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Influence of Guideline Operationalization on Youth Activity Prevalence in the International Children's Accelerometry Database

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ABSTRACT

GAMMON, C., A. J. ATKIN, K. CORDER, U. EKELUND, B. H. HANSEN, L. B. SHERAR, L. B. ANDERSEN, S. ANDERSSEN, R. DAVEY, P. C. HALLAL, R. JAGO, S. KRIEMLER, P. L. KRISTENSEN, S. KWON, K. NORTHSTONE, R. PATE, J. SALMON, L. B. SARDINHA, and E. M. F. VAN SLUIJS, ON BEHALF OF THE INTERNATIONAL CHILDREN'S ACCELEROMETRY DATABASE (ICAD) COLLABORATORS. Influence of Guideline Operationalization on Youth Activity Prevalence in the International Children's Accelerometry Database. *Med. Sci. Sports Exerc.*, Vol. 54, No. 7, pp. 1114–1122, 2022. **Introduction:** The United Kingdom and World Health Organization recently changed their youth physical activity (PA) guidelines from 60 min of moderate- to vigorous-intensity PA (MVPA) every day, to an average of 60 min of MVPA per day, over a week. The changes are based on expert opinion due to insufficient evidence comparing health outcomes associated with different guideline definitions. This study used the International Children's Accelerometry Database to compare approaches to calculating youth PA compliance and associations with health indicators. **Methods:** Cross-sectional accelerometer data (n = 21,612, 5–18 yr) were used to examine compliance with four guideline definitions: daily method (DM; ≥60 min MVPA every day), average method (AM; average of ≥60 min MVPA per day), AM5 (AM compliance and ≥5 min of vigorous PA [VPA] on ≥3 d), and AM15 (AM compliance and ≥15 min VPA on ≥3 d). Associations between compliance and health indicators were examined for all definitions. **Results:**

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Compliance varied from 5.3% (DM) to 29.9% (AM). Associations between compliance and health indicators were similar for AM, AM5, and AM15. For example, compliance with AM, AM5, and AM15 was associated with a lower BMI *z*-score (statistics are coefficient [95% CI]): AM (−0.28 [−0.33 to −0.23]), AM5 (−0.28 [−0.33 to −0.23], and AM15 (−0.30 [−0.35 to −0.25]). Associations between compliance and health indicators for DM were similar/weaker, possibly reflecting fewer DM-compliant participants with health data and lower variability in exposure/outcome data. **Conclusions:** Youth completing 60 min of MVPA every day do not experience superior health benefits to youth completing an average of 60 min of MVPA per day. Guidelines should encourage youth to achieve an average of 60 min of MVPA per day. Different guideline definitions affect inactivity prevalence estimates; this must be considered when analyzing data and comparing studies. **Key Words:** ICAD, ACCELEROMETER, PHYSICAL ACTIVITY, COMPLIANCE, VIGOROUS-INTENSITY PHYSICAL ACTIVITY

Regular physical activity (PA) among youth (5–17 yr) has beneficial effects on health (1). The World Health Organization (WHO) and multiple individual countries promote guidelines specifying how much PA youth should engage in for healthy growth and development. Up until 2019, guidelines stated that youth should accumulate 60 min of moderate- to vigorous-intensity PA (MVPA) per day (1). Interpreted literally, this required youth to do ≥60 min of MVPA on every day of the week, and those who are active for 3 $h \cdot d^{-1}$, 6 $d \cdot wk^{-1}$ are deemed insufficiently active. In comparison, the adult PA guidelines promote a weekly volume (150 $min \cdot wk^{-1}$), permitting a more flexible activity pattern (2). The greater flexibility in the adult guidelines has likely contributed to substantially different estimates of guideline compliance between youth and adults. For example, self-reported data indicate that globally, 76.7% of adults, 21.6% of adolescent boys, and 15.6% of adolescent girls meet PA guidelines (2).

Global surveillance of PA guideline compliance is currently based on self-report methods (2). However, increased use of device-based measurement tools has highlighted inconsistencies in data processing and the operationalization of the youth guidelines, limiting cross-study comparisons (3–5). Some define guideline compliance when MVPA averaged over a measurement period is ≥60 $min \cdot d^{-1}$ (average method [AM]) (6), whereas others define compliance as ≥60 min of MVPA achieved on every measured day (daily method [DM]) (7). The use of different guideline definitions has a substantial influence on the proportion of individuals deemed to be meeting PA guidelines (8,9). For example, studies comparing AM and DM report compliance rates of, respectively, 30.6% versus 3.2% (British youth using the wrist worn GENEActiv accelerometer and Phillips cut points) (3), 51.7% versus 23.7% (Estonian youth using the waist-worn ActiGraph accelerometer and Evenson cut points) (4), and 68% versus 20% (Australian youth using the Multimedia Activity Recall for Children and Adolescents survey) (5). To fully understand the public health burden of physical inactivity, guideline operationalization and the corresponding data analysis approach need to be consistent across research studies. This is in addition to other data collection and processing issues that lack consensus, such as cut point selection and where the monitor should be worn (10).

