Published in final edited form as:
Int J Obes (Lond). 2016 January ; 40(1): 28–33. doi:10.1038/ijo.2015.168.

Europe PMC Funders Author Manuscripts

Cross-sectional and prospective associations between moderate to vigorous physical activity and sedentary time with adiposity in children

Adilson Marques[1], **Cláudia Minderico**[1], **Sandra Martins**[2], **António Palmeira**[1,2], **Ulf Ekelund**[3,4,1], and **Luís B. Sardinha**[1]

[1]Centro Interdisciplinar de Estudo da Performance Humana, Faculdade de Motricidade Humana, Universidade de Lisboa, Portugal

[2]Faculdade de Educação Física e Desporto, Universidade Lusófona de Humanidades e Tecnologias, Portugal

[3]Department of Sport Medicine, Norwegian School of Sport Sciences, Norway

[4]MRC Epidemiology Unit, University of Cambridge, United Kingdom

Abstract

Background—Physical activity (PA) and sedentary time (SED) have both been suggested as potential risk factors for adiposity in children. However, there is paucity of data examining the temporal associations between these variables.

Objective—This study aimed to analyze the cross-sectional and prospective associations between PA, SED and body composition in children.

Methods—510 children (age at baseline 10.1±0.8, age at follow up 11.8±0.9) from 6 Portuguese schools from the Oeiras Municipality participated in this study. PA and SED were measured by accelerometry and trunk fat mass (TFM) and body fat mass (BFM) were measured by Dual energy X-ray absorptiometry (DXA). Fat mass index (FMI) was calculated as BFM divided by height squared. Several regression models adjusted for age, sex, maturity status, follow-up duration, baseline levels of the outcome variable, and SED or MVPA were performed.

Results—Moderate to vigorous PA (MVPA) (min/d) was cross-sectionally inversely associated with adiposity indexes (FMI, TFM, BFM). Adiposity indexes were inversely associated with time in MVPA. In prospective analyses, MVPA was associated with a lower levels of FMI ($\beta=-0.37$, 95% CI: −0.49 to −0.26, $p<0.001$), TFM ($\beta=-0.20$, 95% CI: −0.29 to −0.10, $p<0.001$), and BFM ($\beta=-0.37$, 95% CI: −0.49 to −0.26, $p<0.001$). When the model was adjusted for age, sex, maturity status and for baseline levels of the outcome variables MVPA remained a significant predictor of lower adiposity indexes (FMI: $\beta=-0.09$, 95% CI: −0.16 to −0.01, $p<0.05$; TFM: $\beta=-0.08$, 95% CI: −0.15 to −0.01, $p<0.05$; BFM: $\beta=-0.07$, 95% CI: −0.15 to 0.00, $p<0.05$). Adiposity was not

Corresponding author: Luís B. Sardinha, Faculdade de Motricidade Humana, Universidade de Lisboa, Estrada da Costa, 1499-002 Cruz-Quebrada, Portugal. Telephone: (00351) 214149100, Fax: (00351) 214151248, lsardinha@fmh.ulisboa.pt.

Conflict of interests
Authors declare that there are not any conflicts of interest related to the research reported in the manuscript.

associated with MVPA when modeled as the exposure in prospective analyses. SED was not related with adiposity indexes, except for the relationship with FMI.

Conclusions—In cross-sectional and prospective analyses, MVPA is associated with lower adiposity independent of covariates and SED. Results suggest that promoting MVPA is important for preventing gain in adiposity in healthy children.

Introduction

Childhood physical activity (PA) is associated with present and future health benefits,[1, 2] and there are some evidence that PA may prevent weight gain and obesity.[1] On the contrary, sedentary time (SED) has been linked to overweight and obesity.[3] Therefore, it is recommended that young people should spend less time sedentary and engage in at least 60 minutes of moderate to vigorous PA (MVPA) every day to benefit health and prevent obesity.[4]

PA and SED have been examined as potential risk factors for adiposity in several studies;[3, 5-7] however, the existing evidence is predominantly obtained from cross-sectional studies.[3] A cross-sectional study design is limited as it does not examine the directionality of the relationship between exposure and outcome variables. Thus, it is not possible to determine if low or high levels of PA or SED are the result of accumulated fat mass; or if body composition affect PA levels and SED.[8, 9] It has therefore been suggested that the association between PA, SED and body composition may be bidirectional as previously observed in adults.[10]

Few studies have addressed the issue of bidirectional relationship between PA, SED and body composition.[9, 11-13] Some of these studies observed that body composition predicted PA[9, 12] and SED,[8] but not vice-versa; whereas others did not observe such association.[11, 13-15] Inconsistent results may partially be due to different methods for assessing the exposure and outcome variables, small sample sizes and differences in duration of follow-up. Further, none of these studies examined the cross-sectional and prospective associations between PA, SED and both total and trunk fat mass. Understanding the magnitude and direction of associations between PA, SED and central fat patterning is important for clinical and preventive purposes as a central fat patterning may be more harmful than overall body fat.

