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Is Boys' Physical Activity in Childhood associated with being Overweight in Mid-Adulthood? A Longitudinal Study Spanning 35 Years

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Abstract

The purpose of this study was to investigate the influence of childhood physical activity (PA) on subsequent adult body mass. Using longitudinal data from the Saskatchewan Growth and Development Study (1964 – 1973), PA, height, body mass and percent body fat were assessed on 207 males (age 7 years at study entry). Subjects were categorized into activity groups based on annual composite activity assessments. 58 participants returned during adulthood (between 39-41 years of age) when similar anthropometric measurements were taken. Childhood PA groupings were significantly related to adult BMI, but not body fat. The more active child had a greater BMI in adulthood ($P<0.05$). The results from this study indicate that the active child, in this sample, is not protected against overweight/obesity in adulthood.

Key Words: Physical activity, peak height velocity, longitudinal, body mass index

Résumé

Le but de cette étude était d'examiner l'influence de l'activité physique (AP)pendant l'enfance sur la masse corporelle à l'âge adulte. À l'aide des données longitudinales de la « Saskatchewan Growth and Development Study » (1964 à 1973), l'AP, la taille, la masse corporelle et le pourcentage de tissu adipeux de 207 garçons âgés de 7 ans au début de l'étude ont été mesurés. Les sujets ont été classés dans des groupes d'activité selon des évaluations d'activité annuelles composées. Des mesures anthropométriques similaires ont été prises sur 58 participants qui sont revenus à l'âge adulte (entre 39 et 41 ans). Les regroupements d'AP pendant l'enfance étaient associés de manière significative à l'indice de masse corporelle (IMC) à l'âge adulte, mais non le tissu adipeux. L'enfant plus actif avait un IMC plus élevé à l'âge adulte ($p<0.05$). Les résultats de cette étude indiquent que, dans cet échantillon, l'enfant actif n'est pas protégé contre l'obésité ou le surpoids à l'âge adulte.

Mots-clés: Activité physique, pic de vitesse de croissance, longitudinale, indice de masse corporelle

Introduction

The obesity "epidemic" is of global proportion affecting both developing and industrial nations including Canada. Health professionals are becoming increasingly concerned with regard to the rise in rates of obesity. It has been suggested that in Canada 31% of adult males and 35% of adult females are obese (Katzmarzyk, Hebebrand, & Bouchard, 2002). Low levels of physical activity (PA) and high prevalence's of inactivity and sedentary behavior are widely assumed to be causally linked to obesity, and underlie public health messages globally. The benefit of a physically active lifestyle for the physical and psychological health of individuals is becoming increasingly emphasized. Regular PA contributes to efficient functioning of various body systems, weight maintenance, reduced risk of several degenerative diseases, reduced risk of mortality, and overall improvement in quality of life (Malina, 2001). Although, the Canadian Fitness Survey reveals that PA levels in Canada have shown positive trends since the 1980's, 62% of Canadians are still not active enough to reap the health benefits of a physically active lifestyle (Craig, Russell, Cameron, & Beaulieu, 1999; Craig, Russell, Cameron, & Bauman, 2004). Obesity risk

factors, such as physical inactivity, occurring in adult life provide an insufficient explanation for adult health outcomes; therefore factors occurring at different stages in life need to be considered. Physical activity may be one of several childhood factors involved in the development of adult obesity. Previous longitudinal follow-up studies have given inconsistent results regarding the association between childhood/adolescent PA and adult body composition (Parsons, Power, Logan, & Summerbell, 1999; Parsons et al., 1999; Twisk, Van Mechelen, Kemper, & Post, 1997; van Lenthe, Van Mechelen, Kemper, & Post, 1998; Kemper, Post, Twisk, & Van Mechelen, 1999; Lefevre et al., 2002; Hasselstrom, Hansen, Froberg, & Andersen, 2002; Twisk, Kemper, & Van Mechelen, 2002; Baranowski et al., 1992; Moussa, Skaik, Selwanes, Yaghy, & Bin-Othman, 1994). The aim of this paper is to investigate the relationship between adolescent PA and adult body composition.

