Relative proportion of vigorous physical activity, total volume of moderate to vigorous activity, and body mass index in youth: the Millennium Cohort Study

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Abstract

The present physical activity guidelines suggest that when the overall activity energy expenditure is held constant, moderate and vigorous intensity activities (MVPA) provide equivalent health benefits. We explored associations between vigorous physical activity on body mass index whilst controlling for volume of MVPA. In a longitudinal study with 7 years follow up (n=4,770; aged 7 yrs old at baseline), physical activity was measured objectively at baseline. Body mass index (BMI) was measured at baseline and follow up. Vigorous activity was expressed as the percentage of total MVPA. Participants in the highest vigorous activity tertile at baseline were at lower odds (odds ratio=0.70; 95% CI, 0.55, 0.88) of overweight /obesity at follow up compared with those in the lowest vigorous activity tertile after adjustment for total volume of MVPA, BMI at baseline, sex, ethnicity, and social status. The results suggest vigorous activity, regardless of volume, is important in preventing excessive weight gain in young people.

Introduction

Evidence on the association between physical activity and obesity in young people is inconsistent.[1-3] In particular, past studies have not adequately teased apart the importance of physical activity intensity and volume. In adult populations, epidemiological studies that have examined the association between physical activity intensity and cardiovascular disease, while controlling for the volume of activity, have yielded mixed results.[4-7] Recent work investigated associations between vigorous intensity physical activity and body mass index in children but did not account for total volume of activity.[8,9] The aim, therefore, was to explore longitudinal associations between objectively assessed vigorous physical activity on body mass index whilst controlling for volume of moderate and vigorous intensity activities (MVPA) using a large representative cohort study of children.

Methods

A nationally representative sample of children born in the UK was recruited into The Millennium Cohort Study between September 2000 and January 2002. Eligible children were identified from child benefit records, a benefit covering nearly all families in the UK.[10] The fourth wave of data collection (when participants were aged 7 years: between May 2008 and August 2009) was used as the baseline for the present study as this was the first occasion that objective physical activity data were gathered. Ethical approval was granted by the Northern and Yorkshire Multi-Centre Research Ethics Committee of the NHS and informed consent was obtained from all participating families.

Physical activity and sedentary time were measured objectively using the Actigraph GT1M accelerometers (Actigraph, Pensacola, Florida). In brief, accelerometers were delivered by post to consenting participants and programmed to capture data every 15 seconds. The accelerometers were worn around the waist during waking hours for seven consecutive days but removed for the duration of water-based activities. Devices were returned and downloaded using Actigraph software (Actigraph, Pensacola, Florida). Based on a previous calibration study,[11] moderate intensity activity was defined as 2240 - 3840 cpm and vigorous ≥3841cpm. Reliable accelerometer data were less likely to be acquired from children who were: male; overweight/obese; of white, mixed or 'other' ethnicity; living in disadvantaged areas; had less educated mothers and/or lone mothers.[12]

Trained interviewers measured height and weight at age 7 and age 14. Height was taken using a Leicester height measure stadiometer with a Frankfurt Plane card. Weight was measured using Tanita scales (BF-522W), to the nearest 0.1kg. For both measures the participant was required to wear light indoor clothing and asked to remove their shoes and socks, and items in their pockets. Body mass index was calculated using the formula [weight, Kg/(height, m)^2]. Covariates for the present analyses included parental social occupational group, that was categorised by order of socioeconomic status: managerial/professional (highest); intermediate; semi-skilled/manual; semi-routine/routine (lowest). Other covariates included ethnicity and the cohort member's sex.

Linear regression models were used to examine associations between the proportion of vigorous activity relative to total MVPA (as a continuous variable) with BMI. Models were adjusted for total volume of MVPA, parental social occupational group, ethnicity, and BMI at baseline. Since models were adjusted for BMI at baseline, results represent associations between baseline activity with change in BMI between time-points. We tested for interactions by sex but as none were observed we pooled together boys and girls, and adjusted for sex. We used weighted analyses based on the accelerometry sub-sample.[13] All analyses were conducted using SPSS version 22 with statistical significance set at $p<0.05$.

Results

Based on the inclusion criteria (at least 2 days with ≥10 h wear time),[14] 6497 (3176 boys) study members provided valid accelerometry data at baseline. After exclusion of those with missing covariate and follow-up data, the final analytic sample comprised 4,770 participants. At least five valid wear days were recorded in 77.4% of the sample. In boys 62.9% met the physical activity guideline (60 min daily MVPA on average) whereas this was achieved in 36.5% of girls. Other characteristics were similar between boys and girls (Table 1). On average, BMI was 16.5±2.3 $kg.m^{-2}$ at baseline (age 7) and 21.4±4.2 $kg.m^{-2}$ at follow up (age 14).

