Physical Activity: Absolute Intensity versus Relative-to-Fitness-Level Volumes

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[1]*Department of Health Sciences, University of Jyväskylä, Jyväskylä, FINLAND;* [2]*Department of Signal Processing, Tampere University of Technology, Tampere, FINLAND; and* [3]*Department of Psychology, University of Jyväskylä, Jyväskylä, FINLAND*

ABSTRACT

KUJALA, U. M., J. PIETILÄ, T. MYLLYMÄKI, S. MUTIKAINEN, T. FÖHR, I. KORHONEN, and E. HELANDER. Physical Activity: Absolute Intensity versus Relative-to-Fitness-Level Volumes. *Med. Sci. Sports Exerc.*, Vol. 49, No. 3, pp. 474–481, 2017. **Purpose**: This study aimed to investigate in a real-life setting how moderate- and vigorous-intensity physical activity (PA) volumes differ according to absolute intensity recommendation and relative to individual fitness level by sex, age, and body mass index. **Methods**: A total of 23,224 Finnish employees (10,201 men and 13,023 women; ages 18–65 yr; body mass index = 18.5–40.0 kg·m^{-2}) participated in heart rate recording for 2+ d. We used heart rate and its variability, respiration rate, and on/off response information from R-R interval data calibrated by participant characteristics to objectively determine daily PA volume, as follows: daily minutes of absolute moderate (3–<6 METs) and vigorous (≥6 METs) PA and minutes relative to individual aerobic fitness for moderate (40%–<60% of oxygen uptake reserve) and vigorous (≥60%) PA. **Results**: According to absolute intensity categorization, the volume of both moderate- and vigorous-intensity PA was higher in men compared with women (P < 0.001), in younger compared with older participants (P < 0.001), and in normal weight compared with overweight or obese participants (P < 0.001). When the volume of PA intensity was estimated relative to individual fitness level, the differences were much smaller. Mean daily minutes of absolute vigorous-intensity PA were higher than those of relative intensity minutes in normal weight men ages 18–40 yr (17.7, 95% confidence interval [CI] = 16.9–18.6, vs 8.6, 95% CI = 8.0–9.1; P < 0.001), but the reverse was the case for obese women ages 41–65 yr (0.3, 95% CI = 0.2–0.4, vs 7.8, 95% CI = 7.2–8.4; P < 0.001). **Conclusion**: Compared with low-fit persons, high-fit persons more frequently reach an absolute target PA intensity, but reaching the target is more similar for relative intensity. **Key Words:** EXERCISE, OBJECTIVE MONITORING, HEART RATE, FITNESS

Increasing physical activity (PA) among both healthy people and individuals with chronic disease is linked to many health benefits (22,26,27). The current PA guidelines for aerobic PA (27,39) recommend at least 150 min of moderate-intensity PA (MPA) or at least 75 min of vigorous-intensity PA (VPA) per week, accumulated in bouts of at least 10 min in duration. This recommendation is based mostly on observational cohort studies that most often used self-reported questionnaire measures of leisure-time PA. Results of accelerometer-based (1,7,36) and heart rate–based (25) objective assessments of PA indicate that only a small proportion of adult populations meet the recommendation. PA bouts shorter than 10 min, often occurring during daily life and unplanned (38), are not included when investigating who fulfills this PA recommendation. However, accumulating evidence suggests that short bouts of moderate-to-vigorous PA (MVPA) are associated with reduced levels of cardiometabolic risk factors (6,12,33,38).

PA can be assessed using questionnaires or more objective monitoring methods (34). Recent advances in accelerometer-based PA monitoring techniques help yield good estimates of the intensity of certain types of PA, such as walking and running on a standard surface (37). Heart rate–based monitoring methods, however, are better for determining the intensity of different types of real-life MVPA (34), including bicycling and many work-related activities. Accelerometer-based objective monitoring methods may be more reliable in recording low to very low intensity PA compared with simple heart rate–based devices because of artifacts resulting from excitement and other stimuli unrelated to PA that still influence heart rate (34). The current aerobic PA recommendations are for MVPA characterized in absolute multiples of resting metabolic rate, MET, values. However, maximal exercise capacity in low-fit individuals, in particular among those who are older, obese, or have chronic disease, may be lower than the recommended absolute intensity level of VPA. Consequently, individuals who cannot reach the recommended intensity level do not have this type of PA recorded. Physicians and other professionals giving exercise recommendations need to understand which types of PA are achievable by physically inactive people with low fitness levels, the most important

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Submitted for publication May 2016.
Accepted for publication October 2016.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.acsm-msse.org).

0195-9131/17/4903-0474/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000001134

target group for PA promotion. Although variation exists in how people feel pleasure and discomfort when they exercise at different intensity levels, in general, pleasure is reduced when the ventilatory or lactate threshold is surpassed (8).

The aim of this study was to compare the volumes of objectively monitored PA determined by recommended absolute intensity levels and by intensity levels relative to individual fitness by sex, age, and body mass index (BMI) (normal weight, overweight, and obese) among 23,224 Finnish employees during everyday life. To determine the PA volumes, we used sophisticated and validated methodology (25), including information on continuous heart rate and heart rate variability recordings.

