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Type and intensity distribution of structured and incidental lifestyle physical activity of students and office workers: a retrospective content analysis

Birgit Wallmann-Sperlich^{1*}, Peter Düking², Miriam Müller¹, Ingo Froböse³ and Billy Sperlich²

Abstract

Background: Physical activity (PA) guidelines acknowledge the health benefits of regular moderate-to-vigorous physical activity (MVPA) regardless of bout duration. However, little knowledge exists concerning the type and intensity distribution of structured and incidental lifestyle PA of students and office workers. The present study aimed to i) assess the duration and distribution of intensity of MVPAs during waking hours $\geq 50\%$ of heart rate reserve (HRR), ii) to identify the type of PA through diary assessment, iii) to assign these activities into structured and lifestyle incidental PA, and iv) to compare this information between students and office workers.

Methods: Twenty-three healthy participants (11 students, 12 office workers) recorded heart rate (HR) with a wrist-worn HR monitor (Polar M600) and filled out a PA diary throughout seven consecutive days (i.e. ≥ 8 waking h/day). Relative HR zones were calculated, and PA diary information was coded using the Compendium of PA. We matched HR data with the reported PA and identified PA bouts during waking time $\geq 50\%$ HRR concerning duration, HRR zone, type of PA, and assigned each activity to incidental and structured PA. Descriptive measures for time spend in different HRR zones and differences between students and office workers were calculated.

Results: In total, we analyzed 276.894 s (76 h 54 min 54 s) of waking time in HRR zones $\geq 50\%$ and identified 169 different types of PA. The participants spend 31.9 ± 27.1 min/day or $3.9 \pm 3.2\%$ of their waking time in zones of $\geq 50\%$ HRR with no difference between students and office workers ($p > 0.01$). The proportion of assigned incidental lifestyle PA was $76.9 \pm 22.5\%$.

Conclusions: The present study provides initial insights regarding the type, amount, and distribution of intensity of structured and incidental lifestyle PA $\geq 50\%$ HRR. Findings show a substantial amount of incidental lifestyle PA during waking hours and display the importance of promoting a physically active lifestyle. Future research could employ ambulatory assessments with integrated electronic diaries to detect information on the type and context of MVPA during the day.

Keywords: Incidental lifestyle physical activity, Vigorous intermittent lifestyle physical activities, Physical activity, Diary, Structured physical activity, Context

Background

Physical inactivity is a global challenge [1] and facilitates the development of a variety of unfavorable health consequences such as non-communicable [2] or mental

*Correspondence: birgit.sperlich@uni-wuerzburg.de

¹ Institute of Sports Science, Julius-Maximilian University Würzburg, Judenbühlweg 11, 97082 Würzburg, Germany

Full list of author information is available at the end of the article



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diseases [3]. To tackle the risk of physical inactivity, the World Health Organization (WHO) [4, 5] as well as many nations [6–8] provide physical activity (PA) recommendations to guide and inform governing bodies and individuals about the contribution of PA for promoting health and well-being across the life span [4]. The key message of the recently updated WHO guidelines on PA and sedentary behavior states that “every move counts”, emphasizing that i) the minimum weekly threshold of 150–300 min of moderate-to-vigorous-intensity physical activity (MVPA) as well as ii) the interruption of sedentary behavior with all kinds of PA (regardless of their intensity) essentially counteracts negative health outcomes [4].

Compared to the WHO PA guidelines of 2010, the updated guidelines do not recommend the accumulation of PA in at least 10 min bouts [9]. This recent modification reflects the growing evidence that PA of any bout duration is associated with improved health outcomes, including all-cause mortality [10, 11]. Additionally, the updated British PA guidelines explicitly acknowledge the health benefits of shorter exercise durations comprising of very vigorous-intensity PA such as sprinting or stair climbing [12] or performed as a high-intensity interval exercise (HIIT) with vigorous-intensity exercise “snacks” as described previously [13, 14]. The recognition of short (intense) PA benefiting various dimensions of health supports public health messages advocating lifestyle PA that are unlikely to last 10 min or longer, e.g. climbing staircases, carrying heavy shopping items or toddlers, managing housework [10].

The aforementioned activities are categorized as incidental lifestyle PAs, i.e. activities as part of daily living and not intended for recreational or health purposes without requiring optional time [15]. Incidental PA represents the opposite of structured PA or exercise characterized by scheduled, pre-planned, and intentionally directed activities e.g. visiting a gym, jogging, cycling, or other activities for recreation, improving or maintaining physical fitness, performance, or health [16]. Incidental lifestyle PAs with an intensity exceeding 6 MET or ≥ 14 on Borg’s 6-to-20 scale [17] and shorter than < 5 min are defined as “vigorous intermittent lifestyle physical activities” [18]. However, little knowledge exists of (i) how frequently, (ii) with which type of behavior, (iii) in which PA domain (work, household, transport, or leisure), and (iv) to which extend incidental lifestyle PA, in general (long and shorter bouts), are distributed throughout the waking hours of different populations. To gather first information about the type and intensity distribution of incidental lifestyle PA, the selection of homogenous populations concerning their

learning or working environment seems reasonable. For this study students and office-workers were selected, as these population groups are often prone to an inactive lifestyle [19–21].