We did not observe any association between total MVPA volume and BMI at follow up (adjusted B=0.003, 95% CI, -0.002, 0.007). However, there was an association between the proportion of vigorous activity and BMI (adjusted B= -0.031, 95% CI, -0.044, -0.017) that persisted after adjustment for total MVPA volume and other covariates including baseline BMI. We did not stipulate the wear period to include a weekend day as a minimum wear criterion, although 80.6% of the sample did provide weekend data. We re-ran the models excluding participants without weekend Actigraph data and the association between the proportion of vigorous activity and BMI was not materially changed (adjusted B= -0.025, 95% CI, -0.040, -0.010). We additionally adjusted the models for season of measurement, and results were practically unchanged (adjusted B= -0.031, 95% CI, -0.045, -0.017). We ran models separately in children from different ethnic background since prior results from this cohort have indicated stronger associations with adiposity-related outcomes in south Asian children.[15] In these analyses the association between the proportion of vigorous activity and BMI was evident in south Asian participants (adjusted B= -0.081, 95% CI, -0.13, -0.03) but not white children (adjusted B= -0.003, 95% CI, -0.018, 0.011).

There was a moderate correlation (r=0.50) between the proportion of vigorous activity and total MVPA volume, thus we repeated the analyses after stratifying the sample into tertiles of MVPA volume. The association between the proportion of vigorous activity and BMI was evident in the middle (adjusted B= -0.056, 95% CI, -0.080, -0.030) and upper (adjusted B= -0.028, 95% CI, -0.048, -0.007), but not the lower MVPA tertiles (adjusted B= -0.005, 95% CI, -0.031, 0.022), as displayed in **Figure 1a**. The association between the proportion of vigorous activity and BMI did not change with additional adjustment for sedentary time (adjusted B= -0.018, 95% CI, -0.32, -0.003), and there was no evidence of effect modification (**Figure 1b**).

Using International Obesity Task Force age and sex specific thresholds 23.8% of the sample were overweight or obese at follow up. Participants in the highest vigorous activity tertile at baseline were at lower odds (odds ratio=0.70; 95% CI, 0.55, 0.88) of overweight /obesity at follow up compared with those in the lowest vigorous activity tertile after adjusting for total volume of MVPA, sex, parental social occupational group, ethnicity, and BMI at baseline.

Discussion

We explored longitudinal associations between objectively assessed physical activity and body mass index in childhood. A novel aspect of our analyses was to examine the contribution of vigorous intensity activity whilst controlling for MVPA volume. Consistent with some previous work we did not find any association between total volume of MVPA and BMI.[3] However, relative proportion of vigorous activity was inversely associated with BMI at follow up whilst holding MVPA volume constant. That the association was not observed in the lowest tertile of MVPA volume suggests that associations of vigorous intensity activity are, in part, co-dependent on volume. That is, there may be an absolute threshold of vigorous activity needed to see benefits (i.e., children in the lowest, middle and highest MVPA volume tertiles recorded on average 11, 18, and 31 mins/d vigorous activity, respectively).

Evidence on physical activity and obesity in children is mixed,[1-3] largely because studies have been limited by methodological problems including cross sectional designs, lack of power, and imprecise measurements of activity[8] and adiposity. In addition, studies have tended to combine moderate and vigorous intensities of activity together without attempting to tease apart the effects of volume over intensity. Nevertheless, previous work using gold standard objective assessments of activity and adiposity have also demonstrated the importance of vigorous intensity activity.[9] Although BMI is an objective measure, it is not a direct measure of adiposity. Previous evidence suggests associations between physical activity and adiposity were considerably weaker when using BMI, by a factor of around four, compared to using estimates of fat mass from imaging.[16] Nevertheless, BMI has greater clinical utility.

Experimental studies with outcomes such as metabolic syndrome, cardiorespiratory fitness, blood pressure and lipid profiles[17-20] indicate that the benefits of one minute of vigorous activity outweigh those of two minutes of moderate activity. Inverse associations between vigorous activity and obesity found in this study may be partly driven by favorable adaptations to lipid metabolism and other biological pathways.

We were unable to include important covariates such as diet and sleep, thus cannot rule out the possibility of residual confounding. Our findings that suggested possible ethnic differences should be interpreted cautiously as the south Asian sub-sample was very small (n=361). Indeed, our results are inconsistent with other recent data showing that associations between physical activity and skinfolds were not modified by ethnicity.[21] The analytic sample used in this study was more socially advantaged although weightings were used to reduce possible selection bias. Although associations appeared small in magnitude they may have clinical relevance if physical inactivity persists across the life course into adulthood.

In conclusion, the results show vigorous activity, regardless of MVPA volume, is important in preventing excessive weight gain in adolescence.

