More Days, Greater Health: Associations Between Daily MVPA and Cardiometabolic Risk in Youth

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SUMMARY

Objectives: To examine the associations of moderate-to-vigorous intensity physical activity (MVPA) with cardiometabolic health risks in children and adolescents. We also investigated the differences in MVPA between boys and girls and how the differences in MVPA affect cardiometabolic health.
Methods: Pooled data from 20 studies involving children and adolescents aged 3-18 years old from the International Children's Accelerometry Database (ICAD). MVPA was measured objectively by accelerometry. A Clustered Cardio-Metabolic Risk Score (CCMR) was calculated based on central adiposity, blood pressure, lipid profile, and glucose metabolism indicators.
Results: Boys are more active than girls per week in the study. In regression analysis, the MVPA-adjusted models for the fasting blood sample group indicated that CCMR in category 6 was significantly lower than in category 3($t = 2.41$, $p < .05$). The results are similar in the non-fasting blood sample group.
Conclusions: MVPA is associated with cardiometabolic health. More MVPA is beneficial for cardiometabolic health in children and adolescents.

Keywords: moderate-to-vigorous physical activity; cardiometabolic health.

INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death globally[1]. The CVD death burden increased significantly with ageing, and older people suffer from higher CVD deaths in Western Europe. More than 70% of CVD deaths are attributed to metabolic disorders[2]. Even though the prevalence of CVD is still higher in men, mortality associated with myocardial infarction is increasing in women, and a low socioeconomic context increases the global burden of CVD in women[3]. Finally, people living with low socioeconomic status exhibit more increased CVD event rates and poorer outcomes[4].

CVD risk factors include total and central adiposity, insulin resistance, blood lipids and lipoproteins, blood pressure, inflammatory proteins, and cardiorespiratory fitness. CVD is associated with obesity, diabetes, dyslipidemia, and hypertension[5], [6]. The relation between obesity, especially visceral obesity, and CVD appears to develop at a relatively young age[7]. The relationship between central obesity and CVD is complex. Some researchers have reported that the connection is indirect and dependent on an increased prevalence of diabetes, hypertension, and dyslipidemia. In contrast, others have found that obesity is an independent risk factor for CVD[8], [9], [10].

Regular physical activity (PA) is beneficial for health. Research demonstrated that meeting and maintaining the recommended moderate-to-vigorous intensity physical activity (MVPA) level could reduce cardiovascular risk for adults[11]. However, there is strong evidence that regular engagement in MVPA among children and adolescents is associated with significant health benefits[12]. Accordingly, the 2020 World Health Organization

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(WHO) guidelines on physical activity recommend that young people in this age group engage in at least 60 minutes of MVPA on average each day throughout the week, in addition to participating in vigorous-intensity physical activities and muscle- and bone-strengthening activities at least three days a week.

The 2020 WHO guidelines for children and adolescents introduced a notable shift, no longer requiring 60 minutes of MVPA every single day[13]. Instead, the guidelines allow for achieving "an average of 60 minutes per day" across the week. While the guidelines still encourage practicing MVPA daily, they now account for day-to-day variability.

This shift reflects the scientific evidence from studies that reported the average daily minutes of MVPA rather than an accumulation of 60 or more minutes[13], [14]. Thus, the new guidelines do not imply that there are no additional benefits from participating in MVPA every day but rather recognize the limitations of the existing evidence.

Measurements of PA include self-report methods such as questionnaires, activity logs, and diaries, as well as objective measurements of PA such as direct observation, doubly labelled water, heart rate monitoring, accelerometers, and pedometers[15]. Accelerometry in children and adults is the most commonly used objective PA measurement[15], [16]. Because accelerometers are small, they have a relatively low participant burden and cost. In addition, objective measures do not rely on information provided by the patient, but instead, measure and record the biomechanical or physiological consequences of performing PA, often in real time. As such, objective measures are less subject to the reporting bias or recall problems associated with self-report methods.

In summary, there is a knowledge gap regarding how many days of MVPA are necessary to make a significant difference in the health benefits for young people. Therefore, this study aims to investigate the associations of MVPA with cardiometabolic health risks in children and adolescents using the International Children's Accelerometry Database (ICAD).

METHODS

Participants

The ICAD is a pooled dataset comprising data from 20 studies involving children and adolescents aged 3 to 18 years old, who had their physical activity levels measured via ActiGraph accelerometer (ActiGraph, LLC, Pensacola, FL, USA). For the current analysis, only studies that collected blood samples and required participants to wear an ActiGraph device for seven consecutive days were included. The final sample comprised 5,284 participants from two studies conducted in the United States. After excluding cases with missing values for cardiometabolic risk variables (n=1,927) and Actigraph daily wear-time (n=51), the final sample included 3,306 participants. Among these, 1,308 had fasting blood samples, while 1,998 did not.

