

Does controlling for biological maturity improve physical activity tracking?

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Abstract

Tracking of physical activity through childhood and adolescence tends to be low. Variation in the timing of biological maturation within youth of the same chronological age (CA) might impact participation in physical activity, and may partially explain the low tracking. *Purpose:* To examine the stability of physical activity over time from childhood to late adolescence when aligned on chronological and biological ages. *Methods:* 91 males and 96 females 8 to 15 years of age from the Saskatchewan Pediatric Bone Mineral Accrual Study (PBMAS) were assessed annually for 8 years. Biological age (BA) was calculated as years from age at peak height velocity. Physical activity was assessed using the Physical Activity Questionnaire for Children/Adolescents (PAQ-C/A). Tracking was analyzed using Intra-class correlations for both CA and BA (two-year groupings). To be included in the analysis an individual required a measure at both time points within an interval; however, not all individuals were present at all tracking intervals. *Results:* Physical activity tracking by CA two-year intervals were, in general, moderate in males ($r=.42$ to $.59$) and females ($r=.43$ to $.44$). However, the 9-11 year CA interval was low and non-significant ($r=.23$ to $.30$). Likewise, tracking of physical activity by BA two-year intervals was moderate to high in males ($r=.44$ to $.60$) and females ($r=.39$ to $.62$). *Conclusion:* Accounting for differences in the timing of biological maturity had little impact on tracking of physical activity. However, point estimates for tracking are higher in early adolescence in males and to a greater extent females when aligned by BA versus CA. This suggests that maturity may be more important in physical activity participation in females than males.

Key words: longitudinal, childhood, adolescent, puberty

Introduction

Paragraph 1:

Physical activity levels have generally been reported to decline from childhood through adolescence and into adulthood (19,39,43). Physical activity is important as it is a critical component of a healthy lifestyle and in adults has been found to be related to a lower risk of developing serious illnesses such as cardiovascular disease (4,44), type 2 diabetes (4) and some cancers (6,12). Physical activity is thus promoted as a preventative measure for illnesses in both adults and children. Children and adolescents have been targeted based on the premise that increased physical activity during childhood and adolescence will not only bring about immediate health benefits, but will also track into adulthood and thus be indirectly related to later health (41). Tracking refers to the tendency of an individual variable to maintain its position or rank within a specific group over time (24) and is generally expressed by calculating the correlation between repeated measurements of the same attribute (e.g., physical activity) in the same individual.

Paragraph 2:

Information on how physical activity tracks is important for promotion and implementation of activity interventions. If tracking of physical activity is high from childhood into adulthood, then implementing early interventions is crucial for population level change; however, if tracking is low, suggesting that being an inactive child does not predicate being an inactive adult, then intervention strategies later in life may be more effective. Several studies have assessed tracking of physical activity and, on average, results show low to moderate stability through childhood and adolescence (1,16,17,22,27,28,41,43) and into young adulthood (8,15,24,26,36,40). This low level of tracking indicates that there is considerable within

individual variability in physical activity during adolescence. There is good reason to believe that pubertal development, otherwise termed biological maturation, might impact adolescent participation in physical activity, and may partially explain the low tracking through adolescence (5).

Paragraph 3:

Adolescence hosts momentous physiological, psychological, social, and behavioral changes. It is likely that the change in physiology (e.g., development of secondary sex characteristics, growth spurt in height, etc.) during adolescence, and the social and psychological implications of these changes, impacts participation in physical activity. For example, the appearance of secondary sex characteristics, in particular breast development, may contribute to feelings of self consciousness and perceptions of discomfort associated with participation in physical activity (34). If these changes were to occur at the same time (i.e., age) in every individual, biological maturity would likely not impact the tracking of physical activity; however, this is not the case. The onset of puberty can vary by as much as 4 to 5 years among normal healthy boys and girls (35). Thus, the different degrees of biological maturity attained by children of the same chronological age will likely present variable influences on participation in physical activity. There is evidence to suggest that sex differences in biological maturation contribute to physical activity during late childhood and adolescence (11,33,38). Furthermore, Riddoch et al. (2007) showed that the development of secondary sex characteristics was inversely related to physical activity among 2933 11-yr-old girls, suggesting that biological maturity also plays a role in physical activity within a sex with late maturing girls participating in more activity than early maturing girls.

Paragraph 4:

With regard to the role of biological maturity in tracking of physical activity, Baggett and colleagues (2008) found low-to moderate tracking coefficients between 11 and 14 years of age in girls. The authors suggested that differences in the tempo and timing of sexual maturation may have reduced the tracking during this time period. However, with no measure of biological maturity they were unable to support or refute this suggestion. In fact, to our knowledge, the impact of variation in pubertal development (or biological maturity) on the tracking of physical activity has yet to be investigated.