Assessment of incidental lifestyle PAs or PAs of short duration is challenging since PA questionnaires are ineffective in capturing short and intermittent PA bouts and are prone to recall bias [22]. Advancements in wearable accelerometer-based technologies provide opportunities to reveal incidental PA throughout waking hours, however, accelerometry per se monitors a selection of external load markers and does not allow to judge internal loading. Additionally, obtaining valid accelerometer-based activity data is challenging because of correct accelerometer placement, data smoothing process, cut-off points, etc. [18].

Newly developed optical sensors now allow the continuous recording of heart rate (HR) [23–25] which probably is the most evaluated internal marker in various populations and settings in the field of exercise physiology for the assessment of cardiorespiratory load during movement of any kind including PA [22]. Unfortunately, current consumer-grade wearables do not automatically allow information regarding the type or domain of specific incidental PA behavior, for example, whether a specific HR response occurs due to stair climbing, vacuuming cleaning, carrying groceries, rushing to catch the bus, etc. Matching the HR response with subjective information about the specific type of PA such as through PA diaries would assist to understand the relative internal cardiorespiratory loading of certain (incidental lifestyle) PA. Information about the level of internal load during everyday PA behavior, as well as the frequency, duration, and specific type of PA, and how incidental lifestyle PA and structured PA relate to each other would deepen our knowledge in incidental lifestyle PA research. Deeper insights into incidental lifestyle PA would allow directing future public health messages advocating PA lifestyle behaviors, as incidental lifestyle PA does not encounter the multiple barriers to structured exercises, such as lack of time, costs, equipment, lack of skills, or poor fitness [15].

The present investigation aimed to i) assess the amount and distribution of intensity and duration of PAs during waking hours outreaching $\geq 50\%$ of heart rate reserve (HRR) as an approximate of moderate-intensity PA > 3 MET, ii) to identify the type of these activities through diary assessment, iii) to assign these activities into structured PA and incidental lifestyle PA, and iv) to compare this information between two selected sample groups of students and office workers.

Methods

Study design

The observational study of students and office workers employed a mixed-method approach to assess the amount and distribution of intensity and duration of PAs during waking hours. All participants continuously were equipped with a wrist-worn HR monitor throughout the day for seven consecutive days (besides for charging) and recorded HR. The wrist-worn HR monitor was employed following the manufacturer's recommendations (e.g. wearing location, settings, etc.). Furthermore, all participants were instructed to fill out a diary indicating their performed PA every 15 min throughout the day for 7 days. The study was approved by the ethical committee of the Sports Science Institute of the University of Würzburg (04/2021) and followed the Declaration of Helsinki [26].

Participants

We recruited 23 healthy voluntary participants (11 university students (age range 18–23), 12 office workers (mean age 48 ± 7 yrs., 6 men)) as a convenient sample. We did not assess the sex and precise age of the students due to the anonymization of the rather small sample. All were informed about each experimental procedure and provided written consent to participate.

Experimental procedures

Heart rate monitoring

A wrist-worn HR monitor (Polar M600, Polar Electro Oy, Kempele, Finland) with optical sensors and a sampling rate of 1 Hz recorded the HR throughout the day. This device provides accurate HR readings during periods of steady-state cycling, walking, jogging, and running and is most likely independent of sex, body mass index, maximal oxygen consumption, skin type, or wrist size [27].

Physical activity diary

In the present study, we employed a modified version of the Bouchard activity diary aiming to assess the type of PA subjectively instead of evaluating the energy expenditure [28]. Therefore, we only used the instrument's grid-type table, which divides a day into 96 15-min periods over a 24-h period. We did not employ the original front page in our study (table of activities, energy cost, and corresponding categorical values) [28]). In contrast to Bouchard's original diary, our participants were asked to record the i) type of activity into the grid table and ii) whenever they did not wear the smartwatch, instead of the code for each category of PA. All participants were

asked to fill in the modified diary for seven consecutive days.

Data extraction and processing

All HR data were downloaded from each participant's Polar Flow Applications (Polar, Polar Electro Oy, Kempele, Finland) as a Microsoft Excel file. The HR was smoothed using the average HR of each 15 s interval. Each participant's maximum HR was estimated employing the equation "220 - age", and resting HR was defined as the lowest, constant HR for 10 min recorded during the night while sleeping and averaged for 3 days. The traditional age equation formula (220-age) allows us to sufficiently approximate the HRmax in this rather young sample [29]. However, the formula may tend to underestimate HRmax in older populations with the effect of underestimating the true level of cardiorespiratory stress [29]. For the scope of this study, the underestimation of cardiorespiratory stress vs. overestimating cardiorespiratory stress seems to be a minor challenge.

Based on the individual's maximal and resting HR, 10 individual relative HR zones were defined based on the individual's heart rate reserve (HRR) which was subsequently divided into 10 equal 10% HRR zones. The HRR was calculated by subtracting the resting HR from the maximal HR [22].

To transfer each individual recorded HR into the individual relative HR for each value, the individual resting HR was subtracted from the smoothed average HR, then divided by the HRR and multiplied by 100. Time in each HRR-zone per day was calculated for each individual.