We obtained the ICAD data use agreement to present it in the paper.

Measures

Moderate- to vigorous-intensity physical activity (MVPA): Actigraph raw data were summarized into day-level variables, including wear-time and PA. An epoch length of 60 seconds, a minimum wear-time of 8 hours per day, and a threshold of 2000 intensity counts per minute (CPM) for MVPA were applied. Any day-level MVPA minutes with wear-time shorter than 8 hours were treated as missing values and subsequently imputations using multiple imputations with chained equations (MICE) in Stata 17.0. Twenty complete datasets were created and used for pooled estimation when analyses involved the imputed values. After testing associations with the missing pattern, MICE incorporated ethnicity, type of blood sample (fasting or non-fasting), and the proportion of MVPA per wear-time when wear-time was shorter than 8 hours as auxiliary variables. Day-level MVPA minutes were aggregated to compute total MVPA minutes per week and determine MVPA adherence. MVPA adherence was categorized into five dummy-coded groups: category 0 = did not meet the WHO MVPA guideline (<420 minutes of MVPA per week), and categories 3 through 6 = met the WHO MVPA guideline, with the number of active days (defined as days with 60 or more minutes of MVPA) specified as follows: 1 to 3 days (category 3), 4 days (category 4), 5 days (category 5), and 6 to 7 days (category 6). To balance cell sizes, participants with 1 to 3 active days were combined into category 3, and those with 6 to 7 active days were merged into category 6. Categories are as follows:

Clustered Cardio-Metabolic Risk Score (CCMR): A CCMR was calculated based on central adiposity,

Table 1. MVPA adherence categories

Category	definition	days
Category 0	did not meet the WHO MVPA guideline (<420 minutes of MVPA per week)	0
Category 3	met the WHO MVPA guideline, with the number of active days (defined as days with 60 or more minutes of MVPA)	1 to 3
Category 4		4
Category 5		5
Category 6		6 to 7

blood pressure, lipid profile, and glucose metabolism indicators. These indicators were standardized as sex-specific z-scores. Triglycerides and insulin, which were highly skewed, were normalized using natural log transformation before standardization. Systolic and diastolic blood pressure were averaged. For participants with fasting blood samples, CCMR was calculated as the sum of standardized waist circumference, average of systolic and diastolic blood pressure, triglycerides, glucose, and insulin, subtracted by HDL-cholesterol. CCMR for non-fasting blood samples was calculated without triglycerides, glucose, and insulin, as these indicators are sensitive to food intake before the examination.

Statistical Analysis

Descriptive statistics, including means and standard deviations for age, cardio-metabolic risk indicators, and CCMRs, were calculated for the overall sample, as well as for boys, and girls separately. Estimated mean values with 95% confidence intervals were presented for MVPA minutes per week and MVPA adherence due to the use of imputed data.

Age-adjusted linear regression models were tested using twenty complete datasets from multiple imputations, with MVPA adherence as the independent variables and fasting CCMR or non-fasting CCMR as the dependent variables separately, stratified by sex [overall (age- and sex-adjusted), boys, girls]. Each model was run with and without adjustment for weekly MVPA minutes to explore associations between CCMR and additional active days while holding weekly MVPA constant. When MVPA adherence was statistically significant, Wald tests were performed post-hoc to compare the strength of associations across adherence categories. All analyses were conducted in Stata 17.0, with significance set at $p<0.05$.

RESULTS

Characteristics of all participants

Descriptive statistics stratified by sex are presented in Table 2. The average MVPA minutes per week was 331 minutes. Boys and girls engaged in 396 and 264 minutes of MVPA per week, respectively. The adherence rate to the 2020 WHO MVPA guideline (i.e. an average of 60 or more minutes of MVPA per day per week = 420 or more minutes per week) was 27.2% (95% CI = 25.6–28.7%). Sex-specific adherence rates were 38.9% (95% CI = 36.5–41.4%) for boys and 15.0% (95% CI = 13.2–16.8%) for girls.

Associations between moderate-to-vigorous physical activity adherence and cardiometabolic risk in children and adolescents

Results from MVPA-adjusted regression models for boys and girls separately, as well as MVPA non-adjusted models, are presented in Table 3.