The question of how guidelines should be operationalized has elicited conflicting opinions. The DM has been advocated on the basis of literal interpretation of the guidelines and some evidence that this may be associated with superior beneficial cardiometabolic health (11). Others recommend the AM because most evidence underpinning the guidelines is based on associations between a wide range of health indicators and average levels of MVPA, and there is no evidence that greater flexibility in activity accumulation negatively influences its health benefits (4,12,13). Recently, both the UK and WHO revised the youth PA recommendation from 60 min of MVPA on each day to the achievement of "at least an average of 60 $min \cdot d^{-1}$ of MVPA, across the week" (13,14). This change was based on expert opinion, evidence on the variable nature of youth PA across the week (15), and the rationale that the evidence base is mostly based on the average approach to quantify activity levels (12). However, there is a lack of evidence directly comparing the health benefits associated with each; such evidence is needed to identify the most appropriate public health recommendation.

Global and national PA guidelines also state that youth should participate in vigorous PA (VPA) on ≥3 $d \cdot wk^{-1}$ (1). Compliance with this VPA recommendation is rarely reported, likely because the guidelines do not specify a duration for VPA. However, increasing evidence suggests that VPA is particularly beneficial for child and adolescent health (16). The small number of studies that have attempted to quantify the optimum duration of VPA associated with health benefits suggest that approximately 15 min of VPA/day appears to be associated with improved health outcomes (6,17–19).

In summary, there is a lack of evidence supporting the daily recommendation of 60 min of MVPA for youth, and the daily phrasing of the youth guidelines has contributed to misleading and inconsistent estimates of PA compliance among youth. Previous research comparing different approaches to calculating the proportion of active youth is limited by the use of self-reported data (5), varied accelerometer data reduction decisions, and homogenous samples. A robust analysis of how PA guideline operationalization influences (i) estimates of PA prevalence and (ii) associations between guideline compliance and health indicators is needed. The International Children's Accelerometry Database (20) (ICAD) provides accelerometer-assessed PA and health data on a large, heterogeneous sample, making it suitable to address these questions. The purposes of this study are therefore 1) to quantify the magnitude of differences in compliance estimates when different methods of operationalizing the youth MVPA and VPA guidelines are applied and 2) to test differences in the magnitude of associations between PA guideline compliance and health indicators, using different compliance methods.

METHODS

Study Design

The ICAD (http://www.mrc-epid.cam.ac.uk/research/studies/icad) is a collection of accelerometer-assessed PA data from 20 studies (10 countries). All studies used waist-worn

ActiGraph accelerometers to assess PA in youth (3–18 yr), and all data underwent an identical reduction procedure (20).

Participants

Data in this study are baseline (cross-sectional) measurements from youth (≥5 yr) from 17 studies (nine countries; see Appendix, Supplemental Digital Content, for included studies, http://links.lww.com/MSS/C514). All studies were ethically approved and obtained appropriate consent. Consistent with recommendations, youth with ≥600 min of valid accelerometer wear per day for ≥4 d, including one or more weekend day, were included in analyses (21).

Measurements

PA. Published work (20) describes the accelerometer data reduction process in ICAD. Briefly, PA data were analyzed using vertical axis count data in 60-s epochs (most original data files were only available in 60-s epochs) (20). Non–wear time was defined as 60 min of consecutive zeros (≤2 min of nonzero interruptions allowed) (22). A valid day constituted ≥600 min of valid accelerometer wear time, recorded between 6:00 AM and midnight. Based on the recommendations of previous research (23), Evenson cutpoints were used to classify MVPA (≥2296 counts per minute) and VPA (≥4012 counts per minute) (24).