Methods

Participants

Participants were part of the initial Saskatchewan Growth and Development Study (1964 to 1973) and the Saskatchewan Growth and Development Follow-up Study (1996 to 1998). The study has been described in detail elsewhere (Mirwald, 1978; Thompson, Baxter-Jones, Mirwald, & Bailey, 2002). In brief, in 1964 207 seven year old boys were randomly selected in to the study and were continuously assessed annually until 1973, when 16 years of age. Fifty eight, of the 207 returned for a one time measurement (1998-99) when they were between 39 and 41 years of age. The study received approval from the University and Hospital Advisory Committee on Ethics in Human Experimentation.

Anthropometric Assessment

Anthropometric dimensions were assessed on an annual basis using the same standard procedures (Ross & Marfell-Jones, 1990). Stretched height was measured to the 0.1 cm and body mass to the nearest 0.1 kg. Two measurements were taken; a third measurement was taken if the first two differed by more than 0.4 cm for height or 0.4 kg for body mass. If two measurements were taken the values were averaged, if three were taken the median value was used. Body mass index (BMI) was calculated from height and body mass (wt/ht^2). At each testing point through childhood and adolescence the calculated BMI was compared against Cole's age and gender specific BMI cut-offs (Cole, Bellizzi, Flegal, & Dietz, 2000). Participants were classified in adulthood as normal

weight (BMI < 25 kg/m^2), overweight (BMI > 25 kg/m^2 and <30 kg/m^2) or obese (BMI > 30 kg/m^2) (CDC, 2000).

Chronological age

Chronological age (year) was determined precisely to decimal age. Decimal age was calculated by subtracting date of birth from the measurement date. Chronological age groups were constructed using 1-year intervals, such that the 9 year old age group included individuals between 8.50 and 9.49 years of age.

Biological age

Variability between individuals of the same chronological age in somatic and biological maturity is large and this variability is accentuated around the adolescent growth spurt (i.e. peak height velocity); thus, maturity assessment is an important consideration when investigating this age period. A common maturity assessment technique in longitudinal studies is the determination of peak height velocity (PHV) (Malina, 1978). Peak height velocity is an indicator of somatic maturity and reflects the maximum growth rate in stature during adolescence. Peak height velocity was calculated by fitting a growth curve to whole year height velocities using a cubic spline procedure (GraphPad Prism version 3.00 for Windows, GraphPad Software, San Diego California USA)(Bailey, 1997). A more detailed discussion of the cubic spline procedure has been published elsewhere (Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999).

A biological age was calculated by subtracting the chronological age at time of measurement from the chronological age at PHV (i.e. APHV). Thus, a continuous measure of biological age was generated. Biological age groups were constructed using 1-year intervals such that the -1 year from PHV age group included observations between -2.49 and -1.50 years from PHV.

Child Body Fat Assessment

Skinfold thickness was measured annually at six sites (iliac crest, abdominal, front thigh, chest, triceps and subscapular) using Harpenden skinfold calipers and recorded to the nearest 0.1cm. Body density was estimated using the age-, and gender-specific equations generated by Parizkova (Parizkova, 1961). The following equations were used:

Boys aged 8-12 years:

$$\text{Body density} = -0.027(\log^{10}\text{TRICEPS})-0.0388(\log^{10}\text{SUB-SCAPULAR})+1.108 \quad \text{(Eq. 1)}$$

Boys aged 13-16 years:

$$\text{Body density} = -0.055(\log^{10}\text{TRICEPS})-0.026(\log^{10}\text{SUB-SCAPULAR})+1.130 \quad \text{(Eq. 2)}$$

Percentage fat was estimated using a formula established by Brozek, Grande, Andersen and Keys (1963). The formula utilizes body density values from equations 1 and 2, and is as follows.

$$\text{Percent Fat} = (4.570/\text{body density})-4.14 \quad \text{(Eq. 3)}$$

Adult Body Fat

Total body fat and total body percent fat of the males in adulthood was assessed using Dual Energy X-ray Absorptiometry (DXA) (Hologic 2000, Hologic, Inc., MA, USA) in the array mode, using global software version 7.10. To minimize operator-related variability, all scans were analyzed by the same qualified individual. Standard procedures and positioning were adopted and strictly followed to maximize consistency. Participants removed all metal objects (jewellery, glasses etc.), shoes, and wore loose fitting shorts and t-shirt during the scanning procedure.