For the PA diary assessment, activities were coded and grouped using the five-digit code of the Compendium of Physical activities [30, 31]. If a participant reported a PA that was not listed in the compendium, a new code was created for this specific activity according to the coding scheme of the compendium (see suppl. 1).

All HR and subjective data were synchronized via timestamps obtained from the wrist-worn HR monitor and PA diary.

For data processing, we included all days with a waking time of ≥ 8 h/day. We defined waking time by i) wearing the wrist-worn heart rate monitor and ii) excluding time frames of 'sleeping' and 'snoring' documented in the PA diary. For the scope of the data analysis, only moderate-to-vigorous PA were relevant. Thereby the HRR zones are normally classified as follows [22, 32]: 40- < 60% as moderate, 60- < 85% as vigorous (hard), 85 - < 100 as vigorous (very hard), and the HRR zone of 100% as maximal. In order not to overestimate moderate-to-vigorous PA, we only included PA with $\geq 50\%$ of the HRR and parceled the data into 10% HRR zones to be more accurate through

smaller zones (i.e. Zone 50–60% HRR, Zone 60–70% HRR, etc.). After identifying all PA bouts during waking time with an intensity $\geq 50\%$ HRR, we determined the start and stop time, calculated the seconds in each zone through the objective data, and matched the HR-data with the reported specific type of PA from the diary. Then we listed the duration as well as the HRR zone. In case a participant entered two or more PA in the same 15-min period in the PA diary, then the values were assigned to the more vigorous PA. Values $\geq 50\%$ HRR, which could not be assigned to any PA because of missing subjective PA diary information, were documented as “no answer”.

After classification of the PA type based on the information of the PA diary, we assigned the PA type to incidental or structured PA. Structured PA was defined as i) exercise or performing sports, ii) all activities in the categories conditioning exercise, running and sports, iii) for the activities mountain biking, dance workout/dance, aerobic, dancing, nordic walking, swimming. All other activities were assigned to incidental PA. For every specific type of PA $\geq 50\%$ HRR, we listed the number of participants reporting the PA, the total duration during waking time, the frequency of the type of PA, and the mean duration of PA when occurring.

We calculated the mean minutes per day in zones $\geq 50\%$ HRR. The percentage of waking time in zones $\geq 50\%$ HRR was calculated by dividing the accumulated time in each zone and in the Zone $\geq 50\%$ HRR through the total waking time. To identify the percentage of incidental PA compared to structured PA in zones $\geq 50\%$ HRR, we divided the time of incidental PA through the total time in each zone only for the participants who featured PA bouts in this zone.

Statistical analysis

Mean, standard deviation, median, and confidence intervals for time spend in different HRR zones was calculated. Most of the dependent variables (daily time in zone 50–100% HRR; percentage of waking time per day in Zone 50–100% HRR [%]; percentage of incidental PA compared to structured PA in Zone $> 50\%$ HRR [%]) were not normally distributed (Kolmogorov-Smirnov-Test). To explore differences between students and office workers in the zones of 50–100% of HRR we used the non-parametric Mann-Whitney-U-test. To prevent inflation of type 1 error, we applied an alpha level of $p < 0.01$. All statistical analysis were performed in the SPSS 23.0 (IBM Corp., Armonk, NY, USA) software package for Microsoft, and figures of descriptive numbers were prepared in Excel 2016.

Results

In total, we recorded 179 days of 23 participants which resulted in 141 valid days (≥ 8 h of waking time) and 6.13 ± 1.01 valid days per participant. In total, we matched 6.951.254 s waking time (i.e. $49,114 \pm 4334$ s of waking wearing time per participant per valid day (13 h 38 min 34 s ± 1 h 12 min 23 s)) of objective HR with PA diary data and allocated the HR to the different HRR zones. In summary, 276.894 s (76 h 54 min 54 s) of waking time were in HRR zones $\geq 50\%$ and were employed for further analyses including total time spend in different HRR zones, type of PA (169 different types), frequency of PA $\geq 50\%$ HRR (total of 6.074 events), bout duration and allocation to structured or incidental PA (see Table 1).

Examples of individual HR patterns with matched PA information of participants are illustrated in Fig. 1a-c.

The participants spend 31.9 ± 27.1 min/day or $3.9 \pm 3.2\%$ of their waking time in zones of $\geq 50\%$ HRR with no difference between students and office workers ($p > 0.01$). Office workers spent more time in HRR zones $\geq 90\%$ compared to students (1.73 ± 2.54 min/day vs. 0.03 ± 0.61 min/day; $p < .01$; $0.20 \pm 0.29\%$ vs. $0.003 \pm 0.007\%$, $p < .01$) (see Table 2).

Comparing the proportions of assigned incidental and assigned structured PA $\geq 50\%$ HRR, $76.9 \pm 22.5\%$ was spent in incidental PA with no differences between students and office workers. In zone 90–100% of HRR, the proportion of assigned incidental PA compared to assigned structured PA was $30.3 \pm 45.7\%$.

