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# Prospective Associations Between Physical Activity Level and Body Composition in Adolescence: 1993 Pelotas (Brazil) Birth Cohort

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***Background*:** Physical activity may influence both fat and lean body mass. This study investigated the association between physical activity in children between the ages of 11 and 13 years and both fat and lean mass. ***Methods*:** A subsample of the 1993 Pelotas (Brazil) Birth Cohort was visited in 2004–2005 and 2006–2007. Physical activity was estimated through standardized questionnaires. Body composition (ie, fat and lean mass) was measured using deuterium dilution. Those with moderate-to-vigorous activity greater than 420 min/wk were classified as active, and physical activity trajectory was defined as being above or below the cutoff at each visit. ***Results*:** Four hundred eighty-eight adolescents (51.8% boys) were evaluated. The mean difference in fat mass in boys and girls who reported ≥ 420 min/wk of physical activity in both visits compared with those who were consistently inactive was –4.8 kg ($P \leq .001$). There was an inverse association between physical activity and fat mass among boys in both crude and confounder-adjusted analyses, whereas for girls, the association was evident only in the crude analysis. There was no significant association between physical activity and lean mass. ***Conclusion*:** Physical activity may contribute to tackling the growing epidemic of adolescent obesity in low- and middle-income countries.

***Keywords*:** motor activity, lean body mass, fat mass, epidemiology

Physical activity is inversely associated with the risk of several noncommunicable diseases, such as coronary heart disease, colon and breast cancer, type 2 diabetes, and osteoporosis, and is positively associated with life expectancy.[1] Likewise, there is evidence that physical activity may improve mental health and cognitive function in children and adolescents.[2–5]

Low levels of physical activity, along with inadequate diet, are usually considered the main causes of such a rise. However, many prospective studies have not been able to show a clear positive effect of physical activity on obesity.[6] This lack of association might be explained by methodological limitations related to study design or choice of outcomes. Reverse causation is also likely to occur; physical inactivity may lead to an accumulation of body fat, but the current level of adiposity can also be a determinant for physical inactivity.[7] For this reason, cross-sectional studies are not appropriate to investigate the association between physical activity and body composition. Likewise, the frequently used body mass index does not distinguish between fat and lean mass, and physical activity has been shown to have opposite effects on these tissues.[8–10] Therefore, body mass index fails to pinpoint the exact association between physical activity and obesity.

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The effects of physical activity on body composition are even more challenging to determine in adolescence, because this period of life is characterized by unique aspects of physical development that also influence body composition. There is debate in the literature on current recommendations for physical activity among adolescents[6]and whether the evidence is strong enough to support such a specific amount of physical activity as being effective for preventing body fat accumulation or promoting lean mass gain.[11]

The 1993 Pelotas (Brazil) Birth Cohort represents an excellent opportunity to investigate the association between physical activity and body composition. First, the Brazilian population is undergoing a rapid nutritional transition, which has already taken place in many richer countries. Second, its cohort design allows prospective investigation of the issue. Finally, the methods used in the cohort include a highly reliable measure of both fat and lean mass in adolescents through the deuterium dilution technique. The objective of this study was to investigate the trajectory of physical activity from in children from 11 to 13 years old and its association with fat and lean body mass in those children at 13 years old.

## Methods

In 1993, a birth cohort study was started in Pelotas, a southern Brazilian city. Detailed description on the recruitment of the cohort members, follow-up visits, and variables collected is available elsewhere.[12] All the newborns conceived in the hospitals of the city were eligible to participate in the study. The cohort consisted of more than 5000 children, and subsamples were followed up at the ages of 1, 3, and 6 months, and 1 and 4 years. In 2004–2005 (average age of the cohort, 11.3 years), all cohort members were sought, and 87.5% (n = 4452) were located. Two years later (2006–2007;

average age of the cohort, 12.9 years), all 568 cohort members who had been visited in every one of the previous visits were sought. Of these, 488 were located and were included in the current analyses.

