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Associations between self-reported physical activity and screen time with cardiometabolic risk factors in adolescents: Findings from the 1993 Pelotas (Brazil) Birth Cohort Study

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ABSTRACT

The overall aim of this study was to examine the association of physical activity (PA) and screen time (ST) on indicators of cardio-metabolic risk during adolescence, by examining the combined association of PA and ST at ages 11, 15 and 18 on cardio-metabolic risk factors at 18 years. Data from the 1993 Pelotas (Brazil) Birth Cohort Study (N = 3613) were analysed in 2017. Self-reported PA and ST data were collected at 11, 15 and 18 years. Cardio-metabolic risk factors (fat mass index, waist circumference, triglycerides, blood glucose, non-HDL cholesterol and resting diastolic blood pressure) were examined at age 18. Multivariate linear regression was used to examine the associations between four mutually exclusive PA/ST groups: 1) active (≥1 h/day PA) and low ST (< 5 h/day ST); 2) active (≥1 h/day PA) and high ST (≥5 h/day ST); 3) inactive (< 1 h/day PA) and low ST (< 5 h/day ST); 4) inactive (< 1 h/day PA) and high ST (≥5 h/day ST) at each age, and outcomes at age 18. There were no significant associations between PA/ST at ages 11 and 15 with outcomes at 18 years. In the cross-sectional analyses, adolescents in the most active group had significantly better levels of all the outcomes, regardless of ST. Inactive participants with high ST had the highest levels of glucose and non-HDL-C. For diastolic blood pressure, values were higher among inactive participants. Overall, higher levels of physical activity appeared to be more important than low levels of ST for cardio-metabolic health in adolescents.

1. Introduction

In light of increasing evidence that physical activity can attenuate, or even eliminate the detrimental association between sitting time, television viewing and all-cause, cardiovascular disease and cancer mortality in adults (Ekelund et al., 2016; Ekelund et al., 2018), there is growing interest in the combined effects of sedentary behaviours and physical inactivity on health outcomes. This is especially the case for adolescents, as the potential health effects of sedentary behaviours (defined as activities with energy expenditure of 1.0–1.5 metabolic equivalents [METs]) at this age have received a great deal of research attention in recent years. However, few studies have evaluated associations between sedentary behaviour and indicators of health risk, in the context of different physical activity levels in youth. To date, most studies that have assessed these relationships have been cross-sectional in design and most were from high-income countries (Stamatakis et al., 2015; Ekelund et al., 2012; Ekelund et al., 2006).

Evidence from prospective cohort studies of children and youth is important, because these studies usually collect data on a multitude of potential confounding variables, which can be included in the analyses to improve understanding of specific physical or social exposures during childhood and adolescence, on risks in later life. In the case of sedentary behaviour and physical inactivity, socioeconomic position (SEP) is particularly important, because it is a significant determinant of cardiovascular health and mortality (Galobardes et al., 2004). In adolescents, socioeconomic position is also a correlate of sedentary behaviour, but the direction of this association varies: in high-income countries, there is an inverse association between socioeconomic position and sedentary behaviour, whereas in low- and middle-income countries the reverse is true (Mielke et al., 2016).

The 1993 Pelotas Birth Cohort Study provides an opportunity to improve understanding of the relationships between sedentary

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behaviour, physical activity and cardio-metabolic risk factors in Brazilian adolescents, with consideration of important potential confounding socioeconomic variables. The overall aim of this study was to examine the joint effects of screen time (ST), as an indicator of sedentary behaviour, and physical activity (PA) on indicators of cardio-metabolic risk during adolescence by examining: (i) the combined effects of ST and PA at ages 11 and 15 on cardio-metabolic risk factors at 18 years (prospective analyses); and (ii) joint associations of ST and PA at age 18 with cardio-metabolic risk factors at 18 years (cross-sectional analyses).