Tables 3 and 4 summarize the reported type of PA (incidental and structured) accomplished by all students and office workers (all types of physical activities are reported in the [supplementary material](#)). Within the incidental PA of students' leisure time, activities such as self-care and miscellaneous activities (total of 403.6 min) and transportation activities (total of 306.5 min) were most often reported. Office workers reported most often incidental PA in the categories transportation (total of 960.5 min), household activities (total of 652.6 min), and leisure time activities (total of 573.6 min) in HRR zones $\geq 50\%$.

Discussion

The main findings of our study are that our sample achieved about 30 min per day in zones $\geq 50\%$ HRR and that more than 75% of the PA in $\geq 50\%$ HRR zones were accomplished through incidental lifestyle PA, with little difference between students and office workers. We furthermore identified that most of the incidental lifestyle PA $\geq 50\%$ HRR in students included leisure and transportation activities and in office workers transportation, household, and leisure time activities.

Table 1 Descriptive measures of sample and analyzed wearing time (Mean \pm SD)

	Total	Students	Office workers
Number of participants	23	11	12
Number of recorded days	179	85	94
Number of valid days (> 8 h of waking time)	141	62	79
Number of mean valid days / participant	6.13 (\pm 1.01)	5.64 (\pm 0.81)	6.58 (\pm 1.00)
Total recorded wearing time [s]	11,438,201 (18w 6d 9h 16min 41s)	5,105,611 (8w 3d 2h 13min 31s)	6,332,590 (10w 3d 7h 3min 10s)
Total duration of waking wearing time [s]	6,951,254 (11w 3d 10h 54min 1s)	2,916,268 (4w 5d 18h 4min 28s)	4,034,986 (6w 4d 16h 49min 46s)
Mean total duration of waking wearing time / participant [s]	302,228 (\pm 60,311) (83h 57min 8s)	265,115 (\pm 50,398) (73h 38min 35s)	336,249 (\pm 48,227) (93h 24min 9s)
Mean total duration of waking wearing time / participant / valid day [s]	49,114 (\pm 4334) (13h 38min 34s)	46,847 (\pm 5152) (13h 0min 47s)	51,191 (\pm 1895) (14h 13min 11s)
Total duration of waking time in HRR zones \geq 50% [s]	276,894 (76h 54min 54s)	83,929 (23h 18min 49s)	192,965 (53h 36min 5s)
Mean total duration of waking time in HRR zones \geq 50% per participant [s]	12,039 (\pm 11,576) (3h 20min 39s)	7,630 (\pm 4,821) (2h 7min 10s)	16,080 (\pm 14,478) (4h 28min 0s)
Mean total duration of waking time in HRR zones \geq 50% / participant per valid day [s]	1912 (\pm 1626) (31min 52s)	1370 (\pm 843) (22min 50s)	2408 (\pm 2020) (40min 8s)
Total frequency of bouts in waking time in HRR zones \geq 50%	6,074	1,913	4,161
Daily mean total frequency of bouts in waking time in HRR zones \geq 50% / participant (\pm SD)	264 (\pm 237)	174 (\pm 100)	347 (\pm 296)
Daily mean total frequency of bouts in waking time in HRR zones \geq 50% / participant / valid day (\pm SD)	42 (\pm 34)	31 (\pm 18)	53 (\pm 41)
Number of types of PA reported by all participants in HRR zones \geq 50%	169	82	112

Since the mean duration of PA \geq 50% HRR was > 30 min per day in most participants, our sample sufficiently achieved the updated WHO recommendation for PA and sedentary behavior [9]. Considering the predominant short duration of the bouts in zones \geq 50% HRR it becomes obvious that most of the activities in \geq 50% HRR zones lasted less than 10 min. Recent evidence, however, supports the fact that PA of any bout duration is associated with improved health outcomes [10, 11]. Most of the accomplished PA \geq 50% HRR in the present study (21.87 ± 17.15 min/day) comprised of moderate-intensity PA (i.e. 50 - < 60% HRR) [22, 33]. However, almost one-third of the PA (10.0 ± 12.1 min/day) included vigorous, very vigorous, or maximal intensities (\geq 60% HRR) [22, 33]. Following epidemiological evidence, a proportion of \geq 30% vigorous PA of total PA suggests additional health benefits compared to an equivalent amount of moderate-intensity PA [34–36]. As stated previously [23], future studies should further investigate and compare the roles of low to vigorous-intensity activities (independent of quantifying total activity energy expenditure) for health promotion, disease prevention, and management, so that

public health messaging can be directed more specifically to the type and proportion of different intensity PA should ideally have.

Interestingly, the proportion of assigned incidental compared to assigned structured PA was considerably high with more than 75% of overall PA in zones \geq 50% HRR in the two studied sample populations. The high contribution of incidental PA in our results resembles in part the findings of a representative study in the population of US adults [37], in which lifestyle activities were more frequently reported than sports and/or recreational activities. Our findings reveal to some extent the moderate- and the vigorous-intensities of incidental lifestyle PA and consequently exhibit the importance of promoting a physically active lifestyle to achieve the minimum recommended PA for a healthy life. Especially in physically inactive populations reporting a perceived lack of time or a low priority for exercising [38], lifestyle embedded PA could play an essential role to engage in sufficient MVPA.

