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Twenty four-hour activity cycle in older adults using wrist-worn accelerometers: The seniors-ENRICA-2 study

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Objectives: This study aimed: (a) to provide a detailed description of sleep, sedentary behavior (SED), light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) over the complete 24-hours period using raw acceleration data in older adults; and (b) to examine the differences in the 24-hours activity cycle by sex, age, education, and body mass index (BMI).

Methods: Population-based cohort comprising 3273 community-dwelling individuals (1739 women), aged 71.8 ± 4.5 years, participating in the Seniors-ENRICA-2 study. Participants wore a wrist-worn ActiGraph GT9X accelerometer for 7 consecutive days, and the raw signal was processed using the R-package GGIR.

Results: Participants reached 21.5 m*g* as mean acceleration over the whole day; 32.3% (7.7 h/d) of time was classified as sleep, 53.2% (12.7 h/d) as SED, 10.4% (148.6 min/d) as LPA, and 4.1% (59.0 min/d) as MVPA. No marked differences were found in sleep-related variables between socio-demographic and BMI groups. However, women showed higher LPA but lower SED and MVPA than men. Moreover, SED increased whereas LPA and MVPA decreased with age. Participants with obesity (BMI $\geq$ 30 kg/m^2) accumulated more SED and less LPA and MVPA than those without obesity. As expected, adherence to physical activity recommendations varied widely (9.2%-76.6%) depending on the criterion of MVPA accumulation.

Conclusion: Objective assessment of the 24-hour activity cycle provides extensive characterization of daily activities distribution in older adults and may inform health-promotion interventions in this population. Women, the oldest old, and those with obesity offer relevant targets of strategies to improve lifestyle patterns.

KEYWORDS
body mass index, older adults, physical activity, sedentary behavior, sleep

1 | INTRODUCTION

Older people represents a large and increasing portion of the population,[1] so the promotion of healthy behaviors aimed to ameliorate the age-associated burden of chronic diseases and to increase the quality of life of older adults has become a key public health focus.[1] It is well established that physical activity (PA) is an important factor reducing chronic diseases and fostering a physical, cognitive, and psychosocial healthy aging.[2] In contrast, excessive time spent in sedentary behavior (SED) has been associated with unsuccessful aging and premature mortality,[3] while poor sleep duration and quality have been related to worse health among older people.[4,5]

Rosenberg et al[6] recently proposed a new paradigm—the 24-hour Activity Cycle—consisting of four basic types of activity (ie, sleep, SED, Light PA [LPA], and moderate-to-vigorous PA [MVPA]) that should be comprehensively assessed over the complete 24-hour period to optimally characterize daily patterns and to understand how they may synergistically affect health. Accelerometers are increasingly used to measure PA and SED in epidemiologic studies,[7] but they have habitually been worn on the hip or waist, and they have to be removed during sleep time. In contrast, wrist-worn monitors can be worn over 24 hour, and their use has recently achieved great interest in epidemiology research.[8] Former accelerometer models did not have enough storage capacity and battery to provide raw data to the end user. As a consequence, raw accelerometer data were in-unit processed using proprietary algorithms and converted into "activity counts," a unitless index to describe PA intensity over a period of time (usually 1 minute). Counts are difficult to interpret and are obtained with proprietary algorithms, which could hinder data interpretation and transparency as well as comparison across studies. Technological advances have made possible the access to the raw data that can now be processed using transparent algorithms; specifically, the GGIR R-package has been developed to take advantage of raw accelerometer data and allows to estimate PA, SED, and sleep patterns without high technical and/or programming skills.[9]

Therefore, the aim of this study was to provide a detailed description of sleep, SED, LPA, and MVPA over the complete 24-hour period using raw acceleration data from wrist-worn accelerometers, in a population-based sample of Spanish older adults, which has been scarcely examined in the elderly[10]; in addition, this study examines differences in the 24-hour activity cycle by sex, age, education, and body mass index (BMI) status.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

