Inter-accelerometer comparison to measure physical activity and sedentary time in female fibromyalgia patients: the al-Ándalus project

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ABSTRACT

Objective. *The purpose of the current study was to compare physical activity (PA) levels and sedentary time between two accelerometers, the SenseWear Pro$_3$ Armband (SWA) and the Actigraph GT1M, in Spanish female fibromyalgia patients.*

Methods. *Patients wore the SWA and the Actigraph for 7 consecutive days. Total minutes/day spent in sedentary, light, moderate and moderate-to-vigorous PA were analysed. The agreement between the SWA and the Actigraph were assessed by using Bland-Altman plots.*

Results. *Total PA, light, moderate, and moderate-vigorous PA levels in total-week, weekdays and weekends were higher (all, $p \leq 0.001$), and sedentary time in total-week, weekdays and weekends lower (all, $p<0.001$) for the SWA when compared to the Actigraph. Concordance correlation coefficients between the SWA and the Actigraph ranged from 0.12 to 0.45 and Pearson's correlation coefficients ranged from 0.28 to 0.77. The Bland-Altman plots showed an overall lack of agreement between both methods.*

Conclusion. *The present study showed that the SWA and the Actigraph provide different estimates of PA and sedentary time in Spanish female fibromyalgia patients. Caution must be taken when using different devices and the location on the body must be noted. Our results suggest that the PA levels and sedentary time provided by both devices should be interpreted independently across studies.*

Introduction

Nowadays, there is clear evidence that regular physical activity (PA) promotes important health benefits by reducing the risk of chronic disease such as heart disease, type 2-diabetes, certain cancers as well as in the prevention of chronic somatic symptoms (1). Furthermore, it may promote health preservation with increasing age (2-4). Recent PA programmes have shown positive effects on improving physical fitness (5), reducing pain threshold (6-8), and providing robust psychological benefits (5) in fibromyalgia patients. Consequently, there has been a recent increase of interest in a physically active lifestyle as a possible treatment for fibromyalgia syndrome (9, 10). Although this may be the case, fibromyalgia patients tend to be more sedentary (11) and less physically active than age- and sex-matched healthy peers (12). In a recent study, we observed that 60.6% of female fibromyalgia patients met the PA recommendations of 30 min/day of moderate-to-vigorous PA for 5 or more days a week. However, on average they spent 71% of their waking time (approximately 10 h/day) engaged in sedentary behaviour (13). This lack of PA, thus resulting in an elevated proportion of sedentary behaviour in fibromyalgia patients' lifestyle, might be related to negative consequences such as increased mortality risk (14) and contribute to the development of the obesity (15).

Traditionally, PA levels have been assessed by means of self-reported questionnaires because the administration is easy and inexpensive (16). However, questionnaires are often weak because they pose a risk of bias (17), and recent studies have shown that PA questionnaires are inefficient in fibromyalgia populations (18, 19).

In recent years, PA assessment has increasingly relied on wearable monitors to provide an objective measurement

in the research field (20). These devices (*e.g.* accelerometer, pedometers) have been widely used to objectively measure PA and sedentary time (13, 21, 22). A study performed in bariatric surgery patients provided similar estimates of PA and sedentary behaviour at the group level between two objectives devices (23). Separately, these devices (SenseWear Pro3 Armband (SWA) and Actigraph GT1M) have been validated both in healthy populations (24, 25) as well as in fibromyalgia patients (26). These instruments are preferable over self-reported questionnaires because they may provide real-time assessment, thus avoiding response bias and other threats to validity in subjective methods (20).

Given the increasing use of objective devices to assess PA and sedentary time in fibromyalgia patients (13, 18, 26, 27), there is a need to corroborate whether different accelerometer models are comparable in order to further quantify PA levels and sedentary time in this population. We hypothesised that body location and differences between the accelerometers might lead to differences in PA levels measured between both devices. Therefore, the purpose of the current study was to compare PA levels and sedentary time in Spanish female fibromyalgia patients when measured with two objective devices: the SWA and the Actigraph GT1M.

