Physical activity but not energy expenditure is reduced in obese adolescents: a case-control study[1–3]

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ABSTRACT

Background: The influence of physical activity on body weight in children and adolescents is controversial.

Objective: The objective was to test the hypothesis that the intensity and duration of physical activity differ between obese and normal-weight adolescents, with no difference in estimated energy expenditure.

Design: We compared physical activity in 18 (8 males, 10 females) obese [body mass index (in kg/m^2) > 30] adolescents (14–19 y) with that in a matched, normal-weight (BMI < 27) control group. Total energy expenditure (TEE) was measured with the doubly labeled water method, and physical activity was measured simultaneously by accelerometry. The physical activity level was determined as the ratio of TEE to the resting metabolic rate (RMR) and activity energy expenditure as 0.9 TEE minus RMR. Accelerometry data included total physical activity (counts · min^{-1} · d^{-1}), accumulated and continuous duration of activity, and continuous 10-min periods of physical activity of moderate intensity.

Results: There was no significant difference in adjusted (analysis of covariance) TEE, RMR, or AEE between groups. The physical activity level was significantly lower ($P < 0.05$) in the obese group. No sex × group interaction was observed. Differences in total physical activity ($P < 0.001$), accumulated time ($P < 0.05$), continuous time ($P < 0.01$), and continuous 10-min periods of physical activity of moderate intensity ($P < 0.01$) were observed between groups.

Conclusions: Obese adolescents are less physically active than are normal-weight adolescents, but physical activity–related energy expenditure is not significantly different between groups. The data suggest that physical activity is not necessarily equivalent to the energy costs of activity. *Am J Clin Nutr* 2002;76:935–41.

KEY WORDS Activity monitor, adolescents, doubly labeled water, energy expenditure, obesity, physical activity, case-control study

INTRODUCTION

The influence of physical activity on body weight in children and adolescents is controversial. There is evidence suggesting that overweight and obese children and adolescents are less active than are their normal-weight peers (1–5). However, the aspects of physical activity that may have a protective effect against obesity have not been clearly defined. Some studies (1, 3) have suggested a relation between sedentary behavior (eg, television viewing) and obesity, whereas others have indicated that the total amount of physical activity (2) or the length of time spent at physical activity of vigorous intensity (4, 5) may be the key factors. Conversely, other authors have concluded that there are no differences in resting metabolic rate (RMR), total energy expenditure (TEE), or activity-related energy expenditure (AEE = TEE − RMR) between obese and normal-weight children and adolescents when appropriate adjustments are made for differences in body composition (6–9).

This controversy seems to be at least partly explained by the use of different definitions of physical activity, differences in the aspects of physical activity assessed (eg, time spent when sedentary, intensity and duration of physical activity, total physical activity, TEE, and AEE), and discrepancies in the accuracy of the physical activity assessment techniques used. There is no single method that can quantify the full range of aspects of free-living physical activity (10). Thus, to unravel the influence of different aspects of physical activity on body weight, a combination of different objective methods of assessment is needed.

The objective assessment of free-living physical activity can be based on physiologic (energy expenditure and heart rate monitoring) and biomechanical (accelerometry) methods. Free-living energy expenditure is usually measured with the doubly labeled water (DLW) method, which provides an average measure of TEE over 1–3 wk (11). In conjunction with measurements of RMR by indirect calorimetry, AEE can be estimated. AEE is influenced by body mass and the economy of movement; therefore, AEE is not a good indicator of the amount or duration of physical activity in a person (10). An alternative way of quantifying the physical activity

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level (PAL) from energy expenditure data is to express TEE as a multiple of RMR (PAL = TEE/RMR).

Activity monitors based on accelerometry provide a measure of the intensity and duration of body movement (ie, the dynamic component of movement) in 1–3 planes (vertical, lateral, and anterior-posterior) (12). Raw activity monitor data can be used to assess the relative intensity and duration of physical activity. In addition, activity monitors provide a valid measure of total physical activity (13, 14).

