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PEDIATRIC HIGHLIGHT

Association of objectively assessed physical activity with total and central body fat in Spanish adolescents; The HELENA Study

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Objectives: To examine the association of objectively assessed physical activity (PA) with markers of total and central body fat in adolescents, and to determine whether meeting the current PA recommendations ($\geqslant$60 min day^{-1} of at least moderate intensity PA) is associated with reduced levels of total and central body fat.
Subjects/Methods: A total of 365 Spanish adolescents aged 12.5–17.5 years participated in this cross-sectional study. PA was assessed by accelerometry and expressed as average PA (counts per minute), and min day^{-1} of light, moderate, moderate to vigorous (MVPA) and vigorous PA. MVPA was dichotomized into $<$60 min day^{-1} and $\geqslant$60. Total body fat was measured by DXA, BodPod and the sum of six skinfolds. Central body fat was measured by DXA at three regions (R1, R2 and R3), and waist circumference.
Results: All markers of central body fat were negatively associated with vigorous PA ($P<0.01$) after controlling for sex, age and pubertal status. Abdominal adiposity measured at R1, R2 and R3 was also negatively associated with MVPA ($P\leqslant0.001$), and with average PA ($P<0.01$). All markers of total body fat were negatively associated with vigorous PA ($P<0.01$), MVPA ($P<0.01$) and average PA ($P<0.05$). Adolescents engaged on at least 60 min day^{-1} MVPA presented lower levels of total ($P<0.05$) and central body fat ($P\leqslant0.01$).
Conclusions: The results suggest that vigorous PA may have a greater effect on preventing obesity in adolescents than does PA of lower intensity, whereas both average PA and at least moderate PA may have an impact on total and central body fat in youth.
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Keywords: physical activity; body composition; accelerometer; DXA; adiposity; adolescents

Introduction

There is compelling evidence that objectively assessed physical activity (PA) is negatively associated with markers of total[1–10] and central body fat,[8,11–14] in children and adolescents,[15] but with contradictory results.[16,17] Most of the epidemiological studies used anthropometry to assess body composition because it is the most feasible method when large samples need to be assessed. However, more advanced methods to assess body composition such as Dual-Energy X-ray Absorptiometry (DXA) are also required to minimize the error of measurement and to better understand the association between PA and body fat in youth.

The US Department of Health and Human Services together with several medical institutions recently launched Physical Activity Guidelines for children and adolescents: it is mentioned that this population group should participate

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in 1 h or more of PA per day, and most of the activity should be moderate or vigorous aerobic PA.[18] Whether meeting the current PA recommendations, based on an objective assessment of PA, is associated with a healthier body composition, as measured by accurate methods, remains to be elucidated. For preventive purposes and public health strategies, it is of great interest to understand the impact of PA on levels of total and central body fat in adolescents.

The aim of this study was to examine the association between objectively assessed PA and markers of total and central body fat measured by DXA, BodPod and anthropometry in a Spanish cohort of adolescents participating in the HELENA-CSS (Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional) study. We also determined whether meeting the current PA recommendations was associated with reduced levels of total and central body fat.

Subjects and methods

Subjects

The HELENA-CSS study is a multi-centre, cross-sectional study performed in ten European cities that was designed to obtain reliable and comparable data on a broad battery of relevant nutrition and health-related parameters of a sample of European adolescents:[19,20] dietary intake, food choices and preferences, anthropometry, serum indicators of lipid metabolism and glucose metabolism, vitamin and mineral status, immunological markers, physical activity, fitness and genetic markers.

All participants were recruited at schools and met the general HELENA-CCS inclusion criteria (age range 12.5–17.5 years, not participating simultaneously in another clinical trial and be free of any acute infection lasting less than 1 week before the inclusion).[19,20] A total of 392 adolescents were measured in Zaragoza (Spain), and 365 (182 female and 183 male participants) had valid DXA and PA data, and were then included in this study. After receiving complete information about the aims and methods of the study, all adolescents and their parents or guardians signed the informed written consent.