Methods

Study participants

Fifty-four potentially eligible participants were recruited from a local fibromyalgia association (Granada, Southern Spain). Participants provided written informed consent after receiving detailed information about the aims and study procedures. Participants were excluded from the study if they did not meet the diagnosis of fibromyalgia according to the 1990 American College of Rheumatology criteria (28) or they were not capable or willing to provide informed consent. Due to the very small sample size (n=6), men were not included in the study. Finally, 48 women wore the SWA and the Actigraph, and participated in the study. The study protocol was reviewed and approved by the Ethics Committee of the Hospital Virgen de las Nieves (Granada, Spain).

Procedures

For the duration of the study, the women were visited twice. During the first visit, the tender points count was measured and demographic data were recorded. Patients were asked to simultaneously wear two different accelerometers for 7 consecutive days. Both devices were worn the whole day (24 hours) except during water-based activities such as bathing or swimming. Patients were also advised to continue with their usual lifestyle. At the second visit, patients returned both devices to the researchers.

Measures

• *Body Mass Index*

Weight was measured with an eight-polar tactile-electrode impedanciometer (InBody R20, Portable; Seoul, Korea). The validity and reliability of this instrument has been reported elsewhere (29, 30). Height (cm) was measured using a stadiometer (Seca 22; Hamburg, Germany). BMI was calculated as weight (in kilograms) divided by height (in meters) squared.

• *Tender points count*

Eighteen tender points according to the American College of Rheumatology criteria (28) were assessed using a standard pressure algometer (FPK 20; Wagner Instruments, Greenwich, CT USA). The total count of positive tender points was recorded for each patient. An algometer score was calculated as the sum of the minimum pain-pressure values obtained for each tender point.

• *Visual Analogue Scale*

The visual analogue scale for pain is a simple assessment tool consisting of a 10 cm line with 0 on one end, representing no pain, and 10 on the other, representing the worst pain ever experienced, which a patient marks to indicate the severity of the pain at the present moment.

• The *Beck Depression Inventory II*

The Beck Depression Inventory II (BDI-II) was used to assess depression severity (31, 32). It contains 21 items and the score ranges from 0 to 63, with a higher score indicating greater depression.

• *Log Diary*

This was used to schedule when patients went to bed and when they got up from bed each day that they wore the accelerometers.

SenseWear Pro Armband

The SWA (SenseWear Pro_3 Armband; BodyMedia Inc., Pittsburgh PA) is a device designed to assess the levels of energy expenditure (24, 26). This instrument has been recently used to assess PA levels (16) and sedentary time (33) in fibromyalgia patients. The SWA was placed on the upper right arm over the triceps muscle at the midpoint between the acromion and olecranon processes, as previously described (24, 34). The SWA incorporates a wide range of measured parameters (biaxial accelerometry [±2.00 g], heat flux [0.00 W/m^2 to 300.00 W/m^2], galvanic skin response [56 KW to 20 MW], skin temperature, near-body temperature [20.00°C to 40.00°C]), and demographic characteristics (gender, age, height, and weight) into proprietary algorithms to estimate energy expenditure. Energy expenditure was computed at 1-minute intervals.

Data were excluded from the final study analysis if there were less than 7 days of collection and there was a minimum of 95% "on-body" time. Finally, data obtained were downloaded using software developed by the manufacturer (SenseWear Professional software version 6.1[a]; BodyMedia Inc., Pittsburgh PA). For the final sedentary and PA analyses, sleeping time was subtracted according to the patient log diary.

Sedentary time was estimated as the amount of time accumulated below 1.5 METs per minute during registered time periods. PA levels were set as time (min/day) engaged in light, moderate, and moderate-to-vigorous PA based on a standardised cut-off of 1.5 - <3, 3–6 and ≥3 METs per minute, respectively (35).

Actigraph GT1M

The GT1M accelerometer (Accelerometer (Actigraph™ GT1M; Pensacola,

Florida) is a valid instrument (25) used to assess PA levels and sedentary time in the general population (36) as well as in fibromyalgia patients (13). This uniaxial accelerometer was initialised as described by the manufacturer, and the data were saved in 5 s epochs (an epoch is a division of time-period, in which they are referred to a time-period of 5 seconds). Patients wore the device on the waist, secured with an elastic belt, underneath clothing, close to the centre of gravity.