In the present study, we combined the DLW method and accelerometry to determine whether there were any differences in various aspects of physical activity between obese and normal-weight adolescents. We hypothesized that there would be no difference in estimates of energy expenditure (REE, TEE, and AEE) but that the intensity and duration of body movement and total physical activity, assessed by accelerometry, would differ between the obese and control groups.

SUBJECTS AND METHODS

Subjects

Eighteen obese adolescents aged 14–19 y and with a body mass index (BMI; in kg/m^2) > 30 were identified and recruited through the school health care system in the city of Örebro, Sweden. Obese subjects were individually matched by sex and age with the control subjects (BMI < 27) from the same school. The selection of control subjects from the same school ensured that they would have the same type of education as the obese subjects and at least a similar demographic background. Subjects with chronic diseases (eg, diabetes, hypothyroidism, and asthma) and those taking medication regularly, except for oral contraceptives in girls (5 obese and 4 control subjects), were excluded. All subjects were classified as being in pubertal stage 4 or 5 according to Tanner (15). The subjects or their parents (for those aged < 18 y) provided written, informed consent, and the study protocol was approved by the Ethics Committee of the Örebro County Council.

Study protocol

The subjects were admitted to the laboratory at ≈2200 on day 0. After a baseline urine sample was collected, the subjects were given an oral dose of labeled water and then returned home by car and fasted overnight. In the morning of day 1, the subjects arrived by car at the laboratory at ≈0700. The subjects were asked to minimize all physical activity on day 0. RMR, body weight, height, and body composition were measured in the fasting state. Thereafter, the subjects were served a light breakfast, and a second urine sample was collected. After breakfast, all subjects performed an exercise test consisting of walking on a treadmill, including 2 steady state workloads.

At the end of the visit, the subjects were instructed on how to wear an accelerometer and how to record their physical activity and food intake. The subjects returned to the laboratory on day 8 for the collection of a fourth and fifth urine sample. A 7-d dietary record was also returned at this time. A third visit to the laboratory was scheduled for day 15, when 2 more urine samples were obtained and the activity diary and the accelerometer were returned. For every obese subject, one control subject underwent measurements in the same 14-d period. All measurements (except in one pair of subjects) were performed during the spring, from April to June.

Measurements

Resting metabolic rate

RMR was measured between 0700 and 0800 in the morning, after an overnight fast. After arriving in the laboratory, the subjects rested in the supine position for ≈30 min. Expired air was then collected in Douglas bags with the use of a 2-way nonrebreathing valve (Hans Rudolph Inc, Kansas City, MO) and a nose clip. For all measurements, expired air was collected in 2 Douglas bags for exactly 15 min each. The oxygen content was analyzed with an electrochemical oxygen analyzer (Ametek S-3A; Thermox Instruments, Pittsburgh) and the carbon dioxide content with an infrared carbon dioxide analyzer (Ametek CD-31; Thermox Instruments). The analyzers were calibrated against gases of known concentration before each test. The volume of air in each Douglas bag was measured with a gas meter (Elster Agmainz, Mainz-Kastel, Germany) under constant flow. This system was calibrated against a 350 L Tissot spirometer. RMR was calculated from each of the 2 Douglas bags according to Weir (16). The lower of these 2 values was taken as the RMR. The temperature in the room was kept constant at ≈20–21 °C. The test-retest correlation coefficient (14 d apart) in 12 volunteers for RMR was $r = 0.95$ ($P < 0.01$).