2. Methods

2.1. Sample and study design

This Pelotas birth cohort includes 5249 children who were born in 1993 in the city of Pelotas, Brazil, (from a total of 5265 born in that year). Data were collected at birth and in 2004, 2008 and 2011, when the children were 11, 15 and 18 years old respectively. At 18 years follow up, all participants were invited to visit a clinic for a series of clinical measures; 4106 participants were assessed. Written informed consent was obtained for participation in all phases of the study, including from parents or guardians when the participants were younger than 18 years. All study protocols were approved by the Ethics Committee of the Federal University of Pelotas Medical School. Additional details about the methods and protocols have been published previously (Victora et al., 2008; Goncalves et al., 2014).

2.2. Sedentary behaviour and physical activity measures

Sedentary behaviour was measured at 11, 15 and 18 years, using self-report questions about time spent watching television, playing video games and with a computer, in a typical day. At each age, the following question was used: *In a typical weekday, how much time do you spend [watching TV/playing videogames/using computer]?* A total screen time score (ST) was created by summing the time reported in each activity at each age. Based on recent meta-analyses, which showed higher risk of all-cause, cardiovascular and cancer mortality among adults who reported more than 5 h per day in TV time, (Ekelund et al., 2016; Ekelund et al., 2018) high ST was defined as reporting five or more hours per day in screen-based activities.

Physical activity (PA) was measured by self-report at 11 and 15 years using a questionnaire that asked about frequency and time spent in a range of activities, including leisure activities and active transport to and from school, in the last week. This instrument included a list of activities, which was based on a pilot study that identified the most frequent activities practiced at each age and has acceptable concurrent validity and test-retest reliability proprieties compared with pedometers (Bastos et al., 2008; Hallal et al., 2006). At 18 years, PA was measured using the leisure and active transport sections of the long version of the International Physical Activity Questionnaire. For each age, a daily PA score was calculated as the total minutes per week divided by 7, and categorized as active (≥60 min per day) or inactive (< 60 min/day), according to current guidelines for adolescents (Global Recommendations on Physical Activity for Health, 2010). The participants answered both PA and ST questions at each age without parents help.

To evaluate the joint effects of PA and ST, a variable including four mutually exclusive groups was created: 1) active (≥1 h/day PA) and low ST (< 5 h/day screen time); 2) active (≥1 h/day PA) and high ST (≥5 h/day screen time); 3) inactive (< 1 h/day PA) and low ST (< 5 h/day screen time); 4) inactive (< 1 h/day PA) and high ST (≥5 h/day screen time).

2.3. Cardiometabolic risk factors

All outcome variables were measured at 18 years. Of the 4106 participants who attended the 18-year clinic visit, 3842 provided complete data on body composition measures and 3487 had complete blood exams. The cardiometabolic risk factors analysed in this paper were: fat mass index (FMI, kg/m^2), waist circumference (WC, cm), triglycerides (TG, mmol/L), blood glucose (BG, mmol/L), non-HDL cholesterol (nHDL, mmol/L) and resting diastolic blood pressure (DBP, mm Hg).

Total fat mass was measured following the best-practice and standard protocols at 18 years using Dual-energy X-ray absorptiometry (DXA; model Lunar Prodigi, GE Healthcare, USA). Fat mass index was calculated as weight in kilograms of total fat mass, divided by height in meters squared. Waist circumference was measured twice using a flexible fiberglass measuring tape (to the nearest 1 mm) at the narrowest girth of the trunk or halfway between the costal margin and iliac crest, and the mean of the two measures was used (VanItallie et al., 1990; Ramires et al., 2016).

At 18 years a non-fasting venous blood sample was collected for measurement of glucose, high-density (HDL-C) and total cholesterol using automatic enzymatic colorimetric method in chemistry analyzer BS-380, Mindray (Shenzhen Mindray Bio-Medical Electronics Co., Ltd, China). Non-HDL cholesterol was calculated as the difference between total and HDL cholesterol. Blood pressure was measured using a digital monitor (Omron brand, model 711-AC; Beijing, China). The measure was performed with the participant in a sitting position after resting for 10 min, once at the beginning and again at the end of the assessment session. The mean of the two measures was considered in the analyses.