The Seniors-ENRICA-2 study is a cohort of 3273 community-dwelling individuals, aged 65-94 years, residing in the city of Madrid and four surrounding large towns: Getafe, Torrejón, Alcorcón, and Alcalá de Henares. Study participants were selected between 2015 and 2017 by sex- and district-stratified random sampling of all individuals holding a national healthcare card (data available at: http://www.comunidad.madrid/servicios/salud/tarjeta-sanitaria). Given that all people residing in Spain is entitled to free healthcare, the list of card holders closely approximates the entire resident population of Madrid. Among those invited to participate in the study (n = 6418), 51% accepted.

Baseline data were collected with similar procedures, questionnaires, and instruments to those used in the Seniors-ENRICA-1 cohort.[11] Specifically, data were collected in three sequential stages: (a) a telephone interview on lifestyle, health status, morbidity, and healthcare services use; (b) a first home visit to perform a physical examination and collect blood and urine samples; and (c) a second home visit, conducted 7 days after the first one, to take a diet history and obtain other questionnaire data. The accelerometer was placed on the wrist of participants at the end of the first home visit and was returned at the beginning of the second visit.

Study participants and their relatives provided written informed consent. The study protocol was approved by the Clinical Research Ethics Committee of *La Paz* University Hospital in Madrid.

2.2 | Assessment of the 24-h activity cycle

The ActiGraph GT9X (ActiGraphInc) accelerometer was used to assess the 24-hour activity cycle. This is a small (3.5 × 3.5 × 1.0 cm) and lightweight (14 grams) triaxial monitor that records accelerations in three axes (vertical, antero-posterior, and mediolateral), with a dynamic range of ±8 *g* (https://www.actigraphcorp.com/actigraph-link/). The accelerometer was attached to the non-dominant wrist using a watch band, and the information on steps walked was hidden from users. Participants were asked to wear the accelerometer for seven consecutive days and to only remove it during water-based activities, such as the shower.

Accelerometers were initialized to store accelerations at 100 Hz. Raw data were downloaded as ".gt3x" files and subsequently converted to ".csv" files using the ActiLife v.6 software (ActiGraph). Next, raw data were processed with the R software using the GGIR package (v. 1.7-0, https://cran.r-project.org/web/packages/GGIR/).[12] Briefly, the accelerometer signals were auto-calibrated according to the local gravity.[9] Then, the Euclidean Norm of the raw accelerations Minus 1 (ENMO $[G] = \sqrt{x^2+y^2+z^2} - 1$), with negative values rounded to 0, was calculated over 5-second epochs.[12] Next, non-wear time was detected so that each 15-minute block was classified as non-wear time when the standard deviation of 2 out of the 3 axes was lower than 13 mg during the surrounding 1-hour moving window or the value range in 2 of the 3 axes was lower than 50 mg.[12] At the same time, abnormal high accelerations (ie, ≥5.5 g) were detected; these and non-wear time were imputed by the mean of the acceleration maintained during the same time intervals as the affected periods for the rest of the recording period in each participant. This process avoids equating non-wear time with inactivity nor assumes that wear time is representative of the whole day.[12,13]

Time periods with low variability in the z-angle of the accelerometer (ie, <5° over 5 minutes) were defined as sustained inactivity periods.[14] Then, an automatized algorithm was used to detect sleep onset and offset, and sustained inactivity periods within these times were classified as sleep.[15] Additionally, detected sleep periods were checked for abnormalities and cleaned, so that a whole 24-h period was removed (n = 50 in the total sample) within each participant if: (a) [sleep onset or wake time differed >3 hours from the mean values for all recording period] and [sleep time differed >3 hours from the mean sleep time for all recording period]; or (b) [sleep onset was identified between 12:00 and 7:00] or [wake time was registered between 13:00 and 00:00]; or (c) sleep time was <4 hours. Based on this additional process, fifty 24-hour periods were excluded from the total sample.

