

Physical Activity, Abdominal Adiposity and Clustered Metabolic Risk in  
Portuguese Children: The European Youth Heart Study

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**OBJECTIVE:** To examine the relationships between objectively measured physical activity and abdominal adiposity with features of the metabolic syndrome in children.

**RESEARCH DESIGN AND METHODS:** School-based, cross-sectional study in 259 girls ( $9.8 \pm 0.3$  years;  $18.0 \pm 3.3$  kg/m<sup>2</sup>;  $27.8 \pm 9.3$  % body fat) and 274 boys ( $9.8 \pm 0.3$  years;  $18.24 \pm 3.5$  kg/m<sup>2</sup>;  $22.0 \pm 9.2$  % body fat) randomly selected. Trunk fat mass (FM) and central FM were measured with DXA. Free-living physical activity (PA) was measured with accelerometry for 4 days. We created a standardised continuously distributed clustered metabolic risk variable using the following subcomponents: blood pressure, fasting glucose, insulin, triglycerides, total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol. We examined the associations between PA variables (total volume, time spent at sedentary, moderate and vigorous intensity of PA) with clustered metabolic risk using general linear models.

**RESULTS:** All PA variables were significantly associated with clustered metabolic risk, independent of gender and sexual maturation ( $p < 0.003$ ). These associations remained statistically significant ( $p < 0.05$ ) but were attenuated after further adjustments for central FM, or trunk FM. The explained variance in clustered risk was approximately twice as high for FM ( $r^2 = 0.15$ ,  $P < 0.01$ ) compared with PA ( $r^2 = 0.08$ ,  $P < 0.05$ ).

**CONCLUSIONS:** Physical activity is associated with clustered metabolic risk independently of precisely measured trunk and central FM in children. Our results emphasises the importance of promoting physical activity in children, which may have beneficial effects on metabolic risk factors regardless of the degree of adiposity.

**Keywords:** accelerometry, energy expenditure, metabolic syndrome risk factors, children,

Evidence suggests that children and adolescents may exhibit a cluster of cardiovascular disease risk factors (1,2), characterized by the coexistence of obesity, dyslipidemia, hypertension and glucose intolerance (2-6). Individual risk factors and clustered risk track from childhood and adolescence through adulthood (7,8). Additionally, abdominal obesity is closely associated with this pathological condition (9-13). Intra-abdominal adipose tissue has been linked to insulin resistance (14,15) with visceral adiposity being strongly related to both insulin and lipid risk factors in children and adolescents, contributing to the early stages of metabolic syndrome (15). We have recently shown that more inactive children are likely to be fatter than children that accumulate higher amounts of moderate and vigorous physical activity objectively measured by accelerometry (16). Objectively measured physical activity is also inversely and independently associated with insulin sensitivity (17), and clustered metabolic risk in Danish 9 to 10 year old children (18). Similarly, objectively measured physical activity is inversely associated with clustering of cardiovascular risk factors (19), and that this association is independent of amount of TV viewing (20). However, data on precisely measured abdominal adiposity was not available in any of these studies.

Dual-energy X-ray absorptiometry (DXA) can be used to assess regional adiposity, by analysing segments of the body (21). Trunk fat mass is measured by subdividing the body into the trunk and other areas. Fat mass in the abdominal region (or central fat mass) can be distinguished by identifying an area as a specific region of interest, usually defined as the upper edge of the second lumbar vertebra to the lower edge of the fourth lumbar vertebra (21-23).

The relative contribution of physical activity components (i.e. overall physical activity and time spent sedentary and at different intensity levels) with clustered metabolic risk remains uncertain, and previous studies have not examined whether the association between physical activity and clustered metabolic risk is independent or modified by precisely measured body fat distribution. Therefore, the aim of the present study was to examine associations between objectively measured physical activity and abdominal fat mass, with clustered metabolic risk in 9 to 10-year old Portuguese children.

## RESEARCH DESIGN AND METHODS

The present investigation is a cross sectional, school-based study in 9-10 year-old Portuguese children, as part of the European Youth Heart Study (EYHS). Selection criteria have been reported elsewhere (16,19,20). A total of 533 healthy children, from the county of Madeira, Portugal, were sampled and invited to participate in the study, together with their parents. After written informed consent was obtained from a parent or guardian, data were collected at the University of Madeira.