Sleeping time was subtracted according to the patient log diary. Data were excluded from the final study analysis if there were: i) less than 7 days of collection; ii) bouts of 60 continuous minutes of 0 activity intensity counts; iii) no allowance for any minute with counts between 0 and 100 in the non-wear periods; iv) more than 20,000 counts per minute, and v) less than 10 hours of registration per day. Finally, data reduction, cleaning, and analyses were performed using the MAHUffe programme (available at: www.mrc-epid.cam.ac.uk).

Sedentary time was estimated as the amount of time accumulated below 100 cpm during periods of registered time (37). Physical activity levels were set as time (min/day) engaged in light, moderate and moderate-to-vigorous PA based on a standardised cut-off of 100-1951, 1952-5724 and ≥1952 cpm, respectively (38). We also calculated the total PA as the sum of the light and moderate-to-vigorous PA levels, expressed as minutes per day.

Statistical analyses

Nine women did not satisfy the GT1M accelerometer criteria, therefore they were excluded from the analyses. Thus, the final study sample comprised 39 women.

The first day of recording from both devices was not included in the analysis to diminish the reactivity. The day that patients returned the devices was also excluded. Registered time for the whole day was estimated as the amount of wearing time, excluding sleeping time (recorded through the patients' log diary).

Physical activity levels, sedentary time and registered time variables were logarithmically transformed to obtain a normal distribution. A repeated measures test was selected to analyse the estimated means of PA levels and sedentary time after adjusting for registered time between both devices. The agreement between the SWA and the Actigraph was assessed by Bland-Altman plots (39). PA levels were controlled for registered time from each device (*e.g.* total PA with Actigraph / total PA registered time with Actigraph) and presented as percentage of minutes per day. The mean difference and the 95% limits of agreement (mean difference ± 1.96 standard deviation (SD) of the differences) were calculated. Association between the difference and the magnitude of the measurement (*i.e.* heteroscedasticity) was examined by conducting a regression analysis. The Concordance Correlation Coefficient (r_c) was used to assess the Concordance between the SWA and the Actigraph, whereas the Pearson correlation coefficient (r_p) was calculated as additional information for the r_c (40). The following classification was used to interpret and represent the r_c values(41): minimal, <0.2; poor, 0.2–0.39; moderate, 0.4–0.59; strong, 0.6–0.79; and almost perfect, ≥0.8. The values of the r_p were classified as follows (42): weak or no relationship, <0.25; fair, 0.25–0.49; moderate to good, 0.50–0.75; and good to excellent, >0.75.

All analyses were performed using the Statistical Package for Social Sciences (IBM-SPSS Statistics for Mac, version 22.0. Armonk, NY) and the level of significance was set at $p<0.01$.

Table I. Socio-demographic characteristics of the patients.

Variables	n	Mean (SD)
Age (years)	39	49.4 (7.8)
Body Mass Index (kg/m^2)	39	27.3 (5.1)
Tender points count (0-18)	39	17.1 (1.7)
Algometer score (18-144)	39	35.1 (15.0)
Visual Analogue Scale (0-10)	39	6.4 (1.9)
BDI-II (0-63)	39	26.3 (12.2)
Sleep (min/day)	39	479.5 (68.8)
	n	%
Years since clinical diagnosis*		
≤5 years	20	52.6
>5 years	18	47.4
Marital status		
Married	28	71.8
Unmarried	5	12.8
Divorced/Widowed	6	15.4
Educational status*		
Primary school	14	36.8
Secondary school	15	39.5
University degree	9	23.7
Occupational status*		
Working	14	50.0
Unemployed	4	14.3
Retired	10	35.7

*Missing data. BDI-II: Beck depression inventory II.

Results

Table I summarises the demographic characteristics of the patients and the reported sleeping time (479.5±68.8 min/day). The descriptive data, inter-method mean differences, and SDs between the SWA and the Actigraph according to PA levels, sedentary time and registered time are presented in Table II. The SWA values (min/day) were higher in registered time, total PA, light, moderate, and moderate-to-vigorous PA in total-week, weekday, and weekend (all, $p\leq0.001$), and lower in sedentary time in total-week, weekday, and weekend when compared to the Actigraph (all, $p<0.001$).