Waking periods after sleep onset were classified as WASO (wake after sleep onset), and sleep efficiency was calculated as the percentage of sleep time over the sleep period time. Time in SED and PA intensities was classified using previously proposed thresholds for ENMO in the non-dominant wrist: (a) SED: <45 mg, (b) LPA: ≥45 mg and <100 mg, and (c) MVPA: ≥100 mg.[16] Bouts in each category were considered when the 80% of the minimum required time met the threshold criteria. For this study, we considered SED bouts ≥10 minutes (SED_{10min}), SED bouts ≥30 minutes (SED_{30min}), LPA bouts ≥1 minutes (LPA_{1min}), LPA bouts ≥10 minutes (LPA_{10min}), MVPA bouts ≥ 1 min ($MVPA_{1min}$), and MVPA bouts ≥10 minutes ($MVPA_{10min}$). The complete script containing the analysis specifications set out in the GGIR package can be found in the Appendix S1. An overview of the procedures for processing accelerometer data is presented in Figure S1.

Participants were included in the analysis when they wore the accelerometer at least 16 h/d during ≥4 days, requiring at least 3 weekdays and at least 1 weekend day.[17] Finally, participants were classified according to the PA recommendations (ie, ≥30 min/d of MVPA) [18] considering the total time accumulated in MVPA, $MVPA_{1min}$, and $MVPA_{10min}$, separately. Adherence to the sleep recommendations (ie, 7.00-8.99 h/d) [19] was ascertained based on the sleep period time.

2.3 | Other variables

Sex and age were self-reported, and three age groups were created (65-69, 70-74, and ≥ 75 years). Participants also reported the highest educational level achieved, which was classified as primary or lower, secondary, and university. Height and weight were measured with standardized procedures,[20] and BMI was calculated as weight (kg) divided by squared height (m^2). Overweight and obesity were defined as BMI 25-29.9 and ≥30 kg/m^2, respectively.[20]

2.4 | Statistical analyses

All analyses were performed using STATA v.14.0 for Windows (Science Plus Group), with statistical significance set at P < .05. Descriptive statistics of the study variables are presented as means (standard deviation) or percentages. Differences among groups were assessed by the t test for independent samples (between sex groups), or by one-way analysis of variance (ANOVA) with Bonferroni adjustment for post-hoc comparisons (between age, education, and BMI groups) for continuous variables and by the chi-square test for categorical variables. We additionally performed compositional multivariate analysis of variance (MANOVA) to test whether mean time-use composition differed between groups.[21]

3 | RESULTS

Of the 3273 participants in the Seniors-ENRICA-2 study, 2514 provided valid accelerometer data and formed the analytical sample (Figure S2); it included 1182 men and 1332 women, with mean (SD) age 71.7 (4.4) years. Most reported primary or lower education (63.6%), and mean BMI was 27.7 (4.4) kg/m^2; no significant differences were found between the initial and the analytical sample in sex, age, education, or BMI (all P > .05; data not shown). Participants had a mean (SD) of 4.7 (0.5) valid weekdays and 1.9 (0.3) valid weekend days and wore the accelerometer during an average of 23.8 (0.2) h/d; about 75% had seven valid days of accelerometer recording.

Mean (SD) acceleration over 24-hour was 21.54 (6.74) mg; mean daily acceleration was significantly lower in women, the oldest old, and those with obesity (Figure 1). Time accumulated in sleep, SED, LPA, and MVPA is presented in Table 1. Overall, 32.3% (7.7 h/d) of the daily time was identified as sleep, while 53.2% (12.7 h/d), 10.4% (148.6 min/d), and 4.1% (59.0 min/d) were classified as SED, LPA, and MVPA, respectively. Men spent more time in SED and MVPA than women, whereas women devoted more time to sleep and LPA (all P < .001). SED time increased with age, while time spent