The study was performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000). For the Spanish sample, the study protocol was approved by the Research Ethics Committee of the Government of Aragón (CEICA; Spain). Complete description of ethical issues and good clinical practice within the HELENA-CSS study can be found elsewhere.[21]

Body fat assessment

Body fat assessed by DXA: Body fat was assessed using a paediatric version of the software (QDR-Explorer, Hologic Corp., Software version 12.4, Waltham, MA, USA). The DXA was calibrated using a lumbar spine phantom as recommended by the manufacturer, and adolescents were scanned in supine position. Analysis of total body fat mass was performed using the extended research mode according to the operating manual. Percentage total body fat was calculated as total body fat mass divided by body weight.

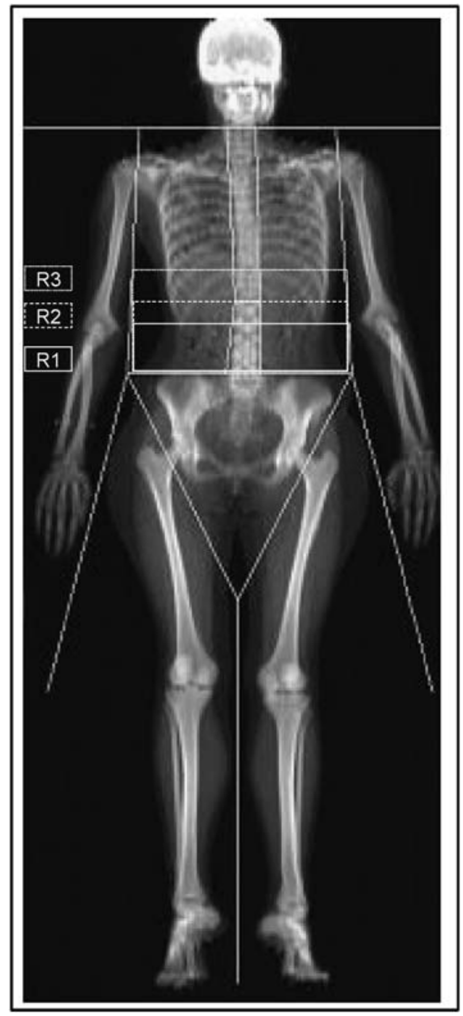

Figure 1 Abdominal fat regions by Dual-Energy X-ray Absorptiometry.

Abdominal adiposity was assessed at three different regions, R1, R2 and R3 (Figure 1).[22,23] A rectangle was drawn on the digital scan image to establish every region. All of them had the lower horizontal border on the top of the iliac crest. For R1, the upper border was established parallel to the end of the lowest rib. The upper border of R2 was parallel to the junction of T12 and L1 vertebrae, and for R3, it was parallel to the middle of the costo-vertebrae articulation of the last rib. The lateral sides of these regions were adjusted to include all the body tissue.

Body fat assessed by BodPod: Body volume was measured by BodPod using standardized procedures.[24] The BodPod was calibrated daily according to the manufacturer's guidelines. Subjects wore clothing according to the manufacturer's recommendation (a swimsuit and a swim cap) to rule out air trapped in clothes and hair. Adolescents were weighed on the BodPod calibrated digital scale and then entered the BodPod chamber. Body volume was measured two times by the machine to ensure measurement reliability. If the first two readings for body volume differed by more than 150 ml, a third measurement was taken. If additional readings were needed, the BodPod was recalibrated and the measurements were repeated for that subject. Percentage total body fat was calculated using the equation reported by Siri.[25] Thoracic gas volume was measured following the manufacturer's recommendations.[24] This value was integrated into the calculation of body volume. Total body fat mass was calculated as percentage total body fat mass multiplied by body mass (kg) and then divided by 100.

Anthropometry. The anthropometric methods followed in the HELENA-CSS study has been described in detail by Nagy *et al*.[20,26] In brief, body height was measured to the nearest 0.1 cm with a stadiometer SECA 225, whereas adolescents were standing barefoot. Body mass was determined to the nearest 100 g using a balance scale SECA 861 with the subject in their underwear. Body mass index was calculated as body mass (kg) divided by height (m) squared.