Therefore, using objectively measures of PA, SED and body composition from PESSOA Project (Physical Activity and Family-based Intervention in Pediatric Obesity Prevention in the School Setting), we analyzed the cross-sectional and prospective associations between MVPA, SED and trunk fat mass (TFM), body fat mass (BFM), and fat mass index (FMI) in children.

Methods and procedures

Study design and population

Participants were recruited from all schools with fifth grade classes (6 schools, 1042 participants) from the Oeiras Municipality, in Lisbon Metropolitan area, Portugal. These

Europe PMC Funders Author Manuscripts

Europe PMC Funders Author Manuscripts

schools participated in a school-based cluster randomized controlled trial (clinical trial registry: ISRCTN76013675) to evaluate the impact of an intervention in childhood obesity between 2010 and 2011, as describes previously.[16] Sample for the present study comprised data from 510 fifth grade children (M_{age}=10.1±0.8) whose parents or guardians provided written informed consent to come to the laboratory for dual energy X-ray absorptiometry (DXA) assessment at baseline and follow-up. At baseline age and sex adjusted body mass index (BMI) was similar ($p>0.05$) in participants of the present study (19.05±3.50 kg/m^2) as compared with those that did not had DXA analysis (18.84±3.48 kg/m^2) and were not included in this study. The program was developed by the Faculty of Human Kinetics from University of Lisbon (former Technical University of Lisbon), and supported by the Portugal's Ministry of Education and Science and Foundation of Science and Technology. Participants were informed about the objectives of the study and informed written consent was obtained from parents and assent was obtained from children. The study protocol was approved by the Scientific Committee of the Faculty of Human Kinetics of University of Lisbon, the Portuguese Minister of Education, and Foundation of Science and Technology.

Assessment of PA and SED

Free living PA and SED were measured with the accelerometer GT1M Actigraph. Participants were instructed to wear the accelerometer, attached tightly to the hip by an elastic belt on the right side, during waking hours except while bathing or doing other water-based activities. The length of the sampling interval was set at 15 seconds to allow a more refined estimate of PA intensity.[17] Data were downloaded to a computer and an automated data reduction program (MAHUFFE) was used to analyze the accelerometer data. Sequences of consecutive zeros for periods with 60 minutes were identified and were defined as missing data. At least three days of recording (two weekdays and one weekend day) with a minimum of 600 minutes wear time was required for inclusion of a day in analysis. Overall activity levels were expressed in terms of counts/min, and intensity thresholds were established according a previous study.[18] MVPA was defined as ≥4 metabolic equivalents (METs) and age-specific intensity thresholds according to those proposed by Freedson et al.[19]. SED was set at a range between 0-100 counts/min.

Adiposity indexes

At the schools, children's height was measured barefoot and wearing minimal clothes to the nearest 0.5 cm, using a portable stadiometer. Weight was measured to the nearest 0.1 kg on an electronic scale. BMI was then calculated based on mass (kilograms) divided by height (square meters). Children were classified normal weight and overweight/obese categories according to age- and gender-specific cut-off points proposed by the International Obesity Task Force.[20] Body fat measures were performed at the Faculty of Human Kinetics of University of Lisbon. DXA whole-body scan was performed to assess TFM and BFM (Hologic Explorer-W, fan-beam densitometer, software QDR for Windows version. 12.4, Hologic). TFM was used as an estimate of a central pattern of fat (visceral and subcutaneous), and BFM was used as an estimate of total body fatness. The same technician positioned the participants, performed the scans and executed the analysis according to the operator's manual using the standard analysis protocol. The scans were performed in the morning. Quality control with spine phantom was made in the mornings prior to each assessment, and with a step phantom every week throughout the measurement period. FMI was then calculated as BFM in kilograms divided by height squared.

Maturity status

Maturity status was predicted with the gender-specific equations of Mirwald, et al.[21] to estimate the maturity offset.

Boys: Maturity offset = −9.236 + 0.0002708 (leg length × sitting height) − 0.001663 (age × leg length) + 0.007216 (age × sitting height) + 0.02292 (weight / height)

Girls: Maturity offset = −9.376 + 0.0001882 (leg length × sitting height) + 0.0022 (age × leg length) + 0.005841 (age × sitting height) − 0.002658 (age × weight) + 0.07693 (weight / height)