Total energy expenditure

TEE was measured with the DLW method as described by Westerterp et al (11). The estimated CV for TEE measured by the DLW is 3.9% in our laboratory (17). The subjects were given a weighted dose of a mixture of 99.8 atom% ^2H_2O in 10.0 atom% $H_2{}^{18}O$ so that the baseline concentrations (ppm) of deuterium and ^{18}O were increased by ≥150 and ≥300 ppm, respectively. Additional urine samples were then collected from the second void of the day and during the evening on days 1, 8, and 15. The samples were analyzed in duplicate with an isotope-ratio mass spectrometer (Optima; VG Isogas Ltd, Micromass, Manchester, United Kingdom). Carbon dioxide production was converted to TEE with the use of an energy equivalent based on the individual food quotient calculated from the macronutrient composition of the diet as described by Black et al (18), assuming that the respiratory quotient was equal to the food quotient. A 7-d precoded food record (19) was used for recording food intakes. The energy intake was calculated by using commercial software (MATs; Rudans Lättdata, Västerås, Sweden) and the food-composition data from the Swedish National Food Administration.

Activity-related energy expenditure and physical activity

AEE was calculated as 0.9 TEE − minus RMR, with correction for a 10% diet-induced thermogenesis (20). PAL was determined as the ratio of TEE to RMR. Physical activity was assessed with a uniaxial accelerometer (model WAM 7164; Computer Science and Applications Inc, Shalimar, FL). The accelerometer is a small (5.1 × 3.8 × 1.5 cm), light-weight (43 g) instrument. We have used this instrument successfully in children and adolescents under free-living conditions for an extended period of time (ie, 14 d) (14, 21). The accelerometer measures vertical accelerations from 0.05 to 2.1 G and is equipped with a passband filter, which discriminates human movements from vibrations (22). Activity data from the accelerometer were sampled on a minute-by-minute basis. The accelerometer was secured directly to the skin on the lower part of the back (L 4–5) with an elastic belt. The subjects wore the accelerometer during the daytime except, during water

TABLE 1
Physical characteristics of the participants[1]

	Obese group		Control group	
	Boys ($n = 8$)	Girls ($n = 10$)	Boys ($n = 8$)	Girls ($n = 10$)
Age (y)	18.1 ± 1.1	17.3 ± 1.9	18.2 ± 1.1	17.3 ± 1.9
Weight (kg)[2]	113.2 ± 9.1	102.4 ± 24.1	73.7 ± 10.5	61.4 ± 9.3
Height (m)[3]	1.83 ± 0.04	1.66 ± 0.08	1.80 ± 0.06	1.66 ± 0.07
Fat-free mass (kg)[2,3]	73.7 ± 6.3	55.2 ± 9.5	61.4 ± 6.9	43.2 ± 5.1
Fat mass (kg)[2,4]	39.5 ± 7.0	47.3 ± 14.8	12.2 ± 5.2	18.3 ± 5.9
Body fat (%)[2,3]	34.8 ± 4.8	45.4 ± 4.3	16.5 ± 5.1	29.2 ± 5.7

[1] $\bar{x}$ ± SD. Fat-free mass and fat mass were determined by dual-energy X-ray absorptiometry. There were no significant sex × group interactions (ANOVA).

[2] Significant group effect, $P < 0.001$ (ANOVA).

[3,4] Significant sex effect (ANOVA): [3] $P < 0.001$, [4] $P < 0.05$.

activities. In addition, they recorded in a diary the time when the monitor was attached and removed each day and all exercise (including bicycling and walking) performed.

Activity data were analyzed and processed with the use of a specially written macro based on Microsoft ACCESS (Microsoft Inc, Redmond, WA). The output from the macro included accumulated time spent at moderate- and high-intensity physical activities. In addition, the macro allows the calculation of continuous time and continuous periods of time spent at physical activity at these intensity levels. Furthermore, the total amount of time (minutes) registered each day was recorded. Total physical activity was expressed as total counts divided by registered time, ie, counts $\cdot$ min^{-1} $\cdot$ d^{-1}. All activity data were averaged over the 14-d period. Only days on which >600 min of data were registered were included in the analysis.

Because of the relatively high interindividual variability in activity counts during walking and running (23), moderate- and high-intensity cutoffs were calculated individually from 2 steady state workloads. The subjects walked for 5 min at both 4 and 6 km/h. Oxygen uptake was measured with an online, open-circuit system (Medical Graphics Inc, St Paul), and activity counts were measured simultaneously in 15-s intervals with the same accelerometer in all subjects. Activity counts were averaged over the last 2 min at each workload.