Table III shows the r_c and r_p for time spent in PA and sedentary time between the SWA and the Actigraph.

Table II. Descriptive physical activity (PA) data by the SenseWear Armband (SWA) and the Actigraph, n=39.

	SWA	Actigraph		
PA Levels-Time Interval	Adjusted Mean (SE)	Adjusted Mean (SE)	P value	Mean difference (SE)
Register time (min/day), mean (SD)	936 (68)	817 (137)	<0.001	119 (111)
Register time weekday (min/day), mean (SD)	946 (83)	825 (140)	<0.001	121 (119)
Register time weekend (min/day), mean (SD)	911 (79)	797 (158)	<0.001	114 (123)
Total PA total-week (min/day)	391 (18)	219 (9)	<0.001	172 (14)
Total PA weekday (min/day)	396 (19)	219 (9)	<0.001	177 (16)
Total PA weekend (min/day)	379 (21)	218 (12)	<0.001	161 (14)
Sedentary total-week (min/day)	545 (18)	599 (14)	<0.001	-54 (21)
Sedentary weekday (min/day)	550 (17)	606 (15)	<0.001	-56 (22)
Sedentary weekend (min/day)	531 (24)	579 (17)	<0.001	-48 (25)
Light total-week (min/day)	281 (14)	170 (6)	<0.001	111 (11)
Light weekday (min/day)	283 (15)	168 (6)	<0.001	115 (13)
Light weekend (min/day)	274 (16)	176 (9)	<0.001	98 (12)
Moderate total-week (min/day)	103 (10)	47 (5)	<0.001	56 (9)
Moderate weekday (min/day)	104 (10)	50 (5)	<0.001	54 (9)
Moderate weekend (min/day)	102 (12)	41 (5)	<0.001	61 (10)
MVPA total-week (min/day)	110 (13)	49 (5)	<0.001	61 (12)
MVPA weekday (min/day)	113 (14)	51 (5)	0.001	62 (13)
MVPA weekend (min/day)	105 (13)	43 (5)	<0.001	62 (11)

Values are adjusted mean (standard error of the mean) unless otherwise indicated. Difference between SWA-Actigraph tested for total PA, sedentary time, light, moderate and moderate and vigorous PA levels using ANCOVA adjusted for registered time.
Analyses were conducted with PA and sedentary outcome variables logarithmically transformed to obtain a normal distribution, yet crude values are presented in the table for easier interpretation.
SWA cut-off values for sedentary, light, moderate, and MVPA were <1.5, 1.5-<3, 3-6 and ≥3 METs, respectively.
Actigraph cut-off values for sedentary, light, moderate, and MVPA were <100, 100-1951, 1952-5724 and ≥1952 counts/min, respectively.
MVPA: moderate-to-vigorous physical activity.

Table III. Concordance correlation coefficient (r_c) and Pearson correlation coefficient (r_p) for time spent in physical activity (PA) levels from the SenseWear Armband (SWA) and the Actigraph data, n=39.

PA Levels	Total-week (min/day)		Weekday (min/day)		Weekend (min/day)	
	r_c	r_p	r_c	r_p	r_c	r_p
Total PA	0.172	0.629**	0.149	0.551**	0.312	0.774**
Sedentary	0.404	0.457**	0.359	0.419**	0.449	0.472**
Light	0.186	0.595**	0.163	0.543**	0.327	0.682**
Moderate	0.242	0.531**	0.247	0.501**	0.312	0.664**
MVPA	0.149	0.345*	0.120	0.277	0.289	0.612**

*p<0.05; **p<0.01.
r_c: Concordance correlation coefficient; r_p: Pearson correlation coefficient; MVPA: moderate-to-vigorous physical activity.