Skinfold thickness was measured to the nearest 0.2 mm in triplicate in the left side at biceps, triceps, subscapular, suprailiac, thigh and medial calf with a Holtain Caliper (Crymych, UK).[26] The sum of six skinfold thickness was used as an indicator of total body fat. The same trained investigator made all skinfold thickness measurements. For all the skinfold thickness measurements, intraobserver technical errors of measurement were smaller than 1 mm and reliability greater than 95%.[27] Waist circumference was measured to the nearest 1 mm in triplicate at the level of the natural waist, which is the narrowest part of the torso, as seen from the anterior aspect with an anthropometric unelastic tape SECA 200, and was used as a surrogate of central body fat. The same trained investigator made all measurements and reliability was greater than 95%.

Pubertal status

Pubertal status was assessed by an experienced physician,[28] as described elsewhere.[29]

Physical activity

A uni-axial accelerometer (Actigraph MTI, model GT1M, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) was used to assess PA. Adolescents were instructed to place the monitor underneath the clothing, at the lower back, using an elastic waist band and wear it for 7 consecutive days. They were also instructed to wear the accelerometer during all time awake and only to remove it during water-based activities. At least 3 days of recording with a minimum of 8 h registration per day, was set as an inclusion criterion. In this study, the time sampling interval (epoch) was set at 15 s. A measure of total volume of activity (hereafter called average PA) was expressed as the sum of recorded counts per epoch divided by total daily registered time expressed in minutes. The time engaged in moderate PA and vigorous PA was calculated and presented as the average time per day during the complete registration. The time engaged at moderate PA [3–6 metabolic equivalents] was calculated based upon a cutoff of 2000–3999 counts per minute. The lower cutoff for moderate activity, that is 2000 counts per minute, is equivalent to walking at $3\,\mathrm{km\,h^{-1}}$.[30] The time engaged at vigorous PA (>6 metabolic equivalents) was calculated based upon a cutoff of $\geqslant 4000$ counts per minute. Also, the time spent in at least a moderate intensity level (>3 metabolic equivalents) was calculated as the sum of time spent in moderate or vigorous PA (MVPA). Time spent in light PA was defined as the sum of time per day in which counts per minute were 500–1999 counts. The cutoffs to define the intensity categories are similar to those used in previous studies.[16,31,32] Each minute over the specific cutoff was summarized in the corresponding intensity level group.

Validation studies examining the accelerometer used in this study and the construction of summary variables for intensity of movement suggests that it is a valid and reliable measure of children's and adolescent's PA.[33,34]

MVPA was dichotomized into <60 and $\geqslant 60\,\mathrm{min\,day^{-1}}$ according to the recent guidelines launched by the US Department of Health and Human Services and other institutions.[18,35]

Statistical analysis

The data are presented as means ± s.d. unless otherwise stated. To achieve normality in the residuals, markers of total and central body fat were transformed to the natural logarithm. Gender differences were assessed by one-way analysis of variance.

Multiple regressions were used to study the association of PA (light, moderate, vigorous, MVPA and average PA) with markers of central body fat (R1, R2 and R3 by DXA, and waist circumference). Likewise, we performed multiple regression analyses to study the association of PA with markers of total body fat (DXA, BodPod and the sum of six skinfolds). All these relationships were analysed in separate regression models that always retained sex, age and pubertal status as the base model (that is, confounders). No interaction effect between sex and any of the PA variables was found (all $P>0.1$), therefore, all analyses were performed jointly for male and female participants. Semipartial correlations were used as the measure of the relationship between PA and the part of the outcome (markers of total and central body fat) that is not explained by the other predictors in the model (sex, age and pubertal status). In other words, it is a measure of the variance in the outcome that PA alone share.

Mean differences in markers of central (R1, R2 and R3 by DXA, and waist circumference) and total body fat (DXA, BodPod and the sum of six skinfolds) by time spent at MVPA (<60 vs $\geqslant 60\,\text{min day}^{-1}$) were analysed by one-way analysis of covariance. Sex, age and pubertal status were entered as covariates. The analyses were performed using the Statistical Package for Social Sciences (SPSS, v. 16.0 for WINDOWS; SPSS Inc., Chicago, USA) and the level of significance was set to <0.05.