Paragraph 5:

In summary, individuals experience dramatic physiological changes during adolescence which likely influence participation in physical activity. Because of the considerable variation in the timing of these changes, when physical activity is aligned to chronological age, the relative order of individuals within a group will likely change. This change could lead to low tracking. Based on this conjecture, when physical activity is aligned to biological age (such as years from the adolescent growth spurt in height), tracking will improve. Thus the purpose of this study was to examine tracking of physical activity over time from childhood to late adolescence when aligned on chronological and biological ages.

Paragraph 6:

We hypothesized that tracking coefficients would be low to moderate when aligned by a chronological age scale but would yield higher point estimates for tracking when data was aligned by a biological age scale.

Methods

Paragraph 7:

Participants and Procedure:

Participants were part of the University of Saskatchewan's Pediatric Bone Mineral Accrual Study (PBMAS; 1991-1999), which has been described in detail elsewhere (38). In brief, the study utilized a mixed-longitudinal design incorporating eight age cohorts. The cohorts were aged between 8 and 15 years at study entry. During eight years of serial data collection, the composition of these clusters remained the same; however, the individuals in each tracking group differed slightly (Table 1) because of differing ages of entry into the study and missed measurements. Between 1991 and 1993, written informed consent was obtained from 251 parents and their children. Of the 94% of participants whose race was known, 95% were Caucasian. By 1999, 197 individuals had been assessed on two or more occasions. In order to be included in the present study, each participant required complete measurements (chronological age, biological age, and physical activity) on at least two measurement occasions separated by 3 years (e.g., 9 and 11 years of age). Therefore, 187 individuals were included in the analysis, 91 males and 96 females; however, it should be noted that not all individuals had measures at all time points. Thirty females and 35 males were present at every time point for both chronological and biological two year age groupings. Data from an 8-year period (9-17 years) was used in the present analysis to assess the effect of tracking during the circum-pubertal years. The study received approval from the University and Hospital Advisory Committee on Ethics in Human Experimentation. Informed consent was provided in writing by all guardians and assent was provided by all participants.

Paragraph 8:

Chronological age: Chronological age (years) was calculated by subtracting the decimal year of an individuals' date of birth from the decimal year of the measurement occasion. One-year intervals were used to construct chronological age groups. Age groups were set up such that the 9-year age group included observations between 8.50 and 9.49 years.

Paragraph 9:

Anthropometry: Anthropometric measurements, including height, sitting height, and body mass, were taken at 6-month intervals by International Society for the Advancement of Kinanthropometry (ISAK) certified personnel, according to the ISAK standards for anthropometric measurement (37). During measurements, participants wore t-shirts and loose fitting shorts, with shoes and jewelry removed. Height was measured as stretch stature to the nearest 0.1 centimeter using a wall stadiometer. Body mass was measured on a calibrated electronic scale and recorded to the nearest 0.1 kilogram. Body mass index (BMI) was calculated as weight (kg)/height (m²). After measurements were obtained, each participant's results were compared to previously recorded results to verify an increase or plateau in values as evidence of confidence in the measurements.

Paragraph 10:

Biological age: Age at peak height velocity (APHV) reflects the maximum growth in stature during a one year time interval in adolescence and also acts as an indicator of biological maturation (38). Using a cubic spline procedure, a growth curve was fitted to each individual's annual height velocity data (GraphPad Prism version 3.00 for Windows, Graphpad Software, San Diego, California, USA) and APHV was established. A cubic spline interpolates polynomials

from information of neighboring points with the goal of obtaining global smoothness. The cubic spline directs the curve through each data point. This approach has the advantage of enhanced flexibility and the ability to preserve the accuracy of the data, since averaging group data does not modify each participant's APHV.

Paragraph 11:

Biological age was calculated by subtracting APHV from chronological age at the time of measurement. Biological age groups (categories) were then constructed in the same manner as the chronological age groups, such that measurements between -2.49 and -1.50 years from PHV were included in the -2 years from APHV group. Physical activity measurements were considered in terms of years before and after APHV.

