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Sedentary behavior patterns in community-dwelling older adults assessed using a commercial wearable device

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Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

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ABSTRACT

Background: This study aimed to characterize sedentary behavior (SB) among community-dwelling older adults using objective and subjective measures, compare estimates obtained from a wearable device and a questionnaire, and examine differences in SB across times of day and between weekdays and weekends.

Methods: This cross-sectional study included 51 older adults (69.9 ± 5.0 years; 76.5% women). SB was estimated using a Fitbit Inspire 2 and subjectively assessed using the Longitudinal Aging Study Amsterdam–Sedentary Behavior Questionnaire (LASA-SBQ). Wearable data were collected over seven consecutive days. Generalized linear models assessed sex differences, generalized linear mixed models examined variations across times of day, and Pearson correlation assessed the relationship between subjective and wearable-derived estimates.

Results: Participants accumulated 11.7 ± 2.3 h/day of wearable-estimated sedentary time and 9,663 ± 4,516 steps/day. No significant sex differences were observed in wearable-estimated sedentary time on weekdays (β = 72 min/day; 95% CI −22 to 167; p = 0.135) or weekends (β = 74 min/day; 95% CI −74 to 222; p = 0.325). Wearable-estimated sedentary time was significantly higher in the evening than in the morning (weekdays: β = 67.8 min/day; 95% CI 53.7–82.0; weekends: β = 61.1 min/day; 95% CI 41.4–80.8; both $p < 0.001$) and afternoon (weekdays: β = 45.5 min/day; 95% CI 35.4–55.6; weekends: β = 46.5 min/day; 95% CI 34.4–58.5; both $p < 0.001$). No significant correlation was observed between questionnaire-based and wearable-derived estimates (r = 0.159; p = 0.265).

Conclusions: Community-dwelling older adults exhibited substantial wearable-estimated sedentary time, particularly during the evening, despite relatively high daily step counts. The lack of a significant correlation between subjective and wearable-derived estimates highlights differences between measurement approaches. Wearable devices may help characterize temporal patterns of inactivity and inform targeted strategies to reduce sedentary time and promote healthy aging.

Keywords: Sedentary behavior; Older adults; Wearable electronic devices; Physical activity monitoring; Diurnal patterns

1 INTRODUCTION

Population aging is a global phenomenon. Approximately one billion people worldwide are aged 60 or older [1], and this demographic shift is accompanied by an increased prevalence of chronic diseases and functional limitations that compromise the autonomy and quality of life in older adults [2]. In this context, sedentary behavior (SB), particularly prolonged sedentary time accumulated throughout the day, has emerged as a significant health risk factor in older populations. [3]. Evidence indicates that older adults spend between 60% and 80% of their waking time in SB, corresponding to approximately 8.5 to 10.5 hours per day, [4]. Prolonged SB has been associated with adverse

metabolic, cardiovascular, and cognitive outcomes, as well as increased all-cause mortality, independent of physical activity level [5, 6].

Despite its clinical relevance, accurately measuring SB remains challenging[7]. Subjective instruments, such as questionnaires and records, are widely used due to their low cost and ease of application but are susceptible to recall bias and limited ability to capture daily patterns of behavioral [8–10]. In contrast, objective methods, such as accelerometers (e.g., ActiGraph and activPAL), provide more precise estimates of SB [11, 12].

In this scenario, commercial wearable devices, including smartwatches and physical activity trackers, have emerged as promising tools for monitoring movement behaviors[13]. These devices allow continuous data collection in real-world environments and have gained increasing acceptance among older adults [14]. However, uncertainties remain regarding their ability to accurately capture sedentary behavior patterns and the relationship between wearable-derived estimates and self-reported measures [12, 15, 16].

To date, studies investigating diurnal patterns of SB in older adults using continuous wearable monitoring under free-living conditions remain limited[8, 17]. Furthermore, few investigations have examined the agreement between subjective and objective measures of SB in this population [18, 19]. Differences in SB between weekdays and weekends are also poorly understood among community-dwelling older adults, whose daily routines may show less occupational variability [20].

To address these gaps, the present study aimed to characterize SB among community-dwelling older adults using objective and subjective measures, compare SB estimates obtained from a wearable device and a questionnaire, and examine differences in SB across times of day and between weekdays and weekends.