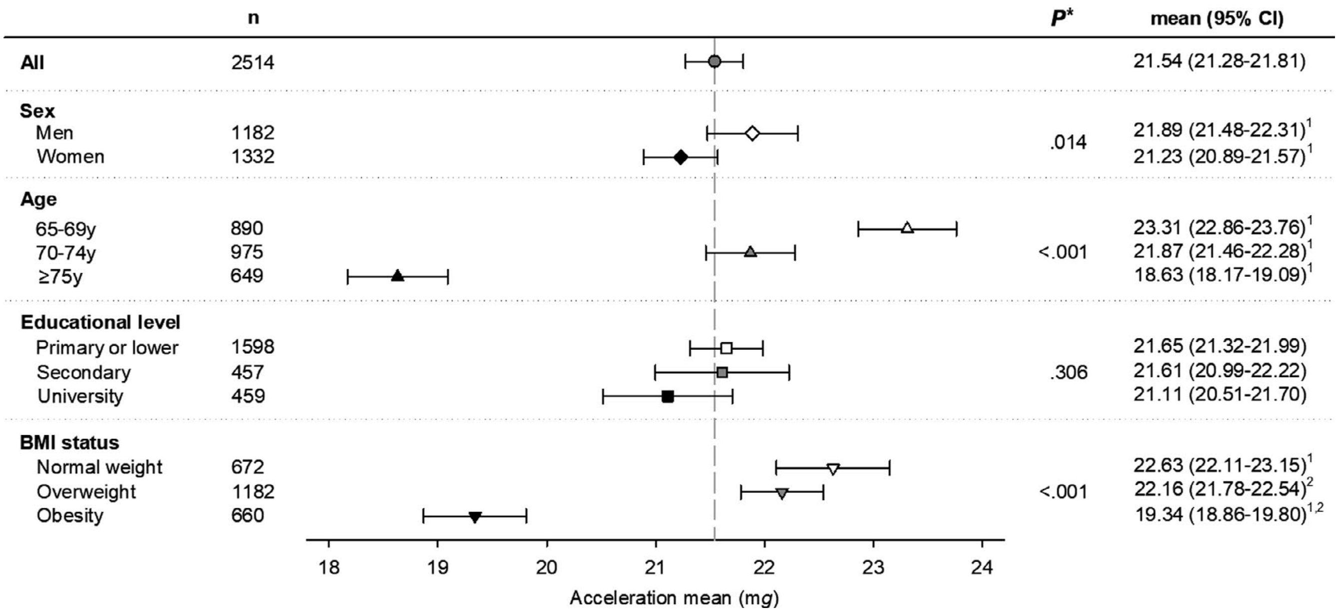

FIGURE 1 Acceleration mean (m*g*) over 24-h in the whole sample and stratified by sex, age, educational level, and body mass index (BMI) status. Represented values are mean (symbols) and 95% confidence intervals (lines). *Differences among groups were analyzed by *t* test for independent samples (sex) and by one-way analysis of variance (ANOVA) with Bonferroni adjustment for post-hoc comparisons (age, educational level, and weight status groups). Common superscripts ($^{1-2}$) indicate a significant difference ($P < .05$) between groups within each variable based on the pairwise comparisons

in MVPA decreased; moreover, participants aged ≥ 75 years accumulated less LPA than their younger counterparts (all $P < .001$). Individuals with primary or lower education spent more time in sleep and LPA than those with university education (all $P < .05$); further, SED was higher in those with university studies ($P < .001$). Finally, individuals with obesity accumulated more SED but less LPA and MVPA than those with overweight or normal weight; also overweight was associated with more SED and less LPA than normal weight (all $P < .001$). Similar results were found when compositional multivariate analysis was performed (Table S1).

The sleep-related variables are presented in Table S2. In the whole sample, the mean bedtime and wake-up time were identified at 00:30 hour and 08:09 hour, respectively. The sleep efficiency was 85.9%, with a mean of 65.9 min/d of WASO, and with 64% of participants meeting the sleep recommendations. There were no marked differences in these sleep patterns according to socio-demographic variables and BMI status.