Complete anthropometric, DXA body composition measurements, clinical and physical activity measurements were available in 308 (147 girls and 161 boys).

### Anthropometric and body composition measurements

Height was measured to the nearest 0.5 cm with a transportable Harpenden stadiometer without shoes. Weight was measured to the nearest 0.1 kg with a calibrated beam balance scale while the children were wearing light clothing. Body mass index (BMI) was calculated as a weight (kg)/ height squared (m<sup>2</sup>). Dual-energy x-ray absorptiometry was used to assess total and regional body composition (QDR-1500, Hologic, Waltman, USA, pencil beam mode, software version 5.67 enhanced whole body analysis). Following the protocol for DXA described by the manufacturer, a step phantom with six fields of acrylic and aluminium of varying thickness and known absorptive properties was scanned alongside each subject, to serve as an external standard for the analysis of different tissue composition. Fat free mass (FFM) was defined as the sum of the fat-free soft tissue and total body mineral content from the whole-body scans. The same technician positioned the subjects, performed the scans, and completed the scan analysis according to the operator's manual using the standard analysis protocol. Trunk fat mass (Trunk FM) was assessed with the DXA standard protocol, and central fat mass (Central FM) included total fat measured in a region of interest between L<sub>2</sub> and L<sub>4</sub>. Total body percent fat (%fat) and regional fat in the trunk were obtained from the total body DXA scan.

Diastolic and systolic blood pressures were measured in a sitting position after 10 minutes rest with an automated blood pressure unit (Dinamap, Critikon, Tampa, FL). The average of the last three readings was calculated.

Maturation was assessed by the data collectors, using Tanner's 5-stage scale for breast development in girls and pubic hair in boys (24).

### **Blood samples**

After a 12-hour overnight fast, venous blood samples were collected into EDTA vacutainer tubes. Samples were stored at  $-80^{\circ}\text{C}$  and analysed for serum glucose, total cholesterol (TC), HDL- cholesterol, triglycerides (TG), and insulin. HDL-cholesterol, and triglycerides were measured by enzymatic methods in all samples (Olympus Diagnostica GmbH, Hamburg, Germany). Glucose was analysed using the Hexokinase method, measured on an Olympus AU600 auto-analyser in all samples (Olympus Diagnostica GmbH, Hamburg, Germany). Plasma specific insulin was determined by two-site immunometric assays with either  $^{125}\text{I}$  or alkaline phosphatase labels. Cross-reactivity was  $<0.2\%$  with intact proinsulin at 400 pmol/l and  $<1\%$  with 32-33 split proinsulin at 400pmol/l. Inter-assay CVs were 6.6% at 28.6 pmol/l (n=99), 4.8% at 153.1 pmol/l (n=102) and 6.0% at 436.7 pmol/l (n=99), respectively.

### **Assessment of Physical activity**

Habitual physical activity was assessed with the Computer Science & Applications (CSA) accelerometer, also known as the MTI Actigraph (Manufacturing Technology Inc., Fort Walton Beach, FL, USA), over 2 weekdays and 2 weekend days, as previously described (16,19,20). Briefly, the children wore the accelerometer in an elastic waist-band on the right hip during the daytime, except while sleeping, bathing and during aquatic activities. Activity data were stored on a minute-by-minute basis and were downloaded to a computer before analysis. Physical activity components were derived as previously described (16, 20), as follows; total volume of physical activity (counts/min/d), time (min/d) spent in sedentary activities ( $<500$  counts/min), in light (500-1999 counts/min), moderate ( $\geq 2000$  counts/min), and vigorous ( $\geq 3000$  counts/min) intensity of physical activity. Children who did not manage to record  $\geq 600$  min/d of activity for  $\geq 3$ d were excluded from the analysis.