Physical Activity

The PA assessment procedures have been described in detail elsewhere (Thompson, Humbert, & Mirwald, 2003). In brief, at the beginning of the study the boys filled out a PA questionnaire (PAQ) once a year until 1970. Between 1970 and 1973 the children annually filled out a Sports Inventory Questionnaire. In addition to these self report questionnaires the teachers were asked to rate the children's PA levels relative to their peers in 1971 and then again retrospectively in 1973. A composite score (based on the two surveys and two teacher ratings of PA) of childhood PA was given for each child. Each participant was classified into one of three activity groups (low active, moderately active, highly active) following each year of testing. Combining the annual classifications generated an overall PA classification for the childhood/adolescent years. The boys who

scored in the bottom 25% of the group were classified as low active, the boys in the middle 50% were classified as moderately active and in the top 25%, as highly active.

Statistical Analysis

Descriptive statistics, means and standard deviations were calculated. One-way analysis of variance test was used to investigate if there was a relationship between childhood PA groupings and body composition. Tukeys post hoc test was used identify between group differences. The alpha level of significance was set at 0.05. SPSS (version 11.5) statistical package was used to analyze the data.

Results

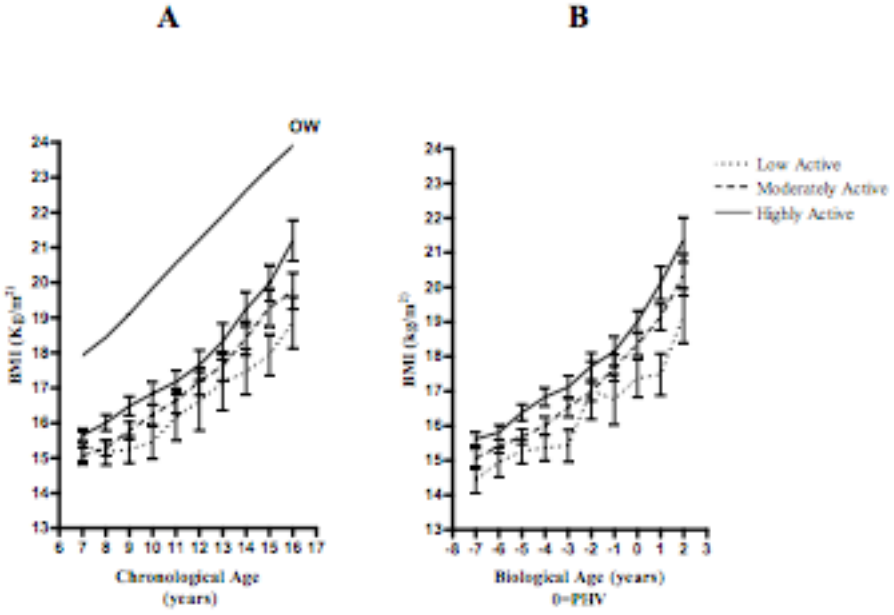
Childhood Results

Figure 1 demonstrates the average childhood developmental patterns of BMI for each of the PA groupings; highly active, moderately active and low active, aligned to chronological age and biological age. Body mass index increased in all PA groupings; from age 7 to 16 years (figure 1A) and from 7 years prior to PHV to 2 years post PHV (figure 1B). There were no differences in the average BMI for the three PA groups at any chronological or biological age ($P>0.05$). All PA groups has significantly lower BMI than the age-specific cut off for overweight (OW)(Cole et al., 2000) and thus would be considered normal weight for their age.

Figure 2 demonstrates the average development of percent fat for each of the PA groupings, aligned to chronological age and biological age. Percent body fat shows similar development in the three PA groupings. Percent fat increases between 7 years and 12 years of age, and then decreases between 12 and 16 years of age (figure 2A). Likewise, percent fat increases between -7 years and -2 years prior to PHV, and decreases from -2 years prior to PHV to 2 years post PHV (figure 2B). There were no differences in the average percent fat in the three PA groups at any chronological or biological age ($P>0.05$).