Activity counts obtained at 4 km/h were regarded as indicating moderate intensity, ie, ≥3 metabolic equivalents of physical activity (24). As an arbitrary indicator of sedentary behavior, counts equal to or below a threshold of 100 counts/min were used in all subjects. Light intensity was defined as activity counts >100 counts/min but less than individually determined counts corresponding to moderate intensity (ie, walking at 4 km/h). Before the measurements, all accelerometers were calibrated with the use of the calibrator provided by and the procedures recommended by the manufacturer (25).

Anthropometry and body composition

Height was measured to the nearest 0.5 cm with a standard wall-mounted stadiometer. Body mass was measured on days 1 and 15, on a standard laboratory scale, to the nearest 0.1 kg while the subjects were wearing light underwear only. Total body composition was measured by dual-energy X-ray absorptiometry with a Lunar DPX-L densitometer (Lunar Corp, Madison, WI). The subjects were scanned in light clothing while lying horizontally on their backs. The adult scan mode was used for all subjects, and the densitometer was calibrated by using the procedures provided by the manufacturer before each test. The CVs for fat mass (FM), fat-free mass (FFM), and bone mineral content were reported to be 2.2%, 1.05%, and 0.64%, respectively (26).

Statistics

The effects of sex and group (obese compared with control subjects), which were considered as fixed factors, on physical-characteristic variables, energy expenditure estimates, and physical activity variables were analyzed by analysis of variance (ANOVA) and analysis of covariance (ANCOVA). When ANCOVA was used, RMR, TEE, and AEE were examined as dependent variables, with FFM as the covariate. The data on total amount of physical activity, when expressed hourly (counts $\cdot$ h^{-1} $\cdot$ d^{-1}), were not normally distributed and were therefore square root transformed. All assumptions for ANOVA and ANCOVA were fulfilled, and the residuals showed a satisfactory pattern. Relations between variables were analyzed by linear regression analysis and partial correlation. SPSS (Statistical Package for the Social Sciences for WINDOWS, 10.0; SPSS Inc. Chicago) was used for statistical analyses. The results are presented as means ± SDs, unless otherwise stated. The level of statistical significance was set at $P < 0.05$.

RESULTS

The physical characteristics of the study participants are presented in **Table 1**. On average, the obese group was 42 kg heavier than the control group; the BMIs of the obese and control groups were 35.6 ± 5.3 and 21.9 ± 2.3, respectively ($P < 0.0001$). The average 14-d weight change in the obese group was −0.2 ± 0.8 kg and in the control group was 0.3 ± 0.7 kg ($P = 0.07$). The individual changes ranged from −2.3 to 1.6 kg and from −1.0 to 1.3 kg in the 2 groups, respectively.

Energy expenditures, PAL, and resting substrate utilization are summarized in **Table 2**. No sex × group interaction was observed for any of the studied variables. ANOVA showed a significant group and sex effect on RMR and TEE. Further, AEE was significantly higher in boys than in girls. PAL was significantly lower in the obese group ($P < 0.05$). The resting nonprotein respiratory quotient did not differ significantly between groups. After adjustment (ANCOVA) for differences in body composition (FFM), no significant effect of group or sex or any interaction effects were observed on RMR, TEE, or AEE (**Table 3**).

RMR was significantly correlated with FFM in both the obese [RMR (MJ/d) = 0.09875 FFM (kg) + 2.065; $R^2 = 0.84$, SEE = 0.55]

TABLE 2

Energy expenditure and resting substrate utilization in adolescent obese and normal-weight control groups[1]