Data analysis

Mean and standard deviation were calculated for baseline and follow up characteristics for the whole sample and for boys and girls separately. T-tests for paired samples were used to examine differences baseline and follow up characteristics. Preliminary analyses showed that MVPA, SED, FMI, TFM, and BFM did not have normally distributed residuals and were therefore log-transformed to achieve normality before further analyses. Correlation coefficient between MVPA and SED was calculated with Pearson's R. The cross-sectional and prospective association between MVPA and SED with adiposity indexes, were assessed using linear mixed models with school as a random factor. We first modeled MVPA and SED as exposure variables and adiposity indexes as outcomes and thereafter examined a potential bidirectional association by modeling adiposity indexes as exposures. As no significant interaction with sex was observed, the main results are presented for both sexes combined, adjusted for sex. Four different models were performed. Model 1 was the crude (unadjusted) analysis between PA and SED with adiposity indexes. Model 2 was adjusted for age, sex, maturity status, and follow-up duration. In the model 3 baseline levels of the outcome variable was added to model 2 (only when examining the prospective associations). Finally, in model 4 SED was added to model when MVPA was the exposure of interest and vice versa. The associations between MVPA, SED, and trunk fat mass were adjusted for residual fat mass (total body fat minus trunk fat mass). Statistical tests were two-sided with significant defined as $p<0.05$. Analyses were completed using IBM SPSS Statistics 22.

Results

Participants characteristics at baseline and follow up are presented in table 1 for both sex combined and separately for boys and girls. For both sexes there were a significant increase in weight, height, FMI, TFM, BFM, and SED. Time in MVPA and prevalence of overweight/obesity decreased significantly among boys and girls.

MVPA at baseline was positively correlated with MVPA at follow up ($r=0.567$, $p<0.001$). Likewise SED at baseline was also positively correlated with SED at follow up ($r=0.401$, $p<0.001$). Conversely, MVPA at baseline was negatively correlated with SED at baseline ($r=-0.439$, $p<0.001$) and at follow up ($r=-0.277$, $p<0.001$). MVPA at follow up was also

Europe PMC Funders Author Manuscripts

negatively correlated with SED at baseline (r=−0.242, $p<0.001$) and at follow up (r=−0.468, $p<0.001$).

In the cross-sectional analyses, MVPA was significant negatively associated with adiposity indexes (FMI, TFM, and BFM) at baseline (age 10.1 years) and at follow up (age 11.8 years) (table 2). Similarly, adiposity indexes were also significant negatively associated with MVPA, suggesting a bidirectional relationship. Each additional minute in MVPA was related to −0.02 units of FMI ($p<0.001$), −0.02 kg of TFM ($p<0.001$), and −0.05 kg of BFM ($p<0.001$) at baseline in the unadjusted analyses. At follow up, each additional minute in MVPA was related to −0.02 units of FMI ($p<0.001$), −0.02 kg of TFM ($p<0.001$), and −0.04 kg of BFM ($p<0.001$). The relationship between MVPA and adiposity indexes was materially unchanged following adjustment for SED. On the other hand, the relationship between SED and adiposity indexes, and vice-versa, were not significant (table 3).

In the prospective analyses, MVPA was inversely associated with FMI (β=−0.37, 95% CI: −0.49 to −0.26), TFM (β=−0.20, 95% CI: −0.29 to −0.10), and BFM (β=−0.37, 95% CI: −0.49 to −0.26) in the unadjusted model (table 4). Following adjustment for age, sex, maturity status, follow-up duration (model 2), and baseline measure of the outcome variable (model 3) the results were attenuated although statistically significant. In the final model we further adjusted Model 3 for SED to examine whether the associations were independent of baseline levels of sedentary time. In this model (model 4) MVPA remained as a significant predictor of lower adiposity indexes (FMI: β=−0.09, 95% CI: −0.16 to −0.01; TFM: β= −0.08, 95% CI: −0.15 to −0.01; BFM: β=−0.07, 95% CI: −0.15 to 0.00). Each additional 10 minutes of MVPA at baseline was associated with a reduction of 0.11 units of FMI ($p=0.004$), 0.10 kg of TFM ($p<0.001$), and 0.23 kg of BFM ($p=0.002$) at follow up. We thereafter modeled FMI, TFM, and BFM as exposure variables to examine a potential prospective bi-directional association. In models adjusted for age, sex, maturity status, MVPA at baseline and also for SED, adiposity indexes were not significantly associated with MVPA at follow up.

Time spent in SED was not significantly associated with any adiposity indexes in the unadjusted an adjusted analyses, except for FMI (β=−0.24, 95% CI: −0.46 to −0.03) when model was adjusted for age, sex, maturity status, follow-up duration, baseline levels of the outcome variable and MVPA (table 5). No association between baseline adiposity indexes (modeled as exposure variables) and SED at follow up was observed in any of the models.

In sensitivity analyses we reanalyzed our data stratified by sex due to the marked difference in both physical activity and body composition between sexes. The results were materially unchanged although the magnitude of associations between MVPA and adiposity were somewhat stronger in boys in cross-sectional analyses and in girls in prospective analyses. However, these differences should be interpreted with caution due to the lack of significant interaction (sex × MVPA) and the relatively small sample size in sex stratified analyses.