2 METHODS

2.1 Study Design and Participants

This cross-sectional study was conducted with community-dwelling older adults in Campina Grande, Paraíba, Brazil. Data collection was carried out at two community-based institutions: the Open University for Maturity (Universidade Aberta à Maturidade – UAMA) and the Community Living Center (Centro de Convivência – CCI). These institutions provide educational, social, and physical activities for older adults and serve as the recruitment settings for the study.

Community-dwelling older adults aged 60 years or older, of both sexes, were recruited using convenience sampling. Eligibility criteria included being literate, presenting no cognitive impairment (defined as a score ≥ 22 on the Léganes Cognitive Test), and having no mobility limitations that prevented independent ambulation or interfered with usual daily activities, wearable device use, or

the completion of questionnaires. Participants with incomplete data for the main variables of interest were excluded from the final analysis. All participants provided informed consent before enrollment.

The study was approved by the Research Ethics Committee of the State University of Paraíba (CAAE: 51155321.0.0000.5187). All procedures were conducted in accordance with the Declaration of Helsinki and Resolution No. 466/2012 of the Brazilian National Health Council. All participants provided written informed consent before enrollment.

Clinical trial number: Not applicable.

2.2 Patient and Public Involvement Statement

Patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

2.3 Objective Assessment of Sedentary Behavior

SB was objective estimated using movement-related metrics obtained from the Fitbit Inspire 2, including step counts, active minutes, and sleep–wake information. The proposed approach aimed to identify periods of waking inactivity characterized by the absence of recorded steps and active minutes, while excluding identified sleep periods. As the device-derived metrics do not directly assess body posture or energy expenditure, the resulting values were considered indirect estimates of SB rather than direct measurements of sitting, reclining, or lying behavior.

The wearable device continuously monitored participants throughout the study period, providing objective measures of daily physical activity and cardiovascular behavior. The variables obtained from the device included daily step count, active minutes, and heart rate. These wearable-derived measures were used to characterize participants' daily activity patterns alongside SB. After the monitoring period, data were synchronized and extracted through the Senior Mobile Health digital platform (Sênior Saúde Móvel – SSM), developed by the Biomedical Computing Laboratory of the Center for Strategic Technologies in Health (NUTES) at the State University of Paraíba (UEPB) [21].

SB was conceptually defined as waking behavior characterized by a low energy expenditure (≤1.5 metabolic equivalents [METs]) while sitting, reclining, or lying posture [22] . For the wearable-based assessment, SB was estimated from the activity metrics available from the Fitbit device by identifying waking periods characterized by the absence of recorded steps and active minutes. Sleep periods were excluded from the estimation of SB. The resulting SB estimates were expressed in minutes and organized according to weekdays and weekends and across different periods of the day (morning, afternoon, and evening) to characterize diurnal sedentary patterns.

2.4 Subjective Assessment of Sedentary Behavior

Subjective SB was assessed using the Sedentary Behavior Questionnaire from the Longitudinal Study of Aging in Amsterdam (LASA-SBQ). This validated questionnaire estimates the time spent in sedentary activities in different domains and periods of the day. The LASA-SBQ was applied after the seven-day monitoring period with the wearable device, allowing for a comparison between subjective estimates and SB objectively measured by the wearable device.

2.5 Complementary Variables

Sociodemographic and clinical characteristics were obtained through a structured interview conducted by trained researchers. Data included age, sex, race/ethnicity, marital status, medical history, medication use, and self-rated health. Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression Scale (CES-D)[23]. Anthropometric measurements were obtained using standardized procedures, including body weight and height, body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2) and classified as normal weight, overweight, or obesity according to World Health Organization (WHO) criteria[24]. Frailty status was assessed according to the Fried frailty phenotype and classified as robust, pre-frail, or frail based on the number of criteria identified[25].

2.6 Data Collection Procedure

Data collection was conducted by trained researchers and comprised of two sequential phases. In the first phase, participants attended an in-person assessment at the study sites. Following informed consent, sociodemographic and clinical data were collected, complementary assessments were performed, and participants received standardized instructions on the use of the wearable device. Participants were also familiarized with the device before initiating the monitoring period.

In the second phase, participants were instructed to wear the Fitbit Inspire 2 on their non-dominant wrist continuously for seven consecutive days, including waking and sleeping periods, while maintaining their usual daily routines. At the end of the monitoring period, the devices were collected and synchronized, and the recorded data were retrieved through the Senior Mobile Health platform for subsequent analysis. At the end of the seven days, wearable-derived data were synchronized with the SSM platform and extracted for analysis. The LASA-SBQ was subsequently administered to obtain a subjective estimate of sedentary time corresponding to the same monitoring period.