METHODS

Study design and participants. This cross-sectional study investigated the amount of absolutely and relatively (i.e., relative to participant's maximal oxygen uptake [$\dot{V}O_{2max}$]) determined PA at different intensity levels (moderate, vigorous, and moderate-to-vigorous combined) during workdays and days off by sex, age, and BMI among a sample of 23,224 Finnish employees (10,201 men and 13,023 women; age range = 18–65 yr, BMI range = 18.5–40.0 kg·m^{-2}) who participated in real-life preventive occupational health care provided by their employers during the years 2007–2015 in Finland (Fig. 1). A wide nonselective range of nonmanual and manual labor employees was included. The employees participated in real-life continuous beat-to-beat R-R interval recordings. The majority of participants were apparently healthy because individuals with chronic disease and medications influencing heart rate did not participate in these recordings. For detailed exclusion criteria for participation in the R-R interval recordings, see Mutikainen et al. (25).

The data obtained from these R-R interval recordings were anonymously stored in a database administered by the software manufacturer (Firstbeat Technologies Ltd., Jyväskylä, Finland). According to written agreements (25), Firstbeat Technologies Ltd. extracted an anonymous data file for the present research purposes. This study was approved by the Ethics Committee of Tampere University Hospital (reference no. R13160).

PA monitoring and assessment. The ambulatory beat-to-beat R-R interval data used to calculate the intensity and amount of PA were recorded during the course of normal everyday life, usually over 3 d (typically including two workdays and 1 d off), using the Firstbeat Bodyguard device with stick-on electrodes with wires (Firstbeat Technologies Ltd.). Monitoring data were first analyzed using Firstbeat Analysis Server software (version 6.3, Firstbeat Technologies Ltd.). To be included, a participant had to have a measurement period, including at least one workday and 1 d off (Fig. 1). We included a workday or a day off in the analysis if the measurement period lasted 16–30 h·d^{-1}. Because the measurement day was determined from waking up to waking up, recordings were allowed to exceed 24 h. The information about the type of day was obtained from participant diaries; a workday had to include ≥4 working hours cumulatively, days off were without any working hours, and the days with reported work time >0 but <4 h were excluded

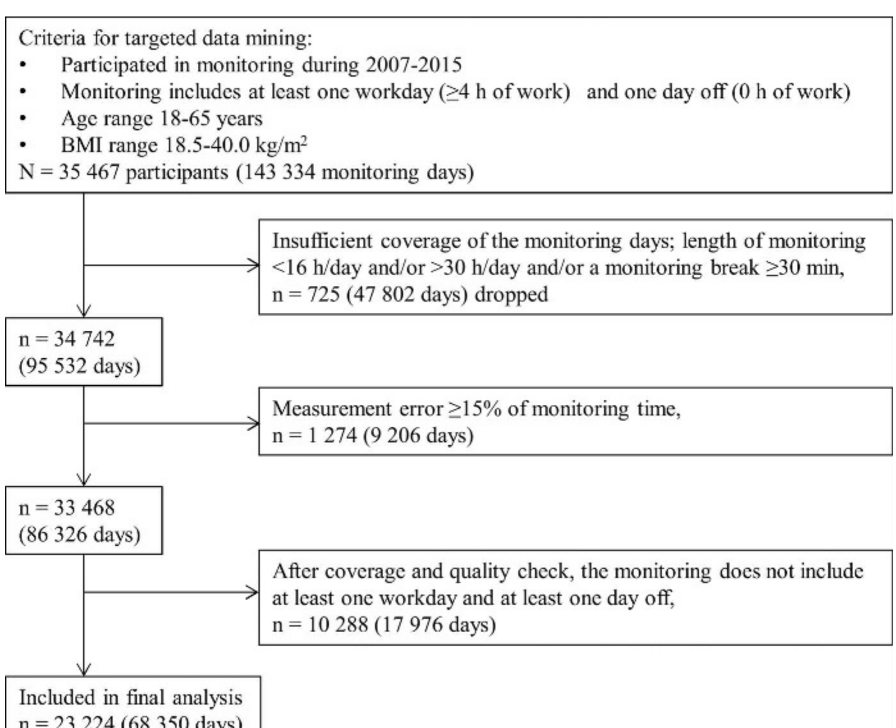

FIGURE 1—Flow of participants and measurement days included in the analysis.

from the analyses. The analyzed data consisted of successfully recorded (measurement error in recording R-R intervals detected with an automatic artifact detection and correction feature for irregular ectopic beats, and signal noise <15% and <30 min recording break) workdays and days off (Fig. 1).