Paragraph 12:

Physical activity: The Physical Activity Questionnaire for Children (PAQ-C) (10,20) and Physical Activity Questionnaire for Adolescents (PAQ-A) (21) were developed for the PBMAS to assess general levels of physical activity during the school year for students beyond grade three. The PAQ-C was administered to children in elementary school (grades 3-8) and PAQ-A was administered once they reached high school (grades 9-12). The two questionnaires are identical with the exception of one question in the PAQ-C, which enquires about activity during recess which is not present in the PAQ-A (as high school students do not have recess). They are self administered seven-day recall questionnaires, which ask students to recall their physical activity for the last seven days. The PAQ-C and PAQ-A were completed in a classroom setting in approximately 10 to 15 minutes. There is reliability and validity evidence supporting use of the PAQ-C and PAQ-A with children and adolescents (10,20,21).

Paragraph 13:

The PAQ-C and PAQ-A measures were administered a minimum of three times per year for the first three years of the study and two times per each subsequent year during childhood and adolescence. Scores were averaged over each year period to create a single score for chronological and biological age. The PAQ-C is a reliable measure to assess physical activity in both younger (9-12yrs) and older (13-15yr) children. The test-retest reliability for males was $r = 0.75$ and for females was $r = 0.82$ (10). The generalizability coefficients exceeded 0.80 for either the average of two or three measurement occasions within the same year (10). The PAQ-A has also found to be a reliable assessment physical activity with generalizability coefficients of 0.85 for the average of two scores and 0.90 for the average of three scores administered over a one year period (21).

Paragraph 14:

Statistical analysis: Sex differences in age, height, weight, BMI, physical activity and years from age at peak height velocity were assessed using independent sample *t*-tests at each age. Intra-class, correlation coefficients were used to assess the stability of physical activity over time. Participants were divided into two year groups, based on CA or BA. For inclusion in the analysis, an individual required a measure of physical activity at both time points (e.g., for inclusion in the two year interval from 9-11, a measure of physical activity was required at both 9 and 11 years of age). The correlation assessed the stability of an individual's mean physical activity score between the two time points. A correlation of $<.30$ was interpreted as a low correlation; $.30$ to $.60$ as a moderate correlation; and $>.60$ as a moderately high correlation (24). BA and CA correlations were compared by examining if one point estimate was greater than the

other. The Statistical Package for the Social Sciences (SPSS; version 18.0; SPSS Inc, Chicago, IL) was used to analyze the data. Alpha level of significance was set at $p < 0.05$.

Results

Paragraph 15:

Participants' physical characteristics and physical activity, by chronological and biological age category, are shown in Tables 1 and 2, respectively. As expected when aligned by either chronological or biological age, both males and females gained height and weight with increasing age. BMI also increased with increasing CA and BA. Based on Cole's International cut off points for overweight and obesity, on average, boys and girls had a normal BMI at all chronological ages (9). Physical activity decreased with increasing chronological and biological age. As expected, boys were significantly less mature than girls at each CA group (Table 1). Furthermore, boys were significantly more active than girls at each CA group (with the exception of 9 and 11 years), but these differences disappeared when data was aligned on BA (38).

Paragraph 16:

The longitudinal developmental pattern of physical activity according to both chronological and biological ages is presented in Figure 1. Physical activity reached its peak in late childhood around 10 years of age (Figure 1a) after which physical activity levels decreased with increasing chronological age for both sexes until approximately 15 to 17 years of age. When data were aligned to a biological age scale (i.e., years from APHV) physical activity reached its peak approximately 1 year prior to APHV (Figure 1b) with a subsequent decrease until three to four years past APHV in both sexes.

Paragraph 17:

Tracking coefficients of physical activity for two-year intervals by chronological and biological age are presented in Table 3. All tracking coefficients were significant, with the exception of 9-11 years of age. Moderate to high tracking of physical activity (.39-.62) was observed when participants were aligned by CA and BA. Aligning participants by biological maturation did not improve the point estimate of the tracking coefficient consistently over adolescence. However, the point estimates did improve in early adolescence when aligned by BA in males (.30, $p>0.05$ vs. .46 $p<0.05$) and to a greater extent in females (.23, $p>0.05$ vs. .62, $p<0.05$).

Discussion

Paragraph 18:

The purpose of this study was to examine the stability of physical activity over time from childhood to late adolescence in boys and girls when aligned on chronological and biological ages to see if controlling for differences in biological maturity improves the tracking of physical activity. As previously shown in this sample (38), physical activity decreased with increasing chronological age from late childhood into adolescence with girls being less active than boys when aligned by CA. Physical activity was found to peak in late childhood generally around 10 years of age for both males and females followed by a decline during adolescence. This decrease in physical activity was also evident when analyzed by biological age, with physical activity peaking prior to APHV and then steadily declining into late adolescence. However, the decrease in physical activity reached a subsequent plateau at approximately 15 to 17 years of age or three to four years post APHV. Furthermore, the sex difference in PA disappeared when aligned by biological age. Within this group of individuals, an average decline in PA by CA and BA has

been observed (38); however, this gives no information as to individuals' PA levels in relation to their peers (i.e., are the most active in early adolescence still the most active in late adolescence, regardless of the decline in PA over this period?). Thus, we used intra-class correlations to examine the ranking of participants in terms of PA levels when aligned by CA and BA.