### **Calculation of the metabolic syndrome Z-Score**

The metabolic syndrome is characterized by the clustering of metabolic disorders, including insulin resistance, hyperglycaemia, hypertension, dyslipidemia, and central obesity. Although previous studies in the pediatric population have examined metabolic syndrome abnormalities (5,7), the cut-offs points for the individual

components of the metabolic syndrome have not been defined in children and adolescents. Therefore, we computed a continuous summary variable for clustered metabolic risk (17,19,20). This variable was derived from the following seven metabolic risk indicators: insulin, glucose, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, and blood pressure. For each of these variables, we computed a Z-Score:  $Z = ([\text{value} - \text{mean}] / \text{SD})$ . This score thus only applies to this population, as it is derived from the SD units of the sample mean. The HDL cholesterol Z-Score was multiplied by -1 to indicate higher metabolic risk with increasing value, similar to the rest of the metabolic variables. Systolic and diastolic blood pressure were averaged to produce a single blood pressure Z-Score.

### **Statistical methods**

Data are presented as means  $\pm$  SDs. All variables were checked for normality. Triglycerides and insulin were logarithmically transformed, to normalize their distribution. Differences between genders in body composition variables, physical activity patterns, and clustered metabolic risk were determined by analysis of variance. Pearson's correlation coefficients were used to examine the bivariate associations between the different features of the metabolic syndrome with each of the physical activity components and also to examine the associations between clustered metabolic risk and physical activity variables. General linear models were used to test the independent associations between physical activity variables with clustered metabolic risk. These analyses were conducted separately for each physical activity variable as all activity variables were highly correlated with each other ( $r > 0.70$ ). All analyses were adjusted for gender and sexual maturity. In order to explore whether gender modified any of the associations between clustered metabolic risk and physical activity, we included the interaction term gender by physical activity, separately for each physical activity component model. Similarly, a 3-way interaction term (gender x sexual maturation x physical activity) was also introduced into the respective models. Additional adjustments for regional adiposity were investigated separately within each physical activity model, primarily adjusting for central fat mass and then adjusting for trunk fat mass. Data were analysed using the Statistical Package for Social Sciences (SPSS, version 14.0 for WINDOWS; SPSSInc, Chicago), and the level of significance was set at  $p < 0.05$ .

## RESULTS

Descriptive characteristics are presented in **Table 1**. Age, weight, height, and BMI did not differ significantly between boys and girls. Body fat (total and regional) percentage fat mass, fasting insulin, and clustered metabolic risk score were significantly higher in girls than in boys. Significant gender differences were also observed for all physical activity components. Boys spent less time sedentary and more time in moderate and vigorous intensity physical activity than girls. Physical activity components were significantly associated with fasting triglycerides, fasting insulin, systolic blood pressure (except for vigorous physical activity), and clustered metabolic risk. Time spent sedentary was significantly associated with total triglycerides and fasting insulin, systolic blood pressure, diastolic blood pressure, and clustered metabolic risk ( $r=0.15, 0.12, 0.16, 0.13$  and  $0.19$  for, respectively;  $p<0.01$ ;  $p<0.05$ ). All physical activity components were significantly associated with the metabolic syndrome Z-Score ( $p<0.01$ ). No significant relationships were observed between PA and fasting glucose, total cholesterol, HDL-cholesterol, LDL-cholesterol ( $p>0.05$ ).

**Table 2** displays the association between clustered metabolic risk and the physical activity variables. These results indicate that the total volume of physical activity ( $p=0.001$ ), time spent at sedentary ( $p=0.001$ ), at moderate ( $p=0.002$ ), and at vigorous ( $p=0.003$ ) intensity physical activity were independently associated with metabolic risk, after adjusting for gender and sexual maturity. No significant interactions were observed.

All physical activity components remained significantly associated with clustered metabolic risk, after further adjustments for central fat mass ( $p<0.05$ ). Similarly, total physical activity, time spent at sedentary and at moderate intensity physical activity were significantly associated with clustered metabolic risk, independently of trunk fat mass ( $p<0.001$ ), and time spent at vigorous intensity physical activity was borderline associated with the metabolic risk score, after adjusting for trunk fat mass ( $p=0.059$ ). As indicated by the regression coefficients, the magnitude of associations seemed to increase by intensity of physical activity. Including trunk fat mass into the model added  $\approx 15\%$  in the explained variance of clustered metabolic risk (adjusted  $r^2=0.08$  for total physical activity; adjusted  $r^2=0.23$  for total physical activity and trunk fat

mass). Gender, sexual maturity, time spent sedentary and total trunk fat mass explained 23% of the variance in the clustered risk score ( $r^2=0.23$ ;  $p<0.01$ ) (data not shown).

