high television viewing; and 4 = maintaining high television viewing.

Discussion

This study mapped and associated trajectories of 3 ubiquitous behaviors from childhood to young adulthood: MVPA, organized sports participation, and television viewing. It confirmed that most children follow a pattern of decline in moderate MVPA from childhood to young adulthood. Most important, a sizeable number of children, especially girls, are inactive as children and stay that way through adolescence. The MVPA trajectory analysis also provided a new insight via the identification of a subset of participants who are consistently active from childhood into young adulthood. Almost 1 in 5 IBDS participants followed this pattern, and many of them routinely watched little television and, as they aged, watched even less television. The consistently active pattern was not previously identified in an IBDS sex-specific analysis, presumably owing to reduced statistical power. The level of MVPA among the consistently active group (approximately 45 min/d) was not as high as the US Physical Activity Guidelines recommend. However, the guidelines are primarily based on epidemiologic studies that linked health outcomes data to self-reported PA or time reported during an exercise intervention, for which both approaches are likely to have a higher count of minutes than are accelerometer measures. Therefore, the consistently active group could be the subpopulation that sustains a desirable level of PA. In future studies, an investigation of group-based trajectories of concurrently measured accelerometer PA and self-reported PA will help to translate the US Physical Activity Guidelines and develop guidelines based on device-measured movement.

This study suggests that, although consistent sports participation is insufficient to maintain healthy MVPA behavior, joining organized youth sports (despite eventually dropping out) could be important to avoid a consistently inactive lifestyle. In addition to the potential causal pathway between no organized sports participation and a low MVPA pattern, shared participant characteristics, such as low socioeconomic status, could partly explain the observed association. In the IBDS population, sex was not a predictor of organized sports participation trajectories. The even distribution by sex in the sports participation trajectory classes is not surprising considering that high schools in Iowa offer girls substantial access to organized sports (high school sports teams accommodate 72% of girls). More research is needed to characterize children in the consistently low MVPA and no sports participation trajectories.
The association between healthy MVPA and television viewing behaviors supports the idea that the developmental pathways of healthy MVPA and television viewing behaviors could be related. Previous studies have shown a cluster pattern for PA and sedentary behaviors. Some of the studies also found an unhealthy clustering of PA and sedentary behavior. In the current study, however, an unhealthy clustering of MVPA and television viewing trajectories was less clear. The development of television viewing behavior among inactive children should be further investigated in future studies.

Several limitations should be acknowledged. First, changes in the PAQ versions might have resulted in a differential bias in estimating organized sports participation and television viewing hours. However, additional group-based trajectory analyses of television viewing and sports participation, including data collected at IBDS waves 3 to 7, produced the same number of distinct subgroups and similar trajectory patterns. Second, because a group-based trajectory model assumes that missing data are random, nonrandom missing data across time could have biased the study findings. However, of those who were included in the data analysis, many (60.3%) completed at least 6 MVPA waves. To our knowledge, the IBDS offers the most complete longitudinal youth accelerometry-measured PA data, including multiple follow-ups that are desirable for group-based trajectory analysis. Third, this study used a sample that was homogeneously white and of high socioeconomic level. Therefore, the results may not be generalizable to other populations. Last, it is important to note that, because group membership was determined based on the maximum likelihood, not all group members perfectly followed their group’s trajectory. Therefore, use of the posterior probability-based classification that does not account for the uncertainty in group classification is prone to classification error of the group and should be interpreted with caution. However, we used this method because the posterior probability-based classification provides a straightforward basis for producing profiles of trajectory members and an easy and transparent communication of the findings.

Despite these limitations, this study has important strengths. This study used the most comprehensive longitudinal data set available for PA, sports participation, and television viewing measurements among youth: MVPA was assessed 7 times and sports participation and television viewing were assessed on average 23 times during 14 years. This study applied an innovative analytic approach—group-based trajectory analysis—that allows for the identification of diverse developmental trajectories of MVPA, sports participation, and television viewing behaviors.

**Conclusions**

This study provided a nuanced look at the known decrease in MVPA from childhood to young adulthood. We identified a consistently active trajectory pattern that represents a seemingly healthy level of MVPA during childhood to young adulthood. This study suggests that sports participation could be critical to avoid a consistently inactive pattern and that the developmental pathways of PA and television viewing behaviors could be related.
Research Original Investigation