Table S3 shows the patterns of accumulation of SED, LPA, and MVPA in bouts of diverse duration. Overall, 10.7 h/d and 9.2 h/d were accumulated in SED_{10min} and SED_{30min}, respectively. Further, 30.1 min/d and 3.7 min/d were hoarded in LPA_{1min} and LPA_{10min}, whereas 26.5 min/d and 9.7 min/d were amassed in $MVPA_{1min}$ and $MVPA_{10min}$, respectively. Time in SED_{10min}, SED_{30min}, $MVPA_{1min}$, and $MVPA_{10min}$ was higher in men than women, while women accumulated more time in LPA_{1min} and LPA_{10min} (all $P < .05$). Time in SED bouts increased, while time in MVPA bouts decreased with age (all $P < .001$). However, participants aged ≥ 75 years accumulated more time in LPA_{10min} than those 65-69 years ($P < .05$). Moreover, participants with university studies hoarded more time in SED bouts, but less in LPA bouts, than those with primary or lower education (all $P < .001$). Lastly, individuals with obesity spent more time in SED bouts, but less time in MVPA bouts, than their counterparts with normal weight and overweight (all $P < .001$). Similar results were found when compositional multivariate analysis was performed (Table S1).

Adherence to the PA recommendations was lower as the required accumulation time of the MVPA bout increased, so that the 76.6%, 35.6%, and 9.2% of participants met the recommendations when total time in MVPA, time in $MVPA_{1min}$, and time in $MVPA_{10min}$ was considered, respectively (Table S4). Differences between groups hold across the three criteria (ie, total MVPA, $MVPA_{1min}$, and $MVPA_{10min}$).

4 | DISCUSSION

This study provides a comprehensive description of sleep, SED, LPA, and MVPA over the complete 24-h cycle from raw accelerometer data in a population-based sample of Spanish older adults. Overall, 32.3%, 53.2%, 10.4%, and 4.1% of daily time was classified as sleep, SED, LPA, and MVPA, respectively. No marked differences were found in sleep patterns by socio-demographic characteristics and BMI, but the time spent in SED, LPA, and MVPA, and the patterns of accumulation of these behaviors in bouts of diverse duration markedly varied. To the best of our knowledge, only one previous study described the time spent in sleep, SED, and PA using raw accelerometry data in older people[10]; our study adds a larger and heterogeneous sample, as well as an in-depth detailed description of sleep and activity parameters.

Raw accelerometry data allow estimating global PA without intensity thresholds, improving the transparency in the analytical process, the interpretation of the data, and the comparison between studies. However, the use of raw data is very recent, so there are only a few studies in older people with which to compare our results. The mean acceleration over 24-hour in our sample was 21.5 m*g*. This value is very close to that reported by Ramires et al[22] in a population-based study with 971 people aged ≥ 60 years in Brazil (ie, 21.7 m*g*). Another report on 1210 individuals, aged 70-94 years, from the Rotterdam Study found a similar total PA expressed in m*g* (ie, 19.8 m*g*).[10] However, among the 96 600 individuals aged 65-74 years from the UK Biobank study, the daily mean acceleration was 25.9 m*g*;[8]these slightly higher values may be due to not considering the oldest old people (ie, ≥75 years), unlike ours and the other studies.[10,22] Moreover, participants in the UK Biobank study used the accelerometer on their dominant wrist,[8] while in the other studies (including ours) participants wore them on their non-dominant wrist.[10,22] The dominant wrist usually records higher accelerations than the non-dominant wrist, so it is possible that the wrist wearing the accelerometer could affect the outcomes.[23,24]

