Original Article

Validation study of *Polar V800* accelerometer

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Background: The correct quantification of physical activity (PA) and energy expenditure (EE) in daily life is an important target for researchers and professionals. The objective of this paper is to study the validity of the *Polar V800* for the quantification of PA and the estimation of EE against the ActiGraph (*ActiTrainer*) in healthy young adults.

Methods: Eighteen Caucasian active people (50% women) aged between 19–23 years wore an *ActiTrainer* on the right hip and a *Polar V800* on the preferred wrist during 7 days. Paired samples *t*-tests were used to analyze differences in outcomes between devices, and Pearson's correlation coefficients to examine the correlation between outcomes. The agreement was studied using the Bland-Altman method. Also, the association between the difference and the magnitude of the measurement (heteroscedasticity) was examined. Sensitivity, specificity and area under the receiver operating characteristic curve (ROC-AUC value) were calculated to evaluate the ability of the devices to accurately define a person who fulfills the recommendation of 10,000 daily steps.

Results: The devices significantly differed from each other on all outcomes (P<0.05), except for *Polar V800's* alerts *vs. ActiTrainer's* 1 hour sedentary bouts (P=0.595) and *Polar V800's* walking time *vs. ActiTrainer's* lifestyle time (P=0.484). Heteroscedasticity analyses were significant for all outcomes, except for Kcal and sitting time. The ROC-AUC value was fair (0.781±0.048) and the sensitivity and specificity was 98% and 58%, respectively.

Conclusions: The *Polar V800* accelerometer has a comparable validity to the accelerometer in free-living conditions, regarding "1 hour sedentary bouts" and "*V800's* walking time *vs. ActiTrainer's* lifestyle time" in young adults.

Keywords: Accelerometry; energy expenditure (EE); physical activity (PA); young adults; validity

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Introduction

Since the middle of the last century the relationship between health, energy expenditure (EE) and physical activity (PA) has been widely studied (1). Regular PA is associated with numerous physical and mental health benefits (2-5). In addition, there is a dose-response relationship between life expectancy and the amount of PA accumulated (6), showing that those who engage weekly in ≥450 min of PA have a higher life expectancy than those who do not (7).

However, it is not enough to meet PA recommendations to guarantee a good metabolic health (8) and also sedentary behavior (SB) has to be taken into consideration (9,10). Researchers and health professionals have different methods to estimate EE, PA and SB levels of their patients/clients. These methods can be classified as subjective and objective (11). The subjective methods (questionnaires, activity diaries, and interviews) are easily applicable but they have a limited validity because their results are determined by the interpretation and the memory of the subject (12). Instead, the objective methods provide information of subject's PA through the quantification of movement. Pedometers and accelerometers are the most frequently used objective instruments in free-living situations (13). Pedometers are characterized by simplicity, comfort and low cost but their validity estimating PA or SB level is limited as they only register the number of steps by time. However some of their limitations could be solved by accelerometers, which register intensity, duration and frequency of PA (14).

Accelerometers also have limitations since they do not identify the movement of all body parts, static exercises, movement on grading terrain or carrying a load (15). However they allow to estimate EE as well as patterns and levels of PA and SB during free-living situations with a high intra- and inter-instrument reliability (16), even slightly higher than the majority of questionnaires (test-retest reliability intraclass correlation coefficients: 0.77–0.90 for the ActiGraph 7164 *vs.* 0.59–0.84 for the questionnaires) (17). Moreover, accelerometers have a moderate validity compared to doubly labelled water estimating EE [0.39 energy expenditure due to PA (AEE) and 0.52 total energy expenditure (TEE) for uni-axial devices and 0.59 AEE and 0.61 TEE for tri-axial devices] (18,19). On average, uni-axial accelerometers underestimated AEE by 24% and TEE by 12%, while tri-axial devices underestimated AEE by 21% and TEE by 7% (19). Average absolute values of the differences between questionnaires and doubly labelled water estimates of AEE and TEE were 32% and 23% respectively (20).

Wearable technology has been identified as the first fitness trend in 2016, so the importance of these devices are increasing in the recent years (21). One example that hit the market was the *Polar V800*, capable of recording accelerometry, heart rate, speed and geolocation (GPS). This device belongs to the renowned Finnish brand Polar Electro, which is one of the leaders in the sector since 1983 launched to the world the first wireless heart rate monitor (22). Although this monitor is used by thousands of researchers, health professionals and athletes, there is no scientific study nowadays evaluating its validity to estimate EE, PA or SB patterns in free-living situations. So, it is necessary do it (4,23,24). For these reasons the aim of the present study was to compare the validity of *Polar V800* against a validated ActiGraph accelerometer (*ActiTrainer*) quantifying EE, PA and SB in young adults.

Methods

Subjects

Twenty-two Caucasian healthy subjects (50% women) ranged between 19 and 23 years old volunteered to participate in the study. The protocol was conducted according to ethical standards derived from the Spanish Medical Ethics Code and the Declaration of Helsinki for research in Human 1974 (last modified in 2013) (25). The study was approved by the University's Human Ethics Committee (University of Zaragoza). Prior to conducting, the study a written informed consent was obtained from each subject.

Experimental design

The subjects were given written and verbal instructions and required to wear both devices simultaneously from the moment they woke up in the morning until bedtime at night, so that a full day could be registered. In addition, both devices had to be removed for aquatic activities to prevent damage to the *ActiTrainer* because it is not waterproof. Subjects were asked to complete a provided diary and note the time of putting on the devices, of removing them at the end of the day, and any time when the devices were removed and reattached during the day.

