Weekly Frequency of Meeting the Physical Activity Guidelines and Cardiometabolic Health in Children and Adolescents

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ABSTRACT

WHITE, D. A., E. A. WILLIS, L. T. PTOMEY, A. M. GORCZYCA, and J. E. DONNELLY. Weekly Frequency of Meeting the Physical Activity Guidelines and Cardiometabolic Health in Children and Adolescents. *Med. Sci. Sports Exerc.*, Vol. 54, No. 1, pp. 106–112, 2022. The current physical activity (PA) guidelines for children and adolescents in the United States recommend ≥60 min of moderate- to vigorous-intensity PA (MVPA), 7 d·wk^{-1} for cardiometabolic health (CmH) benefits. Although the duration and intensity components of the PA guidelines have been rigorously studied, the frequency (7 d·wk^{-1}) component has not been thoroughly researched. **Purpose:** This study aimed to examine the association of the frequency component of the weekly PA guidelines on CmH in youth. **Methods:** Cross-sectional accelerometer data from the 2003–2006 National Health and Nutrition Examination Survey included youth age 6–18 yr with ≥4 d, ≥10 h of wear time, and averaging ≥60 min·d^{-1} of MVPA (*n* = 656). Participants were categorized into quartiles based on the proportion of days where they met the guidelines (≥60 min of MVPA). CmH variables were categorized as weight status/body anthropometrics, blood pressure, cholesterol, and fasting serum laboratory results. Propensity score weighting was applied to quartiles, and general linear modeling was used to compare associations of quartiles with CmH variables. **Results:** Results are displayed as percent of days meeting guidelines (DMG; 95% confidence interval): MVPA in minutes per week: Q1 (*n* = 156; DMG = 45.8% (43.4%–48.1%); MVPA 467.5, min·wk^{-1}), Q2 (*n* = 165; DMG = 62.6% (61.6%–63.7%); MVPA, 474.4 min·wk^{-1}), Q3 (*n* = 148; DMG = 75% (74.1%–75.8%); MVPA, 446.5 min·wk^{-1}), Q4 (*n* = 187; DMG = 92.2% (87.7%–96.6%); MVPA, 453.2 min·wk^{-1}). After adjusting for confounders and multiple comparisons, there were no clinically significant differences in weight status/body anthropometrics, blood pressure, cholesterol, or fasting serum laboratory results between DMG quartiles. **Conclusions:** We found no association between the proportion of DMG and CmH in children and adolescents. Our study suggests that achieving an overall weekly average of 60 min·d^{-1} of MVPA seems to be sufficient for CmH regardless of the 7 d·wk^{-1} frequency requirement of the PA guideline. **Key Words:** YOUTH, WEEKEND WARRIOR, NHANES, METABOLIC SYNDROME, MVPA

The 2018 Department of Health and Human Services (DHHS) physical activity (PA) guidelines for Americans recommend children and adolescents 6–17 yr old participate in moderate- to vigorous-intensity (MVPA) aerobic activities for ≥60 min·d^{-1} and muscle/bone strengthening activities at least 3 d·wk^{-1} to support cardiometabolic health (CmH) and reduce the risk of developing obesity (1,2). This PA guideline and other similar PA guidelines are based on the frequency, intensity, time, and type (FITT) principle with specific recommendations for days per week, duration, intensity, and modality. Although evidence exists to support the benefits of the intensity, duration (time), and modality (type) components of the child/adolescent guideline for CmH and risk of obesity (1,2), there is very little evidence supporting the frequency component of the guideline. The frequency component of the DHHS guideline is based on the "daily minimum method" (3) where children and adolescents are required to participate in MVPA all 7 d of the week for ≥60 min·d^{-1} to sufficiently meet the guideline. Other PA guidelines, including those of the United Kingdom's National Health Service (4) and the World Health Organization (5,6), use a "weekly average method," where children and adolescents can participate in an average of 60 min·d^{-1} of MVPA throughout the week, allowing for some day-to-day flexibility.

In adults, the 2008 PA guidelines transitioned from MVPA 5 d·wk^{-1} for 30 min (daily minimum method) to 150–300 min·wk^{-1} (weekly sum method), which remains in the newest DHHS guideline (1). Experts hypothesized that eliminating the minimum weekly frequency requirement would allow for greater flexibility, permitting adults to customize their weekly routines to meet the PA guidelines in a way that aligns with their schedule (7–9). The 2008 adult guidelines were supported by

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evidence suggesting that accumulating PA in longer duration sessions, but fewer times per week (i.e., "weekend warriors") led to a similar reduction in cardiometabolic disease–related mortality than those who are regularly physically active (≥3 d·wk^{-1}) (9–11).