Standardized assessment protocols were applied to all participants to minimize potential sources of bias. Data collectors received standardized training, validated instruments were used, and SB was objectively monitored using the wearable device. No data imputation procedures were

performed, and participants with missing data for the main study variables were excluded from the analyses.

2.7 Sedentary Behavior Data Processing

Data obtained from the wearable device was extracted using the SSM platform. SB was estimated from the activity metrics available from the Fitbit device, with waking periods characterized by no recorded steps and no active minutes considered indicative of SB. Sleep periods were excluded from the estimation of SB. Wearable-derived SB was expressed in minutes and organized according to weekdays and weekends and across different periods of the day (morning, afternoon, and evening) to characterize diurnal SB patterns. Objective estimates of SB derived from the Fitbit device were subsequently compared with subjective estimates obtained using the LASA-SBQ.

2.8 Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as absolute (n) and relative (%) frequencies. Pearson correlation was used to assess the linear association between SB estimated using the LASA-SBQ and wearable-derived sedentary time estimates obtained from the Fitbit device. Generalized linear models were used to estimate coefficients (β) and 95% Wald confidence intervals (95% CI) for differences in SB between females and males on weekdays and weekends, considering both subjective and objective measures and the different periods of the day.

To evaluate variations in SB across periods of the day, a generalized linear mixed model was employed, with time of day as a fixed effect and participant as a random effect to account for intra-individual variability. Results were expressed as coefficient estimates and 95% Wald confidence intervals, with estimated marginal means and pairwise contrasts presented when appropriate. Statistical significance was set at $p < 0.05$. All analyses were performed using IBM SPSS Statistics, version 27.0 (IBM Corp., Armonk, NY, USA).

3 RESULTS

A total of 51 older adults were included in the final analysis (Figure 1). Table 1 presents the participants' characteristics. Most participants were female (76.5%), Black or Brown (60.8%), and did not live with a partner (72.5%). In addition, 60.8% (n = 31) screened positive for depressive symptoms according to the CES-D. Regarding nutritional status, based on WHO BMI criteria, 29.4% were classified as overweight and 31.4% as having obesity (See Table 1).

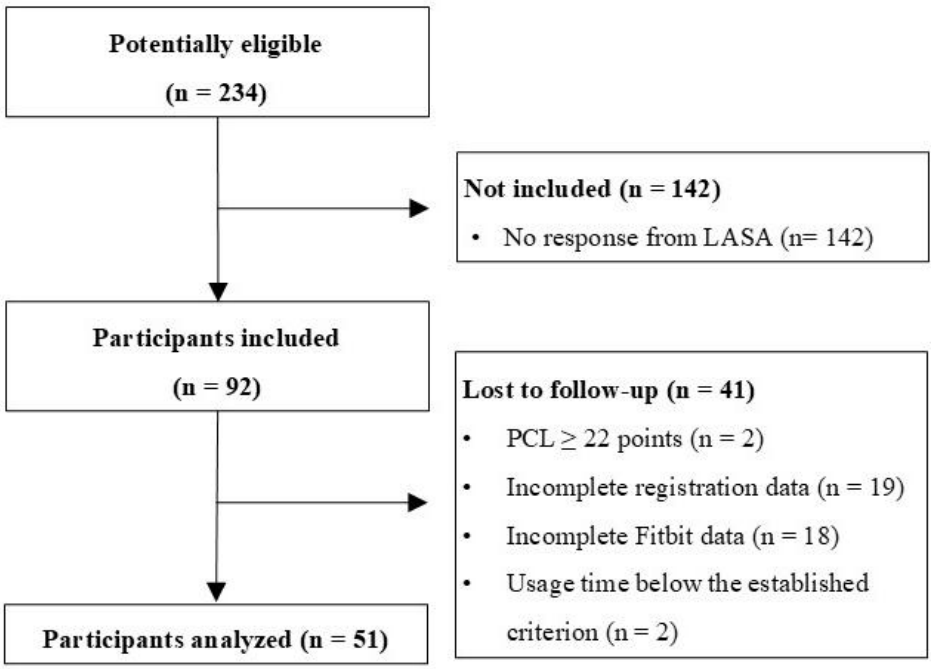

Figure 1. Sample selection flowchart.