Results

The characteristics of the study population by sex are shown in Table 1. Male participants had lower levels of total and central body fat than female participants (all $P \leqslant 0.001$), except for waist circumference, that was higher in the former ($P \leqslant 0.001$). Male participants were more physically active than female participants (all $P \leqslant 0.001$), and the prevalence of male participants achieving at least $60\,\text{min day}^{-1}$ MVPA was also higher than in female participants (57.9 vs 23.6%, respectively, $P<0.001$).

The results of the regression models with markers of central body fat as the outcome variables are shown in Table 2. All the studied markers of central body fat were negatively associated with vigorous PA (all $P<0.01$). Abdominal adiposity measured at R1, R2 and R3 was negatively associated with MVPA (all $P \leqslant 0.001$) and with average PA (all $P<0.01$). There was no association between waist circumference and average PA ($P=0.128$), whereas the association with MVPA was borderline significant ($P=0.059$). No association was observed between markers of central body fat and light or moderate PA (all $P>0.05$), yet the associations of abdominal adiposity measured at R1 and R2 with moderate PA were borderline significant ($P=0.061$ and 0.064, respectively). The results did not materially change after further controlling for height.

The results of the regression models with markers of total body fat as the outcome variables are shown in Table 3. All the studied markers of total body fat were negatively associated with vigorous PA (all $P<0.01$), MVPA (all $P<0.01$) and average PA (all $P<0.05$). No association was observed between markers of total body fat and light or moderate PA (all $P>0.05$), yet, the associations of total body fat measured by DXA and the sum of six skinfolds were borderline significant ($P=0.067$ and 0.091, respectively).

Figure 2 shows the mean sum of central body fat measured at R1, R2 and R3, and waist circumference by time spent at MVPA. The analysis of covariance indicated that markers of central body fat were lower in those adolescents engaged in at least $60\,\text{min day}^{-1}$ MVPA (all $P \leqslant 0.01$), except waist circumference that was similar among MVPA groups ($P=0.202$). The mean sum of total body fat measured by DXA, BodPod and

Table 1 Characteristics of the study adolescents by gender

	Male participants (n = 183)	*Females participants (n = 182)*	*All (n = 365)*
Age (years)	14.7 ± 1.3	14.8 ± 1.2	14.8 ± 1.2
Tanner stage (%)			
Stage 1	0.0	0.0	0.0
Stage 2	4.5	0.6	2.6
Stage 3	10.2	5.1	7.7
Stage 4	20.5	6.3	13.4
Stage 5	64.8	88.0	76.4
Height (m)	1.69 ± 0.1***	1.60 ± 0.1	1.64 ± 0.1
Weight (kg)	61.0 ± 12.5***	54.3 ± 8.9	57.7 ± 11.4
BMI (kg m^{-2})	21.2 ± 3.2	21.1 ± 3.1	21.2 ± 3.2
Sum of six skinfolds (mm)	79.1 ± 39.0***	106.1 ± 32.1	92.4 ± 38.2
Waist circumference (cm)	75.2 ± 8.9***	71.4 ± 7.5	73.3 ± 8.4
Fat mass by DXA (kg)	13.2 ± 6.2***	16.3 ± 5.2	14.7 ± 5.9
Fat mass by DXA (%)	21.3 ± 7.1***	29.9 ± 5.3	25.6 ± 7.6
Abdominal adiposity R1 by DXA (kg)	0.7 ± 0.5***	1.0 ± 0.6	0.9 ± 0.6
Abdominal adiposity R2 by DXA (kg)	1.1 ± 0.7***	1.3 ± 0.8	1.2 ± 0.8
Abdominal adiposity R3 by DXA (kg)	1.2 ± 0.8***	1.5 ± 0.9	1.4 ± 0.9
Fat mass by Bod Pod (kg)	12.4 ± 7.1***	15.4 ± 5.7	14.0 ± 6.6
Fat mass by Bod Pod (%)	19.8 ± 8.9***	27.7 ± 6.5	23.8 ± 8.7
Physical activity			
Light (min day^{-1})	79.6 ± 20.6	76.8 ± 17.3	78.2 ± 19.0
Moderate (min day^{-1})	41.5 ± 14.7***	35.2 ± 12.7	38.4 ± 14.0
Vigorous (min day^{-1})	24.8 ± 14.3***	13.8 ± 11.0	19.4 ± 13.8
MVPA (min day^{-1})	66.3 ± 24.8***	49.1 ± 20.1	57.7 ± 24.1
Average intensity (c.p.m.)	476.7 ± 155.6***	367.9 ± 116.5	422.5 ± 147.7
$\geqslant 60\,\text{min day}^{-1}$ MVPA (%)	57.9	23.6	40.8

