

Role of Cardiorespiratory Fitness on the Association Between Physical Activity and Abdominal Fat Content in Adolescents: The HELENA Study

Authors

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Key words

- abdominal fat content
- adolescents
- cardiorespiratory fitness
- physical activity

Abstract

▼ We examined the role of cardiorespiratory fitness (CRF) on the association between physical activity (PA) and abdominal fat content in adolescents. Abdominal fat content was measured by waist circumference, waist-to-height ratio and dual energy X-ray absorptiometry (DXA) at 3 regions (R1, R2, and R3). PA and CRF were assessed by accelerometry and the 20m-shuttle run test, respectively. Vigorous PA was inversely associated with waist circumference and waist-to-height ratio (β from -0.149 to -0.197 ; $p < 0.05$). In both CRF groups (i.e., low and high),

vigorous and moderate-to-vigorous PA (also average PA in the low CRF group) were inversely associated with abdominal fat (i.e., R1, R2 and R3; β from -0.146 to -0.244 ; $p < 0.05$). This association did not differ according to CRF group (P for interaction > 0.05), yet the percentage of variance in abdominal fat content, when assessed by DXA, explained by PA was slightly higher in adolescents with low CRF (3–8%) compared to those with high CRF (2–4%). The findings indicate that there is not a clear interaction effect of CRF in the association between PA and abdominal fat in adolescents, yet slightly stronger association was observed in the low fit group.

Introduction

▼ Current evidence suggests that abdominal fat content is an independent risk factor for cardiovascular disease [12, 14]. Abdominal fat content can be measured with reference methods such as nuclear magnetic resonance that allows the assessment of visceral and subcutaneous adipose tissue [2]; dual energy x-ray absorptiometry (DXA) is also emerging as a technique allowing to assess abdominal fat content [15]; or it can also be estimated with field measurements such as waist circumference or waist-to-height ratio [23]. Rapid increases in abdominal fat content among children and adolescents have been reported [12], and the negative consequences on the metabolic health status in youth with an excess of abdominal fat, even for a given weight status, are well-known [10]. Central obesity prevention aiming to reduce abdominal fat content should be a target for intervention to reduce the health risk from the first decades of life. PA has shown to be negatively associated with markers of abdominal fat content such as waist circumference or waist-to-height ratio [5, 22], yet the results are contradictory [6, 21]. High levels

of cardiorespiratory fitness (CRF) are also associated with lower abdominal fat content in adolescents [24]. Moreover, CRF seems to be an interacting factor in the relationships between PA and other health outcomes such as cardiovascular disease risk factors [7]. In a previous study conducted in Swedish children and adolescents, we found that the association between PA and waist circumference varied according to the CRF levels, with an unexpected positive association between PA and waist circumference in those participants with high CRF [21]. Whether the methodology used to assess abdominal fat content might have influenced these unexpected findings is not known. Therefore, in the present study we examined the role of CRF on the association between PA and abdominal fat content assessed by waist circumference, waist-to-height ratio and DXA at 3 different regions of the abdomen in a Spanish cohort of adolescents participating in the HELENA-CSS (Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional) study.

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Methods



Subjects

The HELENA-CSS is a multi-centre study performed in adolescents from 10 European cities [16]. All the adolescents meeting the general HELENA inclusion criteria (not participating simultaneously in another clinical trial, free of any acute infection or disease lasting less than 1 week before the inclusion) and with valid data for age, gender and body mass index, were considered the final HELENA-CSS sample: 3528 adolescents aged 12.5 to 17.5 yr. An accurate assessment of abdominal adiposity was crucial for the purpose of the current study, so we focused our analyses on the sub-sample from Zaragoza (Spain), in which DXA assessment was carried out. A total of 122 males and 132 females with complete data on waist circumference, accelerometry, 20 m shuttle run test and DXA were included in the analyses. More details about the sampling procedures, preparation of the field teams, pilot study and reliability of the data can be found elsewhere [16, 17, 19, 20]. Signed informed consent was obtained from all participants and their parents. The study was performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000), for the Spanish cohort the protocol was approved by the Research Ethics Committee of the Government of Aragón (CEICA) and it also was performed in accordance with the ethical standards of the International Journal of Sport Medicine [8].

Body fat assessment

Abdominal fat content was measured by waist circumference and waist-to-height ratio. More details about the anthropometric procedure have been described elsewhere [17]. Moreover, abdominal fat content was also assessed by DXA at 3 different regions R1, R2, and R3 [11] using a pediatric version of the software QDR-Explorer (Hologic Corp., Software version 12.4, Waltham, MA). 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 T12 vertebrae. More details about the characteristics of this sample and study procedures have been described elsewhere [15].