Variable	Mean ± SD or n (%)
Age, years	69.9 ± 5.0
Female, n (%)	39 (76.5)
Lives with partner, n (%)	14 (27.5)
White, n (%)	20 (39.2)
BMI, kg/m^2	28.5 ± 4.2
Obese, n (%)	16 (31.4)
Overweight, n (%)	15 (29.4)
Normal weight, n (%)	20 (39.2)
Diabetes medication, n (%)	20 (39.2)
Lipid-lowering medication, n (%)	9 (17.6)
Antihypertensive medication, n (%)	24 (47.1)
Beta-blocker, n (%)	9 (17.6)
Diagnosis of depression, n (%)	31 (60.8)
Steps per day, steps/day	9663 ± 4516

Active minutes, min/day	67 ± 65
Screen time, h/day	3.8 ± 3.1
Sedentary time	
Wearable, h/day	11.7 ± 2.3
LASA-SBQ, min/day	6.7 ± 3.7

Continuous data are presented as mean ± standard deviation (SD), and categorical data are expressed as absolute (n) and relative (%) frequencies. Abbreviations: BMI, body mass index; h, hour; LASA-SBQ, Longitudinal Aging Study Amsterdam–Sedentary Behavior Questionnaire.

Table 2 compares sedentary behavior (SB) variables measured by questionnaire and estimated by wearable device by participants' sex. Based on the subjective measure, no significant difference in SB was observed between females and males on weekdays (β = 79 min/day; 95% CI –97 to 255; p = 0.378) or on weekends (β = –23 min/day; 95% CI –146 to 100; p = 0.715). Similarly, wearable device-estimated SB did not differ significantly between females and males on weekdays (β = 72 min/day; 95% CI –22 to 167; p = 0.135) or on weekends (β = 74 min/day; 95% CI –74 to 222; p = 0.325).

Regarding wearable device-estimated SB across different periods of the day, no significant sex differences were observed during the morning, either on weekdays (β = 15 min/day; 95% CI –22 to 53; p = 0.419) or weekends (β = –15 min/day; 95% CI –67 to 37; p = 0.569). In the afternoon, no significant difference was observed on weekends (β = 34 min/day; 95% CI –19 to 86; p = 0.207); however, on weekdays, a trend was observed (β = –29 min/day; 95% CI –5 to 63; p = 0.091) for females compared with males. In the evening period, a trend was observed on both weekdays (β = 30 min/day; 95% CI –4 to 65; p = 0.080) and weekends (β = 56 min/day; 95% CI –1 to 112; p = 0.054) when comparing females with males (see Table 2).

	Men	**Women**	**p-value**
LASA-SBQ			
Weekday SB, min/day	406 (252, 560)	485 (400, 570)	0.378
Weekend SB, min/day	357 (249, 465)	334 (274, 394)	0.715
WEARABLE			
Weekday SB, min/day	664 (582, 747)	736 (691, 782)	0.135

Weekend SB, min/day	632 (502, 761)	706 (634, 778)	0.325
Weekdays			
Morning, min/day	199 (166, 231)	214 (196, 232)	0.419
Afternoon, min/day	211 (181, 240)	240 (223, 256)	0.091
Evening, min/day	255 (225, 285)	286 (269, 302)	0.080
Weekends			
Morning, min/day	216 (170, 262)	201 (175, 226)	0.569
Afternoon, min/day	193 (147, 239)	227 (201, 252)	0.207
Evening, min/day	223 (173, 272)	278 (251, 306)	0.054

Table 2. Values are expressed as estimated marginal means (EMM) and 95% Wald confidence intervals (CI). Abbreviations: LASA-SBQ, Longitudinal Aging Study Amsterdam–Sedentary Behavior Questionnaire; SB, sedentary behavior.

Figure 2 and Supplementary Table 1 illustrate differences in participants' SB across different times of day. On weekdays, a significant difference was observed in the evening compared with the afternoon (β = 45.5 min/day; 95% CI 35.4 to 55.6; $p < 0.001$), in the evening compared with the morning (β = 67.8 min/day; 95% CI 53.7 to 82.0; $p < 0.001$), and in the afternoon compared with the morning (β = 22.4 min/day; 95% CI 9.7 to 35.0; $p = 0.001$). On weekends, a significant difference was observed in the evening compared with the afternoon (β = 46.5 min/day; 95% CI 34.4 to 58.5; $p < 0.001$) and in the evening compared with the morning (β = 61.1 min/day; 95% CI 41.4 to 80.8; $p < 0.001$). No significant difference was observed in the afternoon compared with the morning (β = 14.6 min/day; 95% CI: –4.0 to 33.3; $p = 0.123$).