DXA indicates dual-energy X-ray absorptiometry; MVPA, moderate to vigorous physical activity. Abdominal adiposity R1 includes a body area from top of the iliac crest to the end of the lowest rib; R2 includes from top of the iliac crest to the junction of the T12 and L1 vertebrae; R3 includes from top of the iliac crest to the costo-vertebrae articulation of the last rib. ***$P \leqslant 0.001$

Table 2 Multiple regression coefficients (β), semipartial correlations (*sr*), and coefficients of determination (R^2 and R^2 change) examining the association of light, moderate, vigorous, moderate and vigorous physical activity and average physical activity with markers of abdominal adiposity, after controlling for sex, age and pubertal status

Dependent variable	*Predictors*	*β*	P	*sr*	R^2	R^2 *change*
Abdominal adiposity R1 (*n* = 342)	Light	−0.031	0.567	−0.030	0.094	0.001
	Moderate	−1.000	0.061	−0.096	0.102	0.009
	Vigorous	−0.260	<0.001	−0.236	0.149	0.056
	MVPA	−0.198	<0.001	−0.185	0.127	0.034
	Average PA	−0.176	0.001	−0.164	0.120	0.027
Abdominal adiposity R2 (*n* = 342)	Light	−0.029	0.603	−0.027	0.056	0.001
	Moderate	−0.101	0.064	−0.097	0.064	0.010
	Vigorous	−0.265	<0.001	−0.240	0.113	0.058
	MVPA	−0.201	<0.001	−0.188	0.091	0.035
	Average PA	−0.181	0.001	−0.168	0.083	0.028
Abdominal adiposity R3 (*n* = 342)	Light	−0.030	0.598	−0.028	0.047	0.001
	Moderate	−0.092	0.093	−0.089	0.054	0.008
	Vigorous	−0.236	<0.001	−0.214	0.093	0.046
	MVPA	−0.181	0.001	−0.169	0.075	0.029
	Average PA	−0.157	0.006	−0.146	0.068	0.021
Waist circumference (*n* = 350)	Light	0.024	0.656	0.023	0.088	0.001
	Moderate	−0.032	0.551	−0.030	0.089	0.001
	Vigorous	−0.170	0.002	−0.154	0.112	0.024
	MVPA	−0.103	0.059	−0.096	0.097	0.009
	Average PA	−0.084	0.128	−0.078	0.094	0.006

Abbreviations: MVPA, moderate and vigorous physical activity; PA, physical activity. All variables were log transformed, except light and moderate PA.

Table 3 Multiple regression coefficients (β), semipartial correlations (*sr*), and coefficients of determination (R^2 and R^2 change) examining the association of light, moderate, vigorous, moderate and vigorous physical activity and average physical activity with markers of total body fat, after controlling for sex, age, and pubertal status