Guideline compliance. Four interpretations of guideline compliance were examined (Table 1). DM and AM were operationalized based on methods currently used in the youth PA literature (6,7). In addition, two definitions, including compliance with the VPA component of the guidelines, were examined. As current guidelines just specify VPA frequency, not duration, a definition was derived based on recent evidence on the association between VPA and health indicators among youth. Approximately 15 min of VPA per day appears to be associated with improved health outcomes (cardiovascular health indicators, weight status, and body fat percentage) (6,17–19). As such, a duration of ≥15 min of VPA was used to identify compliance/noncompliance for each day. Because some studies report low levels of VPA among youth (8), we also examined a lower threshold of 5 min of VPA per day, to ensure a sufficient sample size for examining associations between compliance and health indicators. Complying with 5 or 15 min of VPA on ≥3 d (1) was combined with AM to create AM5 and AM15, respectively. Compliance with AM5 indicates that a participant achieved an average of at least 60 min of MVPA per day and also engaged in at least 5 min of VPA on at least 3 d of the week. Likewise, compliance with AM15 indicates that a participant achieved an average of at least 60 min of MVPA per day and also engaged in at least 15 min of VPA on at least 3 d of the week. As such, participants complying with AM5 and AM15 represent a subset of those complying with AM.

TABLE 1. Different definitions of PA guideline compliance.

DM	Participants achieving ≥60 min MVPA on every measured day
AM	Participants achieving an average of ≥60 min MVPA per day, over the measurement period
AM5	Participants achieving an average of ≥60 min of MVPA per day including ≥5 min of VPA on ≥3 d
AM15	Participants achieving an average of ≥60 min of MVPA per day including ≥15 min of VPA on ≥3 d

Studies examining the association between VPA and health have typically assessed the influence of VPA as a subset of MVPA, rather than a complement to moderate-intensity PA (MPA). In addition, at least two studies advise that 15 min of VPA be recommended as part of the ≥60-min MVPA recommendation, not in addition to it (18,19). Therefore, we considered participants compliant with AM5 and AM15 definitions regardless of whether the 5 or 15 min of VPA were also part of their ≥60 min of MVPA (i.e., ≥60 min of MVPA per day, including ≥5 or ≥15 min of VPA on ≥3 d). As such, AM15 compliance could be achieved through completing an average of 60 min of MPA per day and 15 min of VPA on ≥3 $d \cdot wk^{-1}$ or through completing an average of 45 min of MPA per day and 15 min of VPA per day.

Health indicators. Details on study-specific data collection and harmonization procedures are published elsewhere (25). All studies contributed height and weight data. Height and weight were measured by trained staff in all studies; BMI was calculated (weight [kg]/height [m^2]) and converted to age- and sex-specific BMI *z*-scores. Other health indicators examined were as follows: waist circumference (partially available for 11 studies/47.0% of participants); resting systolic and diastolic blood pressure (partially available for 10 studies/37.8% of participants); glucose, triglycerides, LDL, and HDL cholesterol (partially available for nine studies/10.5%–29.9% of participants); and insulin levels (partially available for 8 studies/10.4% of participants).

Covariates. Details on the collection of demographic data have been previously published (20). Data on covariates (age, study, country, sex, race, and maternal education) were used to explore the influence of guideline definition on PA prevalence estimates among subgroups for which activity levels are reported to differ. The harmonized maternal education variable indicated whether the mother completed (at most) compulsory education, or any postcompulsory education. Age was calculated using time elapsed between birth date and date of accelerometer assessment. If this information was not available, an alternative age variable was derived from the study's data set. The harmonized race variable classified participants as "White" or "other," based on self- or proxy-reported race.

Statistics

Descriptive statistics (percentages) on compliance with the four guideline definitions for the whole sample and subgroups were examined. Odds ratios were used to explore differences in compliance rates among subgroups (e.g., males vs females), for each definition. Each odds ratio was adjusted for covariates: sex, race, maternal education, age, study, and country. McNemar's tests (a test of paired proportions) were used to examine if there were statistical differences in compliance rates among the four definitions. Linear regression models were used to test associations between guideline compliance and health indicators, adjusting for the same covariates. Of the