Measurement

Anthropometric measurements

Body mass (BM) was measured in light clothing using an electronic balance (to 0.1 kg). Height was measured without shoes to the nearest 0.1 cm using a portable squad stadiometer for all subjects following the procedures defined by International Society for the Advancement in Kinanthropometry (ISAK). Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2).

PA assessment

Subjects wore simultaneously the *Polar V800* and the *ActiTrainer* for 7 consecutive days to observe PA and SB (26).

ActiTrainer: reference accelerometer

The *ActiTrainer*, an ActiGraph's accelerometer, is surrounded by a metal shield and packed into a plastic enclosure measuring 8.6 cm × 3.3 cm × 1.5 cm, weighs around 53 gr and includes a 3 V coin lithium battery. It has a dynamic range of 0.25–2.5 G and a sampling frequency of 30 Hz, measuring acceleration in the Y axis (omnidirectional) (27). The device was mounted on the right hip with an adjusted elastic belt to ensure close contact with the body. Monitors were set to record PA in a 15 s epoch and the "Step count" and "Dual axis" modes were selected; the firmware version used was the 7.1.0.

The results obtained were processed with Actilife version 6.5.4 software (Actigraph, LLC, Pensacola, FL, USA). Registered counts/15 s were reintegrated to 60 s epoch. The classification of wear and non-wear intervals was done by the Choi algorithm (Zero-count threshold during a non-wear time interval; 90 min time window for consecutive zero/nonzero counts; and allowance of 2 min interval of nonzero counts with the up/downstream 30 min consecutive zero counts window for detection of artifactual movements) (28). Also, 10 hours were established as the minimum necessary to be considered a valid day (29) and a minimum of five valid days, one of them on the weekend (30,31), to include the subject in the analysis (26,30). The previous published cut-off points proposed by Freedson (32) were used to estimate PA levels respect to PA intensity: sedentary [0–99 counts per minute (CPM)], light (100–759 CPM), lifestyle (760–1,951 CPM), moderate (1,952–5,724 CPM), vigorous (5,725–9,498 CPM) and very vigorous (>9,499 CPM) (33). Freedson's cut-off points were chosen because the sample used to validate it were similar (25 males, 24.8±4.2 yrs; and 25 females, age 22.9±3.8 yrs). Finally, <100 CPM was defined as SB (34) and the sedentary bouts were calculated for 10 minutes as for 1 hour.

Predicted EE in kcal·min^{-1} of the *ActiTrainer* monitor were calculated using the combined equation specified in the Actilife's software manual (35). Work-energy theorem was used when activity didn't exceed 1,952 CPM threshold [EE (kcal·min^{-1}) = 0.0000191 × CPM × BM (kg)]; and the Freedson equation was used when activity counts exceed 1,952 CPM {EE (kcal·min^{-1}) = 0.00094 × CPM + [0.1346 × BM (kg) – 7.37418]}.

Polar V800

The *Polar V800* measures 37 mm × 56 mm × 12.7 mm and weighs 79 gr, is operated by a 350 mAh Li-pol rechargeable battery. It registers activity by an internal tri-axial accelerometer that records wrist movements, giving several outcomes as EE (Kcal), sedentary alerts, PA (lying time, sitting time and active time -standing, walking and running-) and number of steps. The wrist placement was defined by the subject's preference.

Epoch length, definition of non-wearing time, cut-off points and the formula used for the estimation of EE are pre-fixed by the manufacturer of the *Polar V800* and are not indicated in the manual (36).

Statistical analysis

All statistical analyses were performed using IBM SPSS (v.20 for Windows, Chicago, IL, USA) and the significance level was set at P≤0.05.

Paired *t*-tests were used to analyze significant differences in variables between devices. Pearson's correlation coefficients (r_p) were calculated to examine the correlation between outcomes, defined 0.9–1 as being very high correlation, 0.7–0.9 as high correlation, 0.5–0.7 as moderate correlation, 0.3–0.5 as low correlation and 0–0.3 as negligible correlation (37).

The agreement between monitors was examined using the analysis proposed by Bland-Altman; BIAS, standard deviation (SD) of BIAS and limits of agreement at 95% (LOA) were calculated to evaluate agreement among variables obtained by both devices (38). Also, the association between difference and magnitude of the measurement (e.g., heteroscedasticity) was examined, inserting the difference between the value of the measurement for the *Polar V800* and the value for the *ActiTrainer* as dependent variable, and the average value [(value for the *Polar V800* + value for *ActiTrainer*)/2] as independent variable.

Finally, sensitivity, specificity and area under the receiver operating characteristic curve (ROC-AUC value) were calculated to evaluate the ability of the devices to accurately define a person who fulfills the recommendation of 10,000 daily steps (39). Perfect classification is represented by an ROC-AUC of 1, whereas a complete absence of classification is represented by an area of 0.5 ROC-AUC values, of ≥0.90 are considered to be excellent, values between 0.80–0.90 are considered to be good, values between 0.70–0.80 are fair and values <0.70 are considered to be poor (40).