The MVPA-adjusted models for the fasting blood sample group indicated that CCMR was significantly lower in categories 3 (B = -0.989, 95% CI = –1.945 to –0.034), 4 (B = –1.852, 95% CI = –2.753 to –0.952), 5 (B = –1.856, 95% CI = –2.800 to –0.911), and 6 (B = –2.531, 95% CI = –3.728 to –1.335) compared to category 0, controlling for age and sex. Post-hoc analyses revealed that CCMR in category 6 was significantly lower than in category 3 ($t = 2.41$, $p < 0.05$).

For the non-fasting blood sample group, the MVPA-adjusted models showed that CCMR was significantly lower in categories 4 (B = –0.454, 95% CI = –0.838 to –0.069), 5 (B = –0.845, 95% CI = –1.238 to –0.453), and 6 (B = –0.676, 95% CI = –1.183 to –0.170) compared to category 0. However, category 3 (B = –0.010, 95% CI = –0.422 to –0.402) did not differ significantly from category 0. Wald tests indicated that categories 5 ($t = 3.61$, $p < .001$) and 6 ($t = 2.59$, $p < 0.05$) had significantly lower CCMR compared to category 3.

DISCUSSION

The present study examined the association of MVPA with cardiometabolic health risk in children and adolescents using the ICAD database including studies using objective measurement of PA via actigraphy. The main of the study results are: 1) the number of active days, independent of accumulating an average of 60 or more minutes of daily MVPA (i.e. 420 or more minutes of weekly MVPA), was significantly associated with reductions in cardiometabolic risk in children and adolescents; 2) boys had a higher adherence rate of MVPA and were more active than girls which is consistent with other previous research[17], [18], [19].

Obesity in youth is one of the major health concerns worldwide, notably because of the incidence of poor cardiovascular health in this population. Indeed, it has been demonstrated in children aged from 2 to 15 years old that nearly 20% exhibit fibrous-plaque lesions in the aorta and that 8% have coronary vessel lesions[20]. In addition, it has been demonstrated that adolescents have a high prevalence of advanced atherosclerotic coronary artery plaques[21]. Because of the early altered cardiovascular health, children and adolescents are at risk of having cardiovascular events during their adulthood[22]. In this context, it is important to propose new strategies to prevent obesity in youth and its associated comorbidity and mortality.

Regular physical activity could represent one of the strategies because of its beneficial effects on children with obesity. It has been demonstrated that exercise training is able to improve pulse wave velocity and carotid intima-media thickness markers in children[23]. Moreover, regular physical activity appears to be able

Table 2. Descriptive characteristics of all participants and stratified by sex

Variables	Total (n=3,306)	Boys (n=1,677)	Girls (n=1,629)
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	13.97 (2.81)	14.04 (2.76)	13.89 (2.86)
Fasting plasma glucose (mmol/L)	5.13 (0.81)	5.24 (0.9)	5.01 (0.69)
Fasting serum insulin (pmol/L)	90.81 (81.64)	87.92 (87.33)	94.04 (74.69)
HDL-cholesterol (mmol/L)	1.39 (0.33)	1.36 (0.33)	1.42 (0.33)
Fasting plasma triglycerides (mmol/L)	0.98 (0.68)	0.98 (0.78)	0.97 (0.56)
Systolic blood pressure (mmHg)	108.06 (10.41)	109.93 (10.7)	106.14 (9.72)
Diastolic blood pressure (mmHg)	57.37 (12.31)	56.54 (13.07)	58.23 (11.41)
Waist circumference (cm)	78.08 (15)	77.75 (15.53)	78.42 (14.43)
CCMR fasting samples	0.620 (3.481)	0.614 (3.556)	0.627 (3.399)
CCMR non-fasting samples	0.003 (2.089)	0.031 (2.182)	–0.025 (1.993)
MVPA (minutes/week)	330.72 (4.61)	395.87 (6.48)	263.65 (6.04)
MVPA adherence (%)[1)]			
Not adhered (%)	72.85 (71.26 to 74.44)	61.06 (58.61 to 63.52)	84.98 (83.16 to 86.79)
Adhered (%)	27.15 (25.56 to 28.74)	38.94 (36.48 to 41.39)	15.02 (13.20 to 16.84)
Adhered and for 1 day (%)[2)]	0.62 (0.3 to 0.93)	0.47 (0.03 to 0.9)	0.77 (0.27 to 1.27)
Adhered and active for 2 days (%)	1.80 (1.27 to 2.34)	2.20 (1.38 to 3.02)	1.39 (0.71 to 2.07)
Adhered and active for 3 days (%)	4.29 (3.51 to 5.07)	5.98 (4.67 to 7.3)	2.54 (1.68 to 3.4)
Adhered and active for 4 days (%)	6.96 (6.03 to 7.9)	10.16 (8.6 to 11.72)	3.67 (2.71 to 4.62)
Adhered and active for 5 days (%)	7.49 (6.56 to 8.42)	11.05 (9.45 to 12.66)	3.82 (2.83 to 4.81)
Adhered and active for 6 days (%)	3.98 (3.28 to 4.67)	6.03 (4.85 to 7.22)	1.86 (1.13 to 2.59)
Adhered and active for 7 days (%)	2.02 (1.53 to 2.51)	3.03 (2.2 to 3.86)	0.98 (0.49 to 1.47)