## Exposure: Physical Activity Trajectory

Physical activity practice was investigated through a standardized and previously tested questionnaire.[13] This instrument has been shown to be valid and reliable. Its reliability was good ($\rho = 0.62$; $P < .001$), and 73% of the individuals were consistently classified in a 7-day test-retest interview ($\kappa$ statistics = .58).[13] In terms of concurrent validity, the Spearman correlation coefficient between the questionnaire and total energy expenditure measured by double-labeled water was .41 ($P = .04$)[14]; that between the questionnaire and number of steps (measured by pedometers) was .26 ($P = .02$).[13] The questionnaire gathered data on sports practice and active commuting to and from school in both visits (2004–2005 and 2006–2007) and leisure-time physical activity practice (minutes per week) was calculated multiplying the duration of the activity by its weekly frequency. This score was further dichotomized at 420 min/wk because this is the minimum recommended amount of physical activity for adolescents.[15] Finally, the trajectory of physical activity from ages 11 to 13 years was determined, with 4 categories: (1) < 420 min/wk in both follow-ups (persistently inactive); (2) ≥420 min/wk in both follow-ups (persistently active); (3) <420 min/wk in 2004–2005 but ≥420 min/wk in 2006–2007 (upward trend); and (4) ≥420 min/wk in 2004–2005 but <420 min/wk in 2006–2007 (downward trend).

## Outcomes: Lean and Fat Mass

Lean and fat body mass were measured in 2006–2007 using the deuterium dilution technique. This approach involves the measurement of total body water using deuterium oxide dilution, a method for quantifying the volume of body water by administering a known mass of stable isotope tracer. A detailed description of the measurement procedure is available elsewhere.[16] In brief, children ingested a fixed dose (2.2 g) of deuterium diluted in water, and saliva samples were taken before and 4 to 5 hours after dose administration. Isotope enrichment of the dose solution and saliva samples was determined in duplicate by isotope-ratio mass spectrometry (Delta XP; Thermo-Fisher Scientific, Waltham, MA) at UCL Institute of Child Health, London, UK. Precision of total body water is 1% in this laboratory. Lean mass (kilograms) was calculated from total body water using sex- and age-specific equations for the water content (hydration) of lean tissue.[17] Fat mass (kilograms) was calculated by subtracting lean mass from total mass. Both lean mass and fat mass were further adjusted for height squared (meters). This adjustment was necessary to take into account differences in body size.[18]

## Confounding Variables

Socioeconomic position was measured through an asset index on the basis of household possessions and other characteristics, according to the methodology used by the Brazilian Criterion.[19] Tanner's stage of maturation was used to determine pubertal status using self-report. Consumption of fat and fiber was investigated through the Block Diet Questionnaire,[20] and the continuous score generated for fat and fiber was analyzed.

## Data Collection

All data were collected by interviewers who underwent extensive training in administering the questionnaire, taking anthropometric measurements, and applying the deuterium dilution techniques. Data were collected at the participants' homes, except for the postdose saliva sample, which on some occasions had to be collected in their schools or elsewhere, depending on where the subjects were at the time when collection had to take place.[16]

## Data Analysis

All analyses were stratified by sex. One-way analysis of variance was used to estimate the magnitude of differences in crude analyses of lean and fat mass (kilograms) according to the physical activity trajectories. Unadjusted and adjusted linear regressions were uses to study the effects of physical activity trajectory on both lean and fat mass adjusted for height squared (kilograms per square meter). In the adjusted analyses, socioeconomic position, pubertal status, and fat and fiber intake were included in the model. All assumptions regarding the use of linear regression were checked. Analyses were carried out in Stata (version 12.0; StataCorp, College Station, TX).

## Ethical Aspects

Written consent of the participants' parents and verbal consent from the participants were gathered before data collection. The Ethical Committee of the Faculty of Medicine of the Federal University of Pelotas approved the study protocol.