The r_c displayed moderate correlations for sedentary levels in total-week and weekend levels, ranging 0.404 and 0.449, respectively. Poor r_c were observed for total PA, light and moderate-to-vigorous PA levels during the weekend, and sedentary levels during weekdays, ranging from 0.289 to 0.359. Additionally, there was a poor r_c in total-week, weekday and weekend in moderate PA level, ranging from 0.242 to 0.312. Minimal r_c were found for sedentary levels in total-week, weekday and weekend (all, p<0.01) as well as moderate-to-vigorous PA levels in total-week (p<0.05).

Figure 1 shows the Bland-Altman plots for inter-method agreement between the SWA and the Actigraph. The limits of the agreement between the SWA and the Actigraph measurements for the total PA, sedentary time, light, moderate, and moderate-to-vigorous PA in percentage of minutes per day in total-week were (35, -6), (6, -35), (25, -8), (16, -6) and (20, -9), respectively. There was a positive association between the difference and the magnitude of the SWA and the Actigraph measurements for light, moderate and moderate-to-vigorous PA in total-week (R^2=0.115, R^2=0.342, R^2=0.436, respectively; p=0.035, p<0.001 and p<0.001, respectively). No associations were observed for the total PA and sedentary time in total-week between both devices (both, R^2=0.068; p>0.05).

Discussion

The main purpose of the present study was to compare PA levels from two increasingly popular PA monitors: the SWA and the Actigraph (GT1M), in Spanish female fibromyalgia patients. Our results showed that the SWA and the Actigraph differ when measuring total PA, light, moderate, moderate-to-vigorous PA and sedentary time. Bland-Altman plots showed a lack of inter-method agreement between both devices.

A few studies have suggested that self-reported and objectively measured PA levels and sedentary time differ considerably in fibromyalgia patients (12, 18, 43, 44). Thus, in spite of the raised interest to accurately measure PA levels and sedentary time with objective devices in fibromyalgia patients (13, 16, 27, 45), as far as we know, there are no studies comparing objective measures in this population in order to determine whether these devices are comparable and may be interpreted similarly across studies. Additionally, it is of importance to capture different PA levels in this population, especially sedentary levels, in order to improve inactive lifestyles and reduce disability due to disease. A recent analogous study (23) performed