Although recommending ≥60 min of MVPA on all 7 d·wk^{-1} may help to reinforce formation of daily PA routines/active lifestyles in children and adolescents, the daily frequency requirement may not be feasible for many families. Youth are engaging in more nonsport extracurricular activities, leading to increased levels of stress over homework and academic performance (12). In addition, parental employment demands, especially shift workers with irregular hours, may not have the ability to encourage or support PA participation all 7 d·wk^{-1} (13). Thus, many families may focus PA participation to less-busy days of the week, where, in some cases, the weekly sum volume of MVPA may be the same or greater than peers engaging in 60 min of MVPA daily.

To our knowledge, there is no research exploring the weekly frequency component of the PA guidelines on CmH and obesity in children and adolescents. Unlike the population of adults in the weekend warrior studies, cardiometabolic disease–related mortality is extremely rare in youth. Because of the positive association between obesity and risk factors for cardiometabolic disease in childhood and mortality in adulthood, between-group differences in CmH variables and obesity were chosen as the primary outcome for this study (14,15). The purpose of this study is to examine the association of the weekly frequency component of the PA guidelines on CmH in children and adolescents. Our hypothesis is rooted in the findings of the weekend warrior studies, where weekly frequency of meeting the guidelines will have no significant association with on CmH or weight status.

METHODS

Participants. Cross-sectional data were examined from the 2003–2004 and 2005–2006 Centers for Disease Control and Prevention and the National Health and Nutrition Examination Survey (NHANES), a series of studies examining health and nutritional status through interviews, surveys, and physical examinations in a nationally representative sample of children, adolescents, and adults from the United States. NHANES participants were included if the following conditions were met: 1) child or adolescent, without pregnancy or any known disease or limitation preventing participation in normal PA; 2) 6–18 yr old; 3) completed blood laboratory assessments; and 4) participated in an assessment of PA via accelerometry (16). Of the n = 4020 participants who met these criteria, n = 1257 were excluded for not meeting minimum accelerometer wear time requirements of ≥4 d with ≥10 h of valid wear time. In addition, we excluded participants who did not meet the overall recommendations for PA (accumulated an average of <60 min of MVPA per valid day), leaving n = 656 for analysis. Because of fasting requirements at the time of blood collection, n = 352 children age 6–11 yr were excluded from the analysis of triglycerides, glucose, and insulin but remained in the analysis for all other variables. All participants provided written consent and assent, and research ethics approval was granted by the National Center for Health Statistics.

Cardiometabolic health. Variables representing CmH were organized into four categories: 1) weight status and body anthropometrics (body mass index (BMI) percentile, waist circumference (WC) percentile, waist-to-height ratio (WTHR); 2) blood pressure (systolic and diastolic blood pressure (mm Hg); 3) cholesterol (total cholesterol, HDL (mg·dL^{-1}); and 4) fasting serum laboratory results (LDL, triglycerides, glucose (mg·dL^{-1}), insulin (μU·mL^{-1}). All measurements were collected by a trained research team member in the NHANES mobile examination center with detailed descriptions of all data collection procedures described in the NHANES examination protocol (16).

Weight status and body anthropometric variables were calculated using weight (kg) and height (cm). Weight, height, age, and sex were used to calculate BMI percentile (17). Abdominal WC was measured at the level of the iliac crest to the nearest 0.1 cm and was used to calculate WC percentile and WTHR (18). Blood pressure was measured three to four times after a minimum of 5-min resting quietly in the sitting position by a trained blood pressure examiner. Cholesterol measures were collected via serum blood and shipped to Johns Hopkins Medical Center in Baltimore, MD, for analysis. LDL cholesterol was calculated using the Friedewald equation (19), which requires a triglyceride value. Fasting serum laboratory results were also collected via serum blood and shipped to the University of Missouri in Columbia, MO, for analysis. As per NHANES protocol, fasting triglycerides, glucose, and insulin were collected in participants age 12–18 yr; thus, values for subjects <11.9 yr were not included in this analysis. Specific cholesterol and fasting serum laboratory analysis procedures and methods are described in detail elsewhere (16).

Physical activity. Device-based measures of PA were collected via an ActiGraph AM-7164 (Fort Walton Beach, FL) accelerometer. Participants were provided with materials describing the accelerometer and how to wear the device by a trained member of the research team. They were instructed to wear the accelerometer on a custom-fitted elastic strap around the waist, over the right hip for 7 consecutive days, only allowed to remove the device for water activities such as swimming and bathing/showering and sleeping. The PA data were screened for outliers and/or unreasonable values by the NHANES study team. Accelerometer counts were summed and stored at 60-s epochs, and nonwear time was defined as ≥60 consecutive minutes with 0 counts per minute, with allowance for 1 to 2 min of accelerometer counts between 0 and 100. Sedentary time was classified as valid wear time with accelerometer counts <100. Inclusion criteria for wear time and counts per minute were derived from Troiano et al. (20). Cut points for MVPA described by Evenson et al. (21) were used to classify PA intensity as follows: sedentary, ≤100 counts per minute; light-intensity PA, >100 counts per minute; moderate-intensity PA, ≥2296 counts per minute; and vigorous-intensity PA, ≥4012 counts per minute. The Evenson cut points were chosen because they have demonstrated acceptable classification accuracy for all four levels of PA intensity in children and adolescents (22).