# Results

A total of 488 adolescents (51.8% boys) were evaluated. Table 1 compares the subsample studied with the whole cohort in terms of sex and socioeconomic position. Distribution of these variables in the subsample was similar to that in the whole cohort. Regarding the physical activity trajectory from 11.3 to 12.9 years old, 49.6% (n = 242) were persistently inactive, whereas 10.9% (n = 53) were persistently active. A total of 107 individuals (21.9%) were inactive only in 2004 and 86 (17.6%) were inactive only in 2006.

Figures 1 and 2 show the unadjusted associations between lean and fat mass in boys and girls, respectively. In the sex-stratified analyses, which had been defined a priori, the mean differences in fat mass between persistently inactive and persistently active subjects were +4.3 kg ($P = .02$) for boys and +2.6 kg ($P = .05$) for girls. When both sexes were combined, the difference was +4.8 kg ($P < .001$) (data not shown in the Figures). The mean differences in lean mass across the physical activity categories were smaller, with $P$ levels of .62 for boys and .39 for girls.

Table 2 shows unadjusted and adjusted association between lean mass adjusted for height$^2$ for boys and girls. None of the associations were significant. Table 3 shows unadjusted and adjusted association between fat mass adjusted for height$^2$ for boys and girls. Among boys, those persistently inactive had on average higher fat mass at both unadjusted and adjusted analyses ($P = .02$ and $P = .01$, respectively) than those persistently active. In girls, those who practiced < 420 min/wk of physical activity only at 13 years old (downward trend) had higher coefficients compared with the other

**Table 1 Description of the Sample: 1993 Pelotas (Brazil) Birth Cohort**

| | Whole cohort | | | Subsample | | |
|---|---|---|---|---|---|---|
| **Variable** | **Whole sample (N = 4452)** | **Boys** | **Girls** | **Whole sample (n = 488)** | **Boys** | **Girls** |
| Sex | | | | | | |
| Boys | 2192 (49.2%) | | | 253 (51.8%) | | |
| Girls | 2260 (50.8%) | | | 235 (48.2%) | | |
| Socioeconomic position[a] | | | | | | |
| A (highest) | 164 (3.7%) | 87 (4.0%) | 77 (3.5%) | 16 (3.3%) | 9 (3.6%) | 7 (3.0%) |
| B | 697 (15.8%) | 365 (16.9%) | 332 (14.9%) | 93 (19.1%) | 55 (21.7%) | 38 (16.3%) |
| C | 1511 (34.3%) | 720 (33.2%) | 791 (35.4%) | 168 (34.6%) | 82 (32.4%) | 86 (36.9%) |
| D | 1720 (39.1%) | 837 (38.6%) | 883 (39.5%) | 179 (36.8%) | 95 (37.6%) | 84 (36.1%) |
| E | 309 (7.0%) | 157 (7.3%) | 152 (6.8%) | 30 (6.2%) | 12 (4.7%) | 18 (7.7%) |

[a] As measured in the 2004–05 follow up.