Abbreviations: SD standard deviation, MVPA= moderate- to vigorous physical activity.
1) MVPA adherence = the proportion of individuals who participated in 420 minutes or more minutes of MVPA during a week. Proportions (%) and 95% confidence intervals in parentheses are presented instead of means and standard deviations.
2) The proportion of individuals who participated in 420 or more minutes of MVPA and the number of days with 60 or more minutes of MVPA was only one day.

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Table 3. Associations between MVPA adherence and cardiometabolic risk in children and adolescents

Variables	All (n=3,306)[1]		Boys (n=1,677)[2]		Girls (n=1,629)[2]	
	B (95% CI)	Wald-test[3]	B (95% CI)	Wald-test	B (95% CI)	Wald-test
CCMR$_{fasting}$	n=1308		n=686		n=622	
MVPA min/week adjusted model						
420 mins/wk (C0)	Reference group					
<420 mins/wk, 1-3 activ<e days (C3)	−0.989 (−1.945 to −0.034)	C3>C6	−0.502 (−1.689 to 0.685)		−0.599 (−2.338 to1.141)	
<420 mins/wk, 4 active days (C4)	−1.852 (−2.753 to −0.952)		−1.057 (−2.254 to 0.139)		−1.477 (−3.524 to 0.57)	
<420 mins/wk, 5 active days (C5)	−1.856 (−2.8 to −0.911)		−1.024 (−2.265 to 0.217)		−1.184 (−3.115 to 0.747)	
<420 mins/wk, 6–7 active days (C6)	−2.531 (−3.728 to −1.335)		−1.396 (−3.023 to 0.232)		−1.247 (−3.769 to 1.274)	
MVPA min/week unadjusted model						
<420 mins/wk (C0)	Reference group					
<420 mins/wk, 1-3 active days (C3)	−0.793 (−1.649 to 0.063)	C3>C6	−1.092 (−2.102 to −0.082)	C3>C6	−0.16 (−1.778 to1.459)	
<420 mins/wk, 4 active days (C4)	−1.652 (−2.466 to −0.837)		−1.735 (−2.638 to −0.832)		−1.062 (−3.08 to 0.957)	
<420 mins/wk, 5 active days (C5)	−1.635 (−2.486 to −0.784)		−1.794 (−2.736 to −0.853)		−0.795 (−2.665 to 1.075)	
<420 mins/wk, 6-7 active days (C6)	−2.145 (−3.097 to −1.192)		−2.527 (−3.602 to −1.452)		−0.105 (−2.161 to 1.95)	
CCMR$_{non-fasting}$	n=1998		n=991		n=1007	
MVPA min/week adjusted model						
<420 mins/wk (C0)	Reference group					
<420 mins/wk, 1-3 active days (C3)	−0.01 (−0.422 to 0.402)	C3>C5, C6	−0.236 (−0.776 to 0.305)	C3>C5, C6 C4>C5	0.472 (−0.239 to 1.184)	
<420 mins/wk, 4 active days (C4)	−0.454 (−0.838 to −0.069)		−0.473 (−0.946 to 0.000)		−0.282 (−0.955 to 0.392)	
<420 mins/wk, 5 active days (C5)	−0.845 (−1.238 to −0.453)		−1.103 (−1.576 to −0.63)		−0.181 (−0.871 to 0.509)	
<420 mins/wk, 6-7 active days (C6)	−0.676 (−1.183 to −0.17)		−0.949 (−1.537 to −0.362)		0.361 (−0.557 to 1.28)	
MVPA min/week unadjusted model						
<420 mins/wk (C0)	Reference group					
<420 mins/wk, 1-3 active days (C3)	−0.071 (−0.432 to 0.29)	C3>C5, C6	−0.186 (−0.662 to 0.291)	C3>C5, C6 C4>C5	0.003 (−0.599 to 0.605)	
<420 mins/wk, 4 active days (C4)	−0.515 (−0.856 to −0.174)		−0.419 (−0.844 to 0.006)		−0.729 (−1.306 to −0.152)	
<420 mins/wk, 5 active days (C5)	−0.919 (−1.237 to −0.6)		−1.036 (−1.417 to −0.654)		−0.67 (−1.257 to −0.084)	
<420 mins/wk, 6-7 active days (C6)	−0.789 (−1.137 to −0.441)		−0.847 (−1.249 to −0.444)		−0.392 (−1.058 to 0.274)	