Background information included age, sex, questionnaire-reported height, weight, and PA class (9), modified from Ross and Jackson (28). Then maximal heart rate (210 − 0.65 × age) (16) and $\dot{V}O_{2max}$ (men 67.350 + 1.921 × PA class − 0.381 × age − 0.754 × BMI; women 56.363 + 1.921 × PA class − 0.381 × age − 0.754 × BMI) (15) were estimated, and these values were further used in the estimation of oxygen uptake ($\dot{V}O_2$). If a period with a heart rate higher than the estimate was found from the recording, the maximal heart rate used for further calculations was corrected accordingly. BMI ($kg \cdot m^{-2}$) was calculated from the self-reported weight and height.

The intensity in terms of $\dot{V}O_2$ and volume of PA was first estimated based on the R-R interval recordings (10,17,18,30). The method has been validated previously; the pooled relationship (correlation) between the measured and the predicted $\dot{V}O_2$ across the different activities of daily living was 0.93, and the estimated $\dot{V}O_2$ explained 87% of the variability in the measured $\dot{V}O_2$ (32). In another validation study, Robertson et al. (29) showed that the energy expenditure estimates based on our method correlate strongly with those based on indirect calorimetry across analysis conditions (r = 0.85–0.98). The high validity of this method was achieved by taking into account the R-R interval–derived information about heart rate, respiration rate, and on/off response (increasing or decreasing heart rate) using neural network modeling of the data and the short-time Fourier transform method (10,17,18,30).

Participant mean $\dot{V}O_2$ for each minute was calculated from the second-by-second $\dot{V}O_2$ estimations. For the calculation of the volume of absolutely determined PA, the minute-by-minute $\dot{V}O_2$ estimations were converted to METs by dividing the $\dot{V}O_2$ values by a resting metabolic rate value of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$. On the basis of the MET values, the volume of MPA and VPA ($min \cdot d^{-1}$) at each intensity level was then calculated. These data are called MPA_{Abs} and VPA_{Abs} later in the text. The thresholds for these categories were MPA_{Abs} 3–<6 METs and VPA_{Abs} ≥6 METs (11). MVPA then refers to the sum of MPA and VPA, respectively.

The intensity of PA was also calculated relatively, i.e., in relation to estimated $\dot{V}O_{2max}$. The relative intensity was determined using the percentage of $\dot{V}O_2$ reserve (% $\dot{V}O_2R$). $\dot{V}O_2R$ is calculated by subtracting 1 MET (3.5 $mL \cdot kg^{-1} \cdot min^{-1}$) from the $\dot{V}O_{2max}$. The % $\dot{V}O_2R$ is calculated by subtracting 1 MET from the measured $\dot{V}O_2$, dividing by the $\dot{V}O_2R$, and multiplying by 100% (14). The amount of PA ($min \cdot d^{-1}$) at different intensity levels (moderate and vigorous) was then calculated. These values are called MPA_{Rel} and VPA_{Rel} later in the text. The thresholds for these categories were MPA_{Rel} 40%–<60% $\dot{V}O_2R$ and VPA_{Rel} ≥60% $\dot{V}O_2R$ (11,14). Again, MVPA refers to the sum of MPA and VPA, respectively.

As the general use of resting metabolic rate value of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ to calculate PA METs for individuals with differing sex, age, and BMI may cause misclassification of activities (20), we also recalculated the main results using the original Harris–Benedict formula (13). Results in our article and Supplemental Digital Content 1, http://links.lww.com/MSS/A810, are based on the generally used 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ for resting metabolic rate and those in the Supplemental Digital Content 2, http://links.lww.com/MSS/A811, on calculating the resting metabolic rates using the Harris–Benedict formula.

Statistical analysis. Data processing and statistical analysis were performed using MATLAB version R2015b (The MathWorks Inc., Natick, MA) and R version 3.2.2 (The R Foundation for Statistical Computing, Vienna, Austria).

We calculated mean, SD, and 95% confidence intervals (CI) for continuous variables. First, the total number of 1-min segments in each intensity category during each measurement day for each individual was calculated. If a participant's measurement period included two or more workdays (or days off), an average was calculated. We also calculated the mean daily absolute and relative intensity PA minutes covering both workdays and days off. Then we calculated the amount of MPA_{Abs}, MPA_{Rel}, VPA_{Abs}, and VPA_{Rel} by gender and type of day (i.e., workdays vs days off) for different age (18–30, 31–40, 41–50, and 51–65 yr) and BMI categories (normal weight, 18.5–<25.0 $kg \cdot m^{-2}$; overweight, 25.0–<30.0 $kg \cdot m^{-2}$; and obese, 30.0–40.0 $kg \cdot m^{-2}$). The absolute and relative PA volumes at different intensity levels were compared inside each age and BMI category using the Wilcoxon signed rank test. Differences in the absolute and relative PA volumes between age and BMI categories were analyzed using the Kruskal–Wallis test.

We then calculated how the determined absolute and relative intensity PA minutes overlapped (Figs. 2 and 3). In addition, we calculated at the group level the proportions between VPA_{Abs}/VPA_{Rel} in specific subgroups (Fig. 4). Because of the complexity of the relations between the absolute and the relative intensity minutes, the 95% CI values for the relations were calculated using a percentile bootstrapping method. All P values reported are two-sided, and because of the large sample size, the significance level was set to 0.001.