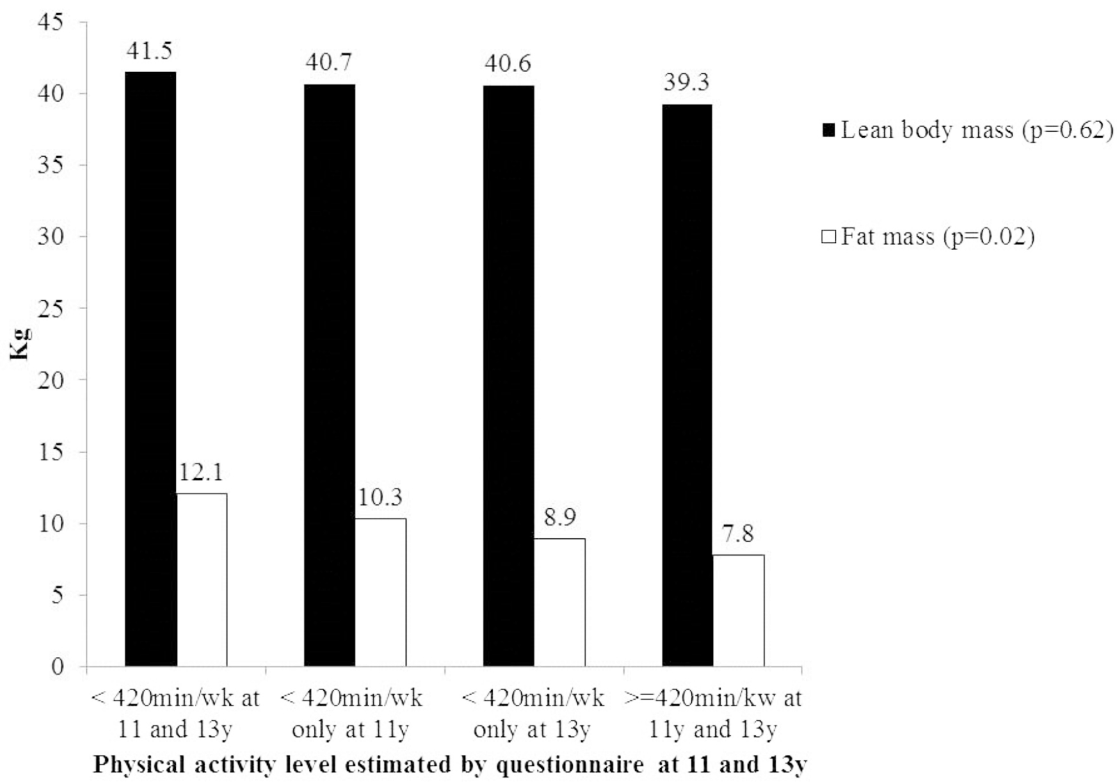


**Figure 1** — Association between trajectory of physical activity from age 11 to 13 years and body composition at age of 13 years in boys.

groups, with *P*-values of .03 and .05 for crude and adjusted analyses, respectively. The interaction term for sex and physical activity had a *P*-value of .01.

## Discussion

Although physical activity is widely recommended to prevent and treat adolescent obesity, few studies have addressed this issue prospectively. General limitations of this field include studies with small and nonrepresentative samples as well as inaccurate measurements of body composition. For example, several studies have used body mass index as an outcome because of its accessibility. However, body mass index does not discriminate fat from lean body mass, an important distinction because physical activity has contrasting effects on these tissues.[10]

In the current longitudinal analyses, those who were persistently inactive from 11 to 13 years old had higher levels of adiposity, particularly in boys. Boys and girls who were persistently inactive had, on average, more than 4 kg excess fat at 13 years compared with those who were persistently active. In boys, this pattern remained even after we adjusted for socioeconomic level, diet, and pubertal status. The apparently weaker effect in girls compared with boys