2.4. Cofounding variables

The following confounding variables were included: birth weight (grams), pre-pregnancy maternal body mass index (kg/m^2), family income (measured as multiples of minimum monthly income at time of birth), maternal education (years of schooling at time of birth), participant BMI at 11 years (kg/m^2) and participant total daily energy intake at 18 years (kcals/day). Participants completed a food frequency questionnaire at age 18 years with a recall period of one year; responses to 88 items were used to calculate energy intake (Schneider et al., 2016).

2.5. Statistical analysis

Analyses were performed in 2017 using Stata software 12.1. Descriptive analyses were used to summarise the sample characteristics. Differences between boys and girls were analysed using Student *t*-tests or chi-squared tests, according to the nature of variable. Means and 95% confidence intervals (95%CI) for each outcome at age 18 were calculated for each of the four levels of the joint exposure variable (active and low ST; active and high ST; inactive and low ST and active and high ST), at age 11, 15 and 18, and compared using analysis of variance (included in a Supplementary File). Multivariate linear regression was then used to examine the relationship between the joint PA and ST exposure at 11, 15 and 18, and each outcome at age 18, with adjustment for all the confounding variables (birth weight, pre-pregnancy maternal BMI, family income at birth, maternal education, 11-year-old BMI, sex and energy intake at 18). Results are expressed as regression coefficients (β) and 95% CIs, representing the difference in the outcome for each category of PA and ST, with the most active (active and low ST) as the referent category. Gender was included as a covariate because there was no evidence of any gender-interaction in the relationships between PA and ST with the outcomes. Final models were tested and no evidence of violation of assumptions was found.

To evaluate the robustness of the main analyses, sensitivity analyses were conducted by: 1) analyses of the associations between ST and

Table 1
Characteristics of analytical sample: 1993 Pelotas Birth Cohort (n = 3613).

Characteristics	All	Boys	Girls	p value
Joint PA and ST at 11 – N (%)				< 0.001
Active – low ST	750 (20.8)	456 (25.9)	294 (15.9)	
Active – high ST	508 (14.1)	337 (19.1)	171 (9.3)	
Inactive – low ST	1421 (39.4)	559 (31.7)	862 (46.7)	
Inactive – high ST	927 (25.4)	409 (23.2)	518 (28.1)	
Joint PA and ST at 15 – N (%)				< 0.001
Active – low ST	640 (17.7)	423 (24.0)	217 (11.7)	
Active – high ST	688 (19.1)	497 (28.2)	191 (10.3)	
Inactive – low ST	1126 (31.2)	365 (20.7)	761 (41.2)	
Inactive – high ST	1158 (32.1)	478 (27.1)	680 (36.8)	
Joint PA and ST at 18 – N (%)				< 0.001
Active – low ST	785 (21.7)	469 (26.6)	316 (17.1)	
Active – high ST	830 (23.0)	534 (30.3)	296 (16.0)	
Inactive – low ST	1129 (31.3)	452 (25.6)	677 (36.6)	
Inactive – high ST	869 (24.1)	309 (17.5)	560 (30.3)	
Confounders – mean (SD)				
Family income	4.3 (5.7)	4.3 (5.6)	4.3 (5.8)	0.574
Birth weight (g)	3186 (522)	3252 (526)	3123 (510)	< 0.001
Pre-gestational BMI	22.9 (3.8)	22.9 (3.9)	22.9 (3.7)	0.878
Maternal education (years)	6.8 (3.5)	6.8 (3.5)	6.8 (3.5)	0.909
BMI at 11 years (kg/m^2)	18.6 (3.6)	18.6 (3.5)	18.5 (3.6)	0.701
Energy intake at 18 year (kcal)	3086 (1991)	3271 (2024)	2911 (1944)	< 0.001
Outcomes – mean (SD)				
Fat mass index (kg/m^2)	6.2 (3.9)	4.2 (3.1)	8.1 (3.6)	< 0.001
Waist circumference (cm)	76.1 (10.0)	78.5 (9.7)	73.9 (9.9)	< 0.001
Triglycerides (mmol/L)	0.91 (0.45)	0.91 (0.49)	0.91 (0.41)	0.834
Glucose (mmol/L)	5.07 (1.10)	5.20 (1.13)	4.94 (1.05)	< 0.001
Non-HDL-c (mmol/L)	2.72 (0.64)	2.60 (0.58)	2.84 (0.67)	< 0.001
Diastolic blood pressure (mm Hg)	70.2 (7.9)	70.9 (7.9)	69.4 (7.8)	< 0.001