Dependent variable	*Predictors*	*β*	P	*sr*	R^2	R^2 *change*
Fat mass (DXA)	Light	−0.021	0.698	−0.020	0.121	0.000
(*n* = 343)	Moderate	−0.096	0.067	−0.093	0.130	0.009
	Vigorous	−0.260	<0.001	−0.236	0.177	0.056
	MVPA	−0.195	<0.001	−0.182	0.154	0.033
	Average PA	−0.178	0.001	−0.165	0.149	0.027
Fat mass (BodPod) (*n* = 346)	Light	0.005	0.928	0.005	0.101	0.000
	Moderate	−0.060	0.253	−0.058	0.104	0.003
	Vigorous	−0.215	<0.001	−0.195	0.139	0.038
	MVPA	−0.144	0.008	−0.134	0.119	0.018
	Average PA	−0.132	0.016	−0.123	0.116	0.015
Sum of six skinfolds (*n* = 338)	Light	−0.008	0.881	−0.007	0.192	0.000
	Moderate	−0.086	0.091	−0.083	0.198	0.007
	Vigorous	−0.238	<0.001	−0.215	0.238	0.046
	MVPA	−0.186	<0.001	−0.174	0.222	0.030
	Average PA	−0.155	0.003	−0.145	0.213	0.021

Abbreviations: MVPA, moderate and vigorous physical activity; PA, physical activity. All variables were log transformed, except light and moderate PA.

the sum of six skinfolds by time spent at MVPA is depicted in Figure 3. The analysis of covariance indicated that markers of total body fat were lower in those adolescents engaged in at least 60 min day^{-1} MVPA ($P<0.05$).

Discussion

The main findings of this study indicate that PA, especially of vigorous intensity, is inversely associated with markers of total body fat and abdominal adiposity in adolescents. The results of this study also indicated that adolescents meeting the current PA recommendations of 60 min day^{-1} MVPA had significant lower levels of total body fat and abdominal adiposity than their less active counterparts. The results were fairly consistent regarding the methodology used to assess body fat mass; yet, the associations were stronger when body fat markers were measured by DXA.

The inverse relationship between objectively assessed PA and body fat agree with previous studies.[1–11] Lohman *et al.*[6] reported a significant association of total body fat assessed by anthropometry with MVPA and vigorous PA. Wittmeier *et al.*[3] investigated 251 Canadian children aged 8–11 years and observed that time spent in MVPA was inversely correlated with body mass index and a skinfold-derived