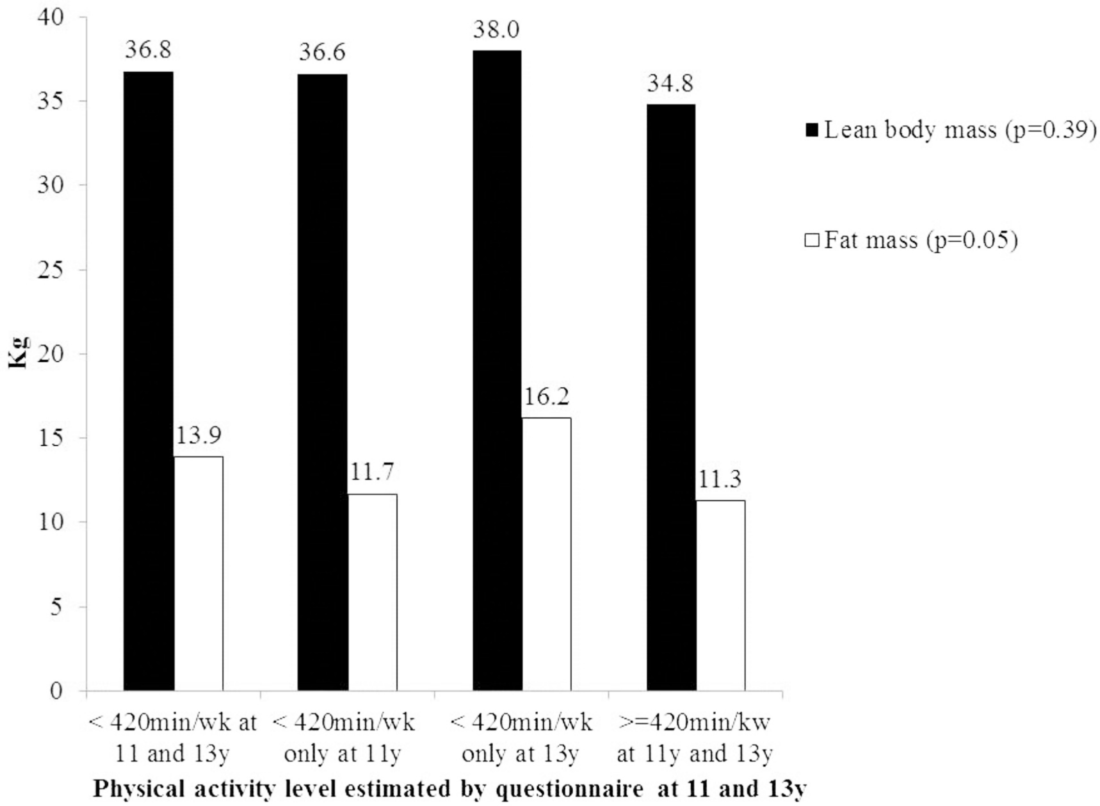


**Figure 2** — Association between tracking of physical activity from age 11 to 13 years and body composition at age of 13 years in girls.

**Table 2 Crude and Adjusted Linear Regression Between Physical Activity Trajectory and Lean Body Mass Adjusted for Height²**

| | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Crude analysis | | Adjusted analysis[a] | | Crude analysis | | Adjusted analysis[a] | |
| | β (95% CI) | P | β (95% CI) | P | β (95% CI) | P | β (95% CI) | P |
| Physical activity trajectory | | .86 | | .69 | | .36 | | .36 |
| ≥ 420 min/wk at 11 yr and 13 yr | Reference group | | Reference group | | Reference group | | Reference group | |
| < 420 min/wk only at 11 yr | 0.29 (–0.52 to 1.10) | | 0.21 (–0.60 to 1.03) | | 0.26 (–1.16 to 1.68) | | 0.19 (–1.22 to 1.60) | |
| < 420 min/wk only at 13 yr | 0.26 (–0.61 to 1.12) | | 0.18 (–0.68 to 1.04) | | 0.88 (–0.51 to 2.28) | | 0.73 (–0.66 to 2.11) | |
| < 420 min/wk at 11 yr and 13 yr | 0.33 (–0.45 to 1.11) | | 0.45 (–0.33 to 1.23) | | 0.35 (–0.95 to 1.65) | | 0.13 (–1.16 to 1.42) | |

[a] Adjusted for family economic level, fat and fiber intake, and pubertal status.

may be explained by the fact that body fat is inherently higher in females during adolescence because of its role in providing energy for reproduction.[21] Thus, the drive to accumulate fat may be stronger in girls during the pubertal period and hence more resistant to the effects of physical activity. Furthermore, the interaction term between sex and physical activity reached a *P* level of .01, supporting the choice to carry out sex-stratified analyses.

These findings highlight the role of physical activity in the development of adolescent obesity. Several experimental studies, usually with smaller sample sizes, have demonstrated the efficacy of physical activity to prevent or treat excessive body fat.[22,23] However, fewer observational studies have described the association of physical activity practice with body composition measures of adolescents.[6] This is important because the findings from experimental studies might not be replicated under real life conditions where several other factors are uncontrolled and might interact with physical activity to determine fat and lean body mass accumulation/losses.