	Obese group		Control group	
	Boys ($n = 8$)	Girls ($n = 10$)	Boys ($n = 8$)	Girls ($n = 10$)
RMR (MJ/d)[2,3]	9.1 ± 0.6	7.7 ± 1.4	7.2 ± 1.2	6.0 ± 0.5
TEE (MJ/d)[2,3]	15.5 ± 1.4	12.4 ± 1.7	13.2 ± 1.7	10.4 ± 0.8
AEE (MJ/d)[3]	4.9 ± 0.9	3.5 ± 0.6	4.6 ± 1.5	3.4 ± 0.7
PAL[4,5]	1.70 ± 0.1	1.63 ± 0.1	1.85 ± 0.3	1.74 ± 0.2
RQ	0.83 ± 0.06	0.82 ± 0.07	0.80 ± 0.04	0.84 ± 0.05

[1] $\bar{x}$ ± SD. RMR, resting metabolic rate; TEE, total energy expenditure; AEE, activity-related energy expenditure; PAL, physical activity level; RQ, respiratory quotient. There were no significant sex × group interactions (ANOVA).

[2,4] Significant group effect (ANOVA): [2] $P < 0.001$, [4] $P < 0.05$.

[3] Significant sex effect, $P < 0.001$ (ANOVA).

[5] PAL = (TEE/RMR).

and control [RMR (MJ/d) = 0.08277 FFM (kg) + 2.415; $R^2 = 0.54$, SEE = 0.73] groups. The relation between TEE and FFM is shown in **Figure 1**.

The mean activity counts corresponding to walking at 4 km/h during laboratory calibration were 1364 ± 457 and 1412 ± 524 counts/min (NS) in the obese and control groups, respectively, and at 6 km/h were 3233 ± 964 and 3668 ± 756 counts/min (NS) in the obese and control groups, respectively. The corresponding values for oxygen uptake were 10.8 ± 0.9 and 11.6 ± 1.4 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ at 4 km/h ($P = 0.05$) in the obese and control groups, respectively, and 15.6 ± 1.9 and 16.2 ± 1.9 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ at 6 km/h (NS) in the obese and control groups, respectively.

The free-living physical activity data obtained by accelerometry are summarized in **Table 4**. The monitors were worn for 13.1 ± 1.0 and 12.4 ± 1.6 d (NS) by the obese and control groups, respectively. The time registered was ≥ 13 h/d in both groups, indicating that the monitors were worn for most of the awake time, except during water activities. There was no significant effect of sex on any of the studied variables or any sex × group interaction effects. The lengths of time (min/d) spent while sedentary and at a physical activity of light intensity did not differ significantly between the 2 groups. Compared with the control group, the obese adolescents showed significantly ($P < 0.05$) less accumulated time at a physical activity of moderate intensity. Furthermore, the obese group spent significantly less time continuously (ie, > 2 min) at such a physical activity ($P < 0.01$), and their daily average number of continuous 10-min periods spent at a physical activity of this intensity level was significantly smaller ($P < 0.01$). In addition, the total amount of physical activity expressed as total counts over the registered time was significantly lower ($P < 0.001$) in the obese group. Total physical activity ($counts \cdot min^{-1} \cdot h^{-1}$) during the awake time, averaged per hour over the 14-d period in the obese and control groups, is shown in **Figure 2**. ANOVA showed significant group ($P < 0.001$) and time ($P < 0.001$) effects.

Percentage body fat was significantly and negatively associated with PAL in the 2 groups combined ($r = -0.53$, $P = 0.001$). This relation was not affected by sex (partial $r = -0.49$, $P = 0.003$). The relation between percentage body fat and PAL is shown in **Figure 3**.

DISCUSSION

The principal finding in the present study was that physical activity measured with the accelerometer was lower in obese adolescents than in age-, sex-, and education-matched control subjects, whereas RMR, TEE, and AEE did not differ significantly between the groups.

The major advantage of the present study was the use of a combination of 2 different methods for assessing physical activity. Energy expenditure associated with physical activity was measured with the DLW method, simultaneously with the direct measurement of physical activity with the accelerometer. The data from the accelerometer enabled the time spent while sedentary and at physical activities of different intensities to be calculated and the total amount of physical activity to be estimated.