In respect to the high contribution of incidental PA in more vigorous intensity zones, the participants in this study displayed a considerable amount of vigorous

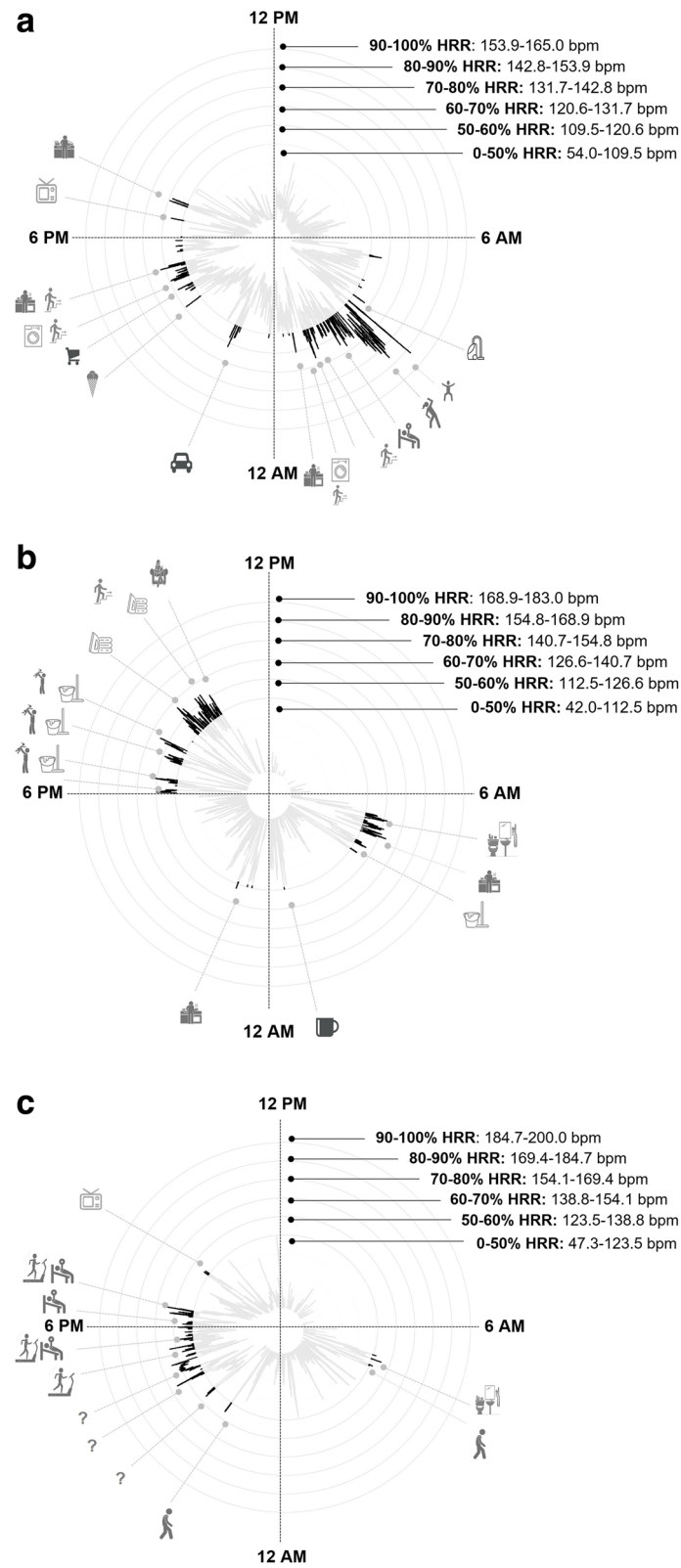


Fig. 1 Examples of 24-h heart rate patterns of **a**) an office worker with a day off, **b**) an office worker in home office and **c**) an university student with matched physical activity information from the physical activity diary. Heart rate zones reflect the relative zones of the individual heart rate reserve

Table 2 Descriptive measures (mean ± standard deviation, median; 95% confidence interval) and the difference between students and office workers concerning time per day of activities ≥50% heart rate reserve, the percentage of time compared to total waking wearing time in heart rate reserve zones ≥50%, and the percentage of assigned incidental lifestyle physical activity compared to assigned structured PA in heart rate reserve zones ≥50%