outcomes after stratification by PA (active/inactive); and 2) repeating the analyses using multiple imputations for missing data.

3. Results

Of the 5249 participants in the original cohort, 3613 adolescents (68.8%) had ST and PA data at all follow ups and at least one cardio-metabolic measure at age 18 (see Fig. 1 - Supplementary). The analytical sample was 68.8% of original cohort. Baseline characteristics of this sample are compared with those of the original cohort in Supplementary Table 1. Participants who were included were more likely to have mothers in the intermediate income and education groups. Participants from intermediate family income quartiles and with mothers in the intermediate education groups were slightly more likely to be included in the analytical sample than their counterparts. Furthermore, participants with low birth weight and whose mothers were normal weight were less likely to be included (Supplementary Table 1).

The characteristics of the 3613 participants are shown in Table 1 for boys and girls and the total sample. For the combined PA/ST variable, > 30% of participants at every age were in the inactive, low ST group, and more than two thirds of the girls were categorized as inactive at every age. For the confounding variables, birth weight and energy intake at 18 were significantly higher in boys than girls, but there were no gender differences in any of the indicators of socio-economic position (SEP). Overall, there was low variability in all the outcome measures, and the girls had markedly higher fat mass index and slightly higher non-HDL-C than the boys at age 18 (see Table 1).

The results of the multivariate linear regression analyses of the joint associations of PA and ST at 11 and 15 years of age, with indicators of cardio-metabolic health at age 18, are shown in Figs. 1 and 2. Participants in the 'active, high ST' group at 11 had slightly higher Fat Mass Index at age 18, as illustrated in the top left hand panel of Fig. 1. The remaining prospective analyses showed no significant relationships. When the effects of ST stratified by PA were investigated, these findings were confirmed (Table 2 - Supplementary).

Cross-sectional analyses of the joint association of activity and ST with cardio-metabolic risk factors at age 18 are shown in Fig. 3. Overall, compared with the most active group (active, with low ST), the least active group (inactive, high ST) had significantly higher levels of all the outcomes. For the body composition (FMI and WC) and TG variables, PA seemed to be important; inactive participants had higher values than active participants, regardless of ST. Inactive participants with high ST had the highest levels of glucose and HDL-C, and stratified analyses confirmed that these values were significantly higher than those for inactive, low ST participants (Table 2 - Supplementary). For DBP, values were higher among inactive participants, and the stratified analyses confirmed that they were also significantly higher in the high ST group than in the low ST group, in both active and inactive participants. When we conducted a post-hoc analysis to examine the effect of 'cumulative' exposure to PA and ST at 11, 15 and 18, the findings were similar to those seen in the longitudinal analyses (data not shown).

4. Discussion

This study examined the joint associations of PA and ST with a range of cardio-metabolic outcomes in adolescents from a middle-income country. There was little evidence of prospective associations between PA and ST at ages 11 and 15 years with cardio-metabolic outcomes at 18 years. There were however consistent associations between the combined exposure variables and cardio-metabolic profile in cross-sectional analyses at age 18 years. Overall, adolescents who, at age 18, reported at least 1 h per day in physical activity, including those with concomitantly high ST, had more favourable fat mass index, waist circumference and triglycerides than inactive adolescents with high ST. Higher levels of glucose and non-HDL cholesterol were only observed among inactive participants with high ST. Among both active and inactive participants, DBP was lower in those with lower ST.