The effects of physical activity on lean body mass are less explored than those on body fat. In general, physical activity, particularly strength, weight-bearing and high-impact activities, are recommended to increase lean body mass and improve bone health.[24–26]

**Table 3 Crude and Adjusted Linear Regression Between Physical Activity Trajectory and Fat Mass Adjusted for Height²**

| | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| | Crude analysis | | Adjusted analysis[a] | | Crude analysis | | Adjusted analysis[a] | |
| | β (95% CI) | *P* | β (95% CI) | *P* | β (95% CI) | *P* | β (95% CI) | *P* |
| Physical activity trajectory | | .02 | | .001 | | .003 | | .005 |
| ≥ 420 min/wk at 11 yr and 13 yr | Reference group | | Reference group | | Reference group | | Reference group | |
| < 420 min/wk only at 11 yr | 0.93 (–0.22 to 2.08) | | 0.90 (–0.24 to 2.04) | | 0.05 (–2.13 to 2.24) | | 0.05 (–2.05 to 2.15) | |
| < 420 min/wk only at 13 yr | 0.35 (–0.88 to 1.58) | | 0.43 (–0.77 to 1.64) | | 1.96 (–0.18 to 4.11) | | 1.75 (–0.32 to 3.81) | |
| < 420 min/wk at 11 yr and 13 yr | **1.58 (0.47 to 2.69)** | | **1.64 (0.56 to 2.73)** | | 0.95 (–1.05 to 2.95) | | 0.66 (–1.27 to 2.58) | |

[a] Adjusted for family economic level, fat and fiber intake, and pubertal status.

*Note.* Bold indicates significantly different from reference group.

Some reviews have reported lower risk of bone related diseases such as osteoporosis in physically active adolescents compared with those who are inactive.[27] We did not detect any association between achieving 420 min/wk of moderate to vigorous physical activity and lean body mass. Previous studies indicated that soccer (among boys) and volleyball (among girls) are the most frequent activities practiced by this population, but gymnastics and strength exercises in fitness centers are rapidly increasing in recent years.[28]

One explanation for the lack of association between physical activity and lean mass is that adolescence incorporates pubertal growth spurts, which may occur at different ages for different people. Substantial variability in lean mass associated with pubertal development would be expected to dilute any association between lean mass and physical activity. Therefore, we remain cautious regarding the lack of an association of lean mass and physical activity. However, the pubertal development is less important for fat mass because fat is a more plastic tissue and would be expected to be more sensitive to physical activity practice.

Further studies are recommended to investigate the effects of specific activities on both fat and lean body mass separately, because it is plausible that different types of physical activity may have distinct effects on body composition. Studies with experimental designs, carried out in controlled settings and with small sample sizes are available but whether their findings are replicable under real-life conditions remains to be verified.

Some positive aspects of the current study should be highlighted. The study had a prospective design and enrolled a large population-based sample. The instruments used to estimated physical activity and body composition have shown to be valid and reliable.[13,29] In addition, several potential confounders were assessed through experienced interviewers. Furthermore, the study was undertaken within a prospective birth cohort study from Brazil, a middle-income country undergoing a rapid nutritional and economic transition in which few such studies are available.

Some limitations of our study should be noted. Ideally, the prospective association between body composition and physical activity should be adjusted for baseline body composition. However, we have no such data available in the cohort. Another aspect to be stressed regards the instrument used to evaluate physical activity. Objective measurements of physical activity, such as accelerometry, have shown stronger associations with health outcomes when they are compared with self-reported measures.[30] Therefore, we speculate that the nonsignificant association between physical activity level and lean mass might be at least partially explained by the instrument used in the current study.

In conclusion, our data suggest that there may be an effect of physical activity practice on body fat in boys but not girls. Those who consistently achieved the recommended amount of physical activity of at least 420 min/wk of moderate to vigorous physical activity at 11.3 and 12.9 years had lower levels of fatness compared with those with lower levels of physical activity, particularly among boys. An association between physical activity and lean body mass was not evident. Physical activity may contribute to tackling the growing epidemic of obesity in low to middle income countries.

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