**Figure 1** shows the means of metabolic syndrome Z-Score stratified by quartiles of total volume (A), time spent at moderate (B), sedentary (C) and vigorous physical activity (D), respectively.

## CONCLUSION

Our results showed that objectively measured physical activity is associated with clustered metabolic risk in children, independently of central fat mass. Further, this association was consistent for all sub-components of physical activity in a dose-response manner. This observation suggests that reducing sedentary behaviour and increasing the totality of activity may have beneficial effects on metabolic risk factors, in healthy 9-10-year old children.

The totality of physical activity and its sub-components, (i.e. time spent at sedentary, at moderate, and at vigorous physical activity) were significantly associated with clustered metabolic risk. Adjusting the analyses for central fat mass attenuated but did not alter these associations. Similar, after adjustments for trunk fat mass, we observed that the fraction of time spent at sedentary activities remained independently and positively associated with metabolic risk, whereas the total amount of activity and time spent at moderate activities remained independently and inversely associated with clustered metabolic risk. In stratified analyses (**Figure 1**), the top quartile of time spent at moderate intensity physical activity had significantly reduced clustered metabolic risk, compared to the two lowest quartiles. The difference between the top quartile and the second quartile was about 60 minutes of activity, equal to walking of about 4 km per hour in 10-year old children (25). Based on the relationship between body movement measured by accelerometry and physical activity energy expenditure (PAEE) measured by doubly labelled water (26,27), the difference in PAEE between the second and fourth quartile is about 800 kJ/day. We have recently suggested that physical activity levels may need to be higher than the current guidelines of 1 hour of moderate intensity physical activity per day (19). The results from this study corroborate our previous findings and underscore the importance of regular physical activity in relation to clustered metabolic risk in children. The association between time spent at vigorous intensity physical activity with clustered metabolic risk was no



longer significant after further adjustments for trunk fat mass. This may be explained by the relatively low amount of time spent at vigorous intensity physical activity in our children. However, an alternative explanation would be that trunk fat mass is a part of the causal pathway between physical activity and clustered metabolic risk. If this is the case, adjusting for trunk fat mass would attenuate the true association. Evidence from exercise training studies in obese children suggests that moderate and vigorous intensity exercise is associated with a favourable metabolic profile (28,29). Some (30-33) but not all (34) previous observational studies have reported an independent association between physical activity and metabolic risk factors in children. For example, subjectively measured physical activity was significantly associated with fasting insulin and insulin sensitivity independently of age, gender, race, maturation, body mass index, percent body fat, waist circumference and lipids levels, in 10 to 16 year old children (30). Further, Ku and colleagues (31) observed an association between vigorous intensity, but not with moderate intensity physical activity, with insulin sensitivity, independent of body fat and fat distribution. However, these studies assessed physical activity by self-report, which limits their possibility to accurately examine the influence of different sub-dimensions of physical activity, as these are likely to be reported with different degree of error. Furthermore, the validity of self-reported physical activity in children is usually considered as poor (35). Few previous studies have examined the association between objectively measured physical activity with clustered metabolic risk in children (17-20). In these studies, an inverse association was observed between the total volume of physical activity with clustered metabolic risk, independent of body fat assessed by skinfolds. The results from the present study are important as they extend our previous observations. First, we showed that not only the total amount of activity, but also time spent sedentary and at moderate intensity activity were associated with clustered metabolic risk in a dose-response manner. Secondly, our results suggest that these associations are independent of precisely measured central and trunk fat mass. The importance of body fat distribution in relation to metabolic disorders in children has been demonstrated previously (12, 36-38). Although, it has been suggested that DXA regional body composition measurements are not superior in relation to metabolic disorders, in comparison with easier anthropometric measurements (39), DXA is a reliable and an accurate method of measuring total and regional body fat (40-42). In the present study, our measure of regional adiposity included both intra-

abdominal and subcutaneous adipose tissue, determined by trunk fat mass (standard DXA analysis protocol), and central fat mass (region of interest between L<sub>2</sub> and L<sub>4</sub>) (21-23). Although this method cannot distinguish between subcutaneous and visceral fat, it is in close agreement with total adipose tissue volume in the abdominal region, measured by the gold standard methods of computed tomography or magnetic resonance imaging (23).