Our finding of no significant differences in TEE and AEE between the obese and control groups, after adjustment for differences in body composition, agrees with previous observations in children, adolescents, and adults (6–9, 27). On the other hand, the intensity and duration of physical activity and the total amount of physical activity in the obese group was significantly less than in the control group, as assessed by accelerometry. The differences in physical activity between the groups that were not reflected by any differences in TEE and AEE could be explained by the increased energy cost of moving a larger body mass, by a difference in body acceleration (ie, activity counts), by a difference in

TABLE 3

Energy expenditure in adolescent obese and normal-weight control groups after adjustment for fat-free mass[1]

	Obese group		Control group	
	Boys ($n = 8$)	Girls ($n = 10$)	Boys ($n = 8$)	Girls ($n = 10$)
RMR (MJ/d)	7.2 ± 0.5	8.0 ± 0.3	6.7 ± 0.3	7.4 ± 0.4
TEE (MJ/d)	13.1 ± 0.7	12.6 ± 0.4	12.5 ± 0.4	12.2 ± 0.5
AEE (MJ/d)	4.6 ± 0.7	3.4 ± 0.4	4.5 ± 0.4	3.6 ± 0.5

[1] $\bar{x}$ ± SEM. RMR, resting metabolic rate; TEE, total energy expenditure; AEE, activity-related energy expenditure. There were no significant sex × group interactions (ANCOVA).

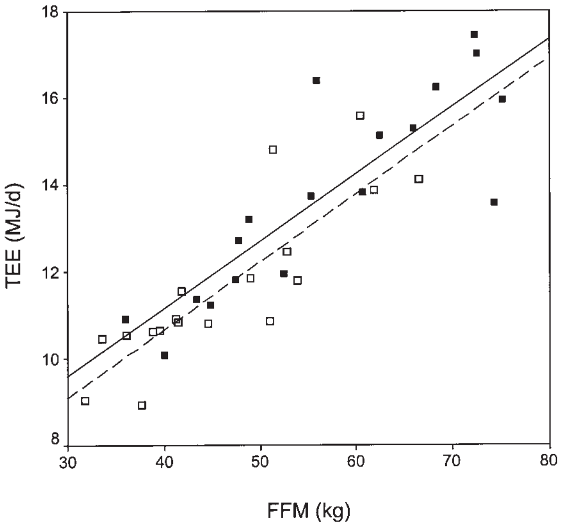

FIGURE 1. Total energy expenditure (TEE) assessed by the doubly labeled water method and expressed as a function of fat-free mass (FFM) in adolescent obese [■; TEE (MJ/d) = 0.155 FFM (kg) + 4.96; $R^2 = 0.71$, SEE = 1.23] and normal-weight control [□; TEE (MJ/d) = 0.157 FFM (kg) + 4.39; $R^2 = 0.71$, SEE = 1.0] groups. The slopes of the regression lines were not significantly different between the 2 groups.

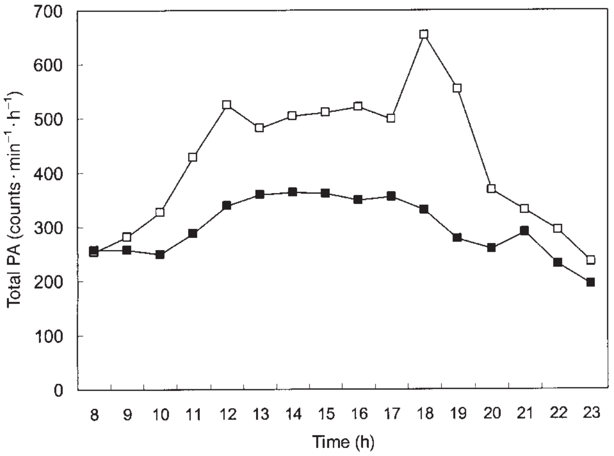

FIGURE 2. Total physical activity (PA) assessed by accelerometry and averaged hourly in adolescent obese (■) and normal-weight control (□) groups. There were significant group ($P < 0.001$) and time ($P < 0.001$) effects by ANOVA. The CVs ranged from 26% to 69% and from 31% to 76% in the obese and control groups, respectively.