Results

The descriptive characteristics of the subjects are presented in *Table 1*. Eighteen of the 22 subjects (50% women) ranged between 19 and 23 years old (mean 21.00±1.24, see *Table 1*) met inclusion criteria for analysis (5 valid days, 1 of them on the weekend). There were no significant differences in age, gender, height, weight and BMI between the 18 subjects included in the study and the 4 with incomplete data that were excluded. Subjects wore the *ActiTrainer* and the *Polar V800* for an average of 874.65±10.76 min·day^{-1} and range of 600–1,222 min·day^{-1}. Variables obtained by both devices are shown in *Table 2*.

Paired *t*-test results are showed in *Figure 1*. *Polar V800's* alerts *vs*. *ActiTrainer's* 1 hour sedentary bouts (P=0.595) and *Polar V800's* walking time *vs*. *ActiTrainer's* lifestyle time (P=0.484) weren't statistically different, although the other variables differed significantly (P<0.05) between methods. *Polar V800's* alerts *vs*. *ActiTrainer's* 1 hour sedentary bouts (P=0.456) and *Polar V800's* walking time *vs*. *ActiTrainer's* lifestyle time (P=0.920) were also the variables that did not differ significantly when they were compared on weekdays (*Figure 2*). However, when weekend days were compared, *Polar V800's* alerts *vs*. *ActiTrainer's* 1 hour sedentary bouts (P=0.875), *Polar V800's* walking time *vs*. *ActiTrainer's* lifestyle time (P=0.296), *Polar V800's* walking time *vs*. *ActiTrainer's* moderate time (P=0.839), non-vigorous active time (P=0.219) and Vigorous active time (P=0.077) weren't significantly different (*Figure 3*).

The r_p of the whole week (*Figure 1*) shows that there was a very high correlation (0.9–1) between steps measured by both accelerometers; there was a high correlation (0.7–0.9) for active time, *Polar V800's* walking time *vs*. *ActiTrainer's* moderate time and non-vigorous active time; and a moderate correlation (0.5–0.7) for *Polar V800's* RMR Kcal *vs*. *ActiTrainer's* Kcal, Sitting time and *Polar V800's* walking time *vs*. *ActiTrainer's* lifestyle time. Results separately for weekday and weekend days show similar trends (*Figures 2,3*).

Bland-Altman results (BIAS, SD of BIAS and LOA) are shown in *Figures 4-6* and *Tables 3-5*. Heteroscedasticity analysis showed a significantly positive correlation between the difference and the mean value for all outcomes, except for *Polar V800's* Kcal *vs*. *ActiTrainer's* Kcal (P=0.868) and sitting time (P=0.616) (*Table 3*). As shown in *Tables 4* and *5* results were similar when only weekdays or weekend days were compared, with the only exception that at the weekend no significant correlation was also found in the non-vigorous active time (P=0.059). So except for the variables

Table 1 Descriptive characteristics of subjects

Parameter (N=18)	Means ± SD	Range
Age (years)	21.00±1.24	19–23
Weight (kg)	64.10±7.90	52.60–79.80
Height (cm)	169.50±6.58	157.8–181.8
BMI ($kg \cdot m^{-2}$)	22.25±1.75	19.71–26.06

Values are means ± standard deviation (SD). BMI, body mass index.

Table 2 Variables compared between devices

Name of the variable	*Polar V800's* variable	*ActiTrainer's* variable
Polar V800's Kcal *vs*. *ActiTrainer's* Kcal	Kcal	Kcal
Polar V800's RMR Kcal *vs*. *ActiTrainer's* Kcal	Kcal-*Polar V800's* RMR for each subject	Kcal
Polar V800's alerts *vs*. *ActiTrainer's* Freedson alerts	Alerts	Freedson Alerts
Polar V800's alerts *vs*. *ActiTrainer's* 10 minutes sedentary bouts	Alerts	10 minutes sedentary
Polar V800's alerts *vs*. *ActiTrainer's* 1 hour sedentary bouts	Alerts	1 hour sedentary
Sitting time	Sitting time	Sedentary time
Active time	Active time	Light time + lifestyle time + moderate time + vigorous time + very vigorous time
Polar V800's walking time *vs*. *ActiTrainer's* lifestyle time	Walking time	Lifestyle time
Polar V800's walking time *vs*. *ActiTrainer's* moderate time	Walking time	Moderate time
Non-vigorous active time	Standing time + walking time	Light time + lifestyle time + moderate time
Vigorous active time	Running time	Vigorous time + very vigorous time
Steps	Steps	Steps

RMR, resting metabolic rate for *Polar V800*.

***Polar V800*'s outcome**		***ActiTrainer*'s outcome**		**P**	**r_p**	**P**
TEE (Kcal)	2,413.97±581.80	1,456.48±731.40	TEE (Kcal)	**<0.001***	0.483**	<0.001
TEE-RMR (Kcal)	1,024.73±731.40			**<0.001***	0.569**	<0.001
Alerts (number of times)	0.61±0.88	2.05±1.84	Freedson (number)	**<0.001***	–0.019	0.837
		16.33±4.34	10' sedentary (number)	**<0.001***	0.235**	0.009
		0.66±0.84	1 h sedentary (number)	0.595	0.295**	0.001
Lying time (min)	232.45±238.36					
Sitting time (min)	525.16±134.08	570.70±117.57	Sedentary time (min)	**<0.001***	0.689**	<0.001
Active time (min) (standing + walking + running)	335.93±107.71	303.95±93.29	Light + lifestyle + moderate + vigorous + very vigorous) (min)	**<0.001***	0.876**	<0.001
Standing time (min)	251.94±83.00	174.78±53.74	Light time (min)			
Walking time (min)	61.78±34.78	63.80±29.49	Lifestyle time (min)	0.484	0.518**	<0.001
		56.61±37.97	Moderate time (min)	0.037*	0.726**	<0.001
Non-vigorous active time (min) (standing + walking)	313.72±100.13	295.19±91.91	Light + lifestyle + moderate (min)	**<0.001***	0.847**	<0.001
		5.03±8.03	Vigorous time (min)			
		3.73±11.61	Very vigorous time (min)			
Vigorous active time (min) (running)	21.60±39.26	8.76±16.12	Vigorous + very vigorous (min)	**<0.001***	0.337**	<0.001
Steps	13,319.40±5,332.44	10,832.43±4,577.96	Steps	**<0.001***	0.904**	<0.001