RESULTS

Most of the R-R interval recordings were from values taken over 3 d (13,052 participants); 7062, 1327, 936, and 847 participants had 2, 4, 5, and 6 measurement days, respectively. Altogether, the number of analyzed days was 39,904 for workdays and 28,446 for days off (Fig. 1). The mean ± SD age of the participants was 44.7 ± 9.8 yr (men = 44.4 ± 9.9 yr, women = 45.0 ± 9.8 yr), and the mean ± SD BMI was 26.0 ± 4.0 $kg \cdot m^{-2}$ (men = 26.6 ± 3.5 $kg \cdot m^{-2}$, women = 25.5 ± 4.4 $kg \cdot m^{-2}$) (Table 1).

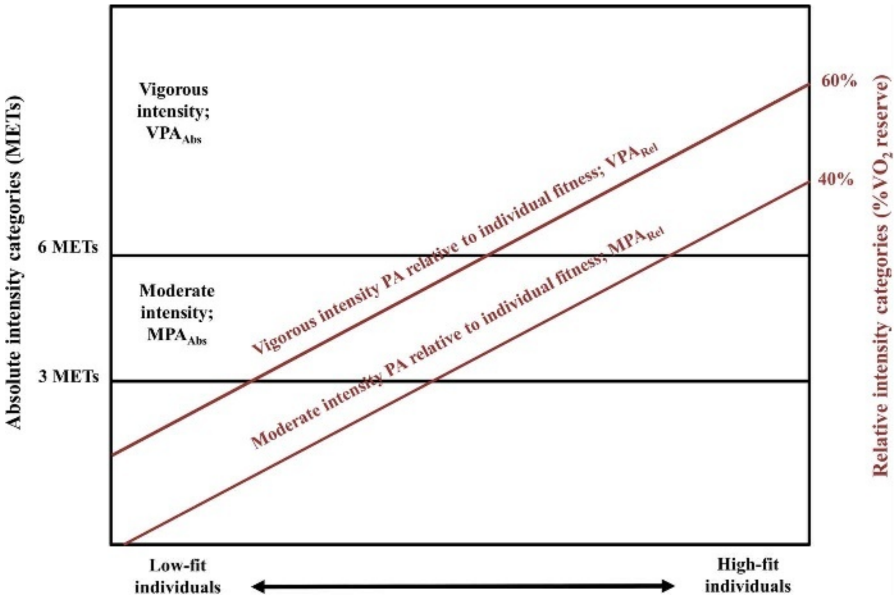

FIGURE 2—Illustration of the theoretical overlap between absolute PA intensity versus PA intensity relative to individual aerobic fitness level. % $\dot{V}O_2$ reserve, percentage of maximal oxygen uptake reserve.

Heart rates and estimated $\dot{V}O_{2max}$. Mean heart rates did not differ substantially between age-groups or between workdays and days off. However, the mean heart rates increased with increasing BMI among both men and women during both workdays and days off, covering time awake and sleeping time (see Table 1 in Supplemental Digital Content 1, Mean heart rates by age, sex, and type of day during whole recording day, http://links.lww.com/MSS/A810). For the estimated mean $\dot{V}O_{2max}$ values by sex, age, and BMI categories, see Table 2 in Supplemental Digital Content 1 (Mean estimated $\dot{V}O_{2max}$ values by sex, age and weight group, http://links.lww.com/MSS/A810).

PA volumes by sex, age, and type of day. According to absolute intensity, as expected, men had higher values for MPA and VPA minutes compared with women (Table 2). The mean values for the $MVPA_{Abs}$ minutes during workdays were 50.5 (95% CI = 49.5–51.4) for men and 33.2 (95% CI 32.6–33.8) for women ($P < 0.001$); during days off, they were 63.7 (62.5–64.9) and 34.7 (34.0–35.4) ($P < 0.001$), respectively [see Tables 3 and 4 in Supplemental Digital Content 1, Amount of absolute and relative moderate and vigorous intensity physical activity (min·d^{-1}) by age groups during workdays and days off among men; Amount of absolute and relative moderate and vigorous intensity physical activity (min·d^{-1}) by age-groups during workdays and days off among women, http://links.lww.com/MSS/A810]. In particular, VPA volumes were low for women (Table 2). However, when calculated as intensity levels relative to individual fitness, the PA volumes