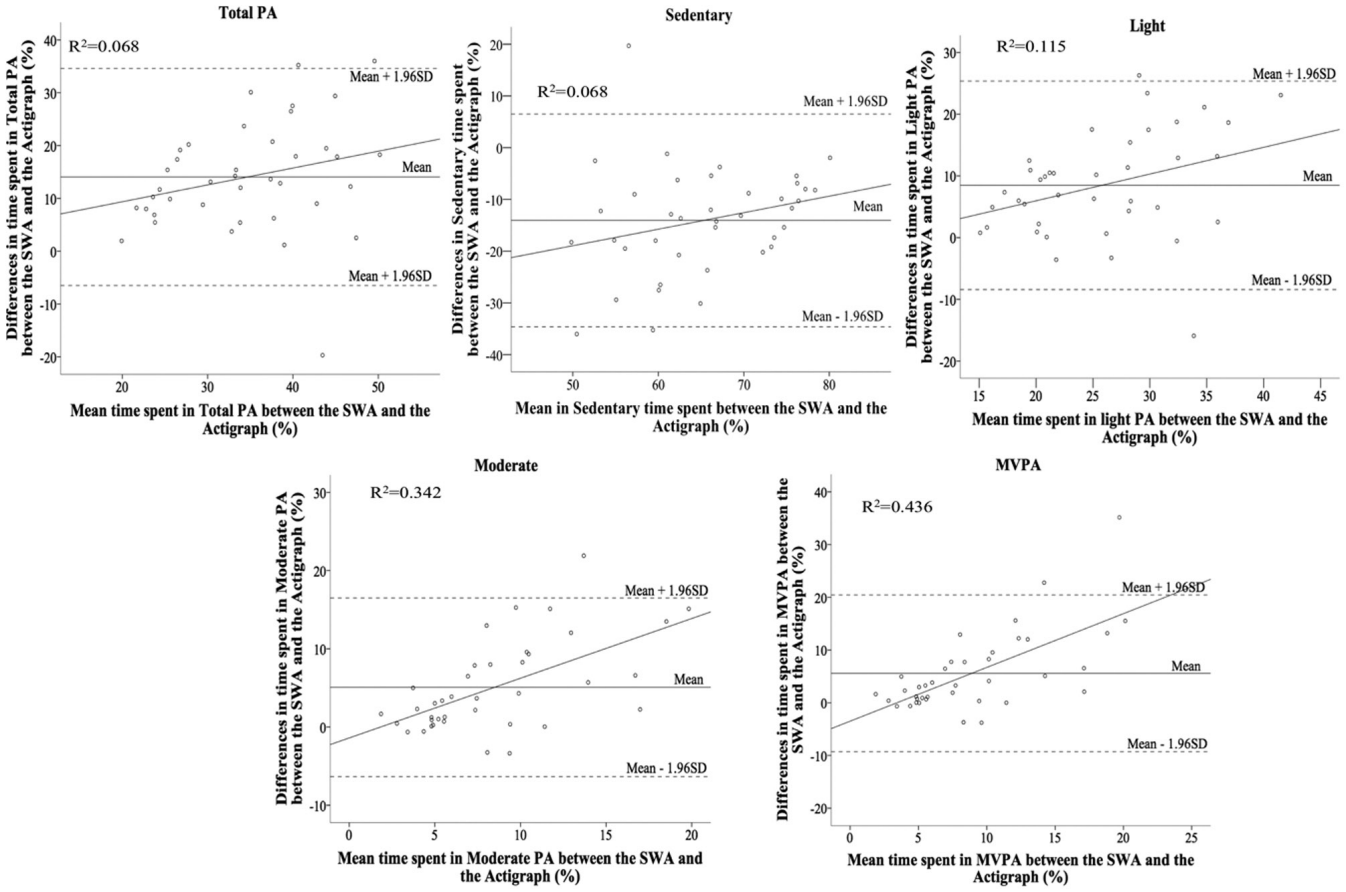

Fig. 1. Bland-Altman plots of the differences between the SenseWear Armband (SWA) and the Actigraph (*i.e.* the SWA minus the Actigraph) for: total-week total physical activity (PA) time, total-week sedentary time, total-week light time, total-week moderate time and total-week moderate-to-vigorous physical activity time (% minutes per day). The means of the differences (solid lines) and limits of agreement (dashed lines) within ±1.96 standard deviations are shown (n=39).

in bariatric surgery patients showed similar estimates of time spent in sedentary, light, moderate-to-vigorous PA, and total PA between the Stayhealthy RT3 (triaxial accelerometer) and the SWA (biaxial accelerometer) in total-week measurements. These results are not in agreement with our findings where total PA, light, moderate, moderate-to-vigorous PA levels and sedentary time differed between the SWA and the Actigraph in total-week, weekday, and weekends. Noteworthy is that all intensity PA values were higher in the SWA than in the Actigraph, except for sedentary time. Additionally, we also studied the differences between PA patterns during weekdays and weekends since these values may differ, yet overall we did not observe any difference between them.

A recent study (46) showed that the SWA overestimates activities related to upper extremity movements such as dressing, washing dishes, and folding laundry. Furthermore, the Actigraph underestimates activities involving upper-body movement such as arts and crafts, weight lifting or cycling (17). Therefore, the SWA might capture some activities that the Actigraph does not. According to some previous studies carried out in fibromyalgia patients (43, 44) and other populations (23, 46), the differences observed between both devices might rely on the device's body-location (waist vs. arm). In fact, several studies have shown conflicting findings in the choice of accelerometer used, and hence in the body-location.

On the one hand, previous studies have recommended accelerometers to be worn on the waist as opposed to wrist-mounted for quantifying total PA (47-50). However, it has been suggested that accelerometers worn on the waist are not able to provide static activity quantification or complex movement patterns (49, 51). On the other hand, wrist-mounted accelerometers are directly involved in upper-body movement activities (47) and may be less sensitive to the physical activities more acutely affected by fibromyalgia (12) (*i.e.* recreational) due to a sedentary lifestyle. Furthermore, the SWA placed in the upper body, contain physiological parameters, which may be advantageous in order to estimate energy expenditure parameters (49). These findings are not in agreement with our results where the elected devices provided the same trend of PA values, yet the SWA values were extremely higher than the Actigraph data adjusted for registered time. Therefore, after registered time was used as cofounder, we could elucidate the observed differences were due to device body location or to different algorithms used for calculating intensity level between devices.