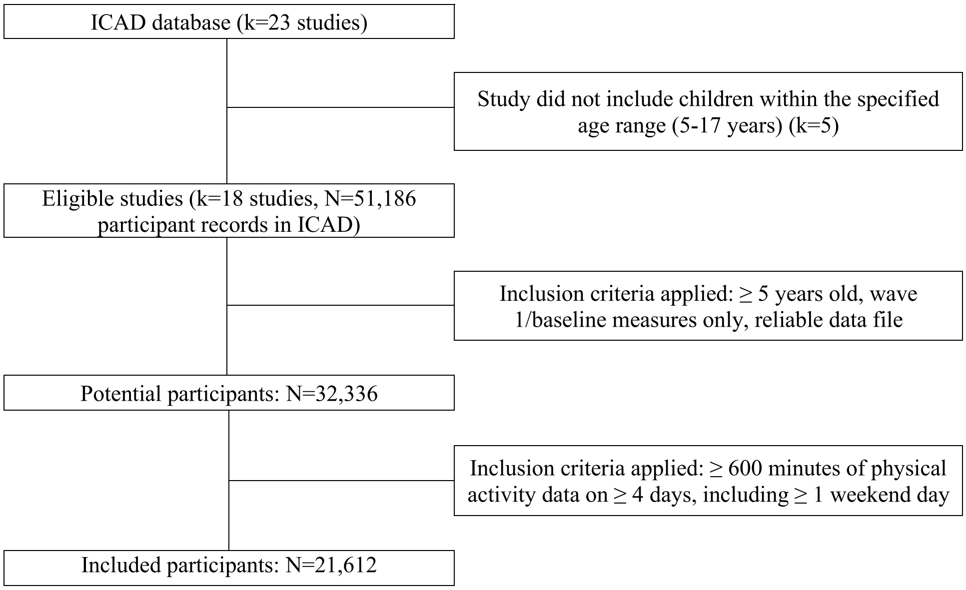

FIGURE 1—Flow chart of included and excluded studies and participants.

included studies, two did not provide data on maternal education (CHAMPS UK, CoSCIS; n = 4798 participants) and four did not provide data on race (CLAN, CoSCIS, HEAPS, KISS; n = 4380 participants), so were excluded from analyses involving these variables. Two-level models were used to account for clustering of children within studies. We conducted sensitivity analyses to examine how data analysis decisions influenced the results. We ran the same statistical procedures using 1) different cut points for MVPA (≥3000 counts per minute) and VPA (≥6000 counts per minute), 2) an MVPA compliance threshold of 55 min (instead of 60), and 3) participants providing 7 d of data (instead of ≥4). We did not conduct sensitivity analyses to examine the influence of including or excluding VPA from the 60-min AM on compliance rates. Statistical analyses were completed using the Statistical Package for the Social Sciences (version 25.0; SPSS Inc, Chicago, IL).

RESULTS

Applying the accelerometer data inclusion criteria resulted in a sample of 21,612 youth (62.4% female; Fig. 1). Included participants provided an average of 5·6 (SD = 1·1) valid days of accelerometer data (range 4–7 d). Of the 21,612 participants, 4758 (22.0%) provided 4 d of data, 4595 (21.3%) provided 5 d, 6538 (30.3%) provided 6 d, and 5721 (26.5%) provided 7 d. Sample descriptive statistics and PA prevalence according to different guideline definitions are shown in Tables 2 and 3, respectively. In addition, Figure 2 shows the proportions of youth complying with different combinations of the guideline definitions. Prevalence estimates varied by definition with the lowest rates associated with DM (5.3%) and the highest rates with AM (29.9%; AM5 = 29.4%, AM15 = 23.7%). McNemar's tests confirmed that prevalence estimates were different across definitions (see Appendix, Supplemental Digital Content, http://links.lww.com/MSS/C514, Tables 3 and 4). There was little difference in prevalence estimates between AM and AM5. Prevalence using AM was approximately 20% higher than with AM15 for the total sample and across most subgroups, suggesting that approximately 80% of youth complying with AM also comply with AM15. Among the youngest participants (5–9.9 yr), the difference between AM and AM15 compliance rates was larger (30%), suggesting that among AM-compliant 5- to 9.9-yr-olds, a smaller proportion comply with AM15 compared with other subgroups.

Regardless of operationalization method, children who were younger, male, White, or had a mother with no more than compulsory education were more likely to comply with guidelines than their reference groups. Associations varied slightly in magnitude across definitions, but the direction was consistent. For

TABLE 2. Descriptive statistics of the ICAD population and study sample.

	Population (N = 32,336)		Study Sample (N = 21,612)	
	n	Mean ± SD or n (%)	n	Mean ± SD or n (%)
Age (yr)	32,336	11.9 ± 2.6	26,612	11.8 ± 2.5
Height (cm)	32,030	149.7 ± 15.2	21,422	149.2 ± 14.5
Weight (kg)	32,053	46.3 ± 17.2	21,442	45.3 ± 16.0
BMI z-score	32,002	0.5 ± 1.2	21,403	0.5 ± 1.2
Average minutes of MVPA per day	21,612	49.2 ± 28.3	21,612	49.2 ± 28.3
Sex: female	32,330	20,305 (63)	21,606	13,472 (62)
IOTF grade: overweight and obese	31,798	8516 (27)	21,323	5393 (25)
Race: White	25,854	15,189 (59)	17,232	10,595 (62)
Maternal education: up to and including compulsory education	24,303	9489 (39)	16,814	6160 (37)

IOTF, International Obesity Task Force.