Monitoring the full 24-h activity cycle provides complete information on the active/inactive behaviors, including the sleep period that has yet been under-studied. This is important because the duration and quality of sleep have significant health consequences in the old age.[4,5] In our study, the mean sleep period duration (ie, interval between bedtime and wake-up time) was 7.7 h/d; given that the sleep efficacy was of 85.9%—with a WASO around 1.1 h/d, and the mean sleep time was 6.6 h/d. These results are similar to those of previous studies using accelerometry in older people, in which the sleep duration ranged from 6.3 to 6.6 h/d.[4,5,25,26] As in previous research,[10] no marked differences were generally observed in sleep patterns by socio-demographic factors and BMI; however, women showed greater sleep time and sleep efficiency than men, who accumulated more WASO time. Moreover, participants with obesity showed lower sleep efficiency and were less likely to meet the sleep recommendations. Among older people from Iceland, Brychta et al[27] also reported that men awoke more often during the sleep period and had shorter sleep durations than women and that higher BMI was associated with lower sleep efficiency. This suggests that special attention should be paid to the quality of sleep of men and those with obesity and to their potential negative impact on health.

Our study confirms that older adults spent most of the day in SED. In our study, SED (12.7 h/d) was higher than previously described for older people from Iceland (10.2 h/d),[28] Norway (9.2 h/d),[29] UK (10.3 h/d),[30] Brazil (10.5 h/d),[31] Canada (10.0 h/d),[32] and United States (8.5 h/d).[33] Nonetheless, in these studies accelerometers were worn only during waking hours, and the non-wear time was deleted, which could underestimate SED.[34] Thus, comparability between our study and the previous research is hampered by differences in data collection and analysis. Interestingly, Koolhass et al,[10] using a similar protocol to ours (ie, 24-hour assessment and analysis of raw data with the GGIR package), reported that SED in older men and women was 13.8 h/d and 13.3 h/d, respectively. Of note, however, is that wrist-worn accelerometers cannot accurately distinguish body postures so that standing could be frequently classified as SED.[24] Also noteworthy is that our recent study, using the IDEEA pattern-recognition activity monitor over the complete 24-hour cycle, found that older adults (n = 432, mean age 71.7 years) spent 7.1 h/d in SED, including lying, reclining, and passive sitting, and 5.1 h/d in standing [35]; thus, the sum of the time engaged in both behaviors (SED + standing) is similar to that identified as SED in the present study (12.7 vs 12.2 h/d). Lastly, most SED was accumulated in bouts lasting ≥10 minutes (10.7 h/d, 84.2%), which coincides with data for US and Swedish people aged 60-75 years where 85% of SED was in bouts of ≥8-10 minutes.[36] Further, we observed an elevated time invested in SED bouts lasting ≥ 30 min (9.2 h/d, 72.4%); this is important because in older people the duration of prolonged SED bouts has been related to poor health status, such as worse physical function.[37]

Participants spent more time in LPA (148.6 min/d) than in MVPA (59.0 min/d), which confirms that low-intensity PA is the predominant form of PA in older people.[28,29,36] Thus, as it has been pointed out,[38] replacing SED with LPA rather than MVPA could be a more realistic target for older people. Our findings concur with those of studies using similar processing methods, where MVPA ranged between 56.7 min/d and 75.0 min/d.[10,22] Nevertheless, other studies with older people from UK,[39] Norway,[40] Iceland,[29] Sweden,[36] United States,[36] and Japan [41] found lower values of MVPA (ranging from about 5 to 40 min/d). These comparisons should be considered with caution because of the use of different devices, placements, and cut points.[17]

Moreover, the use of different bout criteria could affect the estimates of PA.[36] Our results indicate that, contrary to SED, most PA is accumulated in short bouts, since 30.1 min/d and 26.5 min/d were accumulated in LPA_{1min}

TABLE 1 Time spent in sleep, sedentary behavior, light physical activity, and moderate-to-vigorous physical activity in the whole sample and stratified by sex, age, educational level, and BMI status