PA frequency and statistics. To obtain population-representative findings, 2-yr sample weights for each NHANES cycle were combined to provide 4-yr weights for the 2003–2006 survey periods. Because of the nonrandom absence of participants from our sample after we applied the exclusion criteria, new sample weights were calculated based on age, sex, and race/ethnicity.

The proportion of valid days meeting guidelines (≥60 min of MVPA) was calculated. Participants were then categorized into quartiles based on the proportion of valid days meeting guidelines. Because of this study being observational, participants cannot be randomized to a specific frequency of meeting guidelines; therefore, differences in respondent characteristics, which in a randomized trial would be assumed to be null, might explain the observed effects. Therefore, propensity score weighting was utilized to eliminate the differences in the observed characteristics (e.g., age, sex, total MVPA, etc.) between participants in each quartile group. Covariates included in the propensity score model included categorical variables for sex (male/female), age (6–9, 10–13, and 14–18 y), asthma (yes/no), physical disability (yes/no), assessment period (November 1 through April 30 and May 1 through October 31), and quartiles of poverty-to-income ratio (23–25). A continuous variable for total weekly MVPA was also included. Missing values for covariates in the propensity score model were treated as a separate category. The obtained propensity score weights were then combined with the 2-yr sample weights by multiplying the two weights together. Weights that were more than five times the mean weighted value (weight limit) were considered an outlier weight, and that weight was trimmed by making it equal to the weight limit. To show how comparable the quartiles were after applying the propensity score weights, a calculation was made of the maximum standardized mean difference for each variable used to create the weights (Table 1), and absolute maximum standardized differences greater than 0.20 are considered moderate effect size differences (26). To obtain a more robust estimation, the covariates with lingering imbalances (absolute maximum standardized differences >0.20) were added to the final models.

TABLE 1. Maximum standardized effect sizes for unweighted and propensity score weighted covariates.

	Unweighted	Weighted
	Maximum Standard Effect Size	Maximum Standard Effect Size
Age, yr		
6–9 yr	0.04	0.08
10–13 yr	0.02	0.05
14–18 yr	0.02	0.03
Female (%)	0.04	0.04
Race/Ethnicity (%)		
Mexican American	0.01	0.01
Non-Hispanic Black	0.02	0.02
Non-Hispanic White	0.02	0.02
Other	0.01	0.01
Poverty-to-income ratio		
Quartile 1	0.01	0.01
Quartile 2	0.01	0.04
Quartile 3	0.03	0.05
Quartile 4	0.01	0.02
Missing	0.01	0.01
Asthma (yes)	0.01	0.01
Physical disability (yes)	0.01	0.02
Total MVPA (min·wk^{-1})		
Quartile 1	0.35	0.00
Quartile 2	0.02	0.02
Quartile 3	0.07	0.02
Quartile 4	0.29	0.01
Assessment period	0.01	0.04

MVPA, moderate-to-vigorous physical activity.

All outcome variables were checked for outliers (twice the interquartile range). Values outside this range were set to missing. A series of general linear models were conducted to compare the associations of the following variables between the identified quartiles: WC, BMI percentile, blood pressure, total, LDL and HDL cholesterol, triglycerides, glucose, and insulin. Linear contrast tests were used to examine the linear trends across quartiles. Missing values for covariates were treated as a separate category. Serum blood values and blood pressure outcomes were controlled for BMI percentile. All main associations and trends were considered significant at $P < 0.05$. Multiple comparisons for all were accounted for by using the false discovery rate method (i.e., the expected proportion of type I errors among significant findings) to obtain adjusted P values. Analyses were conducted using SAS (version 9.4; SAS Inc., Cary, NC), and PROC SURVEYFREQ, SURVEYMEANS, and SURVEYREG procedures were used to account for sampling strata, the primary sampling unit, and individual combined propensity and sampling weights.

RESULTS

In the analytic sample, mean age was 9.9 yr (range, 6–18 yr), 74% of participants were male, and 56% were non-Hispanic White. Participants in the analytic sample were more likely to be male, be younger, and have lower BMI percentile compared with all potentially eligible participants (Table 2). However, there were no substantial differences in race/ethnicity, poverty-to-income ratio, having asthma, or having a physical disability (Table 2) between the analytic and eligible samples.

Table 3 shows the PA and accelerometer characteristics by quartile of proportion of days meeting PA guidelines. The mean proportion of valid days meeting the guideline (i.e., frequency of meeting the guideline (60 min·d^{-1} of MVPA)) for each quartile is as follows: quartile 1, 45.8%; quartile 2, 62.6%; quartile 3, 75.0%; and quartile 4, 92.2% (Table 3). For the whole sample, average MVPA was 80.7 min·d^{-1} or 460.4 min·wk^{-1}.