Physical activity

A uni-axial accelerometer (Actigraph GT1M, Manufacturing Technology Inc. Pensacola, FL, USA) was used to assess PA [15]. The time spent in moderate PA (3–6 METs) and vigorous PA (>6 METs) were calculated based upon cut offs of 2000 and 4000 counts per

minute, respectively [6, 18]. Furthermore, the time spent in moderate-to-vigorous PA (MVPA) was calculated as the sum of moderate and vigorous periods. These cut-offs points to define the intensity categories are similar to those used in previous studies in youth [6, 18]. Average PA was calculated as the total number of counts divided by the registered time (counts/min).

Cardiorespiratory fitness

CRF was assessed by the 20 m shuttle run test. Participants were required to run between 2 lines 20 m apart, while keeping pace with audio signals emitted from a pre-recorded CD. The initial speed was 8.5 km/h, and was increased by 0.5 km/h per minute (1 min equals one stage). More detailed information about the fitness testing protocol can be found elsewhere [19, 20].

Based on the 20 m shuttle run test performance, maximal oxygen consumption (VO_{2max}) was estimated from Leger's equation [13]. CRF was dichotomised (low/high) using the cut-off values proposed by the FITNESSGRAM [26]. These cut-off values have been proposed by scientists and worldwide recognised organizations to define a healthy CRF level at these ages [4, 26].

Statistical analysis

After square root transformation of moderate PA and vigorous PA, and natural logarithm transformation of height, MVPA, average PA, VO_{2max} and DXA parameters (R1, R2 and R3), all the residuals showed a satisfactory pattern. Interaction effects (i.e., sex × main exposures and age × main exposures) were considered to examine whether age or sex modified the associations between PA and abdominal fat content. Since no interaction was found, all sex and age groups were analysed together. All these relationships were analysed in separate regression models that always retained sex, age and height as covariates (basic model). The association between PA and abdominal fat content was analyzed stratifying by CRF level (low/high). For the main analyses, we used SPSS 17.0 software for Windows (SPSS Inc, Chicago, Illinois) and the significance level was set at 5%. Power analyses were performed using the PASS (Power Analysis and Sample Size) software, version 08.0.13 [9], which is based on Cohen's equations [3].

Results



Table 1 shows the association of PA with waist circumference and waist-to-height ratio by CRF levels. Vigorous PA was inversely associated with waist circumference and with waist-to-height

Table 1 Associations of objectively measured physical activity (PA) with waist circumference and waist-to-height ratio in adolescents, stratifying by cardiorespiratory fitness (CRF) level (n = 254).

		Abdominal fat content by anthropometry					
		Waist circumference			Waist-to-height ratio		
		β	R ² Change	P	β	R ² Change	P
low CRF	moderate PA (min day ⁻¹)*	-0.011	0.001	0.896	0.011	<0.001	0.901
	vigorous PA (min day ⁻¹)*	-0.184	0.029	0.035	-0.197	0.034	0.031
	MVPA (min day ⁻¹) [†]	-0.065	0.004	0.457	-0.075	0.005	0.413
	average PA (counts/min) [‡]	-0.127	0.014	0.146	-0.138	0.017	0.131
high CRF	moderate PA (min day ⁻¹)*	0.011	0.001	0.864	0.019	<0.001	0.787
	vigorous PA (min day ⁻¹)*	-0.149	0.018	0.040	-0.166	0.031	0.022
	MVPA (min day ⁻¹) [†]	-0.061	0.003	0.379	-0.065	0.004	0.378
	average PA (counts/min) [‡]	-0.017	<0.001	0.810	-0.021	0.000	0.810

In waist circumference the basic model is composed of sex, age and height

In waist-to-height ratio the basic model is composed of sex and age

β : standardised linear regression coefficient. * Squared root transformed; [†] Natural logarithm transformed

Table 2 Associations between objectively measured physical activity (PA) and abdominal fat content (R1, R2 and R3) by DXA, stratifying by cardiorespiratory fitness (CRF) level (n = 254).

		Abdominal fat by DXA								
		R1			R2			R3		
		β	R ² Change	P	β	R ² Change	P	β	R ² Change	P
low CRF	moderate PA (min day ⁻¹)*	-0.074	0.005	0.397	-0.065	0.004	0.464	-0.045	0.002	0.611
	vigorous PA (min day ⁻¹)*	-0.278	0.067	0.002	-0.302	0.079	0.001	-0.249	0.045	0.005
	MVPA (min day ⁻¹) [†]	-0.178	0.028	0.044	-0.183	0.029	0.042	-0.146	0.019	0.105
	average PA (counts/min) [‡]	-0.235	0.048	0.007	-0.244	0.052	0.006	-0.196	0.034	0.029
high CRF	moderate PA (min day ⁻¹)*	-0.065	0.004	0.319	-0.078	0.006	0.244	-0.078	0.006	0.249
	vigorous PA (min day ⁻¹)*	-0.221	0.040	0.002	-0.223	0.040	0.002	-0.221	0.040	0.003
	MVPA (min day ⁻¹) [†]	-0.150	0.020	0.027	-0.160	0.023	0.022	-0.159	0.023	0.024
	average PA (counts/min) [‡]	-0.090	0.007	0.193	-0.098	0.008	0.166	-0.096	0.008	0.179