Identifying the detailed association between sub-components of physical activity and metabolic disease risk factors is important to inform primary prevention and future interventions, aimed at increasing physical activity in children. Even if our data suggests that the magnitude of the associations increased by increasing intensity levels, the relative importance of reducing time at sedentary behaviour and increasing the totality of activity, should not be underestimated. This may be important for public health, as an exclusive focus on vigorous intensity physical activity through structured exercise may have counterintuitive consequences, especially in children that find sports and similar high-intensity activities unattractive.

When interpreting the results from this study the following limitations need consideration. First, our study was cross-sectional, thus limiting inferences of causality and its direction. Secondly, although we controlled for the confounding effect of gender and sexual maturity, it is possible that other unmeasured confounders such as genetic variation and early life programming could explain our findings. Thirdly, our results may only be generalisable to Portuguese 9-10 year old children. However, given the increasing evidence of an independent association between objectively measured physical activity, with individual and clustered metabolic risk factors in children and adolescents (17-20), it is likely that our results are generalisable to a large part of healthy children living in affluent societies. Finally, even if we assessed physical activity by an objective and validated method, it has some limitations. The monitor must be removed during bathing and other water activities. It does not pick up upper body movement and other activities which involves minimal vertical acceleration of the body, such as cycling. Regardless, the use of an objective method for assessing physical activity in this study must be considered as a major strength. Other strengths include our precise measure of fat mass by DXA, and the collection of fasting blood samples in a large and randomly selected population of children.

In conclusion, habitual physical activity is inversely associated with metabolic risk independent of central and trunk fat mass, in Portuguese children. Reducing sedentary behaviour and increase the totality of activity may have beneficial effects on metabolic risk factors already in pre-pubertal children. The development and implementation of multidimensional strategies focused on reducing sedentary behaviors and increasing the overall involvement in different types of activities are critically important in the primary prevention of metabolic disorders.

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**REFERENCES**

1. Srinivasan SR, Myers L, Brenson GS. Predictability of childhood adiposity and insulin for developing insulin resistance syndrome (Syndrome X) in young adulthood. The Bogalusa Heart Study. *Diabetes* 2002;51:204-209
2. Andersen LB, Wedderkopp N, Hansen HS, Cooper AR, Froberg K Biological cardiovascular risk factors cluster in Danish children and adolescents: the European Youth Heart Study. *Prev Med* 2003;37:363-7.
3. Chu N-F. Clustering of cardiovascular disease risk factors among obese schoolchildren: the Taipei Children Heart Study. *Am J Clin Nutr* 1998;67:1141-6.
4. Csábi G, Torok K, Jeges S, Molnar D. Presence of metabolic cardiovascular syndrome in obese children. *Eur J Pediatr* 2000;159:91-94.
5. de Ferranti SD, Gauvreau K, Ludwig DS, Neufeld EJ, Newburger JW, Rifai N. Prevalence of the metabolic syndrome in american adolescents. Findings from the Third National Health and Nutrition Examination Survey. *Circulation* 2004;110:2494-2497
6. Invitti C, Maffei C, Gilardini L, Ponitgga B, Mazzilli G, Girola A, Sartorio A, Morabito F, Viberti GS. Metabolic syndrome in obese Caucasian children: prevalence using WHO-derived criteria and association with nontraditional cardiovascular risk factors. *Int J Obes* 2006;30:627-33.
7. Katzmarzyk PT, Perusse L, Malina RM, Bergeron J, Despres JP, Bouchard C. Stability of indicators of the metabolic syndrome from childhood and adolescence to young adulthood: the Quebec Family Study. *J Clin Epidemiol* 2001;54:190-5.