The question of whether or not sedentary behaviour has deleterious consequences for health, 'independent' of PA, has been the subject of much recent debate. In this study, there was no clear evidence that ST in early adolescence is a predictor of poor cardiovascular health at age 18. Previous findings from the Avon Longitudinal Study of Parents and Children (UK) also found no evidence of a direct association between objectively measured sedentary time at age 11 year and metabolic risk at 15 years (Stamatakis et al., 2015). However, moderate to vigorous PA was beneficially associated with cardio-metabolic health, when ST and moderate to vigorous PA were mutually adjusted for each other (Stamatakis et al., 2015). Additionally, a recent systematic review (Saunders et al., 2016) has shown that physical activity, especially moderate-vigorous intensity, appears to be more consistently associated with positive health outcomes than sedentary behaviour in youth and adolescents (Saunders et al., 2016).

Our cross-sectional findings of joint associations between PA and ST with a range of cardiometabolic markers at age 18 are consistent with previous studies that used both self-report and objective measures (Stamatakis et al., 2015; Ekelund et al., 2012). We found that PA was more important than ST for cardio-metabolic health children and adolescents. A pooled cross-sectional analysis of data from > 20,000 children and adolescents (aged 4 to 18) from 14 accelerometry studies, found no association between sedentary time and waist circumference, blood pressure or triglycerides (Ekelund et al., 2012). In that study no longitudinal associations between baseline sedentary time and waist