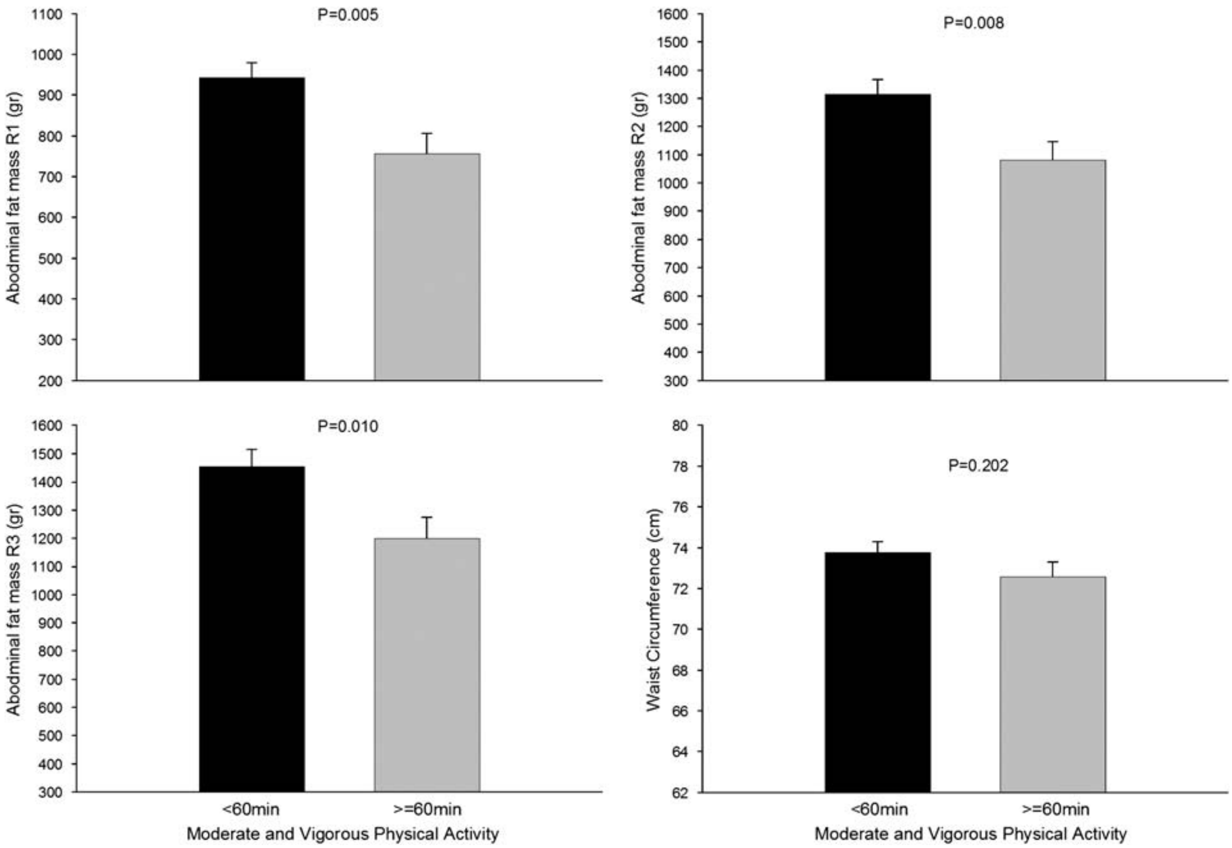

Figure 2 Mean sum of abdominal adiposity measured at R1, R2 and R3, and waist circumference by time spent at moderate and vigorous physical activity (MVPA). Error bars represent s.e.

estimate of body fat, whereas Ruiz *et al.*[5] reported that only vigorous PA was associated with the sum of five skinfold thickness.

Studies using more sophisticated techniques to assess body composition showed more consistent results. Gutin *et al.*[10] investigated 421 US adolescents aged 16 years, and observed a significant association between moderate and vigorous PA and total body fat measured by DXA, which coincide with others.[2,9] Our findings concur with recent studies in children and adolescents showing a negative association between central body fat and PA, especially of vigorous intensity.[8,11–14,36] Saelens *et al.*[14] analysed 42 obese children aged 8 years and found that greater total PA was associated with lower visceral fat measured by magnetic resonance. Ness *et al.*[11] analysed a sample of 5500 12-year-old children enroled in the Avon Longitudinal Study of Parents and Children and observed a strong graded inverse association between PA and trunk fat measured by DXA, especially in male participants. Furthermore, Dencker *et al.*[36] showed that vigorous PA was independently related to abdominal adiposity measured by DXA. Probably, as we observed in our study, waist circumference is not a sensitive marker of central body fat during growth and development.[37]

Evidence from intervention studies support that PA in children and adolescents reduces total and central body fat.[38–42] According to the US Department of Health and Human Services, adolescents must achieve at least 60 min day^{-1} of MVPA.[18] Indeed, findings of this study support these recommendations, showing that adolescents engaged in at least 60 min day^{-1} MVPA have a healthier body composition. Results from cross-sectional and longitudinal studies also indicated that participation in at least 3 h per week of extracurricular physical activities and sport competitions is associated with less body fat mass (measured by DXA) in prepubertal children compared with children who do not participate in sports regularly.[43] Furthermore, those children who regularly participated in sports activities at least 3 h per week during 3 years were more protected against total and regional, especially central fat mass accumulation.[44]

It is important to consider when interpreting the findings from this study that because of the study design (cross-sectional) it is not possible to infer a causal relationship between PA and body fatness. Although we controlled for several potential confounders we cannot be certain that other unmeasured confounders such as dietary intake and genetic variation, have not influenced our observations. It should also be acknowledged that there is poor to moderate agreement between accelerometry and energy expenditure, and that the Actigraph has poor validity against indirect calorimetry and double-labelled water, especially in young