		Sleep		Sedentary		Light physical activity		Moderate-to-vigorous physical activity	
	n	Time (h/d)	Time (%)	Time (h/d)	Time (%)	Time (min/d)	Time (%)	Time (min/d)	Time (%)
All	2514	7.7 (7.7, 7.8)	32.3 (32.1, 32.5)	12.7 (12.6, 12.7)	53.2 (52.9, 53.4)	148.6 (146.6, 150.6)	10.4 (10.3, 10.5)	59.0 (57.5, 60.4)	4.1 (4.0, 4.2)
Sex									
Men	1182	7.6 (7.6, 7.7)^{1}	32.0 (31.7, 32.3)^{1}	12.9 (12.8, 13.0)^{1}	54.1 (53.8, 54.5)^{1}	135.5 (132.9, 138.1)^{1}	9.5 (9.3, 9.7)^{1}	63.3 (61.1, 65.5)^{1}	4.4 (4.4, 4,6)^{1}
Women	1332	7.8 (7.7, 7.8)^{1}	32.6 (32.4, 32.9)^{1}	12.5 (12.4, 12.5)^{1}	52.3 (52.0, 52.6)^{1}	160.2 (157.4, 163.0)^{1}	11.2 (11.0, 11.4)^{1}	55.2 (53.4, 57.0)^{1}	3.9 (3.7, 4.0)^{1}
P^{a}		**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
Age									
65-69 y	890	7.7 (7.6, 7.8)	32.2 (31.9, 32.5)	12.4 (12.3, 12.5)^{1}	51.9 (51.5, 52.3)^{1}	155.0 (151.7, 158.2)^{1}	10.8 (10.6, 11.1)^{1}	71.4 (68.9, 73.9)^{1}	5.0 (4.8, 5.2)^{1}
70-74 y	975	7.7 (7.6, 7.7)	32.2 (31.9, 32.4)	12.7 (12.6, 12.7)^{1}	53.1 (52.7, 53.4)^{1}	151.3 (148.2, 154.3)^{2}	10.6 (10.4, 10.8)^{2}	60.1 (57.9, 62.3)^{1}	4.2 (4.0, 4.3)^{1}
≥75 y	649	7.8 (7.7, 7.9)	32.7 (32.3, 33.1)	13.1 (13.0, 13.2)^{1}	55.0 (54.5, 55.4)^{1}	135.8 (131.7, 139.9)^{1,2}	9.5 (9.2, 9.8)^{1,2}	40.4 (38.0, 42.7)^{1}	2.8 (2.7, 3.0)^{1}
P^{a}		.067	.065	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
Educational level									
Primary or lower	1598	7.8 (7.7, 7.8)^{1}	32.5 (32.3, 32.8)^{1}	12.6 (12.5, 12.6)^{1}	52.7 (52.4, 53.1)^{1}	151.4 (148.8, 154.0)^{1}	10.6 (10.4, 10.8)^{1}	58.9 (57.0, 60.7)	4.1 (4.0, 4.2)
Secondary	457	7.6 (7.6, 7.7)	32.1 (31.8, 32.5)	12.7 (12.6, 12.8)^{2}	53.4 (52.8, 53.9)^{2}	147.2 (142.7, 151.6)	10.3 (10.0, 10.6)	60.7 (57.3, 64.2)	4.2 (4.0, 4.5)
University	459	7.6 (7.5, 7.7)^{1}	31.8 (31.4, 32.2)^{1}	13.0 (12.8, 13.1)^{1,2}	54.4 (53.8, 54.9)^{1,2}	140.3 (136.3, 144.3)^{1}	9.8 (9.5, 10.1)^{1}	57.6(54.4, 60.9)	4.0 (3.8, 4.3)
P^{a}		**.003**	**.004**	**<.001**	**<.001**	**<.001**	**<.001**	.440	.434
BMI status									
Normal weight^{b}	672	7.8 (7.7, 7.9)	32.7 (32.3, 33.0)	12.4 (12.2, 12.5)^{1}	51.8 (51.4, 52.3)^{1}	158.1 (154.2, 162.1)^{1}	11.1 (10.8, 11.3)^{1}	63.3 (60.4, 66.2)^{1}	4.4 (4.2, 4.6)^{1}
Overweight	1182	7.7 (7.6, 7.7)	32.2 (32.0, 32.5)	12.6 (12.5, 12.7)^{1}	53.0 (52.6, 53.3)^{1}	149.1 (146.3, 151.9)^{1}	10.4 (10.2, 10.6)^{1}	62.9 (60.8, 65.0)^{2}	4.4 (4.2, 4.6)^{2}
Obesity	660	7.7 (7.6, 7.8)	32.2 (31.8, 32.6)	13.1 (13.0, 13.2)^{1}	54.9 (54.4, 55.3)^{1}	137.9 (134.1, 141.2)^{1}	9.6 (9.4, 9.9)^{1}	47.6 (45.0, 50.1)^{1,2}	3.3 (3.1, 3.5)^{1,2}
P^{a}		.071	.074	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**