TABLE 3. PA prevalence under different operationalizations of the public health guidelines.

	n	Prevalence, *n* (%)			
		DM	AM	AM5	AM15
Total sample	21,612	1138 (5.3)	6471 (29.9)	6363 (29.4)	5132 (23.7)
Sex					
Male	8134	862 (10.6)	4090 (50.3)	4023 (49.5)	3301 (40.6)
Female	13,472	276 (2.0)	2380 (17.7)	2339 (17.4)	1830 (13.6)
OR (95% CI)[a]		0.19 (0.15–0.23)	0.23 (0.21–0·25)	0.23 (0.21–0.25)	0.24 (0.22–0.27)
Race					
White	10,595	562 (5.3)	3271 (30.9)	3199 (30.2)	2525 (23.8)
Other	6637	194 (2.9)	1308 (19.7)	1288 (19.4)	1019 (15.4)
OR (95% CI)[b]		0.75 (0.61–0.92)	0.74 (0.67–0.81)	0.75 (0.68–0.82)	0.76 (0.69–0.85)
Maternal education					
≤Compulsory	6160	383 (6.2)	1927 (31.3)	1893 (30.7)	1539 (25.0)
>Compulsory	10,654	528 (5.0)	3216 (30.2)	3170 (29.8)	2595 (24.4)
OR (95% CI)[c]		0.80 (0.67–0.95)	0.89 (0.82–0.98)	0.90 (0.82–0.98)	0.89 (0.81–0.98)
Age					
5–9 yr	4219	458 (10.9)	1878 (44.5)	1821 (43.2)	1324 (31.4)
10–13 yr	13,657	617 (4.5)	4086 (29.9)	4041 (29.6)	3417 (25.0)
OR (95% CI)[d]		0.51 (0.42–0.63)	0.46 (0.42–0.52)	0.48 (0.43–0.54)	0.59 (0.52–0.67)
≥14 yr	3676	60 (2%)	498 (13.5%)	492 (13.4%)	384 (10.4%)
OR (95% CI)[d]		0.23 (0.16–0.33)	0·27 (0·24–0·32)	0·29 (0·25–0·34)	0·38 (0·32–0·44)

[a]Reference category = males, adjusted for country, study, race, maternal education, and age.
[b]Reference category = White, adjusted for country, study, sex, maternal education, and age.
[c]Reference category = ≤compulsory education, adjusted for country, study, race, sex, and age.
[d]Reference category = 5–9.9 yr, adjusted for country, study, maternal education, and sex.
AM5, AM +3 d with ≥5 min VPA; AM15, AM +3 d with ≥15 min VPA; OR, odds ratio.

example, the odds ratio for male (reference category) versus female compliance varied from 0.19 to 0.24 across definitions but consistently indicated that females were less likely to comply with guidelines than males.

Sensitivity analyses results are shown in the Appendix (see Appendix, Supplemental Digital Content, Tables 5–8, http://links.lww.com/MSS/C514). Prevalence when using a 55-min MVPA compliance threshold (instead of 60) and when restricting analyses to those with 7 d of data (instead of ≥4) was similar to that reported in the main analysis. However, prevalence dropped substantially when higher-intensity thresholds (cut points) were applied. For example, the proportion of DM-compliant youth was 5.3% in the main analysis, 7.0% with a 55-min MVPA compliance threshold (instead of 60), 4.1% when restricting