Table 4 displays the differences in CmH variables by percentage of days meeting MVPA guideline quartiles. Before adjustment for multiple comparisons, LDL cholesterol and triglycerides were significantly different across quartiles, and there was a significant P for trend in diastolic blood pressure and diastolic blood pressure percentile. However, after adjusting for multiple comparisons, significant between-quartile differences for LDL cholesterol, triglycerides, and the diastolic blood pressure were no longer observed. However, a statistically significant trend in diastolic blood pressure percentile remained after adjustment for multiple comparisons, although this is likely of little clinical significance.

DISCUSSION

The 2018 DHHS PA guidelines for children and adolescents utilize a daily minimum requirement where meeting the

TABLE 2. Population-weighted characteristics of the eligible sample and the analysis sample of US youth age 6 to 18 yr (NHANES 2003–2006).

	Eligible Sample				Analysis Sample			
Descriptive Variables	***n***	**Mean**	**95% CL**		***n***	**Mean**	**95% CL**	
Age (yr)	2820	11.4	11.2	11.6	622	9.9[a]	9.5	10.4
Weight (kg)	2809	47.9	46.8	49.0	621	39.0	36.8	41.1
Height (cm)	2807	149.3	148.3	150.4	620	141.6	139.0	144.2
BMI (%ile)	2807	63.5	61.3	65.7	620	58.0[a]	54.6	61.5
	n	**Pct.**	**95% CL**		***n***	**Pct.**	**95% CL**	
Female	1407	49.2	46.9	51.6	144	26.3[a]	21.3	31.3
Race/Ethnicity								
Mexican American	923	13.4	9.2	17.5	187	14.1	8.8	19.4
Non-Hispanic Black	961	14.9	11.2	18.5	256	19.9	13.6	26.1
Non-Hispanic White	719	60.5	53.5	67.5	130	55.0	46.1	63.9
Other	217	11.3	8.4	14.1	49	11.0	7.0	15.0
Poverty-to-income ratio								
Quartile 1 (<0.80)	853	20.7	17.5	23.9	203	23.0	17.1	28.9
Quartile 2 (0.80–1.40)	712	20.7	18.5	22.9	175	20.7	16.1	25.4
Quartile 3 (1.41–2.31)	653	28.0	25.5	30.6	127	27.1	21.0	33.3
Quartile 4 (≥2.32)	504	28.5	23.9	33.0	100	27.9	20.5	35.3
Missing	98	2.1	1.3	2.9	17	1.2	0.4	2.1
Asthma								
Yes	464	15.6	13.6	17.5	124	20.2	16.4	23.9
No	2352	84.4	82.4	86.4	498	79.8	76.1	83.6
Missing	4	0.1	0.0	0.1	0	0.0	0.0	0.0
Physical disability								
Yes	131	4.2	3.1	5.3	24	3.6	1.2	6.0
No	2689	95.8	94.7	96.9	598	96.4	94.0	98.8
Missing	0	0.0	0.0	0.0	0	0	0	0

[a]Significant difference between eligible and analytic sample.
BMI, body mass index; CL, confidence limits; %ile, percentile.

guideline requires ≥60 min of MVPA all 7 d of the week. The purpose of this study is to examine the association between the frequency component of the PA guidelines on CmH in children and adolescents. As we hypothesized, the results of this study found no clinically significant differences in CmH variables between children and adolescents who accumulated 60 min of MVPA daily (92% of valid days) and those who accumulated the same weekly volume of MVPA but concentrated into fewer days of the week (42% of valid days).

We are unaware of other research exploring weekly frequency of meeting the PA guidelines on CmH in children and adolescents to which we can compare our findings. Unlike the adult studies examining weekly frequency of participating in MVPA, we were not able to analyze the risk of mortality. However, research has demonstrated that CmH risk factors and obesity in childhood are positively associated with mortality in adulthood (14,15).

Previous studies in adults that measured the association between mortality and participation in 150 $min{\cdot}wk^{-1}$ of MVPA most or all days of the week versus participating in 150 $min{\cdot}wk^{-1}$ of MVPA concentrated into fewer days of the week (i.e., weekend warriors). The authors observed little to no difference in the risk of mortality between sufficiently active adults who participated MVPA throughout the week and the weekend warriors (9–11). Lee and colleagues (10) studied the risk of mortality in adults classified as sedentary, insufficiently active, regularly active, or weekend warriors and found that as long as the PA generated an energy expenditure of 1000 $kcal{\cdot}wk^{-1}$, regardless of PA frequency, it was effective in lowering mortality in those with fewer baseline risk factors. Research by Shiroma and colleagues (11) support the conclusions of Lee et al. demonstrating that adults who were classified as weekend warriors had reductions in the risk of mortality, even in those who were only active 1–2 $d{\cdot}wk^{-1}$. O'Donovan et al. (9) studied all-cause mortality, cardiovascular disease mortality, and cancer mortality in >63,000 adults from the Health Survey for England and the Scottish Health Survey and found

TABLE 3. Average accelerometer data of the analysis sample of US youth age 6 to 18 yr (NHANES 2003–2006).