Europe PMC Funders Author Manuscripts

Discussion

This study used repeated measures over two-year follow-up period to assess cross-sectional and prospective association between objectively measured MVPA, SED and adiposity indexes in children. Overall, MVPA was significantly inversely associated with FMI, TFM and BFM independent of confounding factors and sedentary time in both cross-sectional and prospective analyses. In opposite, sedentary time was only related to one of the adiposity indexes in one of the prospective models. When adiposity indexes were modeled as exposure variables, we observed bi-directional associations in cross-sectional but not in the prospective analyses. Taken together, our results suggest that increasing the amount of time spent children engage in MVPA may have substantial impact on adiposity levels whereas reducing SED seems less important from a public health perspective.

Several previous cross sectional studies in children assessing PA with accelerometry have observed inverse associations between MVPA and adiposity measures, such as BMI and FMI;[5, 6, 22, 23] however, the literature are not consistent and rather than giving clear support to the notion that PA or MVPA is associated with lower fat mass results point to a multifaceted relationship between total PA, MVPA and body weight.[3, 11, 24] Prentice-Dunn[3] suggested that the mixed findings could be due to the fact that child weight status influences the intensity and frequency of PA, but unfortunately cross-sectional analyses cannot be used to infer temporality.

The prospective negative association between MVPA and adiposity indexes observed in our study is in agreement with results from the Avon Longitudinal Study of Parent and Children that showed that PA was inversely related with fat mass.[25] In the present study, MVPA remained a predictor of adiposity indexes even when analyses were adjusted for several potential confounders including sedentary time, which reinforce the role of MVPA to possibly prevent unhealthy gain in fat mass. However, the results in the literature for a prospective association between MVPA and adiposity indexes are not consensual. A systematic review of prospective studies among children and adults suggested that PA is not strongly prospectively related with adiposity, and concluded that despite the well-established health benefits of PA,[2] it may not be a determinant of adiposity.[13] Similarly, among Brazilian children no longitudinal association was found between PA and body composition.[11] There are some possible explanations for the differences between studies. Different methods for assessing sedentary time, physical activity and body composition and different analytical procedures may affect the results. The assessment of PA differs between studies, including objective measures[22, 25] and self-report.[11] Furthermore, several methods and variables have been used for assessing adiposity, including anthropometric measures such as BMI,[5, 23] FMI[22] waist circumference,[23] and skinfolds,[6, 11] whereas few previous studies have assessed fat mass by means of DXA scanning.[25] Reassuringly, our results are in agreement with those from the ALSPAC study which also assessed fat mass using DXA.

In agreement with some previous studies[11, 26] we did not observe a prospective association between adiposity indexes (modeled as exposure variables) and time spent in MVPA. In opposite, others[9] observed that increased adiposity was associated with a reduction in PA, suggesting that the prospective association between adiposity and PA may differ pending on the measurement of the adiposity variables.[12, 27] Taken together, the current and opposite findings do not allow a firm conclusion about causality for the direction of the relationship between MVPA and adiposity. This may affect the planning of future interventions, because based on the current knowledge one could conclude that interventions should aim to increase MVPA in order to reduced adiposity,[25, 28] whereas it may be equally likely that intervention programs should targeting adiposity in order to increase PA levels.[29]

Longitudinal studies have suggested that SED is related to weigh gain,[30] and increase in BMI.[14] Screen time has also been reported to be related with adiposity,[31] although accelerometer assessed SED did not predict body fat or BMI.[32] It is therefore likely that sedentary behaviors may be the result of fatness rather than its cause.[14] Findings from this study suggested that SED did not predict adiposity at follow up, confirming findings from a recent review.[33]

Some limitations should be noted. First, the time interval between measurements was less than two years. It would be of importance to follow these children throughout adolescence, due to the marked decline in MVPA and increase SED by increasing age.[34] All participants were from an urban location, which means that results should not be generalized to those who are from rural areas. Although analyses were controlled for potential confounders, we cannot rule out our results are explained by residual confounding due to unmeasured or poorly measured confounders (e.g. socioeconomic status, dietary intake, birth weight and early life growth and genotype). Dietary intake is a possible confounder for the association between MVPA, SED and adiposity indexes, because it is an important factor in determining energy balance.[35] We included all children who provided data for at least 3 days (including one weekend day). Thus, the observed levels of MVPA and SED may not be fully representative of the children's usual activity patterns.

The strengths of the study include the relatively large sample of children in which objective methods was used to assess MVPA, SED, and adiposity indexes, thereby reducing the measurement errors and recall bias associated with self-reported measures. Baseline and follow up data were collected by the same trained staff, which likely reduced the possibility of random measurements error. All exposure and outcome variables were analyzed in their continuous form, decreasing the likelihood of the loss of statistical power that normally occurs when categorical variables are used. Mixed models considered schools as a random factor, taking into account both within-individual and between individual variance, and therefore optimized statistical power. Finally, the prospective analyses allowed determination of the directionality of the relationship between MVPA, SED and adiposity indexes.

In conclusion, results of our study suggest that higher levels of MVPA are inversely associated with lower adiposity and vice-versa in cross-sectional analyses. In prospective analyses, MVPA predicted lower adiposity indexes even after adjustments for covariates and SED. SED was not related with any of the adiposity indexes, except for the relationship with FMI. Promoting PA of at least moderate intensity may be more important than reducing SED for preventing gain in adiposity in healthy children.