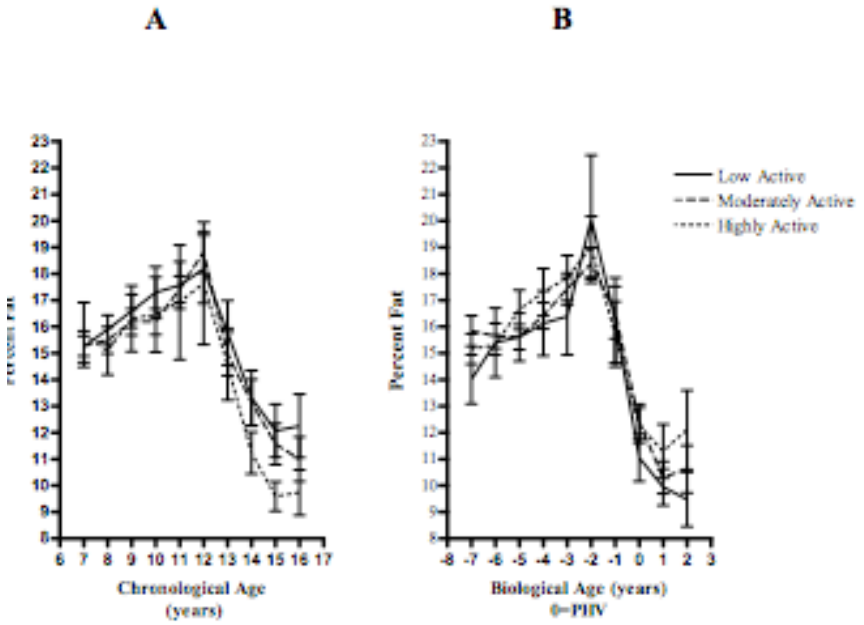
At PHV, 55 (95%) of the boys were classified as normal weight, 3 (5%) were classified as overweight and 0 (0%) were classified as obese, using age specific cut-offs (Cole et al., 2000). Of the boys who were overweight (n=3), 1 was in the low active group and 2 were in the moderately active group. Of the boys

Figure 1
Average Development of Childhood BMI of Boys from the Saskatchewan Growth and Development Study for Three Physical Activity Groups by Chronological and Biological Age



Note: Overweight (OW) = age specific cut off points for body mass index (BMI) of 25 kg/m^2 (Cole, et al., 2000).

Figure 2
Average Development of Childhood of Boys from the Saskatchewan Growth and Development Study for Three Physical Activity Groups showing Percent Fat by Chronological and Biological Age



who were normal weight (n=55) 13 were classified as low active, 23 as moderately active and 19 as highly active. To control for childhood BMI only the individuals who were classified as normal weight at childhood were retained for the remaining analyses.

Table 1 shows the age, height, body mass, percent fat and BMI at PHV for each of the activity groups. There were no significant differences in age, height or percent fat between the activity groups ($P>0.05$). The highly active boys were heavier than the moderately active and the low active boys ($F(2,52)=3.59$, $P<0.05$). The highly active boys also had a greater BMI than the low active boys ($F(2,52)=3.81$, $P<0.05$).

Table 1
The Age, Height, Body Mass, Percent Fat and BMI at Peak Height Velocity (PHV) of the Normal Weight Children grouped by Childhood Physical Activity

Variable	Low Active	Moderately Active	Highly Active
N	13	23	19
Age (years)	13.92 (1.35)	14.10 (0.93)	14.03 (1.12)
Height (cm)	158.131 (6.86)	164.08 (5.72	161.46 (10.24)
Body Mass (kg)	43.70 (7.75	49.60 (5.84)	49.85 (7.95)[a]
Percent Fat	11.05 (3.22)	12.60 (3.19)	12.30 (3.16)
BMI (kg/m^2)	17.37 (1.98)	18.39 (1.61)	19.02 (1.48)[b]

[a]Significantly (P<0.05) greater than both the low active and the moderately active group.
[b]Significantly (P<0.05) greater than the low active group.

Adulthood Results

At adulthood, 21 (38%) of the men were classified as normal weight, 27 (49%) were classified as overweight and 7 (13%) were classified as obese. Out of the low active group, 8 (61.5%) were normal weight, 4 (30.8%) were overweight and 1 (7.7%) was obese as an adult. Out of the moderately active group, 11 (47.8%) were normal weight, 10 (43.5%) were overweight and 2 (8.7%) were obese as adults. Out of the highly active group, 2 (10.5%) were normal weight

(21%), 13 (68.4%) were overweight and 4 (21.1%) were obese as adults. Table 2 shows the adult age, height, body mass, absolute body fat, percent body fat and BMI of the males in each of the activity groups. There were no significant differences in age, height, body mass, absolute body fat or percent body fat between the activity groups ($P>0.05$). However, the males who were highly active as children had a significantly higher BMI than the males who were low active as children ($F(2,52)=3.20$, $P<0.05$).