	Quartile 1 (*n* = 156)			Quartile 2 (*n* = 165)			Quartile 3 (*n* = 148)			Quartile 4 (*n* = 187)			
Variable	**Mean**	**95% CL**		**Mean**	**95% CL**		**Mean**	**95% CL**		**Mean**	**95% CL**		***P***
Days meeting guidelines (% of total days)[a]	45.8	43.4	48.1	62.6	61.6	63.7	75.0	74.1	75.8	92.2	87.7	96.6	<0.0001
Wear days ($d{\cdot}wk^{-1}$)[b]	5.6	5.2	5.9	6.1	6.0	6.2	5.6	5.2	6.0	5.6	4.8	6.4	0.001
Wear time ($min{\cdot}wk^{-1}$)	847.8	813.0	882.7	883.3	852.1	914.6	883.7	853.7	913.7	876.6	847.5	905.7	0.196
Average intensity (counts per minute)	775.4	628.7	922.2	705.5	677.8	733.2	752.2	711.8	792.6	746.6	694.8	798.3	0.140
Sedentary ($min{\cdot}wk^{-1}$)	384.1	336.6	431.6	406.6	379.7	433.5	384.1	353.4	414.8	354.1	311.8	396.4	0.190
LPA ($min{\cdot}wk^{-1}$)[c,d]	379.9	363.2	396.7	398.8	382.5	415.1	418.9	393.4	444.5	442.2	415.6	468.8	<0.0001
MVPA ($min{\cdot}wk^{-1}$)	83.8	66.9	100.6	77.9	75.1	80.7	80.7	77.1	84.2	80.2	72.9	87.5	0.679
Total weekly MVPA ($min{\cdot}wk^{-1}$)	467.5	348.2	586.7	474.4	453.3	495.4	446.5	424.4	468.5	453.2	361.2	545.2	0.200

[a]$P < 0.0001$ for all comparisons.
[b]Q1 vs Q2, $P < 0.05$.
[c]Q1 vs Q4, $P < 0.0001$.
[d]Q2 vs Q4, $P < 0.05$.
CL, confidence limits; LPA, light physical activity; MVPA, moderate-vigorous physical activity.

TABLE 4. Adjusted means (95% CL) for continuous CmH variables across quartiles of MVPA days meeting guidelines in US youth age 6 to 18 yr (NHANES 2003–2006).

	Quartile 1				Quartile 2				Quartile 3				Quartile 4					
Variable	*n*	Mean	95% CL		*n*	Mean	95% CL		*n*	Mean	95% CL		*n*	Mean	95% CL		P^a	P-Trend^a
Weight status and body anthropometrics																		
BMI (%ile)	155	60.7	51.3	70.2	163	56.8	49.2	64.4	148	57.4	51.0	63.9	187	57.9	48.9	67.0	0.929	0.626
WC (cm)	152	68.9	65.3	72.5	163	66.2	63.3	69.0	144	65.6	63.5	67.7	185	63.0	56.9	69.1	0.567	0.235
WC (%ile)	144	52.4	44.4	60.4	156	46.5	40.0	53.0	139	48.4	40.9	55.9	178	41.4	28.3	54.5	0.722	0.303
WTHR	144	0.46	0.45	0.48	156	0.46	0.45	0.47	139	0.46	0.45	0.47	178	0.46	0.45	0.48	0.929	0.626
Blood pressure																		
Systolic BP (mm Hg)	81	107.0	103.4	110.6	72	107.2	104.2	110.3	67	107.9	105.2	110.7	82	102.6	98.1	107.1	0.392	0.404
Systolic BP (%ile)	81	44.4	35.8	52.9	72	47.9	39.7	56.2	67	49.6	40.5	58.7	82	43.3	31.1	55.4	0.9252	0.950
Diastolic BP (mm Hg)	82	60.3	56.2	64.4	72	58.5	55.8	61.3	64	55.2	52.6	57.7	82	54.7	48.4	61.1	0.392	0.235
Diastolic BP (%ile)	82	44.1	32.0	56.2	72	35.1	27.6	42.6	64	27.9	21.9	33.9	82	24.7	15.3	34.2	0.252	0.028**
Cholesterol																		
Total cholesterol (mg·dL^{-1})	143	163.3	155.5	171.2	152	161.8	153.0	170.6	138	165.5	159.1	171.9	167	174.5	156.7	192.3	0.641	0.235
HDL cholesterol (mg·dL^{-1})	143	55.7	53.0	58.3	152	58.6	55.0	62.3	139	58.3	55.1	61.4	168	57.3	53.2	61.4	0.658	0.626
Fasting serum laboratory results																		
LDL cholesterol (mg·dL^{-1})	32	91.7	74.2	109.2	31	95.9	81.6	110.1	28	76.1	65.1	87.1	46	96.6	84.5	108.8	0.252*	0.950
Triglycerides (mg·dL^{-1})	32	112.8	75.2	150.3	31	67.9	37.4	98.4	28	81.4	53.7	109.1	46	80.8	53.8	107.8	0.056**	0.235
Glucose (mg·dL^{-1})	32	89.9	86.3	93.5	33	88.6	86.0	91.2	28	91.2	88.6	93.8	46	91.6	88.3	94.8	0.567	0.808
Insulin (μU·mL^{-1})	32	14.9	6.3	23.6	32	7.4	2.3	12.6	28	9.5	6.0	13.1	46	14.2	8.4	20.1	0.567	0.950