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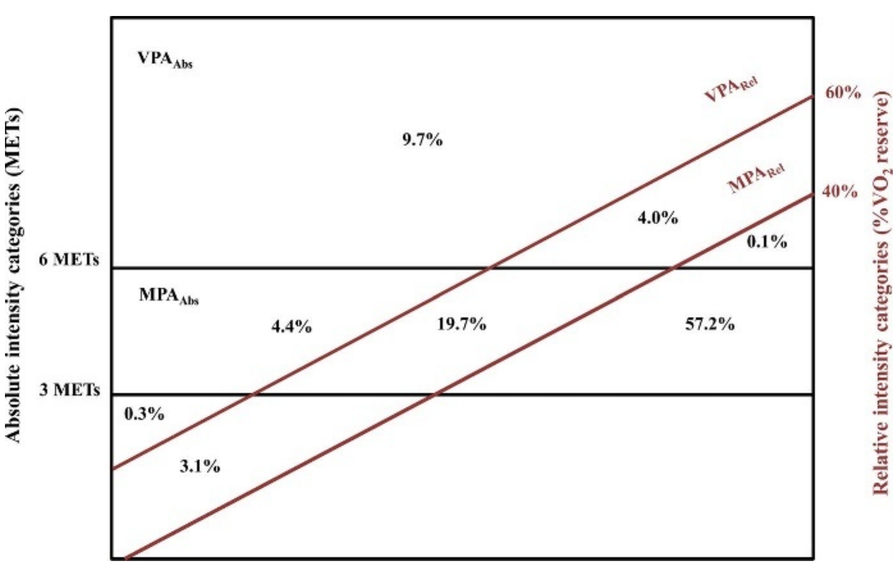

FIGURE 3—Overlap (mean percent of PA minutes falling in different intensity categories) between absolute PA intensity versus PA intensity relative to individual aerobic fitness level. For abbreviation, see Figure 2.

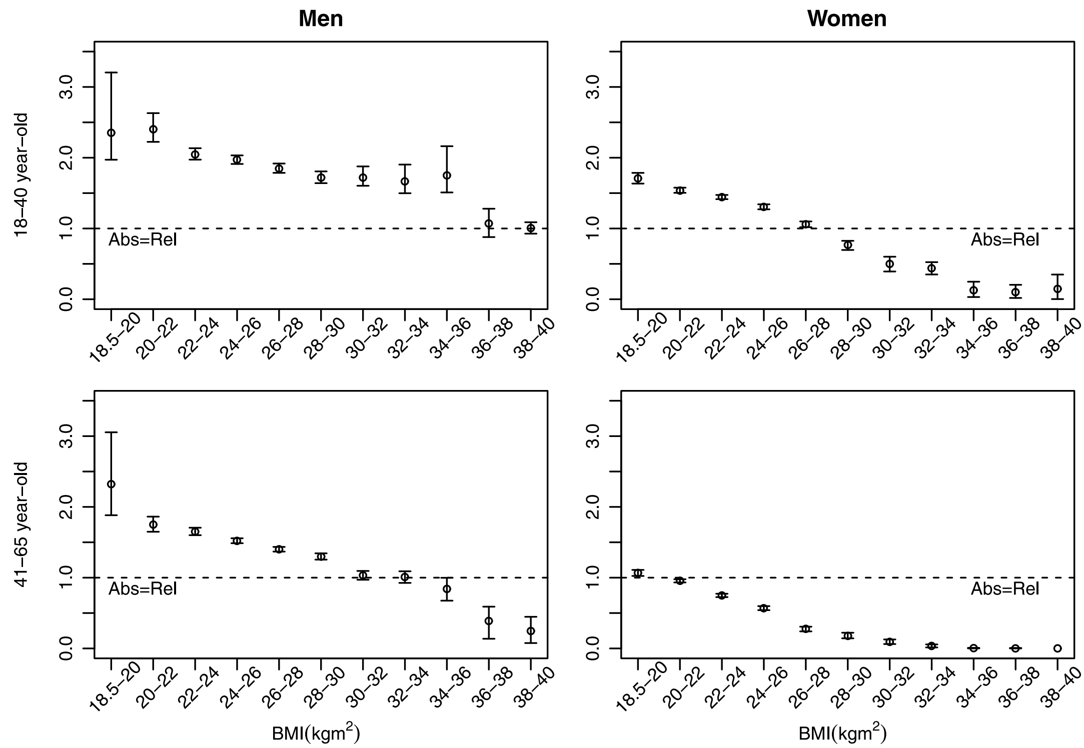

FIGURE 4—Daily VPA_{Abs}/VPA_{Rel} minute ratios among older and younger men and women by BMI categories. VPA_{Abs} = daily minutes of absolute vigorous-intensity (≥6 METs) PA. VPA_{Rel} = daily minutes of VPA relative to individual aerobic fitness (≥60% of oxygen uptake reserve). Error bars represent 95% CI.

for women were about at the same level as for men or even higher (Table 2): mean daily minutes of $MVPA_{Rel}$ were 16.2 for men and 17.3 for women.

Men older than 30 yr had higher $MVPA_{Abs}$ and $MVPA_{Rel}$ minutes during days off than during workdays, but these differences were not as strong in women and in younger men. PA volume in terms of absolute intensity decreased by age among both women and men, during both workdays and days off, but a similar strong age-related reduction of PA was not seen when the intensity was calculated relative to individual fitness level [Table 2, see also Tables 3 and 4 in Supplemental Digital Content 1, Amount of absolute and relative moderate and vigorous intensity physical activity (min·d^{-1}) by age groups during workdays and days off among men; Amount of absolute and relative moderate and vigorous intensity physical activity (min·d^{-1}) by age groups during workdays and days off among women, http://links.lww.com/MSS/A810]. Among the oldest women (51–65 yr), the amount of VPA_{Rel} was higher compared with VPA_{Abs} ($P < 0.001$).