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Table 1. Characteristics of the sample at baseline (age 7)

	Boys (n=2,441)	Girls (n=2,329)
Parental social status (%) Managerial/professional Intermediate Semi-skilled/manual Semi-routine/routine	 31.8 20.1 13.6 34.5	 31.3 19.2 13.4 36.1
Ethnicity (%) White Mixed South Asian Black Other	 82.3 5.6 7.6 2.8 1.8	 82.9 4.7 7.5 2.8 2.0
Moderate PA (min/d)	47.3± 13.5	38.3± 11.5
Vigorous PA (min/d)	22.3± 11.5	17.7± 9.5
% Vigorous in relation to total MVPA volume	30.5±7.8	30.2± 7.4
Valid days of Actigraph wear	5.7 ±1.6	5.5 ±1.6
Body mass index ($kg.m^2$)	16.5 ± 2.4	16.6 ± 2.4

Figure legend

Figure 1. The association between proportion of vigorous activity and BMI at follow up stratified by tertile of MVPA volume (panel a) and sedentary (panel b). Data are marginal means (±standard error bars) adjusted for, sex, parental social occupational group, ethnicity, and BMI at baseline. Black, grey, and hatched bars reflect < 27%, 27 – 33.5%, and ≥33.5%, respectively, of vigorous activity in relation to total MVPA volume. For the main analysis the exposure variable was treated continuously but here the data are presented by tertiles with marginal means for illustrative purposes only.

Figure 1 (panel a)

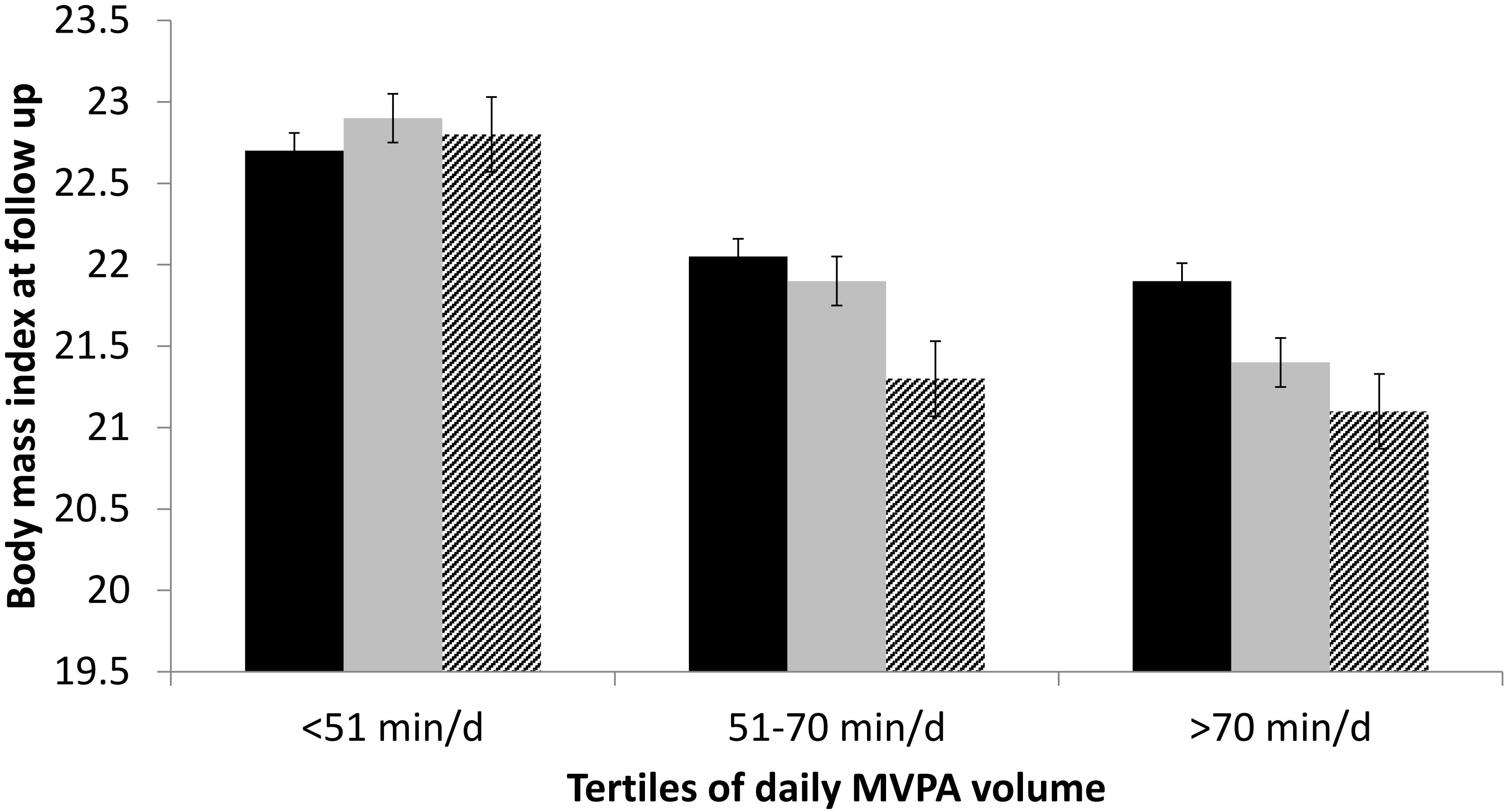

Figure 1 (panel b)