Triglycerides, glucose, and insulin were only collected on subjects age 12–17.9 yr and who fasted at the time of data collection. Triglycerides are required for calculation of LDL.

[a]Adjusted P values accounting for multiple comparisons using the false discovery rate method.

*Unadjusted significance, $P < 0.05$.

**Unadjusted significance, $P < 0.01$.

BMI, body mass index; BP, blood pressure; CL, confidence limits; CmH, cardiometabolic health; MVPA, moderate to vigorous physical activity; NHANES, National Health and Nutrition Examination Survey; %ile, percentile; WC, waist circumference; WTHR, waist-to-height ratio.

that weekend warriors had risk reductions in each category of mortality compared with those who were insufficiently active, and the risk reduction was similar to those who were regularly active. Similar to Shiroma et al., O'Donovan and colleagues (9) noted that as few as 1–2 sessions of MVPA per week were related to decreased mortality, and as long as the weekly PA guidelines were met, frequency of MVPA was not important.

Children of families with multiple obligations or inconsistent work schedules may have significant barriers to accumulating 60 min of MVPA all 7 d·wk^{-1} (27). Many families have other non–PA-related obligations (e.g., school/academic, church, clubs, music lessons, etc.) that may impede participation in 60 min of MVPA all days of the week. In 2011, Brown and colleagues (12) studied n = 882 children and adolescents (9–13 yr old) and found that 86% of the participants were engaged in at least one extracurricular activity and 39% were participating in at least three extracurricular activities. In addition, 41% of the sample reported feeling stressed "always" or "most of the time" because of time requirement needed to complete homework assignments and the number of their extracurricular obligations.

Allowing flexibility on the frequency by which children and adolescents obtain the 420 min of weekly MVPA may aid in better PA adherence without compromising health benefits. With the daily minimum requirement, if a child participated in 60 min of MVPA per day for 5 d and 120 min of MVPA on 1 additional day, that child would not meet the daily frequency requirement and would not be compliant with the guideline, although they would accumulate the same total weekly volume of MVPA.

The 2020 World Health Organization PA guidelines for children and adolescents transitioned from requiring a minimum daily threshold (7 d·wk^{-1}) to requiring an average of 60 min·d^{-1} throughout the week. This change was justified because PA research has generally utilized a weekly average of 60 min·d^{-1} in their analysis, rather than a minimum daily threshold of 60 min when assessing the benefits of PA on health outcomes (6). Although this allows for some flexibility in how children and adolescents accumulate their MVPA, this may have significant implications for PA surveillance (28). For example, studies on adherence to child/adolescent PA guidelines, which require a minimum weekly frequency of 7 d·wk^{-1}, may be significantly undercounting the proportion of the population that is physically active when compared with studies that require a weekly average of 60 min·d^{-1} over 7 d. In a study of n = 2961 Brazilian adults, researchers found that approximately 78% of the sample was meeting the 150 min·wk^{-1} guideline. However, when a minimum weekly frequency of at least 5 d·wk^{-1} was applied, the prevalence of adults who met the guideline decreased by ~11% (29). Similar discrepancies have been reported in youth. Price and colleagues (30) observed that when an average of 60 min·d^{-1} over 7 d was applied, 30.6% of the sample met the guideline. However, when the authors required 60 min·d^{-1} and also applied a minimum weekly frequency of 7 d·wk^{-1}, only 3.2% of the sample met the guideline. Williamson et al. (3) compared estimates of children and adolescents meeting PA guidelines in England (who require 60 min·d^{-1} over 7 d) and Scotland (who require an average of 60 min·d^{-1} over 7 d). The authors found that when the Scottish guidelines were applied to a sample of children and adolescents from England, the estimates of those meeting the guidelines increased from 22.6% to 54.3%. Our study expands on the research by Price et al. and Williamson et al. because they did not explore the association between weekly frequency of meeting the guideline on CmH. A qualitative study on preferences for PA by Bevington et al. (31) found that many parents, children, and adolescents dislike the "one size fits all" approach, with a strong preference for flexible PA recommendations that focus on how PA can be broken into chunks that fit into daily/weekly routines.