movement economy, or by a combination of these factors. The absolute energy expenditures while walking at 4 and 6 km/h, during the laboratory calibration, were ≈35% higher in the obese group. Conversely, there were no significant differences in body acceleration between the 2 groups during these standardized walking exercises. Furthermore, the movement economy (mL $O_2 \cdot kg^{-1} \cdot min^{-1}$) has been reported to not differ between lean and obese children (28) and did not differ significantly between our 2 groups in the present study at walking paces of 4 and 6 km/h. Thus, the increased energy cost of moving a larger body mass would explain why the obese group was significantly less active than the control group, as indicated by the accelerometer, and why there were no group differences in AEE. Our data suggest that physical activity is not equivalent to the energy cost of activity.

Only in a small number of studies have different methods been combined for assessing both energy expenditure concurrently with the intensity and duration aspects of physical activity in relation to obesity in children and adolescents. From a study of prepubertal children, Goran et al (29) concluded that only a small proportion of the variance in body FM was explained by time spent in recreational activity, as assessed by a questionnaire, and that none of the variance was explained by AEE, as measured by the DLW method. They also concluded that the time spent on physical activity may be a more significant factor than energy expenditure attributable to physical activity in the maintenance of whole energy stores. The results from the present study, using a direct measure of physical activity, agree with the findings of Goran et al (29) and suggest that the amount of time spent on physical activity of moderate intensity as well as the total amount of physical activity, but not AEE, might be associated with obesity and its development in children and adolescents.

It was recently suggested that the total amount of time devoted to physical activity in the low-to-moderate intensity range (eg, activities such as walking and cycling) seems to influence TEE and determines the PAL value to a greater extent than does high-intensity physical activity (30). The data from the present study indicated a difference in the overall physical activity between the obese subjects and their normal-weight peers throughout the entire day (Figure 2). This difference was not due to sport- and fitness-related activities of high intensity only, except for the peak in the activity level (as confirmed by diary records) at ≈1800–1900 in

TABLE 4
Physical activity variables in adolescent obese and normal-weight control groups as assessed by accelerometry[1]

	Obese group		Control group	
	Boys ($n = 8$)	Girls ($n = 10$)	Boys ($n = 8$)	Girls ($n = 10$)
Recorded time (min/d)	801 ± 43	775 ± 62	785 ± 44	788 ± 65
Sedentary (min/d)	421 ± 33	465 ± 132	414 ± 81	397 ± 69
Light activity (min/d)	255 ± 29	244 ± 50	254 ± 46	258 ± 59
Moderate activity or greater (min/d)[2]	58 ± 30	60 ± 28	82 ± 36	98 ± 58
Continuous time (min/d)[3]	10 ± 7	7 ± 6	19 ± 16	26 ± 18
Continuous 10-min periods (periods/d)[3]	0.7 ± 0.5	0.5 ± 0.4	1.2 ± 0.9	1.3 ± 0.8
Total activity ($counts \cdot min^{-1} \cdot d^{-1}$)[4]	378 ± 87	339 ± 104	496 ± 164	534 ± 162

[1] $\bar{x}$ ± SD. There were no significant sex × group interactions (ANOVA).

[2–4] Significant group effect (ANOVA): [2] $P < 0.05$, [3] $P < 0.01$, [4] $P < 0.001$.