In addition to the body-location of the monitors, the most frequent activities involved with the sample studied should also be taken into account (17). That being said, these patients could

have carried out a high number of activities related with upper-body (*e.g.* household activities). Household activities are classified as light or low-moderate PA levels are the more common in fibromyalgia patients (12). However, sedentary activities involved in upper-body movements such as sewing clothes, surfing the Internet, or drinking tea might be classified as light PA by the SWA instead of being registered as sedentary time activities. Therefore, this misclassification might explain the overestimation in light PA levels as well as the underestimation in sedentary time activities by the SWA. Thereby, the selection of an appropriate device must be done taking into consideration that some activities might not be well detected.

Unick *et al.* (23) showed significant correlations in sedentary, light, moderate-to-vigorous PA, and total PA levels between the accelerometer (RT3) and the SWA in total-week measurements (r=0.60, 0.67, 0.48 and 0.66, respectively; all, $p<0.001$). Thus, these relationships are stronger than the results obtained from the present study. However, there are some methodological differences with our findings that should be mentioned. The study was carried out in bariatric surgery patients during free-living context, whereas our study was performed in fibromyalgia patients. The Stayhealthy RT3 was one of the accelerometers elected by Unick *et al.* (23) instead of the Actigraph (GT1M), which was chosen in the present study. Furthermore, the conflictive results obtained in our study might be due to the different cut-off levels selected (38) by the different accelerometers, which may suggest that none of the cut-off points were ideal (52). Thus, PA levels classification might differ depending on the device (*e.g.* the Actigraph classifies an activity as light, whereas the SWA classifies it as moderate)

The study by Unick *et al.* (23) displayed an agreement between the accelerometer (RT3) and the SWA in total PA at the group level with a mean difference of 7.2±64.2 min, and an absence of agreement at the individual level, with a greater variability in estimates ranging from -165 (SWA higher) to 197 min (RT3 higher) and an average difference between both devices for each patient of 45.6±45.4 min. Thus, these results concur partially with our study, where differences at the group level as well as individual level showed an absence of agreement as we could observe on the extremely high limits obtained for each PA levels (*e.g.* 35%, -6%) (see Table II; Fig. 1). Therefore, the low association in PA levels as well as the analysis of the Bland-Altman plots indicated low agreement between the SWA and the Actigraph (see Table II). The higher the PA levels assessed by the devices, the higher the differences between both of them. Therefore, these results suggest that the increase in the values of the SWA is related to the increase in the Actigraph due to the higher differences obtained between both devices when PA levels increased in the Actigraph. The presence of heteroscedasticity between these two devices explain the higher values of PA in the SWA compared to the Actigraph, because the Actigraph underestimates activities that involve upper-body movements (17) as we have clarified above.

Finally, this study is an inter-method comparison between two objective measures and is not a validation study because the devices have not been compared to a "gold standard" (*e.g.* doubly labelled water methods), and therefore should be interpreted as such. Moreover, the strength of the present study was the quality of data provided by the SWA and the Actigraph with 7 valid days and at least 10 hours/day of registered time compared with others studies with minor recording days (12, 45). These facts should be considered in order to prescribe exercise or estimate the lifestyle of the fibromyalgia patients.

Study limitations

The present study has some limitations that need to be mentioned. Although the Actigraph GT1M has proved to be a valid instrument, it only allows measuring one axis, which limits the registry of diverse human movements. Future studies should verify the findings of the present study with the newest Actigraph and SWA triaxial versions, since these are meant to improve the movement registering. Due to the lack of male participants we could not confirm whether these findings may apply to men.

The present study showed that the SWA and the Actigraph provide different estimates in PA levels and sedentary time in Spanish female fibromyalgia patients. Our results suggest that the PA levels and sedentary time provided by both devices should be interpreted independently across the studies. Further studies are needed in order to determine the validity of these monitors as well as to quantify PA levels and sedentary patterns on weekdays and weekends.

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