The presence of cardiometabolic disease in children and adolescents is rare, especially in the participants included in this study who were meeting the duration and intensity components of the DHHS guidelines. Because our research question focused on the independent effects of the frequency component of the child/adolescent DHHS PA guideline on CMH, it was necessary to include participants who were meeting the duration and intensity component of the guidelines, allowing us to compare differences in the frequency component. Unsurprisingly, we observed that our participants were overall "healthy" with no significant cardiometabolic disease risks including obesity, and the frequency component of the DHHS guideline did not provide additional benefits above the duration and intensity components. Although we saw this as unavoidable in our study, future clinical trials where children/adolescents with some degree of cardiometabolic disease risk are prescribed a matched weekly "dosage" of exercise and grouped by days per week of participation may provide additional insight into the effects of weekly frequency on CMH.

Research on child and adolescent PA patterns such as bouts of MVPA (32), tendency to participate in PA on specific days or times of the day (33,34), and preferred PA modality (35) has shaped the design of PA programming and tailored exercise prescriptions. Future studies should continue to examine all aspects (frequency, intensity, modality, duration) of the PA guidelines to identify approaches that encourage and reduce barriers to being active while also providing CmH benefits. Research such as this could help shape future editions of the PA guidelines, giving families more flexibility to sufficiently meet the public health recommendation.

Strengths and limitations. This study has several strengths and limitations that should be addressed. To our knowledge, this is the first study to thoroughly examine the association between device-based measures of PA frequency on CmH in children and adolescents. We utilized sophisticated statistical methods to identify a generalizable sample and to identify and consider all potential confounding variables. Because of the cross-sectional nature of this study, conclusions are limited to associations and do not provide any causal inference. The sample size for the some of the CmH, especially the fasting serum laboratory results, was limited, which may have affected the likelihood of identifying between-quartile differences. We did not have measures of maturation or pubertal stage for our sample. Although research shows that CmH risk clustering is consistent throughout adolescence (36), the interaction of sex, puberty, and maturation on CmH is significant and was not accounted for (37). It is possible that the fasting serum laboratory values may have been affected by when participants engaged in the most recent bout of exercise related to when their laboratory results were collected by NHANES personnel. Also, CmH variables may be affected by medications. Medications were not included as a covariate, and we recognize this as a limitation. Few participants had 7 d of valid wear time, which limited our ability to directly compare those who met the guideline with those who accumulated 420 min of MVPA per week without meeting the guideline. Because our sample averaged 5.7 d of wear time, we made quartiles based on the proportion of valid days that the participant met the guideline, possibly limiting our conclusions. Lastly, the NHANES data that were utilized for this study were from 2003 to 2006 and is >15 yr old. Much of the PA data from later cycles of NHANES utilize wrist-worn accelerometry with cut points for MVPA that have not been rigorously studied, and the data have not been released.

Conclusions. We examined the frequency component of the PA guidelines (i.e., 60 min of MVPA per day, 7 $d \cdot wk^{-1}$) in children and adolescents and found no clinically significant differences in CmH between those who accumulated 60 min of MVPA daily and those who accumulated the same weekly volume of MVPA but concentrated into fewer days of the week. The results of the current study suggest that allowing flexibility on the minimum weekly frequency by which children engage in MVPA may not diminish the health benefits as long as the total weekly volume equals an average of 60 $min \cdot d^{-1}$ or 420 $min \cdot wk^{-1}$.

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EPIDEMIOLOGY

REFERENCES

1. Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. *JAMA*. 2018;320(19):2020–8.
2. Powell KE, King AC, Buchner DM, et al. The Scientific Foundation for the Physical Activity Guidelines for Americans, 2nd Edition. *J Phys Act Health*. 2018;16(1):1–11.
3. Williamson C, Kelly P, Strain T. Different analysis methods of Scottish and English child physical activity data explain the majority of the difference between the national prevalence estimates. *BMC Public Health*. 2019;19(1):1–9.
4. Foster C, Department of Health and Social Care. *Physical Activity Guidelines: UK Chief Medical Officers' Report*. London, UK: Department of Health and Social Care; 2019 [cited 2021 April 27]. Available from: https://www.gov.uk/government/publications/physical-activity-guidelines-uk-chief-medical-officers-report.
5. World Health Organizaion. *WHO Guidelines on Physical Activity and Sedentary Behavior*. Geneva, Switzerland: WHO; 2020 [cited 2021 April 27]. Available from: https://www.who.int/publications/i/item/9789240015128.
6. Chaput J-P, Willumsen J, Bull F, et al. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents age 5–17 years: summary of the evidence. *Int J Behav Nutr Phys Act*. 2020;17(1):1–9.