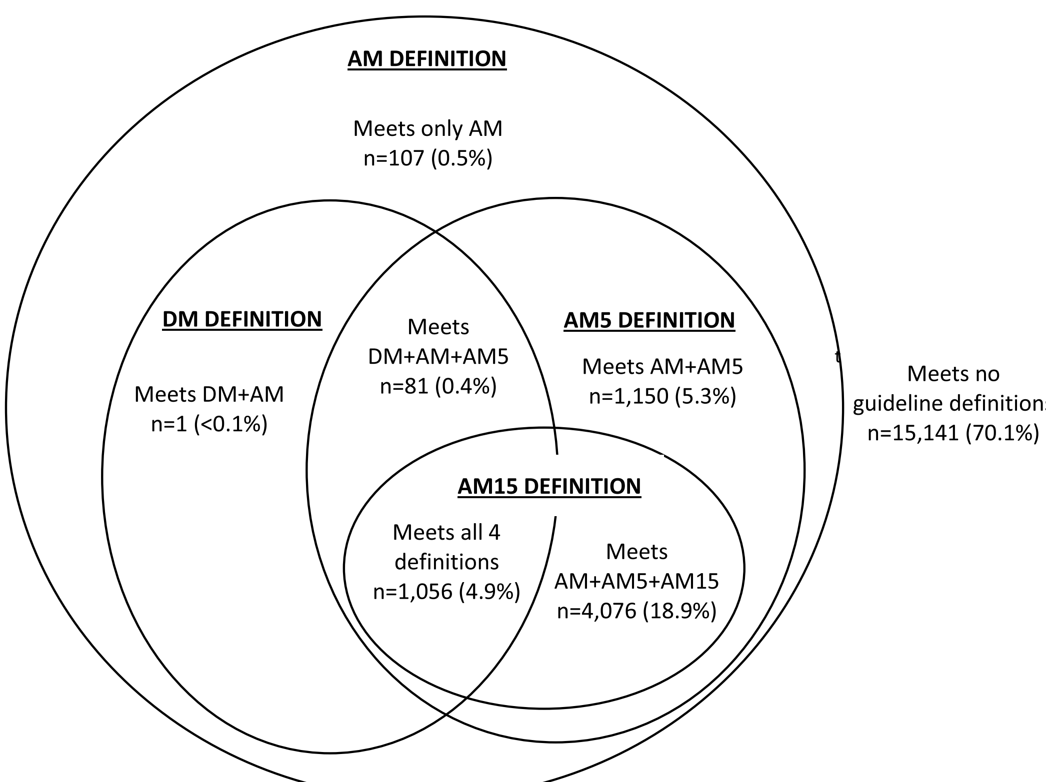

FIGURE 2—Venn diagram showing the number and percentage of the total sample (N = 21,612) meeting different combinations of the guideline definitions. AM5 = AM +3 d with ≥5 min VPA; AM15 = AM +3 d with ≥15 min.

EPIDEMIOLOGY

TABLE 4. Associations between health indicators and different definitions of PA guideline compliance.

	BMI, *z*-score	Waist (cm)	LDL (mmol·L^{-1})	Insulin (pmol·L^{-1})	HDL (mmol·L^{-1})	Glucose (mmol·L^{-1})	Triglycerides[a]	DBP (mm Hg)	SBP (mm Hg)
N[b]	14,026	10,157	5049	2248	6467	2267	5040	8172	8194
DM									
n[c]	1127	866	494	250	566	254	489	753	755
Est. (SE)	−0.21 (0.05)	−1.93 (0.41)	−0.09 (0.04)	−7.94 (3.89)	0.05 (0.02)	−0.10 (0.04)	−0.03 (0.01)	−0·.41 (0.37)	−1.74 (0.46)
P value	<0.001	<0.001	0.02	0.04	0.01	0.01	<0.001	0.27	<0.001
AM									
n[c]	6407	4983	2570	1118	2999	1130	2549	4129	4137
Est. (SE)	−0.28 (0.03)	−2.63 (0.21)	−0.06 (0.02)	−10.62 (2.22)	0.05 (0.01)	−0.09 (0.02)	−0.02 (0.01)	−0.80 (0.20)	−2.01 (0.24)
P value	<0.001	<0·.001	<0.001	<0.001	<0·.001	<0·.001	<0.001	<0.001	<0.001
AM5									
n[c]	6299	4895	2532	1086	2957	1098	2511	4055	4063
Est. (SE)	−0.28 (0.03)	−2.65 (0.21)	−0.06 (0.02)	−10.26 (2.23)	0.04 (0.01)	−0.09 (0.02)	−0.02 (0.01)	−0.79 (0.20)	−1.96 (0.24)
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
AM15									
n[c]	5083	3915	2073	785	2432	794	2057	3307	3314
Est. (SE)	−0.30 (0.03)	−2.82 (0.22)	−0.07 (0.02)	−10.60 (2.45)	0.05 (0.01)	−0.10 (0.02)	−0.02 (0.01)	−0.66 (0.21)	−1.70 (0.25)
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Associations were adjusted for sex, ethnicity, maternal education, age, study, and country.
[a]Triglyceride values (mmol·L^{-1}) were log-transformed due to skewed data.
[b]Number of participants with data for each health indicator.
[c]Number of participants with data for the health indicator and complying with the PA guideline definition.
AM5, AM +3 d with ≥5 min VPA; AM15, AM +3 d with ≥15 min VPA; Est, estimate; S.E., standard error; LDL, low-density lipoprotein cholesterol; HDL, high-density lipoprotein cholesterol; DBP, diastolic blood pressure; SBP, systolic blood pressure.

analyses to those with 7 d of data (instead of ≥4), and 0.8% with higher-intensity thresholds (see Appendix, Supplemental Digital Content, Table 5, http://links.lww.com/MSS/C514). Subgroup differences, however, remained similar, suggesting that different analysis decisions did not alter the overall pattern of results.