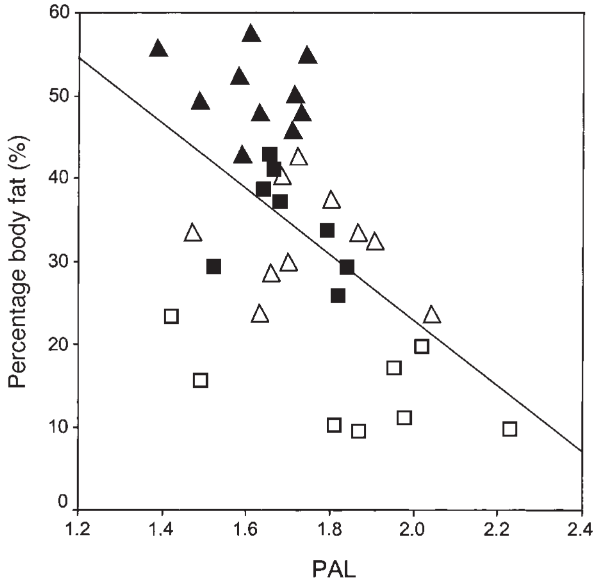

FIGURE 3. Percentage body fat assessed by dual-energy X-ray absorptiometry, expressed as a function of the physical activity level (PAL = total energy expenditure/resting metabolic rate) in adolescent obese girls (▲) and boys (■) and in normal-weight control girls (△) and boys (□). There was a significant inverse relation between the variables ($r = -0.53$, $P = 0.001$). This relation was not affected by sex (partial $r = -0.49$, $P = 0.003$).

the control group, because all subjects spent most of their daytime in the same environment, ie, at school. The present data indicated that the everyday physical activity of moderate intensity was significantly lower in the obese group and, therefore, influenced the total physical activity and the PAL value. Thus, the significantly higher PAL value found in the control group was due not only to participation in high-intensity activities but also to a higher everyday activity level of moderate intensity.

Contrary to previous studies in obese and normal-weight children and adolescents (6–9), which failed to show differences in PALs, we observed a significantly lower PAL in the obese group than in the control group. This finding was supported by the significantly lower total physical activity (counts $\cdot$ min^{-1} $\cdot$ d^{-1}) in the obese group, as measured by the accelerometer (Table 4). Most previous studies (6–8) included prepubertal children, in whom the average PAL value, regardless of body weight, was lower than that in adolescents (31). Thus, the only study comparable with ours appears to be that reported by Bandini et al (9). The absolute differences in PAL values between their study and the present one are small. The PAL value was consistently lower in both boys and girls in the obese group than in the control boys and girls in the present study, whereas it was higher in obese girls than in control girls in the study by Bandini et al (9). This finding probably explains the differences between the studies.

An inverse association between percentages body fat and body FM on the one hand and DLW-measured PAL on the other hand was previously observed in children (2), adolescents (9), and adults (32, 33). In accordance with these findings, we found a significant negative relation between percentage body fat and PAL (Figure 3). Contrary to findings in adults (33), this relation was not affected by sex.

It has been suggested that a relatively high PAL is needed to maintain energy balance in a society with unrestricted possibilities of excessive food consumption and that a PAL value of ≈1.75 is permissive for weight gain (34). Interestingly, the mean PAL values in the obese and normal-weight groups were 1.66 and 1.79, respectively. Furthermore, ≤3 of the 18 subjects with a BMI > 30 had a PAL value ≥1.75 compared with 10 subjects in the normal-weight group.

The present study was limited by its cross-sectional design. Thus, we cannot draw any conclusions as to whether an inactive lifestyle causes obesity or whether obesity leads to a physically inactive lifestyle. Most previous studies in children (1–3, 6–8, 29), adolescents (1, 4, 5, 9), and adults (33, 34) that addressed the relation between physical activity and obesity have been cross-sectional. One prospective study in children suggests that aerobic fitness and not AEE is a significant predictor of weight gain (35). Unfortunately, other aspects of physical activity, eg, intensity and duration, were not measured in that study (35). Thus, it is clear that longitudinal studies using a combination of direct measurement techniques, which can capture both energy expenditure aspects and body movement dimensions of physical activity, are needed to further evaluate the relation between physical activity and the development of obesity in children and adolescents.

In conclusion, the obese adolescents in the present study were less physically active, on the basis of both total physical activity and the time spent at physical activity of moderate or higher intensity, than were a matched control group. Nevertheless, no significant difference in AEE was observed between the 2 groups. Our data suggest that physical activity is not equivalent to the energy costs of activity.

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