8. Andersen LB, Hasselstrom H, Gronfeldt V, Hansen HS, Froberg K. The relationship between physical fitness and clustered risk, and tracking of clustered risk from adolescence to young adulthood: eight years follow-up in the Danish Youth and Sport Study. *Int J Behav Nutr Phys Act* 2004;1:6.
9. Brambilla P, Manzoni P, Sironi S, Simone P, Del Maschio A, di Natale B, Chiumello G. Peripheral and abdominal adiposity in childhood obesity." *Int J Obes* 1994;18:795-800.
10. van Lenthe FJ, van Mechelen W, Kemper HC, Twisk J. Association of a central pattern of body fat with blood pressure and lipoproteins from adolescence into adulthood. The Amsterdam Growth and Health Study. *Am J Epidemiol* 1998;147: 686-93.
11. Daniels SR, Morrison JA, Sprecher DL, Khoury P, Kimball TR. Association of body fat distribution and cardiovascular risk factors in children and adolescents. *Circulation* 1999;99:541-5.
12. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. *Am J Clin Nutr* 1999;69:308-17.
13. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, Georgiou C, Kafatos A. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. *Int J Obes* 2000;24:1453-8.
14. Caprio S. Relationship between abdominal visceral fat and metabolic risk factors in obese adolescents. *Am J Human Biol* 1999;11:259-266.

15. Gower BA. Syndrome X in children: Influence of ethnicity and visceral fat. *Am J Human Biol* 1999;11:249-257.
16. Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S, Cooper AR, Andersen LB, Riddoch C, Froberg K. Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *Am J Clin Nutr* 2004;80:584-90.
17. Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, Froberg K. Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children: the European Youth Heart Study (EYHS). *Diabetes Care* 2004;27:2141-8.
18. Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, Froberg K. Objectively measures physical activity correlates with indices of insulin resistance in Danish children. *Int J Obes* 2004;28:1503-1508.
19. Andersen LB, Harro M, Sardinha LB, Froberg K, Ekelund U, Brage S, Anderssen SA. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet*. 2006;368:299-304
20. Ekelund U, Brage S, Froberg K, Harro M, Anderssen SA, Sardinha LB, Riddoch C, Andersen LB. TV viewing and physical activity are independently associated with metabolic risk in children: The European Youth Heart Study. *PLoS Medicine* 3(12):e488
21. Jebb SA. Measurement of soft tissue composition by dual energy X-ray absorptiometry." *Br J Nutr* 1997;77:151-63.

22. Treuth, MS, Hunter GR, Kekes-Szabo T. Estimating intraabdominal adipose tissue in women by dual-energy X-ray absorptiometry. *Am J Clin Nutr* 1995;62: 527-32.
23. Kamel EG, McNeill G, Van Wijk MC. Usefulness of anthropometry and DXA in predicting intra-abdominal fat in obese men and women." *Obes Res* 2000;8:36-42.
24. Tanner JM. *Growth at adolescence. 2nd ed.* Oxford, UK: Blackwell Scientific, 1962.
25. Brage S, Wedderkopp N, Andersen LB, Froberg K. Influence of step frequency on movement intensity predictions with the CSA accelerometer: a field validation study in children. *Pediatr Exerc Sci.* 2003;15:277-287
26. Ekelund U, Yngve A, Brage S, Westerterp K, Sjöström M. Body movement and physical activity related energy expenditure in children and adolescents: implications for the interpretation of physical activity data. *Am J Clin Nutr.* 2004;79:851-856
27. Ekelund U, Sjöström M, Yngve A, Poortvliet E, Nilsson A, Froberg K, Wedderkopp N, Westerterp K. Physical activity assessed by activity monitor and doubly labeled water in children. *Med Sci Sports Exerc.* 2001;33:275-281
28. Ferguson MA, Gutin B, Le NA, Karp W, Litaker M, Humphreis M, Okuyama T, Riggs S, Owen S. Effects of exercise training and its cessation on components of the insulin resistance syndrome in obese children. *Int J Obes.* 1999;23:889-95.
29. Gutin B, Owens S. Role of exercise intervention in improving body fat distribution and risk profile in children. *Am J Hum Biol.* 1999;11:237-247.