	All (n = 23)	Students (n = 11)	Workers (n = 12)	Z p
Daily time in Zone 50–100% HRR [min]	31.86 ± 27.1 27.1 [20.14; 43.58]	22.84 ± 14.05 23 [13.40; 32.38]	40.13 ± 33.66 28.36 [18.74; 61.51]	−.92 .38
Daily time in Zone 50–60% HRR [min]	21.87 ± 17.15 15.57 [14.45; 29.28]	16.85 ± 10.93 15.57 [9.51; 24.19]	26.47 ± 20.76 16.47 [13.28; 39.66]	−.86 .41
Daily time in Zone 60–70% HRR [min]	5.08 ± 5.21 4.58 [2.82; 7.33]	3.80 ± 2.95 4.58 [1.82; 5.78]	6.24 ± 6.58 4.66 [2.07; 10.42]	−.86 .41
Daily time in Zone 70–80% HRR [min]	2.79 ± 5.71 0.78 [0.32; 5.26]	1.73 ± 2.17 0.74 [0.28; 3.19]	3.77 ± 7.67 1.25 [− 1.10; 8.64]	−.59 .57
Daily time in Zone 80–90% HRR [min]	1.21 ± 1.97 0.4 [0.35; 2.06]	0.43 ± 0.90 0 [− 0.17; 1.04]	1.91 ± 2.43 1.04 [0.37; 3.46]	−2.2 .03
Daily time in Zone 90–100% HRR [min]	0.92 ± 2.0 0 [0.05; 1.78]	0.03 ± 0.61 0 [− 0.02; 0.07]	1.73 ± 2.54 0.22 [0.12; 3.35]	−2.69 .01*
Percentage of waking time per day in Zone 50–100% HRR [%]	3.87 ± 3.22 3.34 [2.48; 5.26]	2.91 ± 1.71 3.33 [1.76; 4.06]	4.74 ± 4.03 3.34 [2.18; 7.31]	−.62 .57
Percentage of time per day in Zone 50–60% HRR [%]	2.67 ± 2.05 1.94 [1.78; 3.56]	2.17 ± 1.36 1.94 [1.25; 3.08]	3.13 ± 2.5 1.98 [1.54; 4.72]	−.55 .61
Percentage of time per day in Zone 60–70% HRR [%]	0.62 ± 0.62 0.58 [0.35; 0.89]	0.48 ± 0.36 .58 [0.24; 0.72]	0.74 ± 0.79 0.55 [0.24; 1.24]	−.68 .53
Percentage of time per day in Zone 70–80% HRR [%]	0.33 ± 0.68 0.11 [0.04; 0.63]	0.21 ± 0.25 .09 [0.04; 0.38]	0.45 ± 0.91 0.15 [− 0.13; 1.02]	−.59 .57
Percentage of time per day in Zone 80–90% HRR [%]	0.14 ± 0.23 0.05 [0.04; 0.24]	0.05 ± 0.11 0 [− 0.02; 0.12]	0.23 ± 0.29 0.12 [0.04; 0.41]	−2.2 .03
Percentage of time per day in Zone 90–100% HRR [%]	0.11 ± 0.23 0 [0.01; 0.21]	0.003 ± 0.007 0 [− 0.002; 0.01]	0.20 ± 0.29 0.03 [0.02; 0.39]	−2.69 .01*
Percentage of incidental PA compared to structured PA in Zone ≥50% HRR [%]	76.89 ± 22.51 (n = 23) 77.37 [67.15; 86.62]	70.27 ± 24.18 (n = 11) 73.15 [54.02; 86.51]	82.96 ± 19.96 (n = 12) 93.50 [70.28; 95.64]	− 1.51 .15
Percentage of incidental PA compared to structured PA in Zone 50–60% HRR [%]	87.53 ± 16.58 (n = 23) 94.26 [80.36; 94.70]	77.59 ± 19.44 (n = 11) 76.93 [64.51; 90.63]	96.66 ± 4.0 (n = 12) 98.33 [94.12; 99.20]	−2.39 .02
Percentage of incidental PA compared to structured PA in Zone 60–70% HRR [%]	70.50 ± 29.90 (n = 23) 74.11 [57.57; 83.43]	60.12 ± 33.15 (n = 11) 67.11 [37.85; 82.39]	80.01 ± 24.14 (n = 12) 87.87 [64.68; 95.35]	− 1.52 .15
Percentage of incidental PA compared to structured PA in Zone 70–80% HRR [%]	47.88 ± 44.78 (n = 19) 29.76 [26.30; 69.47]	43.17 ± 43.82 (n = 8) 27.91 [6.54; 79.80]	51.31 ± 47.27 (n = 11) 30.21 [19.55; 83.07]	−.68 .55
Percentage of incidental PA compared to structured PA in Zone 80–90% HRR [%]	36.29 ± 47.12 (n = 15) 4.44 [10.20; 62.38]	20.00 ± 44.72 (n = 5) 0 [− 35.53; 75.53]	44.43 ± 48.41 (n = 10) 19.95 [9.80; 79.07]	− 1.45 .21
Percentage of incidental PA compared to structured PA in Zone 90–100% HRR [%]	30.32 ± 45.70 (n = 11) 0 [− 0.38; 61.03]	0 ± 0 (n = 2) 0	37.07 ± 48.27 (n = 9) 1.97 [− 0.04; 74.17]	− 1.30 .33

* $(p \leq 0.01)$

Table 3 Description of reported incidental lifestyle PA and structured PA of $n = 11$ students in the HRR zone $\geq 50\%$ with total reported duration during waking time, frequency, and mean duration of PA when it occurred (total duration of waking time in HRR zones $\geq 50\% = 83.929$ s (23.31 h); total frequency in waking time in HRR zones $\geq 50\% = 1913$)