Note: Values are mean (95% Confidence Intervals). Common superscripts ($^{1\text{-}2}$) in the same column indicate a significant difference between groups within each variable based on the pairwise comparisons. Statistically significant values ($P < .05$) are shown in bold.

Abbreviations: BMI, body mass index.

[a]Differences among groups were analyzed by t test for independent samples (sex groups) and by one-way analysis of variance (ANOVA) with Bonferroni adjustment for post-hoc comparisons (age, educational level, and weight status groups).

[b]This group included 12 participants classified as underweight (sensitivity analysis was performed and the results did not change when the underweight participants were excluded).

and $MVPA_{1min}$, respectively. This suggests that traditional accelerometer data, which have been usually recorded at a 60-sec epoch that conceptually approaches to 1-min bouts, might underestimate PA in older adults. This may also affect the estimates of accordance with MVPA recommendations. We noted that 76.6%, 35.6%, and 9.2% of participants met the recommendations when total MVPA, $MVPA_{1min}$, and $MVPA_{10min}$ were considered, respectively. Accordingly, in a population-based study with UK older people (70-93 years), Jefferis et al[42] warned that 60.1% and 13.5% of participants achieved MVPA (>1040 counts per minute) recommendations (ie, ≥150min/wk) in bouts lasting ≥1-minute and ≥10-minutes, respectively.

We confirmed previous findings[28,36,40,42] indicating that women accumulate more total time in LPA, but less in SED and MVPA than men. Differences between sexes remained identical when analyzing bouted time in the different activities. The traditional sex roles, by which women are more often enrolled in household chores, gardening, or child care activities than men, could explain the higher LPA and lower SED observed in women.[29] Moreover, our results agree with previous research[22,29,38,42] that SED increases while LPA and MVPA declines with age. Finally, participants with obesity had higher SED and lower levels of LPA and MVPA that those with normal weight or overweight. These results coincide with existing literature[10,28,41] and suggest that interventions should target those with higher BMI.

This study has some limitations. Although the age and sex distribution of participants in the Seniors-ENRICA-2 study is comparable to that in the population aged 65-94 years in Madrid and overall in Spain in 2017, those in the Seniors-ENRICA-2 study had a higher percentage of university studies (data available at: http://www.ine.es/jaxiT3/Datos.htm?t=6347); of note is that phone surveys usually lead to overrepresentation of people with higher education as compared to face-to-face surveys and that, in most health surveys, the response rate tends to be higher among those with higher education.[43] This limitation, however, did not hamper in properly assessing the variation in SED, PA, and sleep patterns across socio-demographic variables and BMI. On the other hand, using raw accelerometer data is a relatively new process and, therefore, the cut-off points to classify intensity of behaviors have not been specifically established for older people.

5 | PERSPECTIVE

This study provided a detailed description of sleep, SED, LPA, and MVPA patterns over the 24-hours cycle in Spanish older adults. While no large differences were identified in sleep-related variables by socio-demographics and BMI, SED, LPA, and MVPA patterns varied with sex, age, education, and BMI. Mainly, women, the oldest people and those with obesity could potentially benefit most from targeted interventions to increase PA and reduce SED.

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CONFLICT OF INTEREST

The authors declare none conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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