Acknowledgment

The study was supported by the Portuguese Foundation of Science and Technology. Support/grant: PTDC/DES/108372/2008.

References

1. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity--a systematic review of longitudinal studies. BMC Public Health. 2013; 13:813. [PubMed: 24010994]
2. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010; 7:40. [PubMed: 20459784]
3. Prentice-Dunn H, Prentice-Dunn S. Physical activity, sedentary behavior, and childhood obesity: A review of cross-sectional studies. Psychology Health & Medicine. 2012; 17:255–273.
4. WHO. Global recommendations on physical activity for health. World Health Organization; Geneva, Switzerland: 2010.
5. Chaput JP, Lambert M, Mathieu ME, Tremblay MS, Loughlin JO, Tremblay A. Physical activity vs. sedentary time: independent associations with adiposity in children. Pediatric Obesity. 2012; 7:251–258. [PubMed: 22461356]
6. Ekelund U, Sardinha LB, Anderssen SA, Harro M, Franks PW, Brage S, et al. 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; 80:584–590. [PubMed: 15321796]
7. Tanaka C, Reilly JJ, Huang WY. Longitudinal changes in objectively measured sedentary behaviour and their relationship with adiposity in children and adolescents: systematic review and evidence appraisal. Obes Rev. 2014
8. Hjorth MF, Chaput JP, Ritz C, Dalskov SM, Andersen R, Astrup A, et al. Fatness predicts decreased physical activity and increased sedentary time, but not vice versa: support from a longitudinal study in 8- to 11-year-old children. Int J Obes. 2013
9. Richmond RC, Smith GD, Ness AR, den Hoed M, McMahon G, Timpson NJ. Assessing causality in the association between child adiposity and physical activity levels: A Mendelian randomization analysis. Plos Medicine. 2014; 11
10. Golubic R, Wijndaele K, Sharp SJ, Simmons RK, Griffin SJ, Wareham NJ, et al. Physical activity, sedentary time and gain in overall and central body fat: 7-year follow-up of the ProActive trial cohort. Int J Obes. 2014
11. Hallal PC, Reichert FF, Ekelund U, Dumith SC, Menezes AM, Victora CG, et al. Bidirectional cross-sectional and prospective associations between physical activity and body composition in adolescence: birth cohort study. J Sports Sci. 2012; 30:183–90. [PubMed: 22141438]
12. Metcalf BS, Hosking J, Jeffery AN, Voss LD, Henley W, Wilkin TJ. Fatness leads to inactivity, but inactivity does not lead to fatness: a longitudinal study in children (EarlyBird 45). Arch Dis Child. 2011; 96:942–7. [PubMed: 20573741]
13. Wilks DC, Besson H, Lindroos AK, Ekelund U. Objectively measured physical activity and obesity prevention in children, adolescents and adults: a systematic review of prospective studies. Obes Rev. 2011; 12:e119–29. [PubMed: 20604868]
14. Mitchell JA, Pate RR, Beets MW, Nader PR. Time spent in sedentary behavior and changes in childhood BMI: a longitudinal study from ages 9 to 15 years. Int J Obes. 2013; 37:54–60.
15. Burgi F, Meyer U, Granacher U, Schindler C, Marques-Vidal P, Kriemler S, et al. Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: a cross-sectional and longitudinal study (Ballabeina). Int J Obes. 2011; 35:937–944.
16. Quaresma AM, Palmeira AL, Martins SS, Minderico CS, Sardinha LB. Effect of a school-based intervention on physical activity and quality of life through serial mediation of social support and exercise motivation: the PESSOA program. Health Educ Res. 2014; 29:906–17. [PubMed: 25274722]

17. Ward DS, Evenson KR, Vaughn A, Rodgers AB, Troiano RP. Accelerometer use in physical activity: best practices and research recommendations. Med Sci Sports Exerc. 2005; 37:S582–8. [PubMed: 16294121]

18. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc. 2011; 43:1360–8. [PubMed: 21131873]

19. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. Med Sci Sports Exerc. 2005; 37:S523–30. [PubMed: 16294115]

20. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. Br Med J. 2000; 320:1240–1243. [PubMed: 10797032]

21. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. Med Sci Sports Exerc. 2002; 34:689–94. [PubMed: 11932580]

22. Pearce MS, Basterfield L, Mann KD, Parkinson KN, Adamson AJ, Reilly JJ. Early predictors of objectively measured physical activity and sedentary behaviour in 8-10 year old children: The Gateshead Millennium Study. Plos One. 2012; 7

23. Steele RM, van Sluijs EM, Cassidy A, Griffin SJ, Ekelund U. Targeting sedentary time or moderate- and vigorous-intensity activity: independent relations with adiposity in a population-based sample of 10-y-old British children. Am J Clin Nutr. 2009; 90:1185–92. [PubMed: 19776141]