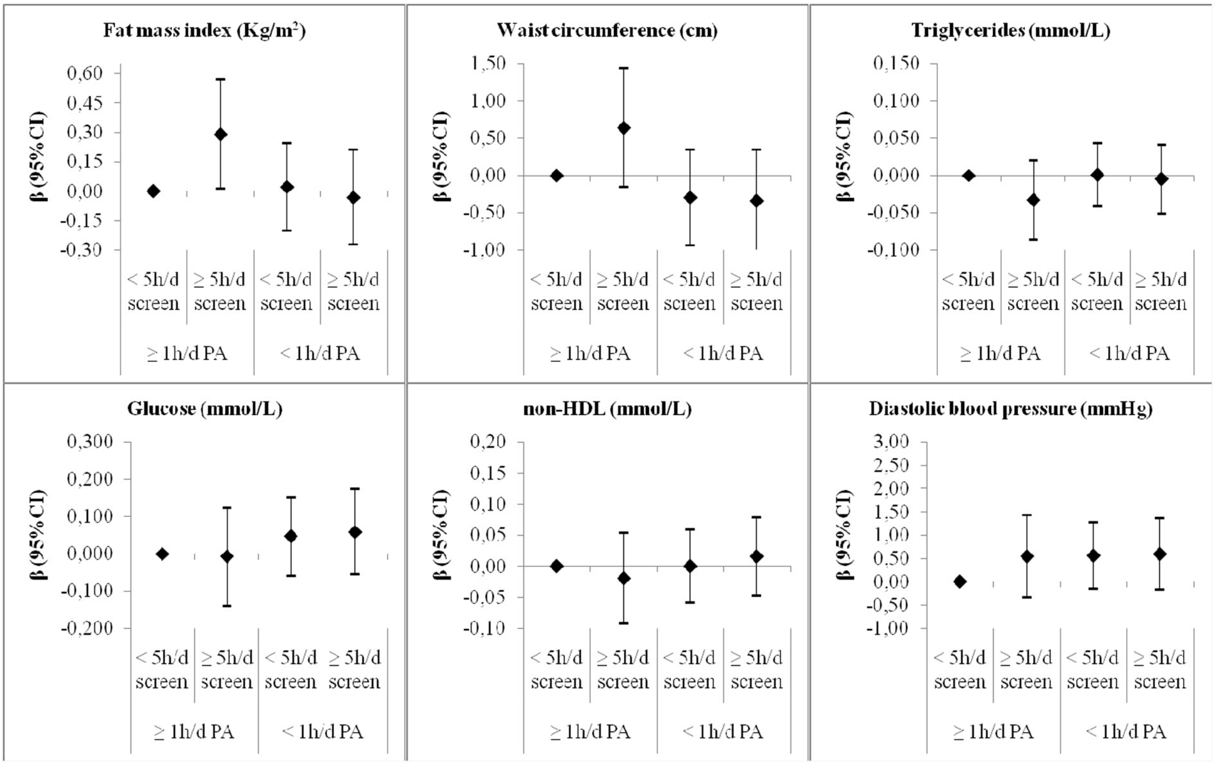

Fig. 1. Joint effect of screen time and physical activity at 11 years on cardio metabolic risk factors at 18 years. Adjusted for birth weight, pre-pregnancy maternal body mass index, family income, maternal education, participant BMI at 11 years and participant total daily energy intake at 18 years.

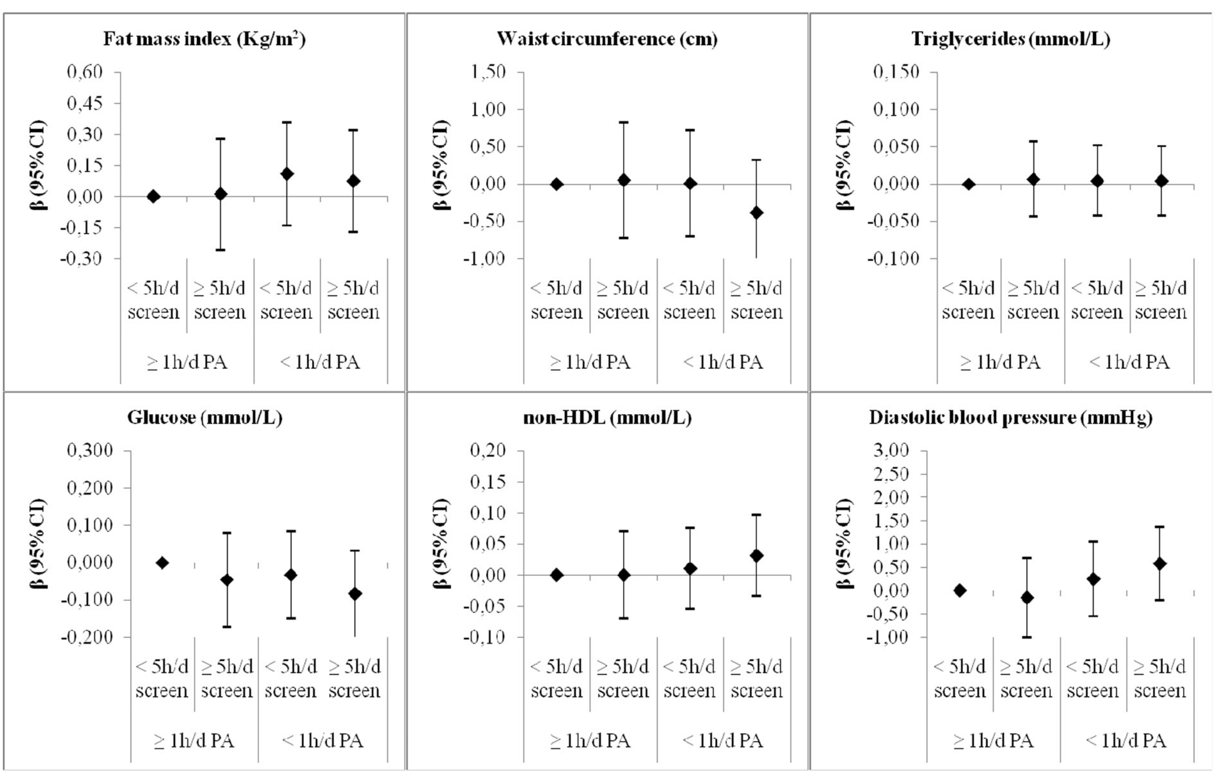

Fig. 2. Joint effect of screen time and physical activity at 15 years on cardio metabolic risk factors at 18 years. Adjusted for birth weight, pre-pregnancy maternal body mass index, family income, maternal education, participant BMI at 11 years and participant total daily energy intake at 18 years.

