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International Journal of Obesity (2015), 1–6

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ORIGINAL ARTICLE

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

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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: A total of 510 children (age at baseline 10.1 ± 0.8, age at follow-up 11.8 ± 0.9) from six 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. 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 moderate to vigorous PA (MVPA) were performed.
RESULTS: MVPA (min per day) was cross-sectionally inversely associated with adiposity indexes (FMI, TFM and 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% confidence interval (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 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.

International Journal of Obesity accepted article preview 25 August 2015; doi:10.1038/ijo.2015.168

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 min 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 objective 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. Q3

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Received 20 February 2015; revised 6 July 2015; accepted 13 August 2015

MATERIALS AND METHODS

Study design and population

Q4 Participants were recruited from all schools with fifth grade classes (six schools, 1042 participants) from the Oeiras Municipality, in Lisbon Metropolitan area, Portugal. These schools participated in a school-based Q5 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 ($M_{age} = 10.1 \pm 0.8$) 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

Q6 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 s 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 min were identified and were defined as missing data. At least 3 days of recording (2 weekdays and 1 weekend day) with a minimum of 600 min wear time was required for inclusion of a day in analysis. Overall activity levels were expressed in terms of counts per min, and intensity thresholds were established according to a previous study.[18] MVPA was defined as $\geqslant 4$ metabolic equivalents and age-specific intensity thresholds according to those proposed by Freedson *et al.*[19] SED was set at a range between 0 and 100 counts per 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 cutoff 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, Q7 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 before 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 s.d. 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 mass minus trunk fat mass). Statistical tests were two-sided with significant defined as $P < 0.05$. Analyses were completed using IBM SPSS Q8 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 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 ($\beta = -0.37$, 95% CI: − 0.49 to − 0.26), TFM ($\beta = -0.20$, 95% CI: − 0.29 to − 0.10) and BFM ($\beta = -0.37$, 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

Table 1. Participant characteristics at baseline and at follow

	Total			*Boys*			*Girls*		
	Baseline (n = 510)	*Follow-up (n = 497)*	*P-value*	*Baseline (n = 258)*	*Follow-up (n = 235)*	*P-value*	*Baseline (n = 252)*	*Follow-up (n = 262)*	*P-value*
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)[a]	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)[a]	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 per 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 per 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: BMI, body mass index; FMI, fat mass index; MVPA, moderate to vigorous physical activity. [a]Measured by dual energy X-ray absorptiometry (DXA). Age, weight, height, adiposity indexes, MVPA, and sedentary time were tested by *t*-tests for paired samples. BMI (%) was tested by χ^2.

Table 2. Cross-sectional associations between MVPA with fat indicators

Exposure	*Outcome*	*Baseline*		*Follow-up*	
		Model 1	*Model 2*	*Model 1*	*Model 2*
		β (95% CI)	*β (95% CI)*	*β (95% CI)*	*β (95% CI)*
MVPA (min per 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 per 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 per 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 per 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 per 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 per 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)**

Abbreviations: CI, confidence interval; FMI, fat mass index; MVPA, moderate to vigorous physical activity. 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. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Q9
Q10

Table 3. Cross-sectional associations between sedentary time with fat indicators

Exposure	*Outcome*	*Baseline*		*Follow-up*	
		Model 1	*Model 2*	*Model 1*	*Model 2*
		β (95% CI)[1]	*β (95% CI)*[2]	*β (95% CI)*[1]	*β (95% CI)*[2]
Sedentary time (min per 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 per 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 per 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 per 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 per 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 per 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)

Abbreviations: CI, confidence interval; FMI, fat mass index. 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.~~

predictor of lower adiposity indexes (FMI: $\beta = -0.09$, 95% CI: − 0.16 to − 0.01; TFM: $\beta = -0.08$, 95% CI: − 0.15 to − 0.01; BFM: $\beta = -0.07$, 95% CI: − 0.15 to 0.00). Each additional 10 min 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 bidirectional association. In models adjusted for age, sex, maturity status,

Table 4. Prospective associations between MVPA and fat indicators

Exposure[a]	*Outcome*[b]	*Model 1*	*Model 2*	*Model 3*	*Model 4*
		β *(95% CI)*	β *(95% CI)*	β *(95% CI)*	β *(95% CI)*
MVPA (min per 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 per 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 per 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 per 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 per 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 per 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)

Abbreviations: CI, confidence interval; FMI, fat mass index; MVPA, moderate to vigorous physical activity. MVPA, sedentary time, FMI, TFM and BFM did not have normally distributed residuals and were therefore log-transformed for analyses. 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. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. [a]Baseline results ($M_{age} = 10.1$ years). [b]Follow-up results ($M_{age} = 11.9$ years).

Q11

Table 5. Prospective associations between sedentary time and fat indicators

Exposure[a]	*Outcome*[b]	*Model 1*	*Model 2*	*Model 3*	*Model 4*
		β *(95% CI)*	β *(95% CI)*	β *(95% CI)*	β *(95% CI)*
Sedentary time (min per 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 per 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 per 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 per 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 per 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 per 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: CI, confidence interval; FMI, fat mass index; MVPA, moderate to vigorous physical activity. 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 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~~. [a]Baseline results ($M_{age} = 10.1$ years). [b]Follow-up results ($M_{age} = 11.9$ years).

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 ($\beta = -0.24$, 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.

DISCUSSION

This study used repeated measures over 2-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 bidirectional 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 < 2 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 (for example, 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.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

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

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