24. Aires L, Silva P, Silva G, Santos MP, Ribeiro JC, Mota J. Intensity of physical activity, cardiorespiratory fitness, and body mass index in youth. J Phys Act Health. 2010; 7:54–9. [PubMed: 20231755]

25. Riddoch CJ, Leary SD, Ness AR, Blair SN, Deere K, Mattocks C, et al. Prospective associations between objective measures of physical activity and fat mass in 12-14 year old children: the Avon Longitudinal Study of Parents and Children (ALSPAC). Br Med J. 2009; 339

26. Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA. 2012; 307:704–12. [PubMed: 22337681]

27. Kwon S, Janz KF, Burns TL, Levy SM. Effects of adiposity on physical activity in childhood: Iowa Bone Development Study. Med Sci Sports Exerc. 2011; 43:443–8. [PubMed: 20631643]

28. Wittmeier KD, Mollard RC, Kriellaars DJ. Physical activity intensity and risk of overweight and adiposity in children. Obesity (Silver Spring). 2008; 16:415–20. [PubMed: 18239653]

29. Deforche B, Haerens L, de Bourdeaudhuij I. How to make overweight children exercise and follow the recommendations. Int J Pediatr Obes. 2011; 6(Suppl 1):35–41. [PubMed: 21905814]

30. Butte NF, Cai G, Cole SA, Wilson TA, Fisher JO, Zakeri IF, et al. Metabolic and behavioral predictors of weight gain in Hispanic children: the Viva la Familia Study. Am J Clin Nutr. 2007; 85:1478–85. [PubMed: 17556682]

31. Boone JE, Gordon-Larsen P, Adair LS, Popkin BM. Screen time and physical activity during adolescence: longitudinal effects on obesity in young adulthood. Int J Behav Nutr Phys Act. 2007; 4:26. [PubMed: 17559668]

32. Janz KF, Burns TL, Levy SM. Tracking of activity and sedentary behaviors in childhood: the Iowa Bone Development Study. Am J Prev Med. 2005; 29:171–8. [PubMed: 16168865]

33. Ekelund U, Hildebrand M, Collings PJ. Physical activity, sedentary time and adiposity during the first two decades of life. Proc Nutr Soc. 2014; 73:319–329. [PubMed: 24548769]

34. Baptista F, Santos DA, Silva AM, Mota J, Santos R, Vale S, et al. Prevalence of the Portuguese population attaining sufficient physical activity. Med Sci Sports Exerc. 2012; 44:466–73. [PubMed: 21844823]

35. Hill JO, Wyatt HR, Peters JC. Energy balance and obesity. Circulation. 2012; 126:126–132. [PubMed: 22753534]

Europe PMC Funders Author Manuscripts

Table 1

Participant characteristics at baseline and at follow.

	Total			Boys			Girls		
	Baseline (n=510)	**Follow up (n=497)**	***p***	**Baseline (n=258)**	**Follow up (n=235)**	***p***	**Baseline (n=252)**	**Follow up (n=262)**	***p***
Age (years)	10.1±0.8	11.8±0.9	<0.001	10.2±0.8	11.9±1.0	<0.001	10.0±0.7	11.7±0.9	<0.001
Weight (kg)	39.5±9.3	47.2±10.9	<0.001	39.0±8.9	46.7±11.3	<0.001	40.1±9.7	47.8±10.4	<0.001
Height (m)	1.4±0.1	1.5±0.1	<0.001	1.4±0.1	1.5±0.1	<0.001	1.4±0.1	1.5±0.1	<0.001
FMI (kg/m^2)	5.5±2.6	5.8±2.7	<0.001	5.0±2.5	5.3±2.8	0.007	6.0±2.5	6.3±2.5	<0.001
Trunk fat mass (kg)[1]	4.2±2.7	4.7±2.9	<0.001	3.7±2.5	4.0±2.9	<0.001	4.8±2.8	5.3±2.9	<0.001
Body fat mass (kg)[1]	11.2±5.6	12.6±6.2	<0.001	10.1±5.3	11.1±6.2	<0.001	12.4±5.6	13.8±5.8	<0.001
MVPA (min/day)	59.3±23.5	53.7±24.8	<0.001	67.8±25.6	64.2±25.3	0.044	51.4±18.1	44.8±20.6	<0.001
Sedentary time (min/day)	526.1±68.9	544.7±73.9	<0.001	520.4±73.0	537.5±79.1	0.004	531.3±64.5	550.8±68.7	0.001
BMI (%)			<0.001			<0.001			<0.001
Normal weight	67.0	69.0		69.1	70.0		64.6	68.0	
Overweight/obese	33.0	31.0		30.9	30.0		35.4	32.0	

Abbreviations: FMI, fat mass index; PA, physical activity, MVPA, moderate to vigorous physical activity; BMI, body mass index.

Age, weight, height, adiposity indexes, MVPA, and sedentary time were tested by T-tests for paired samples. BMI (%) was tested by Chi-square.