30. Schmitz KH, Jacobs DR Jr, Hong CP, Steinberger J, Moran A, Sinaiko AR. Association of physical activity with insulin sensitivity in children. *Int J Obes* 2002;26:1310-6.
31. Ku CY, Gower BA, Hunter GR, Goran MI. Racial differences in insulin secretion and sensitivity in prepubertal children: role of physical fitness and physical activity. *Obes Res* 2000;8:506-15.
32. Platat C, Wagner A, Klumpp T, Schweitzer B, Simon C. Relationships of physical activity with metabolic syndrome features and low-grade inflammation in adolescents. *Diabetologia*. 2006;49:2078-2085.
33. Imperatore G, Cheng YJ, Williams DE, Fulton J, Gregg EW. Physical activity, cardiovascular fitness, and insulin sensitivity among U.S. adolescents: the National Health and Nutrition Examination Survey, 1999-2002. *Diabetes Care*. 2006;29:1567-72.
34. Ball GDC, Shaibi GQ, Cruz ML, Watkins MP, Weigensberg MJ, Goran MI. Insulin Sensitivity, Cardiorespiratory Fitness, and Physical Activity in Overweight Hispanic Youth. *Obes. Res*. 2004;12:77-85.
35. Kohl III HW, Fulton FE, Caspersen CJ. Assessment of physical activity among children and adolescents: A review and synthesis. *Prev Med* 2000;31:S54-76.
36. Zonderland ML, Erich WB, Erkelens DW, Kortlandt W, Wit JM, Huisvelt IA, De Ridder CM. Plasma lipids and apoproteins, body fat distribution and body fatness in early pubertal children." *Int J Obes* 1990;14:1039-46.
37. Owens S, Gutin B, Ferguson M, Allison J, Karp W, le NA. Visceral adipose tissue and cardiovascular risk factors in obese children. *J Pediatr* 1998;133:41-45.



38. Goran MI, Malina RM. Fat distribution during childhood and adolescence: Implications for later health outcomes. *Am J Human Biol* 1999;11:187-188.
39. Teixeira PJ, Sardinha LB, Going SB, Lohman TB. Total and regional fat and serum cardiovascular disease risk factors in lean and obese children and adolescents. *Obes Res* 2001;9:432-42.
40. Walton C, Lees B, Crook D, Worthington M, Godsland IF, Stevenson JC. Body fat distribution, rather than overall adiposity, influences serum lipids and lipoproteins in healthy men independently of age. *Am J Med* 1995;99:459-64.
41. Margulies L, Horlick M, Thornton JC, Wang J, Ioannidou E, Heymsfield SB. Reproducibility of pediatric whole body bone and body composition measures by dual-energy X-ray absorptiometry using the GE Lunar Prodigy. *J Clin Densitom* 2005;8:298-304.
42. Buisson AM, Ittenbach RF, Stallings VA, Zemel BS. Methodological agreement between two-compartment body-composition methods in children. *Am J Hum Biol* 2006;18:470-80.

**FIGURE LEGEND**

**Figure 1:** Mean of metabolic syndrome Z-Score stratified by quartiles of physical activity components (total volume, moderate, sedentary and vigorous PA). Errors bars represent 95% CIs. \* Indicates significant differences between quartiles (Tukey *post hoc* analysis).

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**Table 1.** Physical characteristics of the children.