Figure 1 *Polar V800* and *ActiTrainer* outcomes recorded during all week (mean ± SD). Values are means ± standard deviation (SD). The leftmost P is for the paired-samples *t*-test (*, $P<0.05$). r_p, Pearson's correlation coefficient (**, $P<0.05$). TEE, total energy expenditure; RMR, resting metabolic rate for the *Polar V800*.

***Polar V800*'s outcome**		***ActiTrainer*'s outcome**		**P**	**r_p**	**P**
TEE (Kcal)	2,419.86±533.51	1423.00±625.65	TEE (Kcal)	**<0.001***	0.337**	0.002
TEE-RMR (Kcal)	1,031.60±423.00			**<0.001***	0.428**	<0.001
Alerts (number of times)	0.66±0.89	2.09±1.82	Freedson (number)	**<0.001***	0.057	0.606
		16.52±4.51	10' sedentary (number)	**<0.001***	0.227**	0.036
		0.74±0.87	1h sedentary (number)	0.456	0.342**	0.001
Lying time (min)	223.48±230.63					
Sitting time (min)	533.55±141.99	583.34±120.90	Sedentary time (min)	**<0.001***	0.655**	<0.001
Active time (min) (standing + walking + running)	339.58±95.06	303.86±85.43	Light + lifestyle + moderate + vigorous + very vigorous (min)	**<0.001***	0.842**	<0.001
Standing time (min)	253.27±76.59	175.59±52.69	Light time (min)			
Walking time (min)	63.46±33.26	63.80±27.61	Lifestyle time (min)	0.920	0.492**	<0.001
		55.48±32.71	Moderate time (min)	**0.001***	0.806**	<0.001
Non-vigorous active time (min) (standing + walking)	316.73±90.12	294.87±83.76	Light + lifestyle + moderate (min)	**<0.001***	0.810**	<0.001
		6.00±8.37	Vigorous time (min)			
		2.99±9.19	Very vigorous time (min)			
Vigorous active time (min) (running)	21.91±35.63	8.99±13.54	Vigorous + very vigorous (min)	**0.001***	0.246**	0.023
Steps	13,325.22±4,560.07	10,930.78±4,040.51	Steps	**<0.001***	0.888**	<0.001

Figure 2 *Polar V800* and *ActiTrainer* outcomes recorded during the week days (mean ± SD). Values are means ± standard deviation (SD). The leftmost P is for the paired-samples *t*-test (*, $P<0.05$). r_p, Pearson's correlation coefficient (**, $P<0.05$). TEE, total energy expenditure; RMR, resting metabolic rate for the *Polar V800*.

Polar V800's outcome		*ActiTrainer*'s outcome		P	r_p	P
TEE (Kcal)	2,400.43±687.97	1,533.41±935.92	TEE (Kcal)	**<0.001***	0.668**	<0.001
TEE-RMR (Kcal)	1,008.95±587.49			**<0.001***	0.735**	<0.001
Alerts (number of times)	0.51±0.84	1.95±1.93	Freedson (number)	**<0.001***	–0.206	0.221
		15.89±3.96	10' sedentary (number)	**<0.001***	0.244	0.461
		0.49±0.73	1 h sedentary (number)	0.875	0.125	0.721
Lying time (min)	253.05±257.35					
Sitting time (min)	505.89±113.31	541.68±105.41	Sedentary time (min)	**0.007***	0.758**	<0.001
Active time (min) (standing + walking + running)	327.57±133.45	304.16±110.54	Light + lifestyle + moderate + vigorous + very vigorous (min)	**0.010***	0.925**	<0.001
Standing time (min)	248.89±97.22	172.92±56.78	Light time (min)			
Walking time (min)	57.92±38.26	63.81±33.81	Lifestyle time (min)	0.296	0.567**	<0.001
		59.19±48.36	Moderate time (min)	0.839	0.644**	<0.001
Non-vigorous active time (min) (standing + walking)	306.81±121.14	295.92±109.64	Light + lifestyle + moderate (min)	0.219	0.899**	<0.001
		2.81±6.81	Vigorous time (min)			
		5.43±15.87	Very vigorous time (min)			
Vigorous active time (min) (running)	20.89±47.10	8.24±21.09	Vigorous + very vigorous (min)	0.077	0.442**	0.006
Steps	13,305.87±6,889.51	10,604.00±5,704.53	Steps	**<0.001**	0.924**	<0.001

Figure 3 *Polar V800* and *ActiTrainer* outcomes recorded during the weekend days (mean ± SD). Values are means ± standard deviation (SD). The leftmost P is for the paired-samples *t*-test (*, P<0.05). r_p, Pearson's correlation coefficient (**, P<0.05). TEE, total energy expenditure; RMR, resting metabolic rate for the *Polar V800*.