[1]Measured by dual energy X-ray absorptiometry (DXA).

Europe PMC Funders Author Manuscripts

Table 2

Cross-sectional associations between MVPA with fat indicators.

		Baseline		Follow up	
		Model 1	Model 2	Model 1	Model 2
Exposure	Outcome	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
MVPA (min/day)	FMI (kg/m^2)	−0.23 (−0.34 to −0.13)***	−0.24 (−0.36 to −0.12)***	−0.12 (−0.21 to −0.03)*	−0.14 (−0.25 to −0.03)*
MVPA (min/day)	Trunk fat mass (kg)	−0.12 (−0.19 to −0.04)**	−0.11 (−0.19 to −0.02)*	−0.10 (−0.17 to −0.03)**	−0.14 (−0.22 to −0.06)***
MVPA (min/day)	Body fat mass (kg)	−0.23 (−0.33 to −0.13)***	−0.24 (−0.35 to −0.13)***	0.12 (−0.20 to −0.03)**	−0.15 (−0.24 to −0.05)**
FMI (kg/m^2)	MVPA (min/day)	−0.22 (−0.33 to −0.13)***	−0.18 (−0.28 to −0.09)***	−0.22 (−0.39 to 0.05)*	−0.20 (−0.36 to −0.05)*
Trunk fat mass (kg)	MVPA (min/day)	−0.20 (−0.33 to −0.06)**	−0.14 (−0.26 to −0.02)*	−0.27 (−0.46 to −0.09)**	−0.30 (−0.47 to −0.13)***
Body fat mass (kg)	MVPA (min/day)	−0.24 (−0.35 to −0.14)***	−0.20 (−0.30 to −0.11)***	0.23 (−0.39 to −0.06)**	−0.22 (−0.37 to −0.07)**

Abbreviation: MVPA, moderate to vigorous physical activity; FMI, fat mass index; CI, confidence interval.

MVPA, sedentary time, FMI, TFM, and BFM did not have normally distributed residuals and were therefore log-transformed for analyses.

The association between sedentary time and trunk fat mass, and vice versa, was adjusted for residual fat mass (total body fat minus trunk fat mass).

Model 1: Analyses were adjusted for age, sex, and maturity status. Model 2: Analyses were adjusted for age, sex, maturity status, and sedentary time.

* $p<0.05$,

** $p<0.01$,

*** $p<0.001$.

Europe PMC Funders Author Manuscripts

Table 3

Cross-sectional associations between sedentary time with fat indicators.

		Baseline		Follow up	
		Model 1	Model 2	Model 1	Model 2
Exposure	Outcome	β (95% CI)[1]	β (95% CI)[2]	β (95% CI)[1]	β (95% CI)[2]
Sedentary time (min/day)	FMI (kg/m^2)	0.30 (0.03 to 0.63)	−0.04 (−0.40 to 0.33)	0.08 (−0.28 to 0.44)	−0.17 (−0.58 to 0.23)
Sedentary time (min/day)	Trunk fat mass (kg)	0.22 (−0.02 to 0.45)	−0.07 (−0.19 to 0.34)	0.08 (−0.34 to 0.18)	−0.31 (−0.59 to 0.01)
Sedentary time (min/day)	Body fat mass (kg)	0.28 (−0.02 to 0.58)	−0.05 (−0.39 to 0.28)	0.03 (−0.29 to 0.36)	−0.22 (−0.58 to 0.14)
FMI (kg/m^2)	Sedentary time (min/day)	0.03 (0.00 to 0.07)	−0.00 (−0.03 to 0.03)	0.01 (−0.04 to 0.06)	−0.02 (−0.06 to 0.02)
Trunk fat mass (kg)	Sedentary time (min/day	0.04 (0.00 to 0.09)	0.01 (−0.03 to 0.05)	−0.02 (−0.07 to 0.04)	−0.05 (−0.10 to 0.00)
Body fat mass (kg)	Sedentary time (min/day	0.03 (0.00 to 0.07)	−0.01 (−0.04 to 0.03)	0.00 (−0.04 to 0.04)	−0.02 (−0.06 to 0.02)

Abbreviation: FMI, fat mass index; CI, confidence interval

MVPA, sedentary time, FMI, TFM, and BFM did not have normally distributed residuals and were therefore log-transformed for analyses.

The association between sedentary time and trunk fat mass, and vice versa, was adjusted for residual fat mass (total body fat minus trunk fat mass).

Analyses were adjusted for age, sex, and maturity status.

Model 1: Analyses were adjusted for age, sex, and maturity status. Model 2: Analyses were adjusted for age, sex, maturity status, and physical activity.

* $p<0.05$,

** $p<0.01$,

*** $p<0.001$.

Europe PMC Funders Author Manuscripts

Table 4

Prospective associations between MVPA and fat indicators.