For all guideline definitions, associations with health indicators were in expected directions (with compliance favorably associated with each indicator; Table 4). For example, meeting each guideline definition was associated with a lower BMI *z*-score (statistics are coefficient [95% CI]): DM (−0.21 [−0.31 to −0.11], AM (−0.28 [−0.33 to −0.23]), AM5 (−0.28 [−0.33 to −0.23], and AM15 (−0.30, [−0.35 to −0.25]). The magnitude of associations between compliance and health indicators (assessed by comparing parameter estimates) was similar for AM, AM5, and AM15, whereas compliance with DM was less consistently associated with health indicators. For example, meeting the AM, AM5, or AM15 definitions was associated with a lower waist circumference (cm), with coefficients between −2.63 and −2.82, whereas the coefficient for DM compliance was −1.93. Sensitivity analyses results are shown in the Appendix (see Appendix, Supplemental Digital Content, Tables 9–17, http://links.lww.com/MSS/C514). Most associations were similar in magnitude to those reported in the main analysis; associations between guideline compliance and waist circumference and insulin levels were stronger when analyses included participants with 7 d of data (instead of ≥4).

DISCUSSION

Different methods of operationalizing youth PA guidelines yield different compliance estimates (5.3%–29.9%). Of the youth achieving an average of 60 min of MVPA per day, the majority (79.3%) also engaged in ≥15 min of VPA, on ≥3 d·wk^{-1}. Associations between guideline compliance and health indicators were favorable and similar in magnitude for AM, AM5, and AM15, but less consistent for DM.

Guideline operationalization and compliance estimates. As expected, AM and DM definitions produced different compliance estimates, with the stricter DM producing lower estimates. An additional 24.6% of youth were classified as compliant when AM was used, compared with DM. This is consistent with previous studies reporting discrepancies of 27%–28% (accelerometer data) and 48% (self-report data) (3–5). Even with the most lenient AM definition, only 29% of youth complied with guidelines, consistent with previous estimates (26).

Compliance with AM was 50.3% among males and 17.7% among females; this difference is consistent with previous estimates based on objective PA monitoring and use of the AM approach to assess guideline compliance among youth (3,17,27). Compliance with DM was 10.6% among males and 2% among females; these estimates are similar to previous estimates based on accelerometer data and the DM approach (5.5% for boys, 1.2% for girls) (3) although lower than estimates based on self-report data and the DM approach (21.6% for boys, 15.6% for girls) (2). Differences in device-based versus self-report estimates support the shift toward using device-based methods for PA surveillance. The findings also support the need for consistent guideline operationalization to permit cross-study comparisons of compliance estimates. Importantly, with the DM, the proportion of compliant youth will tend toward zero as the number of measurement days increases (5). Our main analysis included youth with ≥4 d of data, and 5.3% were DM compliant. Sensitivity analyses restricted to those with 7 d of data showed that DM compliance dropped to 4.1%. Although there is a small drop in absolute terms, a relative change of ~20% implies the importance of accounting for measurement day frequency when calculating DM compliance. As such, DM compliance estimates to some extent reflect the availability of accelerometer data within a sample. To permit cross-study comparisons of DM compliance measurement day frequency would need to be standardized within and across studies, or reported separately for individuals with different numbers of valid days of data. Conversely, sensitivity analyses showed that compliance rates for AM, AM5, and AM15 increased (by 5.2%, 5.6%, and 7.9%, respectively) when examining participants with 7 d of data instead of those with ≥4 d. This might be explained by higher PA levels among participants who wear their accelerometer for a greater number of days. Previous research reports that more active youth wear their monitors more, and are more likely to provide reliable accelerometer data (28,29).

Compliance rates for AM, AM5, and AM15 were similar, and ~80% of youth compliant with AM also complied with AM15. This suggests that the majority of youth engaging in 60 min of MVPA also engage in ≥15 min of VPA, on ≥3 $d \cdot wk^{-1}$. This is encouraging as evidence indicates the health gains from VPA are greater than from MPA for youth (6,18). These findings are consistent with several studies which report average VPA levels among youth to be ≥15 $min \cdot d^{-1}$ (18,19). Recent studies suggest that a daily dose of 15–20 min is beneficial for health; however, the VPA compliance threshold in this study (≥15 min on ≥3 d) means estimates may not reflect daily compliance. As research on the dose, duration, and frequency of VPA needed for health benefits evolves, it will be important to evaluate whether the VPA component of the guidelines (VPA on ≥3 $d \cdot wk^{-1}$) needs to be revised (i.e., adding duration and/or changing the frequency recommendation).