Domain	Major heading of Compendium	Total duration in activity in waking time [s]	Frequency of activity in waking time	Mean duration of activity [s]
Household		4.000	102	42.59
	Home activities	3.643	88	45.69
	Home repair	357	14	22.43
Leisure Time		24.216	595	38.78
	Inactivity quiet/light	3145	92	50.00
	Miscellaneous	14.750	351	36.20
	Playing music	941	23	32.92
	Self-care	5.168	120	41.33
	Sports	212	9	17.06
	Occupation/ Study		4.401	91
Transportation	Occupation/student activities	3.833	76	49.63
	Volunteer activities	568	15	32.42
		18.387	398	39.04
Others/Combination	Combined transportation	1.725	36	53.01
	Bicycling	982	27	28.97
	Transportation	7.995	170	39.93
	Walking	7.685	165	30.41
Not Specified		2.856	57	34.94
	Home activities; walking	927	12	53.15
	Inactivity quiet/light; self-care	637	14	32.91
	Inactivity quiet/light; self-care; walking	8	1	8.00
Sport	Self-care; walking	1.284	30	34.26
		1.979	45	33.74
Sport		28.090	625	41.48
	Conditioning exercise	5.828	141	33.40
	Dancing	99	5	19.80
	Running	9.097	174	53.76
	Sports	10.745	267	35.15
	Walking	1.931	28	57.30
	Water activities	390	10	37.22

lifestyle PA [15, 18] (i.e. Home activities ('cleaning', 'cooking', 'putting away groceries', 'hanging laundry', etc.), 'sightseeing', 'celebrating', 'playing piano', 'biking', 'walking', 'climbing stairs' etc.). Following the results of previous experimental studies, also short intense exercise bouts of incidental PA could, at least to some extent, positively impact cardiorespiratory fitness [13, 14]. To date, the knowledge about vigorous intermitted (short) lifestyle PAs is limited [18] and the relatively high contribution of these activities in our study sample supports the importance and need for the recently established research framework to better understand the health potential of vigorous intermitted lifestyle PA [18]. For example, it seems meaningful i) to better understand the

contribution of vigorous intermitted lifestyle physical activities in PA patterns, ii) to recognize and understand the short and long-term dose-response of vigorous intermitted lifestyle PA concerning health, and iii) to gain knowledge about how to convince and empower people to be more physically active in their daily lives [15].

We detected a marginally greater contribution of time in the $\geq 90\%$ HRR zone in office workers than in students (1.73 ± 2.54 min vs. 0.03 ± 0.61 min). Recognized PA of the diary was predominately identified during leisure time with activities such as 'jogging', 'walking the dog', 'mountain biking', 'circuit training', 'treadmill', 'Qi Gong (shaking exercise)' etc. but also unstructured activities such as 'getting changed' in office workers. One reason

Table 4 Description of reported incidental lifestyle PA and structured PA of $n = 12$ office workers in the HRR zone $\geq 50\%$ with total reported duration during waking time, frequency, and mean duration of PA when it occurred (total duration of waking time in HRR zones $\geq 50\% = 192.965$ s (53.60 h); total frequency in waking time in HRR zones $\geq 50\% = 4161$)

Domain	Major heading of Compendium	Total duration in activity in waking time [s]	Frequency of activity in waking time	Mean duration activity (s)
Household		39.155	837	36.42
	Home activities	36.217	777	36.47
	Home repair	2.377	44	44.98
	Lawn and Garden	561	16	29.71
Leisure Time		34.416	837	39.77
	Inactivity quiet/light	10.036	243	40.37
	Miscellaneous	896	27	25.86
Occupation/ Study	Self-care	23.484	567	43.62
		8.830	240	32.61
Transportation	Occupation/student activities	8.830	240	32.61
		57.628	1.367	49.77
Others/Combinations	Combined transportation	1.167	23	78.61
	Bicycling	5.872	154	39.32
	Transportation	10.064	241	47.15
	Walking	40.525	949	46.67
Not Specified		7.753	161	56.89
	Conditioning exercise; self-care	101	5	20.20
	Home activities; walking	2.979	40	118.92
	Home activities; self-care	1.384	31	36.58
	Home activities; transportation	1.235	30	27.00
	Home activities; transportation; walking	1.598	37	39.17
	Inactivity quiet/light; self-care	115	6	27.10
	Miscellaneous; self-care	22	2	11.00
	Occupation/student activities; walking	258	7	27.08
Self-care; walking	61	3	17.00	
Sport		118	4	29.50
Sport		45.065	715	47.05
	Bicycling	9.780	210	47.92
	Conditioning exercise	32.438	428	56.04
	Dancing	2.772	68	38.18
	Sports	75	9	8.30

for little time spent in $\geq 90\%$ HHR may also arise from the inert kinetics of HR. Typically, after the onset of vigorous activity, the neuro-humoral and metabolic mechanisms stimulating HR increase require several seconds to meet the oxygen need of the working muscle, and usually HR plateaus after approximately 60s with high intensity [39]. Thus, any type of vigorous activity < 60 s will not be sufficiently described by continuous HR recording.