Exposure[1]	Outcome[2]	Model 1	Model 2	Model 3	Model 4
		β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
MVPA (min/day)	FMI (kg/m^2)	−0.37 (−0.49 to −0.26)***	−0.25 (−0.37 to −0.12)***	−0.08 (−0.15 to −0.02)*	−0.09 (−0.16 to −0.01)*
MVPA (min/day)	Trunk fat mass (kg)	−0.20 (−0.29 to −0.10)***	−0.14 (−0.24 to −0.04)**	−0.08 (−0.14 to −0.02)*	−0.08 (−0.15 to −0.01)*
MVPA (min/day)	Body fat mass (kg)	−0.37 (−0.49 to −0.26)***	−0.23 (−0.34 to −0.11)***	−0.07 (−0.14 to 0.01)**	−0.07 (−0.15 to −0.00)*
FMI (kg/m^2)	MVPA (min/day)	−0.25 (−0.39 to −0.11)***	−0.08 (−0.27 to 0.11)	0.03 (−0.12 to 0.19)	0.03 (−0.11 to 0.18)
Trunk fat mass (kg)	MVPA (min/day)	−0.14 (−0.30 to 0.02)	−0.03 (−0.25 to 0.19)	0.05 (−0.12 to 0.22)	0.05 (−0.11 to 0.20)
Body fat mass (kg)	MVPA (min/day)	−0.24 (−0.37 to −0.12)***	−0.10 (−0.29 to 0.09)	0.01 (−0.15 to 0.17)	0.01 (−0.14 to 0.16)

Abbreviation: MVPA, moderate to vigorous physical activity; FMI, fat mass index; CI, confidence interval.

MVPA, sedentary time, FMI, TFM, and BFM did not have normally distributed residuals and were therefore log-transformed for analyses.

[1] Baseline results (Mage=10.1 years).

[2] Follow up results (Mage=11.9 years).

The association between MVPA and trunk fat mass, and vice versa, was adjusted for residual fat mass (total body fat minus trunk fat mass).

Model 1: Unadjusted analyses. Model 2: Analyses were adjusted for age, sex, maturity status and follow-up duration. Model 3: Analyses were adjusted for age, sex, maturity status, follow-up duration, and baseline levels of the outcome variable. Model 4: Analyses were adjusted for age, sex, maturity status, follow-up duration, baseline levels of the outcome variable, and sedentary time.

* $p<0.05$,

** $p<0.01$,

*** $p<0.001$.

Europe PMC Funders Author Manuscripts

Table 5

Prospective associations between sedentary time and fat indicators.

Exposure[1]	Outcome[2]	Model 1 β (95% CI)	Model 2 β (95% CI)	Model 3 β (95% CI)	Model 4 β (95% CI)
Sedentary time (min/day)	FMI (kg/m^2)	0.06 (−0.30 to 0.43)	−0.03 (−0.41 to 0.37)	−0.09 (−0.28 to 0.10)	−0.24 (−0.46 to −0.03)*
Sedentary time (min/day)	Trunk fat mass (kg)	0.11 (−0.18 to 0.40)	0.11 (−0.18 to 0.41)	0.00 (−0.19 to 0.19)	−0.14 (−0.35 to 0.08)
Sedentary time (min/day)	Body fat mass (kg)	0.19 (−0.18 to 0.55)	0.08 (−0.27 to 0.44)	−0.06 (−0.23 to 0.12)	−0.17 (−0.38 to 0.03)
FMI (kg/m^2)	Sedentary time (min/day)	0.03 (0.00 to 0.07)	0.02 (−0.03 to 0.06)	0.01 (−0.03 to 0.06)	0.01 (−0.04 to 0.05)
Trunk fat mass (kg)	Sedentary time (min/day)	0.00 (−0.04 to 0.04)	0.00 (−0.06 to 0.05)	−0.01 (−0.07 to 0.04)	0.02 (0.07 to 0.04)
Body fat mass (kg)	Sedentary time (min/day)	0.03 (0.00 to 0.07)	0.02 (−0.03 to 0.07)	0.01 (−0.04 to 0.06)	0.00 (−0.04 to 0.04)

Abbreviation: MVPA, moderate to vigorous physical activity; FMI, fat mass index; CI, confidence interval.

MVPA, sedentary time, FMI, TFM, and BFM did not have normally distributed residuals and were therefore log-transformed for analyses.

[1] Baseline results (Mage=10.1 years).

[2] Follow up results (Mage=11.9 years).

The association between sedentary time and trunk fat mass, and vice versa, was adjusted residual fat mass (total body fat minus trunk fat mass).

Model 1: Unadjusted analyses. Model 2: Analyses were adjusted for age, sex, maturity status and follow-up duration. Model 3: Analyses were adjusted for age, sex, maturity status, follow-up duration, and baseline levels of the outcome variable. Model 4: Analyses were adjusted for age, sex, maturity status, follow-up duration, baseline levels of the outcome variable, and MVPA.

* $p<0.05$,

** $p<0.01$,

*** $p<0.001$.