The overlap of the minutes that fulfilled the criteria for either $MVPA_{Abs}$ or $MVPA_{Rel}$ in different absolute and relative intensity categories is shown in Figure 3. An average

TABLE 1. Number of participants by sex, age, and weight status.

		Weight Status		
		Normal Weight	Overweight	Obese
Age Group	*n*		*n* (%)	
18–30 yr				
Men	940	524 (55.7)	349 (37.1)	67 (7.1)
Women	1148	873 (76.0)	199 (17.3)	76 (6.6)
31–40 yr				
Men	2794	1115 (39.9)	1321 (47.3)	358 (12.8)
Women	3087	1995 (64.6)	751 (24.3)	341 (11.0)
41–50 yr				
Men	3333	1048 (31.4)	1708 (51.2)	577 (17.3)
Women	4512	2318 (51.4)	1386 (30.7)	808 (17.9)
51–65 yr				
Men	3134	968 (30.9)	1646 (52.5)	520 (16.6)
Women	4276	1887 (44.1)	1511 (35.3)	878 (20.5)
Total				
Men	10,201	3655 (35.8)	5024 (49.3)	1522 (14.9)
Women	13,023	7073 (54.3)	3847 (29.5)	2103 (16.1)

Normal weight = BMI 18.5–<25.0 kg·m^{-2}.
Overweight = BMI 25.0–<30.0 kg·m^{-2}.
Obese = BMI 30.0–40.0 kg·m^{-2}.

TABLE 2. Mean[a] daily amount of absolute and relative MPA and VPA ($min \cdot d^{-1}$) by age groups and by weight status among men and women.

	MPA_{Abs}	MPA_{Rel}	VPA_{Abs}	VPA_{Rel}	$MVPA_{Abs}$	$MVPA_{Rel}$
	Mean (95% CI), min					
Activity volumes by age groups						
Men						
18–30 yr	71.3 (68.3–74.2)	9.1 (8.5–9.6)	17.9 (16.8–18.9)	7.8 (7.1–8.4)	89.1 (85.7–92.6)	16.9 (15.8–17.9)
31–40 yr	49.2 (47.9–50.4)	8.4 (8.1–8.7)	14.5 (13.9–15.1)	8.0 (7.6–8.4)	63.7 (62.1–65.3)	16.4 (15.8–17.0)
41–50 yr	41.4 (40.4–42.4)	8.9 (8.5–9.2)	12.0 (11.5–12.5)	7.7 (7.3–8.1)	53.4 (52.2–54.6)	16.5 (16.0–17.1)
51–65 yr	37.2 (36.2–38.2)	9.2 (8.9–9.5)	8.2 (7.8–8.7)	6.3 (6.0–6.7)	45.4 (44.3–46.6)	15.5 (14.9–16.1)
Women						
18–30 yr	55.1 (53.3–56.8)	12.5 (11.9–13.0)	15.6 (14.7–16.4)	9.5 (8.9–10.1)	70.6 (68.4–72.8)	21.9 (21.0–22.9)
31–40 yr	34.1 (33.3–34.9)	9.5 (9.2–9.8)	8.4 (8.0–8.8)	7.0 (6.7–7.3)	42.5 (41.5–43.5)	16.5 (16.0–17.0)
41–50 yr	25.2 (24.7–25.7)	9.5 (9.3–9.8)	5.1 (4.8–5.4)	6.8 (6.5–7.0)	30.3 (29.6–31.0)	16.3 (15.9–16.7)
51–65 yr	19.8 (19.3–20.3)	10.7 (10.4–11.0)	2.0 (1.8–2.2)	6.8 (6.5–7.1)	21.8 (21.2–22.4)	17.5 (17.0–18.1)
Activity volumes by weight status						
Men						
Normal	51.6 (50.4–52.8)	9.2 (8.9–9.5)	16.0 (15.5–16.6)	8.8 (8.4–9.2)	67.6 (66.2–69.1)	18.0 (17.5–18.6)
Overweight	43.0 (42.1–43.8)	8.6 (8.3–8.8)	11.0 (10.6–11.4)	7.0 (6.7–7.3)	54.0 (53.0–55.0)	15.6 (15.1–16.0)
Obese	35.8 (34.3–37.3)	8.8 (8.4–9.3)	6.1 (5.5–6.6)	5.2 (4.7–5.7)	41.9 (40.2–43.6)	14.0 (13.2–14.8)
Women						
Normal	35.3 (34.7–35.9)	10.4 (10.2–10.5)	9.1 (8.8–9.3)	8.2 (7.9–8.4)	44.4 (43.7–45.1)	18.5 (18.2–18.9)
Overweight	22.8 (22.2–23.4)	9.2 (9.0–9.5)	2.6 (2.4–2.7)	5.0 (4.8–5.3)	25.3 (24.7–26.0)	14.2 (13.8–14.7)
Obese	14.0 (13.4–14.6)	11.3 (10.8–11.8)	0.6 (0.4–0.7)	7.1 (6.6–7.6)	14.6 (14.0–15.2)	18.4 (17.5–19.3)
All men	45.0 (44.4–45.6)	8.9 (8.7–9.0)	12.1 (11.8–12.4)	7.4 (7.2–7.6)	57.1 (56.3–57.9)	16.2 (15.9–16.6)
All women	28.2 (27.8–28.5)	10.2 (10.0–10.3)	5.8 (5.6–5.9)	7.1 (6.9–7.2)	33.9 (33.5–34.4)	17.2 (17.0–17.5)

[a]Mean of all monitored work days and days off.