In both samples, transportation activities such as walking, cycling, and transportation or combinations of these contribute considerably to the PA behaviors exceeding 50% HRR, which is in line with previous findings [40] and underpins the importance of promoting active

transportation for health and PA promotion [41–43]. Household activities $\geq 50\%$ HRR were more present in office workers than in students, potentially because office workers live in households with more than one person and take more actions for cleaning, washing, grocery shopping, etc. Students may often live in single-room flats, or in their family homes, where they might engage in fewer household activities. Therefore, cognitive restructuring [44, 45] of often unpopular household activities, i.e. highlighting the health potential of carrying heavy shopping bags or vacuum cleaning could be a strategy to support PA promotion and achieving recommended PA. Unexpectedly, leisure time self-care

activities such as showering, eating, dressing (see supplementary material 1) often exceeded 50% HRR. This could be due to frequent changes in body positions during showering and dressing, possible time constraints or possible inaccuracy i) arising from faulty PA diary recording, or ii) HR monitoring due to fluid interference with the optical sensors of the wrist-worn HR monitor.

Limitations

Assessing HR and linking the data to PA has some limitations as the HR not only responds to the oxygen needs in connection with PA. Numerous other factors including changes in body position (e.g. moving from supine to erect posture in healthy adults may induce an immediate increase in heart rate) [46], smoking [47], consumption of alcohol [48], and neurohormonal factors such as psychological stress [49] and emotional circumstances may cause sympathetic reactivity (e.g. due to scary or enjoyable situations) triggering plasma catecholamines increase, which is a main driver for HR elevation [50].

Hence, changes in HR throughout the day are the result of a quite complex interplay and may affect present HR data. However, controlling these factors while freely living is challenging. The HR monitor employed in the present study is accurate during periods of steady-state endurance exercise [27] but has not been validated for all-day activities. Furthermore, the validation of the used HRmax formula in our sample and further integration of anthropometric variables could add accuracy to future studies. Additionally, the sex of the student population was not recorded, which may have an impact on the interpretation of the results.

In some cases, reported PAs in the diary, e.g. sitting and working which were assigned to sedentary behaviors (i.e. a metabolic equivalent of < 1.5 MET [51]) revealed short durations with heart rates $\geq 50\%$ HRR zones. These findings point out that within sedentary or low-intense behaviors (e.g. sitting, working, or driving a car) short durations of intense cardio-respiratory loading may occur. One explanation could be that these moderate-to-vigorous-intensity behaviors are not always captured by the relatively long diary reporting time frame (i.e. 15 min) for PA assessment [28]. Another reason could be that participants reported a (longer) bout of intense PA (e.g. jogging) within one or two 15 min-frames and this activity could have lasted several minutes (e.g. 3 min) within the proceeding 15-min frame but without mentioning in the PA diary. Another reason could be that the HR elevation may have been caused by non-movement situations, i.e. psychological stress.

The identified challenges suggest a methodological modification for future studies. One modification could be to ask participants to document non-movement

events that may have triggered a rise in HR (i.e. emotional event, alcohol intake, smoking, etc.). A more sophisticated possibility could be to employ ambulatory assessment including movement monitoring (i.e. external load) via e.g. accelerometry and HR (internal load) with ecological momentary assessment, such as electronic diaries [52] to capture real-time self-reported information. The strengths of ambulatory assessments are the acquisition of data near real-time, thereby i) minimizing retrospective biases in real-world settings and ii) enabling ecological valid findings [52].

Conclusion

The present study provides initial insights regarding the type, amount, and distribution of intensity of structured and incidental lifestyle PA $\geq 50\%$ HRR during the day in students and office workers. The present findings revealed that more than 75% of the PA $\geq 50\%$ HRR was assigned to incidental lifestyle PA and that a substantial amount was spent engaging in vigorous intensity. The present data underline the importance of promoting a physically active lifestyle next to structured PA and points to the need for future research to better understand the health potential of incidental lifestyle PA. Therefore ambulatory assessments with integrated electronic diaries could help to detect information on the type and context of MVPA during the day.

Abbreviations

PA: Physical activity; MVPA: Moderate-to-vigorous physical activity; HR: Heart rate; HRR: Heart rate reserve.

Supplementary Information

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Additional file 1.

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Authors' contributions

BWS and PD designed the present study, PD and MM carried out the data acquisition, MM coded the physical activities according to the diaries, BWS & PD & MM performed statistical analyses, interpreted the data, BWS wrote and drafted the initial manuscript, PD & BS edited the manuscript and provided critical revision. IF participated in the conception and design of the study and provided critical revision of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets of the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

We confirm that all study procedures were in accordance with the Declaration of Helsinki and have been approved by the Institute of Sport Science, University of Würzburg. All participants gave informed consent to participate in the study.

Competing interests

The authors declare that they have no competing interests.

Author details

¹Institute of Sports Science, Julius-Maximilian University Würzburg, Judenbühlweg 11, 97082 Würzburg, Germany. ²Integrative and Experimental Exercise Science and Training, Institute of Sport Science, University of Würzburg, Judenbühlweg 11, 97082 Würzburg, Germany. ³Institute of Movement-Therapy and movement-oriented Prevention and Rehabilitation, German Sport University Cologne, Am Sportpark Müngersdorf 6, 50933 Köln, Germany.

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