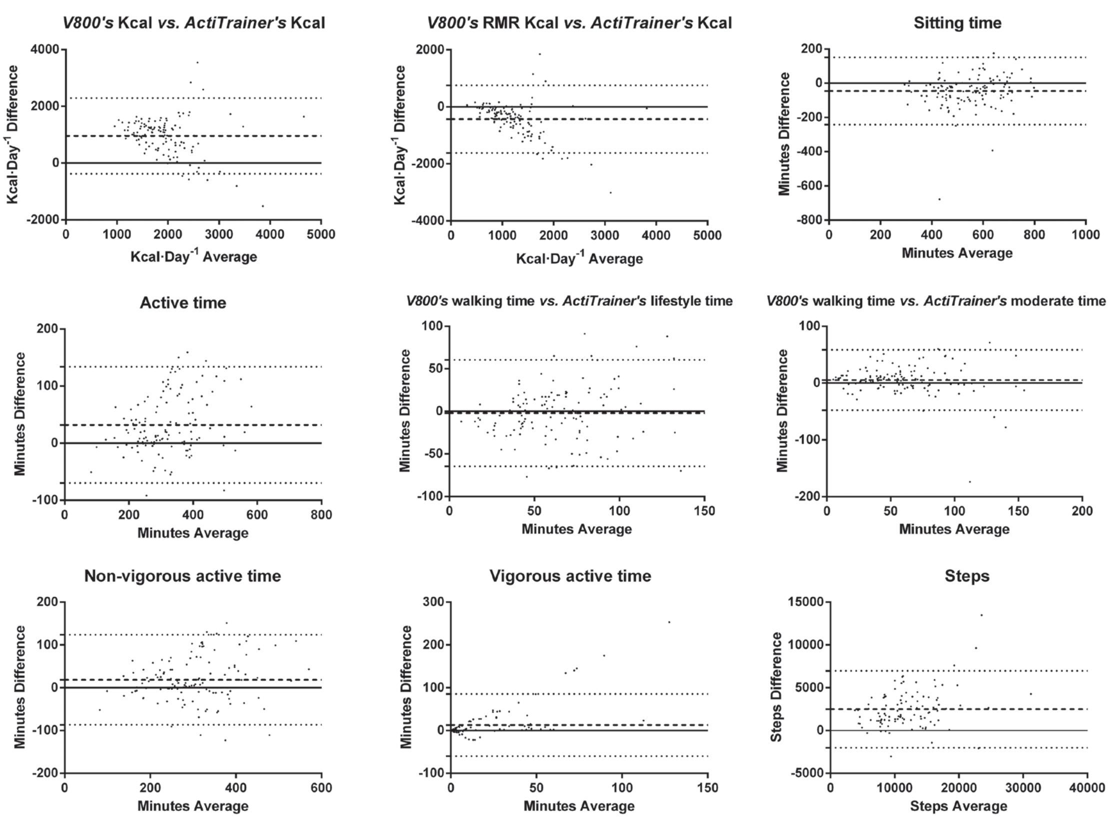

Figure 4 Bland-Altman results during all week.