7. Tremblay MS, Warburton DE, Janssen I, et al. New Canadian physical activity guidelines. *Appl Physiol Nutr Metab*. 2011;36(1):36–46.
8. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. *Am J Prev Med*. 2010;39(4):305–13.
9. O'Donovan G, Lee I-M, Hamer M, Stamatakis E. Association of "weekend warrior" and other leisure time physical activity patterns with risks for all-cause, cardiovascular disease, and cancer mortality. *JAMA Intern Med*. 2017;177(3):335–42.
10. Lee I-M, Sesso HD, Oguma Y, Paffenbarger RS Jr. The "weekend warrior" and risk of mortality. *Am J Epidemiol*. 2004;160(7):636–41.
11. Shiroma EJ, Lee I-M, Schepps MA, Kamada M, Harris TB. Physical activity patterns and mortality: the weekend warrior and activity bouts. *Med Sci Sports Exerc*. 2019;51(1):35–40.
12. Brown SL, Nobiling BD, Teufel J, Birch DA. Are kids too busy? Early adolescents' perceptions of discretionary activities, overscheduling, and stress. *J Sch Health*. 2011;81(9):574–80.
13. Fenwick R, Tausig M. Scheduling stress: family and health outcomes of shift work and schedule control. *Am Behav Sci*. 2001;44(7):1179–98.
14. Gunnell DJ, Frankel SJ, Nanchahal K, Peters TJ, Davey Smith G. Childhood obesity and adult cardiovascular mortality: a 57-y follow-up study based on the Boyd Orr cohort. *Am J Clin Nutr*. 1998;67(6):1111–8.
15. De Gonzalez AB, Hartge P, Cerhan JR, et al. Body-mass index and mortality among 1.46 million White adults. *N Engl J Med*. 2010;363(23):2211–9.
16. Centers for Disease Control and Prevention. National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Questionnaire (or examination protocol, or laboratory protocol) 2006 [cited 2021 April 27]. Available from: http://www.cdc.gov/nchs/nhanes.htm.
17. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. *Adv Data*. 2000;(314):1–27.
18. Sharma AK, Metzger DL, Daymont C, Hadjiyannakis S, Rodd CJ. LMS tables for waist-circumference and waist-height ratio *z*-scores in children age 5–19 y in NHANES III: association with cardio-metabolic risks. *Pediatr Res*. 2015;78(6):723–9.
19. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972;18(6):499–502.
20. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181–8.
21. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. *J Sports Sci*. 2008;26(14):1557–65.
22. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. *Med Sci Sports Exerc*. 2011;43(7):1360–8.
23. Carson V, Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. *BMC Public Health*. 2011;11(1):1–10.
24. Holman RM, Carson V, Janssen I. Does the fractionalization of daily physical activity (sporadic vs. bouts) impact cardiometabolic risk factors in children and youth? *PLoS One*. 2011;6(10):e25733.
25. Belcher BR, Berrigan D, Dodd KW, Emken BA, Chou C-P, Spuijt-Metz D. Physical activity in US youth: impact of race/ethnicity, age, gender, & weight status. *Med Sci Sports Exerc*. 2010;42(12):2211–21.
26. Cochran WG. The effectiveness of adjustment by subclassification in removing bias in observational studies. *Biometrics*. 1968;24:295–313.
27. Mailey EL, Huberty J, Dinkel D, McAuley E. Physical activity barriers and facilitators among working mothers and fathers. *BMC Public Health*. 2014;14(1):1–9.
28. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451–62.
29. von Koenig Soares EMK, Molina GE, Saint Martin D, et al. Questionnaire-based prevalence of physical activity level on adults according to different international guidelines: impact on surveillance and policies. *J Phys Act Health*. 2019;16(11):1014–21.
30. Price L, Wyatt K, Lloyd J, et al. Are we overestimating physical activity prevalence in children? *J Phys Act Health*. 2018;15(12):941–5.
31. Bevington F, Piercy KL, Olscamp K, Hilfiker SW, Fisher DG, Barnett EY. The move your way campaign: encouraging contemplators and families to meet the recommendations from the Physical Activity Guidelines for Americans. *J Phys Act Health*. 2020;17(4):397–403.
32. White DA, Oh Y, Willis EA. The effect of physical activity bout patterns on metabolic syndrome risk factors in youth: National Health and Nutrition Examination Survey 2003–2006. *J Phys Act Health*. 2018;16(1):12–21.
33. Mota J, Santos P, Guerra S, Ribeiro JC, Duarte JA. Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biol*. 2003;15(4):547–53.
34. Jago R, Anderson CB, Baranowski T, Watson K. Adolescent patterns of physical activity differences by gender, day, and time of day. *Am J Prev Med*. 2005;28(5):447–52.
35. Kudlacek M, Fromel K, Groffik D. Associations between adolescents' preference for fitness activities and achieving the recommended weekly level of physical activity. *J Exerc Sci Fit*. 2020;18(1):31–9.
36. Goodman E, Daniels SR, Meigs JB, Dolan LM. Instability in the diagnosis of metabolic syndrome in adolescents. *Circulation*. 2007;115(17):2316–22.
37. Eissa MA, Mihalopoulos NL, Holubkov R, Dai S, Labarthe DR. Changes in fasting lipids during puberty. *J Pediatr*. 2016;170:199–205.