Paragraph 19:

Previous research has demonstrated low to moderate tracking of physical activity from childhood, through adolescence into young adulthood (7,8,16,17,24,26,27,36,40,43), indicating considerable within individual variability and that BA may be more closely related to physical activity than chronological age (13,38). Thus, based on these findings, we hypothesized that physical activity would track better when aligned by biological age than chronological age. Contrary to our hypothesis, when data was aligned to BA, it did not yield tighter, less variable point estimates for tracking than data aligned to CA. In fact, there was no consistent difference in the two-year tracking estimates when aligned on biological and chronological age scales. With the exception of two tracking groups (-3 to -1 years and 15-17 years), boys showed slightly higher point estimates than girls when aligned on both chronological and biological ages. In boys, the tracking of physical activity appeared to improve slightly with increasing age and maturity, with the highest coefficients occurring between 13 and 15 years of age and 0 and 2 years post APHV.

Paragraph 20:

Partial support for the hypotheses was found during early adolescence. Point estimates for tracking were very similar when aligned by CA and BA with the exception of early adolescence when girls' point estimates improved considerably when aligned by BA ($r=.62$) than CA ($r=.23$) and boys' tracking estimates improved, albeit more moderately ($r=.46$ vs. $r=.30$). So,

although aligning physical activity data by biological age did not consistently improve the tracking point estimates as hypothesized, it does appear to improve tracking of physical activity during early adolescence, especially in females. However, it should be noted that the tracking coefficients between 9-11 years were not significant, and thus our confidence in these two coefficients is reduced.

Paragraph 21:

The greater point estimates for tracking of physical activity during early adolescence in females could be a reflection of the early maturing girls dropping out of physical activity when they experience dramatic physical changes, such as an increase in fat deposition, breast development, and widening of the hips (35). These physical changes can influence a girl's performance and also willingness to be physically active (32). A reason why we do not observe the same magnitude of improvement in males' point estimates could be because the physical changes occurring during adolescence in males are less detrimental to physical performance and; therefore, physical activity participation. The physical changes that males experience such as gains in height, weight, weight for height, and lean mass, result in a physique better suited for success in many forms of physical activity, particularly those that emphasize speed, power, and strength (14,30). Although, as shown in this study and numerous others (18,39,42), males display a decrease in physical activity during adolescence it may be that biological maturity plays less of a role in the adolescent decline in physical activity in males.

Paragraph 22:

In the present study the two-year PA tracking coefficients were, in general, moderate to high when aligned on either biological or chronological age. This is in contrast to the majority of previous literature which has found low-to-moderate tracking of PA during adolescence

(1,16,17,22,25,27,28,43). Malina (2001), in a comprehensive review of tracking literature, found that the majority (81%) of inter age correlations fell between .10 and .49. However, caution must be taken when comparing results. In the present study intra-class correlations were considered if they had $p < 0.05$, which indicates that we can be confident in the r value (tracking coefficient), but this was not the case in all studies reviewed by Malina (24). In fact, the two non-significant tracking coefficients observed between 9-11 years were low-to-moderate ($r = .23$ for females and $.30$ for males). The inclusion of non-significant interage correlations in past work could explain some of the discrepancies between the current findings and previous research.

Paragraph 23:

Another possible explanation for the higher tracking coefficients may be related to the manner in which the physical activity data was collected. The PAQ-C and PAQ-A measures were administered a minimum of three times per year for the first three years of the study and two times per each subsequent year during adolescence. The physical activity score may be stronger due to the fact that scores were averaged over each year period to create a single score for each chronological and biological age. The use of multiple sampling may have created a more accurate picture of activity participation. The PAQ-C and PAQ-A are self report questionnaires; therefore, the data may be influenced by the ability of a child, especially at younger ages, to accurately recall activity levels. However, both questionnaires were structured by segmenting the day (before school, at lunch, etc.) and separating weekday and weekend activities which has been found to enhance memory recall in children (3). Additionally, research has found little difference in reliability between younger (9-12) and older (13-15) children (10).