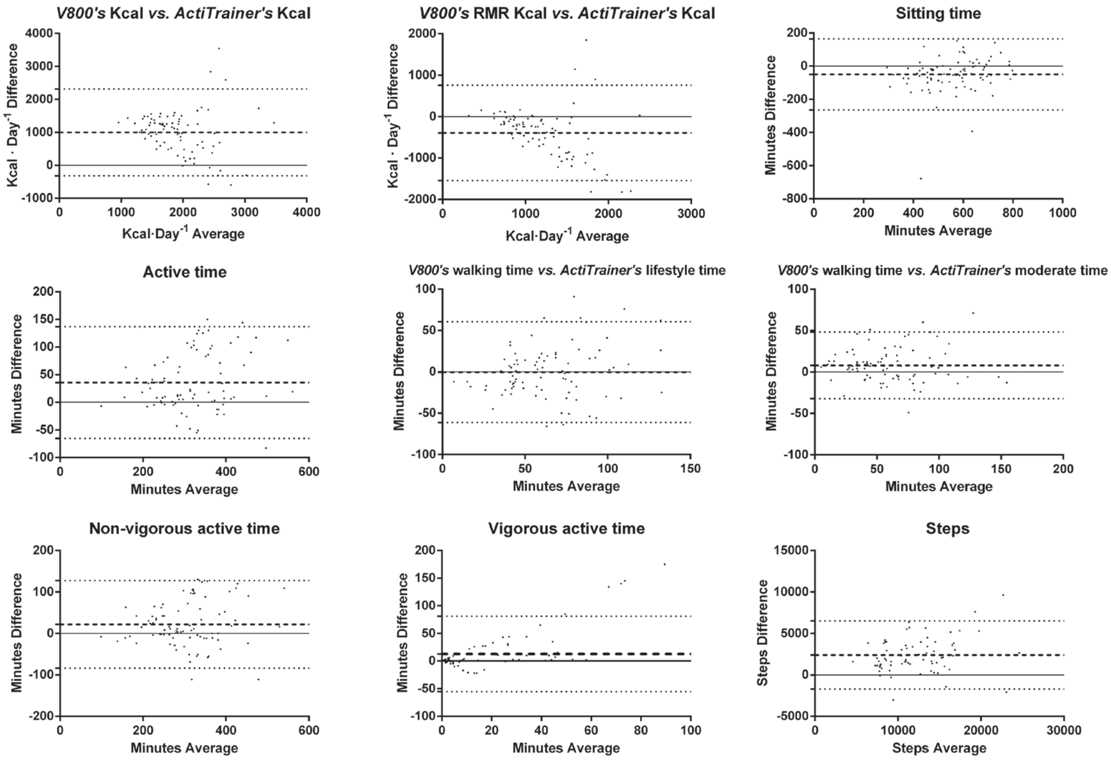

Figure 5 Bland-Altman results during the week days.

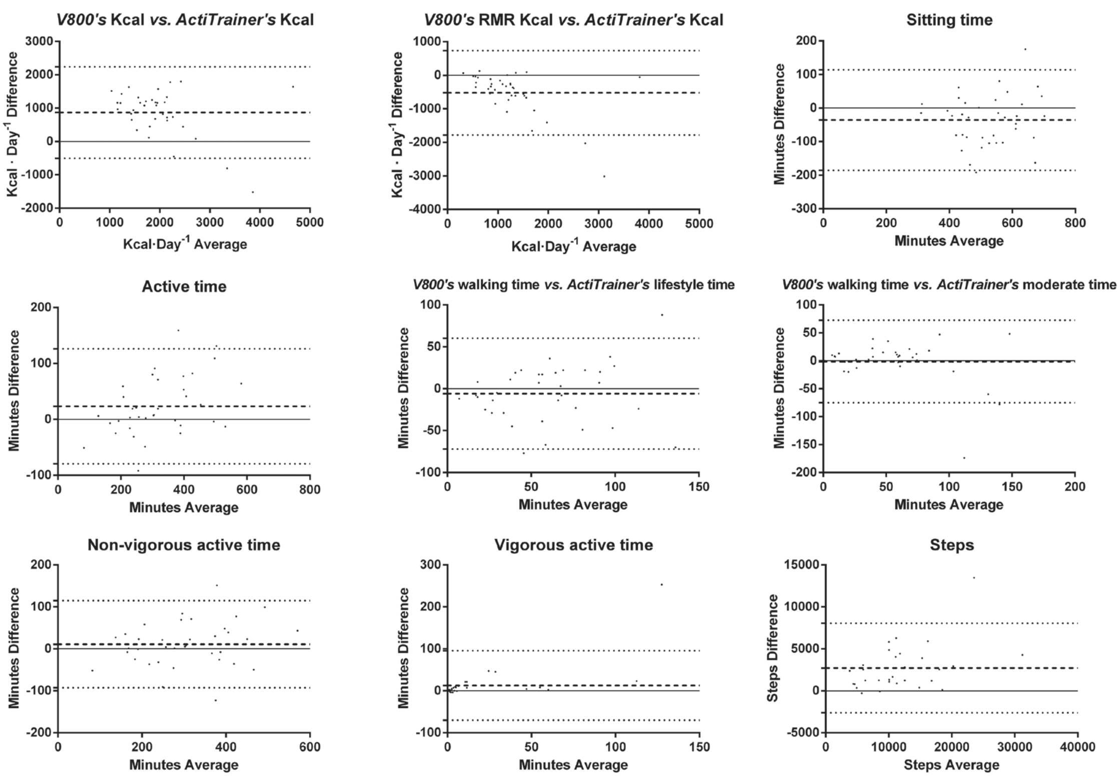

Figure 6 Bland-Altman results during the weekend days.

Table 3 Bland-Altman results during all week

Polar V800's outcome	*ActiTrainer's* outcome	BIAS	SD	LOA	r_p	P
TEE (Kcal)	TEE (Kcal)	957.5	679.9	–375.2 to 2,290	–0.015	0.868
TEE-RMR (Kcal)		–431.8	604.4	–1,616 to 752.8	0.627*	<0.001
Sitting time (min)	Sedentary time (min)	–45.5	100.4	–242.3 to 151.2	–0.046	0.616
Active time (min) (standing + walking + running)	Light + lifestyle + moderate + vigorous + very vigorous (min)	32.0	52.0	–69.8 to 133.8	0.323*	<0.001
Walking time (min)	Lifestyle time (min)	–2.0†	31.9	–64.0 to 60.4	0.375*	<0.001
	Moderate time (min)	5.2	27.1	–47.9 to 58.3	0.358*	
Non-vigorous active time (min) (standing + walking)	Light + lifestyle + moderate (min)	18.5	53.7	–86.6 to 123.7	0.339*	<0.001
Vigorous active time (min) (running)	Vigorous + very vigorous (min)	12.8	37.1	–59.8 to 85.1	0.735*	<0.001
Steps	Steps	2,487	2,293	–6,982 to 2,008	0.395*	<0.001

r_p, Pearson's correlation coefficient; †, P>0.05 for the paired-samples *t*-test; *, P<0.05 for the Pearson's correlation coefficient. BIAS, is expressed as mean; SD, standard deviation; LOA, limits of agreement at 95%; TEE, total energy expenditure. RMR, resting metabolic rate for the *Polar V800*.