β : standardised linear regression coefficient. * Squared root transformed; [†]Natural logarithm transformed; DXA: dual energy x-ray absorptiometry; 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 costovertebrae articulation of the last rib

Basic model: adjusted by sex, age and height

ratio to a similar extent in both low and high CRF levels (β ranged from -0.149 to -0.197 ; p from 0.022 to 0.040). **Table 2** shows the associations between PA and abdominal fat content assessed using DXA (R1, R2 and R3) by CRF levels. In adolescents with low CRF, vigorous PA (β ranged from -0.249 to -0.302 ; p from 0.001 to 0.005) and average PA (β ranged from -0.196 to -0.244 ; p from 0.006 to 0.029) were inversely associated with abdominal fat content. Similar results were found for MVPA with R1 and R2 (β from -0.178 to -0.183 ; p from 0.042 to 0.044). In adolescents with high CRF level, vigorous PA (β ranged from -0.221 to -0.223 ; p from 0.002 to 0.003) and MVPA (β from -0.150 to -0.160 ; p from 0.022 to 0.027) were inversely associated with abdominal fat content. This association did not significantly differ according to CRF group (p for interaction >0.05), yet, the percentage of variance in abdominal fat content, when assessed by DXA, explained by PA was slightly higher in adolescents with low CRF (3–8%) compared to those with high CRF (2–4%). For vigorous PA the percentage of variance explained ranged from ~5–8% in low CRF, while it was ~4% in high CRF adolescents. For average PA the percentage of variance explained ranged from ~3–5% in low CRF, while it was ~0.1% in high CRF adolescents. The results did not change when the analyses were repeated using the age- and gender-specific median to dichotomise the CRF level, instead of the FITNESSGRAM cut offs.

Discussion

Cardiorespiratory fitness has shown to be an interacting factor in the relationships between PA and some health outcomes, e.g. metabolic risk factors [7]. Cardiorespiratory fitness has an important genetic component [1], however PA is the main determinant. People genetically predisposed towards having a better fitness level may also be predisposed towards having a lower fat content, thus PA being less influential. The main hypothesis tested in this study was that the association between PA and abdominal fat would be stronger in the group of adolescents with low CRF compared to that in the group of high CRF. We observed that despite the percentage of variance in abdominal fat explained by PA was slightly greater in the low CRF group, no significant CRF \times PA interaction was found and the differences observed cannot be considered meaningful. The findings observed in this study do not therefore support the working

hypothesis. In a previous study we observed paradoxical findings since vigorous PA was positively associated with abdominal fat content in children and adolescents with high CRF level [21], which do not concur with the present results.

It is important to consider when interpreting these findings that due to 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, did not influence the observations. It is also noteworthy that the accelerometers do not compensate for the relative increase in energy expenditure by increase in body size and non-weight bearing activities such as swimming or cycling are not properly measured by the accelerometers. Despite the limitations highlighted above, accelerometry has proven to correlate reasonably with doubly labelled water-derived energy expenditure [25], and is considered nowadays a method of choice for objectively measuring PA in everyday life of children and adolescents.

DXA data were available only in a sub-sample of the HELENA study. As we failed to find a significant CRF \times PA interaction in relation to abdominal fatness in the present study, considerations about statistical power and type-II error need to be discussed. We performed power analyses on the multiple regression models presented in this study. For a level of significance of 0.05 , with the current sample size, taking into account the R-squared of all the covariates in the model, the number of covariates, and the R-squared added by the interaction term, we observed a power of 40–45% for the main models. The low power observed should be considered a limitation of this study. For exploratory purposes, we made power calculations repeating the same models but using waist circumference from the whole HELENA study sample (i.e., >2000 participants) and the statistical power increased to ~95%. The results for waist circumference using the whole HELENA sample are similar to the ones using the DXA sub-sample (data not shown). This finding suggests that the current results are not likely to differ substantially by increasing the sample size. In addition, the lack of interaction by sex or age suggests that the associations observed in this study are consistent for adolescents of different age, and for boys and girls. The absence of differences among boys and girls in the association between PA and abdominal adiposity has been reported elsewhere [21], and that partially supports our results. The use of

sophisticated methods such as accelerometers and also DXA are notable strengths of our study.

In conclusion, the results indicate that there is not a clear interaction effect of CRF in the association between PA and abdominal fat in adolescents, yet slightly stronger association was observed in the low fit group. The lack of significant interactions suggests that adolescents with either higher or lower CRF levels are similarly susceptible to being positively influenced by PA. Further research is warranted.

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