In regards to the influence of guideline operationalization on subgroup compliance, among the youngest participants (5- to 9.9-yr-olds), a lower proportion of those compliant with AM also complied with AM15 compared with other subgroups, indicating lower levels of VPA among the youngest group. The more sporadic/incidental nature of younger children's activity is more likely to be moderate in nature than vigorous, and the use of 60-s epochs means that short bursts of VPA were likely not detected (10). Consistent with previous research, groups more likely to comply with guidelines were males (8), White youth (30), and younger children (8). The overall pattern of results was consistent across guideline definitions, suggesting that while absolute estimates of compliance from studies using different definitions are not comparable, our understanding of differences in subgroup compliance is not affected by guideline operationalization.

The influence of different guideline operationalization methods on PA prevalence estimates has implications for making cross-study comparisons and synthesizing evidence. Guideline operationalization method adds to the other youth accelerometry data analysis issues, which lack consensus, including epoch length (10), cut points (10), and raw versus count-based processing methods (31). Researchers need to be explicit when describing their methodologies to facilitate interpretation of results and appropriate synthesis of evidence.

Guideline operationalization and associations between compliance and health indicators. The strength of associations between health indicators and guideline compliance demonstrated minimal variation across definitions. Given that previous research has reported a dose–response relationship between MVPA and several health indicators (32,33), it was reasonable to expect that the present study would find stronger associations between DM compliance and health indicators than between AM definition compliance and health indicators. However, this study found that associations between DM compliance and health indicators were generally similar or weaker than associations between health indicators and compliance with AM definitions. One explanation could be that youth participating in >60 min of MVPA every day have a preference for MPA over VPA, and MPA is more weakly associated with metabolic health (16). However, the results should be interpreted cautiously—in the present study, only 5.3% of participants complied with DM, and only a portion of the DM-compliant participants provided health data (22.0%–99.0% depending on which health indicator is considered). The smaller sample size and resulting lower variability in exposure and outcome data may explain why this study found weaker and/or inconsistent associations between DM compliance and health indicators. Notwithstanding this, our findings support the recent changes to the UK and WHO youth PA guidelines to AM wording. Further to this, the use of AM wording permits youth to engage in their characteristically varied PA pattern across the week (34) and allows for rest and sick days.

Consistent with previous research, guideline compliance was associated with favorable health outcomes (lower resting blood pressure (32), waist circumference (35), blood glucose and insulin levels (35), and a favorable lipid profile) (33); the magnitude and the direction of the associations were consistent across the three AM definitions. Given the growing evidence base reporting the health benefits of VPA (6,18,19), it is noteworthy that in these analyses, compliance with AM15 did not demonstrate stronger associations with health indicators than AM. Approximately 80% of AM-compliant youth also complied with AM15, so the statistics are based on similar participant pools, which could explain the similarity in estimates of association. Importantly, VPA has benefits beyond the health outcomes examined in this study (e.g., bone health, mental health) (32,36), and the findings cannot be generalized to those health outcomes.

Strengths and limitations. Strengths of this study include the large, heterogeneous sample of youth and harmonized accelerometer, exposure, and outcome data. We also conducted sensitivity analyses to explore the influence of data analysis decisions on results. Limitations include that a small proportion of the sample were compliant with DM and had health indicator data. As such, associations between DM compliance and health indicators should be interpreted cautiously. There is still underrepresentation of youth from low- and middle-income countries, and of older adolescents (15–18 yr old) in the ICAD, which limits the generalisability of the findings. In addition, the use of a 60-s epoch may have underestimated time spent above the VPA threshold for younger children (10,37–39). Finally, the use of absolute thresholds/count cut points for MPA and VPA assumes that they are suitable for all participants (regardless of age and sex); as such, it is possible that PA intensity was misclassified for a proportion of the participants in the heterogeneous sample. The Evenson intensity cut points used for this study were calibrated for 15-s epochs, and therefore their application to 60-s epoch data is a deviation from their intended use. However, previous research recommends the use of the Evenson intensity cut points over other sets of cut points among 5- to 15-yr-olds (23). In addition, the Evenson intensity cut points have been regularly used to explore ICAD accelerometer data (as recently 2021) for the same age range of participants as included in this study (7,40–43). Further, our sensitivity analyses showed that even if a different set of cut points are applied, our main conclusions hold (although the compliance estimates change).

CONCLUSIONS

Youth achieving 60 min of MVPA every day do not experience superior health benefits to youth achieving an average of 60 min·d^{-1} of MVPA. The majority of youth achieving an average of 60 min of MVPA also achieve 15 min of VPA, indicating that some VPA is typically included in youth activity patterns. These findings provide evidence to support the recent change to the UK and WHO guidelines (to the AM approach), which are currently based on expert opinion due to a lack of evidence on the health benefits of the DM. The AM should be used for guideline operationalization and public health promotion.

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EPIDEMIOLOGY

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