Table 4 Bland-Altman results during the week days

Polar V800's outcome	*ActiTrainer's* outcome	BIAS	SD	LOA	r_p	P
TEE (Kcal)	TEE (Kcal)	996.9	671.6	–319.5 to 2,313	–0.065	0.553
TEE-RMR (Kcal)		–391.4	586.5	–1,541 to 758.2	0.672*	<0.001
Sitting time (min)	Sedentary time (min)	–49.8	109.3	–264.1 to 164.5	–0.104	0.314
Active time (min) (standing + walking + running)	Light + lifestyle + moderate + vigorous + very vigorous (min)	35.7	51.6	–65.4 to 136.8	0.323*	0.003
Walking time (min)	Lifestyle time (min)	–0.3†	31.1	–61.2 to 60.5	0.342*	0.001
	Moderate time (min)	8.0	20.5	–32.3 to 48.2	0.235*	0.030
Non-vigorous active time (min) (standing + walking)	Light + lifestyle + moderate (min)	21.9	53.9	–83.8 to 127.5	0.361*	0.001
Vigorous active time (min) (running)	Vigorous + very vigorous (min)	12.9	34.9	–55.4 to 81.2	0.764*	<0.001
Steps	Steps	2,394	2,097	–6,505 to 1,716	0.356*	0.002

r_p, Pearson's correlation coefficient; †, P>0.05 for the paired-samples *t*-test; *, P<0.05 for the Pearson's correlation coefficient. BIAS, is expressed as mean; SD, standard deviation; LOA, limits of agreement at 95%; TEE, total energy expenditure; RMR, resting metabolic rate for the *Polar V800*.

just mentioned, evidence of "heteroscedasticity" between the devices was found, in other words, the width of the random scatter increased as the general size of measured.

Regarding *ActiTrainer*, *Polar V800's* ability to accurately define a person who fulfills the recommendation of 10,000 daily steps was fair (ROC-AUC: 0.781±0.048; P<0.001; LOA =0.687–0.874) and the sensitivity and specificity was 98% and 58%, respectively.

Conclusions

The results of this study show that 1 hour sedentary periods

Table 5 Bland-Altman results during the weekend days

Polar V800's outcome	*ActiTrainer*'s outcome	BIAS	SD	LOA	r_p	P
TEE (Kcal)	TEE (Kcal)	867.0	699.6	–504.2 to 2,238	0.084	0.620
TEE-RMR (Kcal)		–524.5	642.1	–1,783 to 734.1	0.582*	<0.001
Sitting time (min)	Sedentary time (min)	–35.8	76.4	–185.6 to 114.0	0.169	0.316
Active time (min) (standing + walking + running)	light + lifestyle + moderate + vigorous + very vigorous (min)	23.4	52.4	–79.3 to 126.2	0.336*	0.042
Walking time (min)	Lifestyle time (min)	–5.9†	33.8	–72.1 to 60.3	0.444*	0.006
	Moderate time (min)	–1.3†	37.7	–75.1 to 72.6	0.495*	0.002
Non-vigorous active time (min) (standing + walking)	light + lifestyle + moderate (min)	10.9†	53.0	–92.9 to 114.7	0.313	0.059
Vigorous active time (min) (running)	vigorous + very vigorous (min)	12.6†	42.3	–70.2 to 95.5	0.701*	<0.001
Steps	Steps	2,702	2,720	–2,630 to 8,034	0.440*	0.013

r_p, Pearson's correlation coefficient; †, P>0.05 for the paired-samples *t*-test; *, P<0.05 for the Pearson's correlation coefficient. BIAS, is expressed as mean; SD, standard deviation; LOA, limits of agreement at 95%; TEE, total energy expenditure; RMR, resting metabolic rate for the *Polar V800*.

estimated by the *Polar V800* and the ActiGraph *ActiTrainer* were similar. Also, the time defined as walking by the *Polar V800* was similar to the time dedicated in activities falling just below 3METs (defined by Freedson as Lifestyle intensities) in young adults (33). However, the *Polar V800* did not estimate accurately the rest of the variables [e.g., TEE (Kcal), sitting time, active time, *Polar V800's* walking time *vs*. *ActiTrainer's* moderate time, non-vigorous active time, vigorous active time and steps].

The outcomes provided by an accelerometer depend on several variables as brand, generation, wearing position, epoch length, definition of non-wearing time, definition of a valid day, required number of days of monitoring, cut-off points, use and definition of activity bouts, or accelerometer firmware version (20). Some of the aforementioned variables (e.g., epoch length, definition of non-wearing time, cut-off points or the formula used for the estimation of EE) are pre-fixed by manufacturers of the *Polar V800*; moreover these settings are unknown by the user/researcher. This fact increases the complexity of the *Polar V800*'s outcome comparisons.