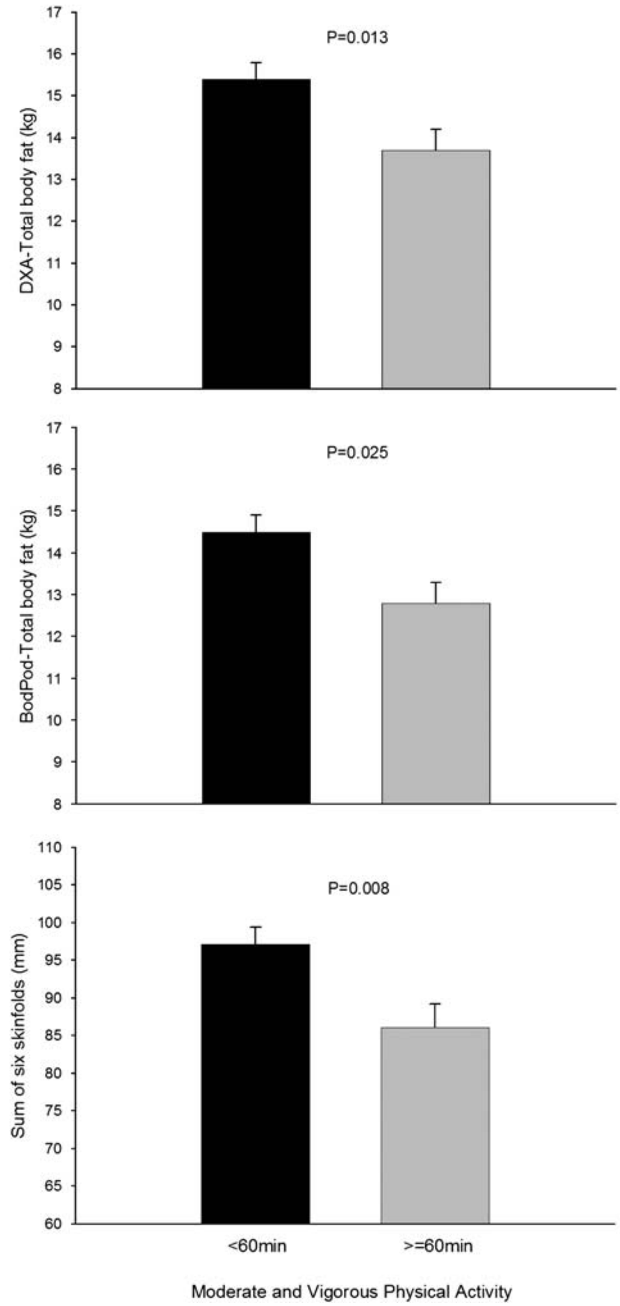

Figure 3 Mean sum of total body fat measured by DXA, BodPod and the sum of six skinfolds by time spent at moderate and vigorous PA. Errors bars represent s.e.

children,[45] whereas less evidence exist for adolescents. It should be mentioned that the cutoff points used in this study to define physical activity intensities are similar to those used in previous studies,[16,31,32] and that seem to be useful and valid for estimating participation in moderate and vigorous physical activity in children and adolescents, particularly time spent in vigorous physical activity.[46,47] Furthermore, it seems that among the commercially available accelerometers, the one used in this study (Actigraph MTI, model GT1M) showed the best correlation with doubly labelled water derived energy expenditure.[48] It would have been ideal to collect PA data after a few days of wearing the activity monitors; however, owing to logistic reasons, this was not possible. The use of sophisticated methods such as DXA to assess total body fat and abdominal adiposity and the use of accelerometers to assess PA in a relatively large sample of adolescents with a short sampling interval (15 s) are strengths of our study.

The findings of this study support and extend previous findings,[5,8–11,14] and suggest that general exercise recommendations for adolescents should encourage vigorous PA. It is reasonable to recommend moderate PA (for example, walking, cycling at low intensity) for obese and unfit adolescents until higher intensities (for example, playing sports, running) can gradually be attained. Therefore, it seems convenient to encourage less active and obese adolescents to engage in moderate PA and appropriate dieting, gradually progressing to higher intensities as they become less fat and most likely more fit. Further interventional studies examining genetic and dietary factors, in addition to body composition and objectively assessed PA are still needed for a better understanding of these associations in young people.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

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