	All (n=308)	Boys (n=161)	Girls (n=147)
Age (yrs)	9.81 ± 0.3	9.81 ± 0.3	9.82 ± 0.3
Weight (kg)	34.1 ± 7.8	34.3 ± 7.7	33.9 ± 7.8
Height (m)	1.37 ± 0.1	1.37 ± 0.1	1.37 ± 0.1
BMI (kg/m <sup>2</sup> )	18.0 ± 3.1	18.1 ± 3.2	17.9 ± 3.0
Total PA (counts/min)	654.0 ± 240.5	724.1 ± 268.0	577.2 ± 177.8**
Sedentary Activity (min.d <sup>-1</sup> )	976.5 ± 82.2	967.1 ± 86.3	986.8 ± 76.5*
Moderate Activity (min.d <sup>-1</sup> )	153.6 ± 51.2	166.0 ± 52.4	140.1 ± 46.2**
Vigorous Activity (min.d <sup>-1</sup> )	23.4 ± 19.0	29.3 ± 21.8	16.9 ± 12.4**
Fat mass (kg)	9.10 ± 5.6	8.19 ± 5.6	10.1 ± 5.4*
Fat mass (%)	24.8 ± 9.4	21.9 ± 9.0	28.0 ± 8.8**
Trunk fat mass (kg)	2.82 ± 2.5	2.39 ± 2.5	3.29 ± 2.5*
Central fat mass (kg)	0.67 ± 0.6	0.59 ± 0.5	0.77 ± 0.5*
SBP (mmHg)	96.8 ± 8.9	97.2 ± 9.3	96.3 ± 8.5
DBP (mmHg)	55.5 ± 6.6	55.2 ± 7.2	55.7 ± 5.8
Glucose (mmol/l)	5.2 ± 0.3	5.2 ± 0.3	5.2 ± 0.4
Total cholesterol (mmol/l)	4.2 ± 0.7	4.2 ± 0.7	4.2 ± 0.8
HDL-C (mmol/l)	1.5 ± 0.3	1.5 ± 0.3	1.5 ± 0.3
LDL-C (mmol/l)	2.4 ± 0.6	2.3 ± 0.6	2.4 ± 0.6
Triglycerides (mmol/l)	0.6 ± 0.3	0.6 ± 0.3	0.6 ± 0.3
Insulin (pmol/l)	42.4 ± 24.2	37.1 ± 19.5	8.3 ± 27.4**
Clustered metabolic risk (Z-Score)	-0.004 ± 0.5	-0.06 ± 0.5	0.06 ± 0.5*

Data are means ± SD. \* $p < 0.05$ ; \*\* $p < 0.001$  for gender differences

**Table 2**  $\beta$ -coefficients from generalized linear models, adjusted for gender and sexual maturation (models 1 to 4), and after further adjustment for central fat mass (models 5 to 8) and trunk fat mass (models 9 to 12).

	$\beta$ -coefficient	95% C	<i>p</i> -value
Model 1: PA (Counts/min)	-0.0004	(-0.001 ; 0.000)	0.001
Model 2: Sedentary (min/d)	0.0010	(0.000 ; 0.002)	0.001
Model 3: Moderate (min/d)	-0.0018	(-0.003 ; -0.001)	0.002
Model 4: Vigorous (min/d)	-0.0047	(-0.008 ; -0.002)	0.003
Model 5:			
Central Fat Mass	0.0004	(0.000 ; 0.000)	<0.001
PA (Counts/min)	-0.0003	(-0.001 ; 0.000)	0.014
Model 6:			
Central Fat Mass	0.0004	(0.000 ; 0.000)	<0.001
Sedentary (min/d)	0.0010	(0.000 ; 0.002)	0.003
Model 7:			
Central Fat Mass	0.0004	(0.000 ; 0.000)	<0.001
Moderate (min/d)	-0.0014	(-0.002 ; 0.000)	0.008
Model 8:			
Central Fat Mass	0.0004	(0.000 ; 0.000)	<0.001
Vigorous (min/d)	-0.0030	(-0.006 ; 0.000)	0.043
Model 9:			
Trunk Fat Mass	0.0852	(0.064 ; 0.107)	<0.001
PA (Counts/min)	-0.0003	(-0.001 ; 0.000)	0.013
Model 10:			
Trunk Fat Mass	0.0875	(0.066 ; 0.109)	<0.001
Sedentary (min/d)	0.0010	(0.000 ; 0.002)	0.003
Model 11:			
Trunk Fat Mass	0.0866	(0.065 ; 0.108)	<0.001
Moderate (min/d)	-0.0014	(-0.002 ; 0.000)	0.008
Model 12:			
Trunk Fat Mass	0.0861	(0.064 ; 0.108)	<0.001
Vigorous (min/d)	-0.0030	(-0.006 ; 0.000)	0.059

Physical activity components were entered separately into the models.