Paragraph 24:

Anderssen et al., (2005) proposed explanations as to why tracking of physical activity during adolescence may be stronger in some samples than others. They suggested that the tracking of physical activity may be related to stable psychological characteristics of the individual (e.g., a psychological readiness for physical activity and a propensity for sports involvement). The current study did not assess psychological characteristics; however, it may be that the individuals in the current study had increased stability in psychological factors which impact physical activity and inactivity. They also proposed that tracking during adolescence improves with stability of living arrangements: living within the same family and neighborhood and relating to the same friends over the years (1). Saskatoon has a relatively stable population; furthermore, the participants in the current cohort were from middle-high socioeconomic status families, which may result in more stable social characteristics. Individuals from the same elementary school also generally attend the same high school, keeping friend groups intact during the transition from childhood to adolescence. The psychological and social profile of the present cohort may help to explain the higher than expected tracking of physical activity.

Paragraph 25:

The physiological (e.g., fat mass, BMI, aerobic capacity) changes that occur with the transition from childhood through adolescence have been well established (35) and the impact of these changes on the tracking of physical activity has been investigated (15,27). Other biological factors (e.g., ethnicity, body fatness, physical fitness), psychological parameters (e.g., type-A behavior, other personality characteristics), adverse lifestyle behaviors (e.g., alcohol consumption, smoking) and motor performance/ability may also influence tracking of physical activity during adolescence and requires investigation (25). There is a need to conduct studies

examining the tracking of physical activity in relation to psychological and social changes that occur during the transition from childhood to late adolescence.

Paragraph 26:

This research suggests that in females in early adolescence controlling for differences in the timing of biological maturity may improve tracking of PA. This piece contributes to a body of research that supports the importance of biological maturity in adolescent PA (38,33,11). It may be that future interventions, especially in girls, are implemented based on BA groupings rather than CA. However, the viability of such programs would need to be investigated. The moderate-to-high tracking observed in the present study also supports the assertion that future adult physical activity might be improved through promoting physical activity in childhood and adolescence. This health promotion strategy would have long term implications as physical activity in adulthood has been found to be related to a lower risk of developing serious illnesses such as CVD, type II diabetes, and some cancers (4,6, 44,12). A strength of this study is the length of follow-up and the number of repeated measures on each participant. Furthermore, because of the timing of the serial measures of height, we were able to measure the timing of APHV in the majority of the individuals enrolled in the study, and thus had an accurate measure of biological maturity.

Paragraph 27:

The present study has some limitations. Physical activity was assessed via a self-report survey (PAQ-A and PAQ-C). Although the questionnaires demonstrate good internal consistency and validity with several other evaluations of activity level (10), it is a self-report assessment and therefore has associated limitations (e.g., inaccurate recalling/reporting of PA). However, the use of the PAQ-C/A allowed for multiple sampling within a time period which may not be possible

with direct measures of physical activity such as accelerometers or direct observation. Age at peak height velocity was estimated from serial measures and used as our measure of biological maturation. Other measures of maturation such as development of secondary sex characteristics, especially in girls, may be important in predicting participation in physical activity. However, age at peak height velocity and skeletal age are the only two measures of biological maturation which are appropriate when comparing males and females biological maturity (31). Skeletal age involves subjecting participants to radiation and was not available in this cohort; therefore, age at peak height velocity was the most appropriate method to assess the effect of biological maturation on the tracking of physical in both males and females. Because of the mixed longitudinal nature of the BMAS study, the individuals in each tracking group differed slightly (because of differing ages of entry into the study and missed measurements). This resulted in an inability to statistically compare the CA and BA tracking coefficients for each 2-year tracking group. A pure longitudinal study that followed the same individuals from late childhood to early adulthood would enable direct comparisons between the different tracking groups. Finally, the data was collected approximately ten years ago. While it is unlikely that the relationship between biological maturity and tracking of physical activity has changed in the preceding ten years, we do not have evidence to support or refute this.

Paragraph 28:

In summary, variation in the timing of biological maturation within youth of the same chronological age might impact participation in PA, and may partially explain the low tracking through adolescence. We examined the stability of PA over time from childhood to late adolescence when aligned on chronological and biological age scales and found moderate to high tracking of physical activity in both males and females aligned by either chronological or

biological age. Accounting for differences in timing of biological maturity had little impact on tracking of PA in males; however, there appears to be higher point estimates for tracking in early adolescence in females when aligned by biological versus chronological age. This suggests that maturity may play a more prominent role in early adolescent PA participation in females.

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Figure Legends

Figure 1. Physical Activity Scores by Chronological and Biological Age Scales.