There was a statistically significant difference between absolute and relative intensity physical activity ($P < 0.001$, Wilcoxon signed rank test) in all age-groups and weight status groups and intensity categories.

Except for MPA_{Rel} in men ($P = 0.006$), there was a statistically significant difference ($P < 0.001$, Kruskal–Wallis test) in all intensity categories between age-groups.

There was a statistically significant difference ($P < 0.001$, Kruskal–Wallis test) in all activity types between weight status groups.

MPA_{Abs} = MPA, absolutely determined intensity: 3.0–<6.0 metabolic equivalents (METs); MPA_{Rel} = MPA, relatively determined intensity: 40%–<60% oxygen uptake reserve ($\dot{V}O_2R$); VPA_{Abs} = VPA, absolutely determined intensity: ≥6.0 METs; VPA_{Rel} = VPA, relatively determined intensity: ≥60% $\dot{V}O_2R$.

Normal = BMI 18.5–<25.0 $kg \cdot m^{-2}$.

Overweight = BMI 25.0–<30.0 $kg \cdot m^{-2}$.

Obese = BMI 30.0–40.0 $kg \cdot m^{-2}$.

of 9.7% (95% CI = 9.5–9.9) of these minutes were vigorous and 19.7% (95% CI = 19.4–20.0) were moderate intensity, according to both absolute and relative criteria.

PA volumes and BMI. The amount of PA in terms of absolute intensity decreased with increasing BMI among both women and men. However, a similar strong BMI-related reduction of PA was not seen when the intensity was calculated relative to individual fitness level [Table 2, see also Tables 5 and 6 in Supplemental Digital Content 1, Amount of absolute and relative moderate- and vigorous-intensity physical activity ($min \cdot d^{-1}$) by weight status during workdays and days off among men; Amount of absolute and relative moderate- and vigorous-intensity physical activity ($min \cdot d^{-1}$) by weight status during workdays and days off among women, http://links.lww.com/MSS/A810]. In men, the volume of MPA_{Rel} was significantly lower than that of MPA_{Abs} ($P < 0.001$) in each BMI category. Except for obese men during days off, the amount of VPA_{Rel} was also significantly ($P < 0.001$) lower than that of VPA_{Abs} in each BMI category among men.

Among women, the volume of MPA_{Rel} was significantly ($P < 0.001$) lower than that of MPA_{Abs} in each BMI category. However, among overweight and obese women, the amount of VPA_{Rel} was significantly ($P < 0.001$) higher than that of VPA_{Abs}. Of note, among obese women, 93% during workdays and 95% during days off had no VPA_{Abs}, with percentages of 41% and 54% for no VPA_{Rel}, respectively.

Mean daily VPA_{Abs} minutes were higher than VPA_{Rel} minutes in younger (18–40 yr) normal weight men (17.7, 95% CI = 16.9–18.6, vs 8.6, 95% CI = 8.0–9.1; $P < 0.001$). The reverse was the case for older (41–65 yr) obese women (mean 0.3, 95% CI = 0.2–0.4, vs 7.8, 95% CI = 7.2–8.4; $P < 0.001$).

Figure 4 shows the relations between all VPA_{Rel}/VPA_{Abs} minutes among younger (18–40 yr) and older (41–65 yr) men and women split into smaller BMI categories. The number of VPA_{Rel} minutes was higher than the number of VPA_{Abs} minutes among older men with BMI more than 34 $kg \cdot m^{-2}$, younger women with BMI more than 28 $kg \cdot m^{-2}$, and older women with BMI more than 20 $kg \cdot m^{-2}$. Concerning the overlap of the absolute vs relative intensity minute categories (Fig. 3), among normal weight men, there were no minutes in the category below MPA_{Abs} and $MVPA_{Rel}$, but an average of 27.7% of the recorded PA minutes fell into these categories among obese women.