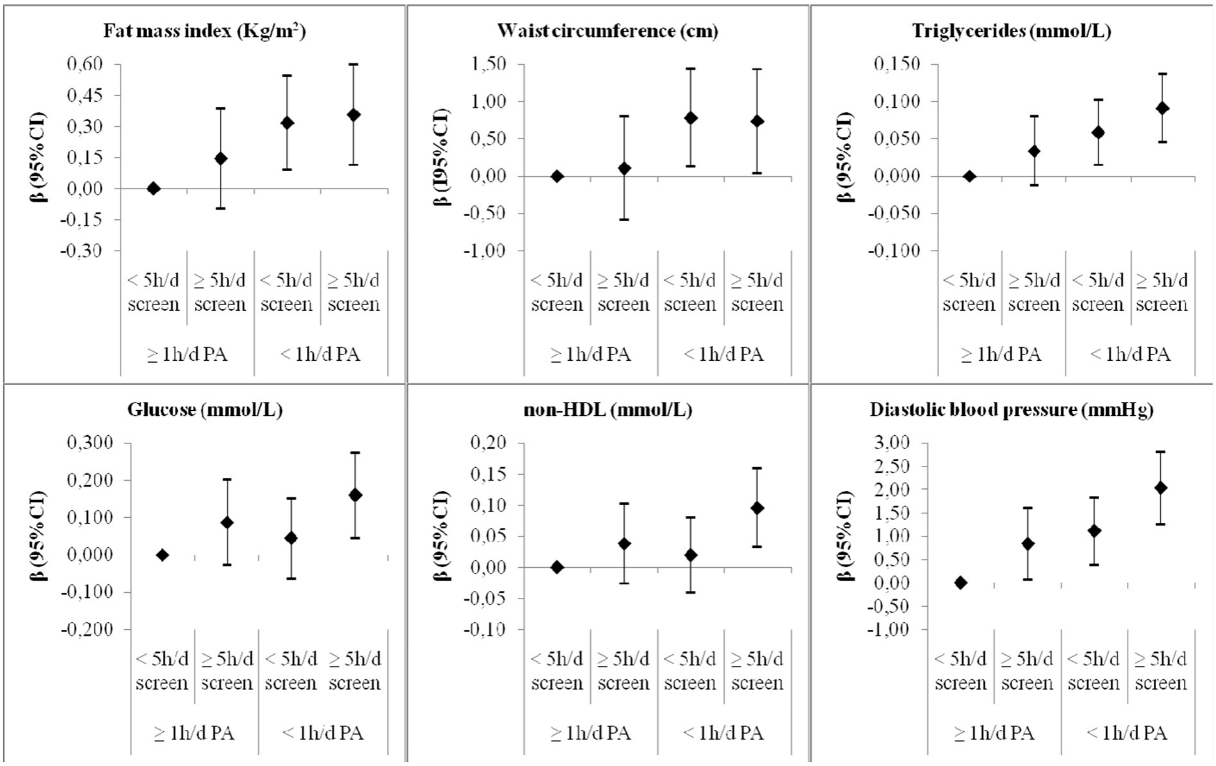

Fig. 3. Joint effect of screen time and physical activity at 18 years on cardio metabolic risk factors at 18 years. Adjusted for birth weight, pre-pregnancy maternal body mass index, family income, maternal education, participant BMI at 11 years and participant total daily energy intake at 18 years.

circumference were observed.

In our study, the absence of longitudinal associations between early exposures and late cardiometabolic markers may reflect the lack of variability in the blood outcome measures at age 18, as reflected by the small standard deviations around mean values (Table 1). Moreover, the fact that these behaviours may change markedly in the 3 and 7-year intervals between surveys could also explain the lack of associations between exposures at ages 11 and 15 with cardiometabolic outcomes at 18 years, as indicated by the correlational data (Supplementary Table 3).