Abbreviations: CCMR$_{fasting}$ = Clustered Cardio-Metabolic Risk score for individuals with fasting blood samples (calculated by summing the standardized serum glucose, insulin, triglycerides, blood pressure, and waist circumference, then subtracting the serum HDL-cholesterol level), CCMR$_{non-fasting}$ = Clustered Cardio-Metabolic Risk score for individuals with non-fasting blood samples (calculated by summing the standardized blood pressure and waist circumference, then subtracting the serum HDL-cholesterol level).

1) age- and sex-adjusted models.
2) age-adjusted models.
3) Post-hoc Wald-test tested differences between the regression coefficient among the MVPA adherence categories at alpha=0.05 (*e.g.* C3>C5, C6 indicates that the regression coefficients of C5 and C6 are significantly greater than C3).

to improve vascular function and induce beneficial changes in fat and lean body mass in children and adolescents with obesity[24].

Current WHO guidelines, along with most national physical activity recommendations, specify a minimum volume of MVPA (a combination of intensity, duration, and frequency) for children and adolescents[25]. These guidelines also state that exceeding the minimum recommended volume may offer additional health benefits, such as adiposity reduction. However, evidence supporting the dose-response relationship between daily MVPA volume and health benefits for this age group has been limited[26].

Moreover, evidence linking the frequency of MVPA and health risk reduction has not yet been well established. According to Tremblay et al.[14], The most supporting evidence for 60 minutes of daily MVPA was based upon "average" daily MVPA, which is calculated as the total MVPA divided by the measurement periods. Acknowledging this limitation, the 2020 WHO guidelines now recommend that children and adolescents aim for an "average" of 60 minutes per day of MVPA [12].

In this context, the investigation of the relationship between the number of days children and adolescents engaged in 60 or more minutes of MVPA and cardiometabolic risk revealed that performing 60 or more minutes of MVPA on as many days as possible throughout the week was correlated with a lower CCMR. Thus, engaging in MVPA consistently, rather than accumulating activity over fewer days, appears to be more effective in reducing cardiometabolic risk. It should be interesting for young people to have consistent PA because it has been shown that consistency in PA is related to greater MVPA and potential exercise routine stability that may induce greater health benefits [27]. The consistency of PA may also limit or prevent the risk of becoming obese and suffering from its complications during adulthood. The consistency of PA should also be beneficial, especially for girls who should be mothers one day in the early prevention of non-communicable diseases for their future children[28].

Acute and long-term improvements in metabolic function and cardiovascular fitness resulting from regular MVPA provide a plausible explanation for these points. Research suggests that PA may have favorable effects among patients with insulin resistance, metabolic syndrome, type 2 diabetes or obesity[29], [30]. Regular exercise provides many benefits, like improvements in blood glucose control and the ability to prevent or delay type 2 diabetes. PA improves lipid metabolism and blood pressure; it may also reduce total daily insulin requirements in people on insulin treatment and is at least as effective in diabetes prevention as medicines[30], [31].

This study, however, has limitations. First, it relied on cross-sectional data, which restricts the ability to establish a cause-and-effect relationship between MVPA and cardiometabolic health risks. Second, the analyses did not account for other known behavioral risk factors, such as nutritional intake. While the aim of this paper was to explore how effective MVPA is in mitigating risks associated with cardiovascular diseases in children and adolescents, the condition is not caused by just the conditions reported as measures in the selected sources of evidence or themes in the findings section. As such, a correlation between MVPA and a reduction in the risks of cardiovascular diseases cannot be verified. Further studies are thus needed to include more cardiovascular risk factors and empirically investigate how they are affected by MVPA.

Possible proposals and solutions provided

- To convince parents, schools, communities, and governments that children should be provided with opportunities to engage in moderate-to-vigorous physical activity (MVPA) on as many days as possible throughout the week, not only during physical education classes but also through extracurricular activities.
- To educate children and their parents about the importance of regular physical activity in improving cardiometabolic health and reducing the risk of cardiovascular disease (CVD) in adulthood.
- To encourage researchers to investigate the additional benefits of frequent MVPA, independent of total volume, through longitudinal studies.

CONCLUSION

In conclusion, physical activity, especially consistent MVPA, is important for cardiometabolic health in children and adolescents. To prevent the clustering of cardiovascular disease risk factors, further research should focus on the duration and amount of MVPA, the mechanism of cardiovascular disease and their associations in this specific population.

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