When reanalyzing the main results using resting metabolic rate calculated individually according to the Harris–Benedict formula, expectedly, the resting metabolic rates were lower than 3.5, in particular among aged, obese females [for details see Table 1 in Supplemental Digital Content 2, Mean estimated resting metabolic rates ($\dot{V}O_2$ values) by sex, age and weight groups according to Harris–Benedict formula, http://links.lww.com/MSS/A811]. In this reanalysis, the number of absolute PA minutes was higher [please, compare Table 2 in the Supplemental Digital Content 2 (Mean estimated resting metabolic rates ($\dot{V}O_2$ values) by sex, age and weight groups according to Harris–Benedict formula) vs. Table 2 in the manuscript, http://links.lww.com/MSS/A811]. The overlap of the minutes that fulfilled

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the criteria for either $MVPA_{Abs}$ or $MVPA_{Rel}$ in different absolute and relative intensity categories was lower than that in our primary analysis [see Figure 1 in Supplemental Digital Content 2 (Overlap between absolute PA intensity vs. PA intensity relative to individual aerobic fitness level) vs. Figure 3, http://links.lww.com/MSS/A811], and the number of VPA_{Rel} minutes persisted higher than the number of VPA_{Abs} minutes in particular among older women with high BMI.

DISCUSSION

Objectively measured absolute volumes of MVPA were higher in men compared with women in this study, and higher in younger compared with older and in normal weight compared with obese individuals. When the MPA and VPA volumes were categorized according to % $\dot{V}O_2R$, the differences were not as stark. The mean cardiovascular strain, when indicated with mean heart rate during all of the recording days, was higher among individuals with higher BMI.

As many of our participants were physically fit and usually healthy employed individuals, the absolute PA volumes were higher compared with relative volumes in many of the studied age and body weight categories (Table 2). The findings on the ratios between absolute versus relative PA volumes according to age and sex reflect the previously reported international (31) and Finnish (24) results on the distribution of measured population fitness. It was rather easy for high-fit individuals to reach MVPA intensity levels according to absolute criteria compared with criteria relative to individual fitness level, but the situation reversed among the unfit individuals. This phenomenon was similar during days off and workdays. Our findings are in line with data from U.S. adults showing that VPA determined in absolute terms using an accelerometry method is low among older, female, and obese individuals (36).

Because we are not aware of large population studies of overlap between absolute and relative intensity PA volumes, we cannot compare our results with other studies. In PA counseling, the intensity of PA should be tailored individually (11), but this recommendation is often disregarded in practice. When trying to find effective solutions to increase PA among physically inactive low-fit individuals, we need to take into account the individual fitness level to focus on behavior changes that are easy to adopt and sustain rather than expect people to become highly motivated to adopt and maintain effortful behaviors that include too vigorous PA. In PA counseling, appropriate PA intensity may be guided most easily by using simple terms describing exercise intensity or using Borg Rating of Perceived Exertion scale (from 6 to 20) (3), where 12–13 indicates MPA and 14 or more vigorous PA. Heart rate monitoring during exercise would be a more accurate alternative to guide and control target exercise intensity. Individuals with severe chronic disease usually need personal advice from health care professionals and related to medical clearance for exercise participation/rehabilitation the intensity levels are usually given in a way proper for each condition, such as determination of symptom-free exercise intensities among patients with heart disease. In a previous real-life lifestyle intervention, increasing PA was a good indicator of success in improving the cardiovascular and metabolic risk factor levels, including body weight reduction (23).

Strengths and limitations. Although we did not have direct oxygen uptake recordings in our large real-life data, we used a validated ambulatory method to assess the intensity of PA. This method provides more accurate estimates of the intensity of PA compared with heart rate information only (32). The use of % $\dot{V}O_2R$ is relatively valid also among obese individuals (5) and patients with heart disease (4). However, there are no specific validation studies comparing the validity of our methodology between representative BMI and age groups. Our recordings had good coverage of typical workdays and days off.

Our study was a cross-sectional study. Randomized controlled trials are needed to confirm that PA recommended with guidelines applying subjective intensity levels is more feasible in the long-term compared with those using absolute intensity levels in the important target group of low-fit formerly inactive overweight and obese individuals. Although MPA relative to individual fitness level improves fitness (35) and other cardiometabolic risk factor levels (19) among low-fit individuals, a comprehensive understanding about which PA intensity is most beneficial for health in the long term is still lacking.

CONCLUSIONS

Compared with low-fit individuals, it is easier for high-fit individuals to reach MVPA intensity levels according to absolute criteria and easier for men compared with women, younger people compared with older, and lean compared with obese individuals. When the target is set as relative intensity, the frequency of reaching the target is more similar in low- and high-fit individuals. Thus, when boosting MVPA in inactive, low-fit, and/or obese individuals, intensity guidelines relative to individual fitness may be more feasible than using recommended absolute intensity classifications. Because PA counseling is suggested to be made a priority in clinical practice (2,21), our findings should be considered when taking action in the most important target group of low-fit individuals. Also, our findings need to be taken into account when interpreting the results of population studies that have used accelerometer-based monitoring of PA volumes with absolute criteria.

This study was supported by TEKES—the Finnish Funding Agency for Technology and Innovation (grant no. 40116/14).

Myllymäki reports being employed also by Firstbeat Technologies Ltd., Jyväskylä, Finland, and Korhonen reports being employed also by PulseOn Oy, Espoo, Finland. Authors have no other conflicts of interest to declare.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

The authors declare that the results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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