Table 2
The Age, Height, Body Mass, Percent Fat and BMI at Adulthood of the Males who were categorized as Normal Weight Children grouped by Childhood Physical Activity

Variable	Low Active	Moderately Active	Highly Active
N	13	23	19
Age (years)	40.36 (0.76)	40.12 (0.48)	40.22 (0.46)
Height (cm)	177.01 (6.94)	180.01 (5.00)	176.56 (9.55)
Body Mass (kg)	77.63 (14.00)	83.69 (13.68)	87.67 (16.79)
Absolute Fat (g)	18163.52 (10048.98)	20639.57 (99501.32)	21818.16 (107464.63)
Percent Fat	22.51 (8.59)	24.15 (7.05)	24.12 (8.36)
BMI (kg/m^2)	24.69 (3.56)	25.80 (3.81)	28.00 (3.98)[a]

Means (SD)
[a]Significantly ($P<0.05$) greater than the low active group.

Discussion

The purpose of this study was to investigate the relationship between PA during adolescence and body composition in mid-adulthood (39-41 years of age). In this sample childhood PA did not appear to protect against adult overweight/obesity. In fact, the active boys had a significantly greater BMI than the inactive boys. However, PA as a child did not directly relate to adult body fat, as there was no significant difference in DXA assessed adult body fat (absolute and percent) among childhood PA groupings. The lack of an inverse association between the adolescent PA and adult obesity is consistent with some earlier findings, which defined adult obesity using BMI (Kemper et al., 1999),

by measures of abdominal obesity (Twisk et al., 1997; Hasselstrom et al., 2002; Twisk et al., 2002) or by skinfold thickness (Twisk et al., 1997; Baranowski et al., 1992; Moussa et al., 1994).

Some past research has suggested that the change in PA during adulthood is more predictive of adult body composition than adolescent PA (Tammelin, Laitinen, & Nayha, 2004; Hasselstrom et al., 2002; Haapanen, Miilunpalo, Vuori, Oja, & Pasanen, 1997). The research has shown that becoming inactive in adulthood is more harmful than being persistently inactive from adolescence into adulthood. One explanation for this may be that it is difficult to adjust energy intake from food to account for decreased levels of PA, which in the long term may lead to an increase in weight (Tammelin et al., 2004). This could explain why in the present study childhood PA was positively associated with adult BMI. To shed light on this issue longitudinal observations are needed on males spanning child, adolescent and adult years; at present there is paucity of such studies.

Outside of the discussion of PA the prevalence of adult obesity, observed in this sample, are quite startling. In this sample of children born in 1957 at PHV (approximately 14 years of age) only three out of the 58 were considered overweight, none were considered obese. Furthermore, between 7 and 16 years of age the boys' average BMI was well below the cut-off values for overweight. However, when the males returned as adults (39-41 years of age) a large percentage (61.8%) were overweight or obese. Previously, a comparison was made between the sum of skinfolds of the present Saskatchewan birth cohort and a sample of boys residing in the same location but born 30 years later (Thompson, Baxter-Jones, Mirwald, & Bailey, 2002). The study showed that males born in 1957 (the present sample) had significantly lower percent body fat than boys of the same age born between 1976 and 1978. Considering the large number of normal weight boys who became overweight/obese adults in this sample, this suggests a possibly large prevalence of overweight adults in the future.

General Comment

One of the advantages of this study is its longitudinal design. All the data gathered over the adolescent period were measured at that time and not retrospectively reported in adulthood. Furthermore, the serial measures of height during childhood allowed for the assessment, and thus consideration, of physical somatic maturity in the analysis. However, the longitudinal design is also one of the disadvantages because the number of subjects is limited (n=55). Although the children who participated in this study were considered representative of the

Canadian population for height and body mass, the sample was limited to those of Caucasian descent. No measure of socioeconomic status was available thus it was impossible to control for possible socioeconomic confounders.

Conclusions

The purpose of this paper was to analyze the relationship between PA during adolescence and body composition in mid-adulthood. In conclusion, PA during childhood was not related to body fatness and was positively related to BMI at an adult age (39-41 years). The findings suggest that being physically active during adolescence does not protect against overweight/obesity at an adult age. Thus, promotion of PA in the adolescent period may not be sufficient in the prevention of obesity in adults.

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