As with all observational cohort studies, there are some limitations to consider. Even though numerous confounding variables were included in the analyses, there may have been residual confounding due to unmeasured variables. There may also have been some biases due to sample selection, or due to missing data in the selected sample. However, the sample was remarkably similar to the original cohort which included all children born in Pelotas in 1993, and when the analyses were repeated after multiple imputations of missing data, the results were unchanged. The use of different self-reported PA questionnaires at ages 11, 15 and 18 may be a limitation when comparing whether the associations between PA, sedentary time and cardiometabolic outcomes change at different ages. However, at the population level, these measures clearly identify those individuals at both ends of the PA spectrum. We are therefore able to compare low and high active participants. Assuming random measurement error in the PA estimate, the magnitude of any effect would be underestimated. Variation in the duration of fasting before blood collection might also have introduced some bias. However, sensitivity analyses were conducted with adjustment for fasting duration and once again, the results were unchanged. Others have suggested that the magnitude of association between ST and indicators of cardio-metabolic risk might vary according to the ST measure (Stamatakis et al., 2013; Carson and Janssen, 2011; Goldfield et al., 2011). However, when we analysed our data using only time spent watching television, the observations were materially unchanged (data not shown).

Another limitation is that the modest coefficients reported here could be interpreted to mean low clinical relevance. However, at this period of life even small differences in cardio-metabolic markers could signal the initiation of longer-term detrimental metabolic and physiological processes. Indeed, secondary analyses were performed using the cut-offs recommended for the definition of metabolic syndrome in children and adolescents, a complex disorder associated with several cardiovascular risk factors in adulthood (Zimmet et al., 2007a; Zimmet et al., 2007b), and the direction of all associations was unchanged, which reinforces the clinical relevance of our findings.

We are not able to draw any conclusions about causality from the cross-sectional analyses at age 18, and reverse-causality cannot be ruled out. Although blood metabolites are unlikely to directly affect behaviours, people with higher fat mass may tend to be less active and to sit more, which may in turn lead to higher fat mass index. Lastly, because of the high number of statistical tests, we cannot disregard the possibility that some of the reported associations appeared by chance. As our purpose was exploratory rather confirmatory, further studies are required to confirm our observations.

One of the strengths of this study is that it included a relatively large sample size from a contemporaneous birth cohort. A second is that the study included repeated measures of both PA and ST, and several indicators of cardio-metabolic risk, including an objective measure of fat mass index. We also included multiple potential confounders, including measures of SEP and energy intake. This is important because it has been suggested that cross sectional associations between ST and health outcomes may be impacted by 'snacking' which is prevalent in UK studies of adolescent sitting time (Hobbs et al., 2015; Ekelund, 2012; Pearson et al., 2014; Pearson and Biddle, 2011). Even though the magnitudes of the coefficients were attenuated when energy intake was included in the models (data not shown), the associations did not change.

The findings reported here are important in terms of planning interventions to improve cardio-metabolic health during adolescence. They suggest that encouraging young people to spend on average an hour or more per day in moderate to vigorous activity may be more important than focussing on reducing ST. Indeed, spending time sitting at a computer is becoming more important for academic progression in middle-income countries, and sitting for transport is sometimes inevitable, depending on logistic and environmental factors, which constrain active transport.

Current guidelines for physical activity and sedentary behaviour for young people recommend that adolescents should accumulate at least 60 min of moderate-vigorous physical activity every day (Global Recommendations on Physical Activity for Health, 2010; Okely et al., 2012; Tremblay et al., 2016). Our results indicate that it may be even more important for young people who 'have to' sit for long periods, to accumulate on average 60 min of PA daily, but not necessarily every day, to avoid the onset of detrimental cardio-metabolic and physiological effects prior to adulthood.

In conclusion, this study contributes to improved understanding of the relationships between activity, ST and cardio-metabolic health in adolescents. We found no evidence of joint associations between PA and ST in early adolescence with measures of cardio-metabolic risk at age 18. In the cross-sectional analyses at age 18, overall higher levels of physical activity appeared to be most important for cardio-metabolic health.

Conflict of interest statement

There are no potential conflicts of interest, real or perceived.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2018.12.008.

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