EE estimated by the *Polar V800* was significantly higher than estimated by the *ActiTrainer* (P<0.001), the origin of this difference could be multifactorial. Firstly, the average wear time between both accelerometers was significantly different (P<0.001), the *ActiTrainer* was worn for 218.89 minutes/day less than the *Polar V800*. This difference in wear time may be due to the fact that the *Polar V800* is more comfortable (41). In addition, some subjects did not follow the instructions and wore the *Polar V800* during sleep and water activities; moreover the *Polar V800* overestimated SB because it classifies some non-used time as lying because it does not have galvanic sensors which can detect if it is worn. Secondly, literature shows that tri-axial accelerometers underestimate TEE 5% less compared to the uni-axial accelerometers (18,19), which is in line with our results as the *Polar V800* is tri-axial and the *ActiTrainer* is uni-axial (omnidirectional). Lastly, for the subjects who recorded training sessions, the *Polar V800* used GPS and heart rate data (if the band is used) to estimate EE, thereby it could be more accurate. These reasons could explain why the correlation of this variable (r_p =0.483) was found to be lower than the one found by a recent study between other daily use monitors (Fitbit Flex, Jawbone UP 24, Misfit Shine, Nike + Fuelband SE and Polar Loop) (r_p =0.71–0.9) or research devices (Actigraph GT3X+ and BodyMedia Core) compared with indirect calorimetry (42). Even though the correlation was low for this variable, homoscedasticity was observed (P=0.868); so the difference between methods remains constant, which is probably explained because each device estimates the EE from its own formula.

In regards to sedentary alerts, no significant difference was found between the *Polar V800's* alerts and *ActiTrainer's* 1 hour sedentary bouts (P=0.595), so both devices could be valid for measuring these important indicators of SB. The *Polar V800* can be an useful tool to modify these long periods sitting, such negative for health, since vibration and a screen message alerts the user when he/she spends too much time on SB (9,43). Such real-time feedback is suggested to be important to improve weight loss in obese and overweight adults (44).

Concerning the time spent in each zone of PA intensity, significant differences were observed for all variables except for *Polar V800's* walking time *vs*. *ActiTrainer's* lifestyle time (P=0.484). However at a theoretical level, even this seems coincidental, since: (I) both devices use different cutpoints, e.g., walking activity according to Freedson's cutpoints could be "Moderate" (1,952–5,724 CPM) or even "Vigorous" (5,725–9,498 CPM) (33,45,46); (II) as it has been previously discussed, wearing time of the two devices was not similar; (III) the correlation shown in non-vigorous active time (r_p =0.847) is similar to the correlation found in other studies between daily use devices (Fitbit One, Fitbit Zip, Jawbone UP, Misfit Shine, Nike Fuelband, Striiv Smart and Withings Pulse) and research accelerometers (BodyMedia SenseWear and ActiGraph GT3X+) (r_p =0.52–0.91) (47).

Steps registered by each monitor were significantly different (BIAS: 2,487±2,293 steps/day; P<0.001). The *ActiTrainer* has been validated for steps recording in a similar study population (48), so it may be that the *Polar V800* is not valid for registering steps, but it cannot be forgotten that wearing time of the devices was not the same. Besides, although it showed heteroscedasticity (P<0.001), the correlation between the steps of both methods was very high (r_p =0.904), which is similar to those between other daily devices (Fitbit One, Fitbit Zip, Jawbone UP, Misfit Shine, Nike Fuelband, Striiv Smart and Withings Pulse) and research accelerometers (BodyMedia SenseWear,and ActiGraph GT3X+) (r_p >0.8) (47).

Finally, the ability of the *Polar V800* to define if a person meet the recommendation of 10,000 daily steps compared with the *ActiTrainer* has been studied. The 98% of the cases who met the recommendations, was classified as they fulfilled them (sensitivity), 58% of the subjects not meeting the recommendations was classified as they did not comply (specificity), and the ROC-AUC value was fair (0.781±0.048). Results presented can probably be explained by the wear time difference, because *Polar V800* has been measuring more time, so more people can fulfill the recommendations according to this device.

In the last years it has been repeatedly pointed out how the use of new technologies can help to improve health and prevent future diseases (49). Some studies even suggest that the new wearables (e.g., Fitbit) are more effective to increase PA than those used a few years ago, such as pedometers (50). However, as said by some authors, most companies that manufacture wearable devices do not provide information nor guarantee the reliability, effectiveness or accuracy of their services and devices (51).

The main limitation of the present study was that the wear time of both devices was not the same, a possible solution would be to fragment both recordings in bouts (27), but *Polar V800* only gives overall results of all day, so the best solution would be to compare with an waterproof accelerometer. Secondly, as the intensity of activities has been calculated with different cutpoints, the number of intensity levels obtained is different (6 *vs*. 5) (33). Moreover, even though the comparison has been made regarding an accelerometer that has been widely used in research and has shown its reliability, validity and comparability (29,34,52), in the future, validation of *Polar V800's* PA and EE outcomes should be evaluated against gold standard (such as direct calorimetry and/or double labelled water). Among the strengths it is found that the study was conducted during free-living so there is a greater ecological external validity and therefore the results are more generalizable than in laboratory studies; besides, although having an inclusion criteria (5 valid days, one of them in the weekend) more demanding than the usual (4 valid days), the number of lost subjects is similar to other studies (18% *vs*. 17%); in addition there were no significant differences in the characteristics of valid subjects and those who don't met inclusion criteria. Likewise, among subjects who met the inclusion criteria, the percentage that did not have valid data for all days of measurement (55%), and the average wearing time (14.6 h) are comparable to those observed in literature: (27–74%) and (13–15 h) respectively (20).

This study shows that the tri-axial accelerometer of *Polar V800* has a comparable validity to the use of the *ActiTrainer's* accelerometer as a standard reference assessing "1 hour sedentary bouts" and "lifestyle time" in young adults in free-living.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by the

University's Human Ethics Committee (University of Zaragoza) and written informed consent was obtained from all patients.

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