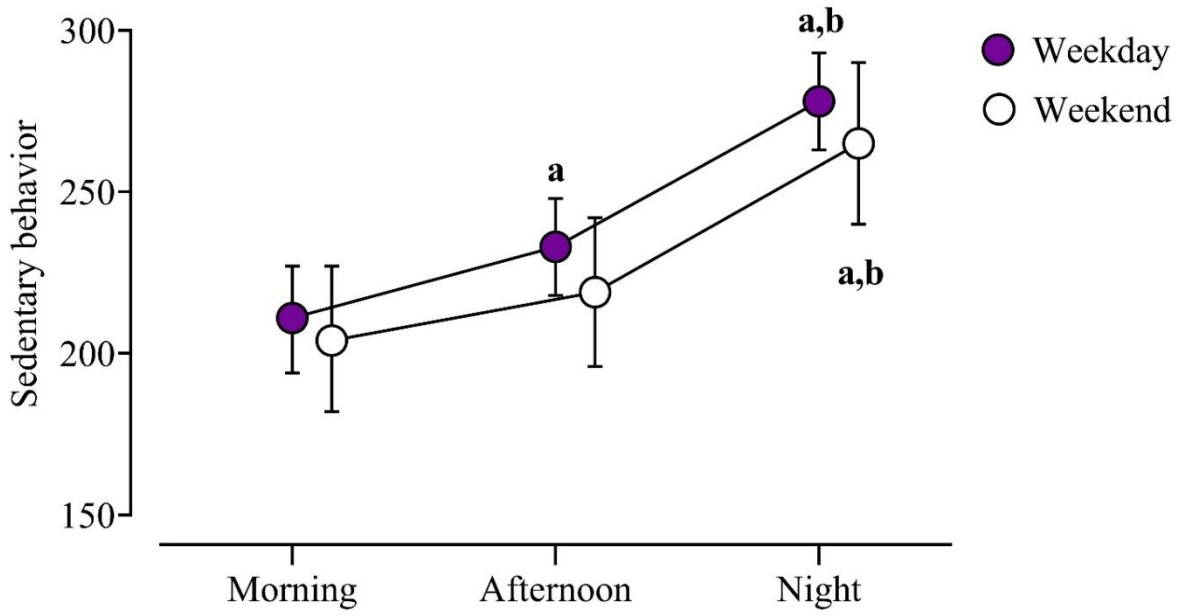

Figure 2. Values are presented as estimated marginal means and 95% Wald confidence intervals (CI). v[a] Significant difference compared with the morning period ($p < 0.05$). [b] Significant difference compared with the afternoon period ($p < 0.05$).

4 DISCUSSION

This study provides one of the first comprehensive characterizations of SB in community-dwelling older adults using both objective (wearable device) and subjective (LASA-SBQ) measures, while also examining differences between weekdays and weekends and across times of day. Overall, participants accumulated a high amount of SB despite achieving relatively high daily step counts. The results revealed a clear diurnal pattern, with SB progressively increasing throughout the day and reaching its highest levels during the evening period on both weekdays and weekends. No significant differences were observed between sexes, although women tended to spend more time in sedentary activities during the evening.

Our study showed that SB increased significantly in the evening compared with other times of day among older adults. During the evening period, this increase was approximately 68 and 45 minutes higher than in the morning and afternoon periods, respectively. In addition, SB was significantly higher in the afternoon than in the morning (22.4 minutes), suggesting a progressive accumulation of SB throughout the day. These findings highlight the importance of understanding the factors that contribute to increased SB during the evening period. Evidence suggests that this behavior may be associated with common leisure-time habits, such as increased time spent watching television, using electronic devices, or engaging in other sedentary activities before bedtime [26]. This pattern is clinically relevant, as the literature indicates an association between prolonged evening SB and poorer glycemic indices [27] a higher risk of chronic diseases [28]. Moreover, each additional 60 minutes of SB per day has been associated with the likelihood of multimorbidity in older adults

[26]. This relationship may be explained by the negative effects of prolonged SB on aerobic capacity, muscle strength, metabolic function, and glycemic control [5, 29]. Taken together, these findings highlight the importance of developing strategies to mitigate ST, particularly during the evening period.

On weekends, SB among older adults was also higher in the evening than in the morning or afternoon, suggesting that the diurnal pattern observed on weekdays persisted. This behavior may be influenced by leisure-time habits commonly performed during the evening, such as watching television or using other electronic [30, 31]. Increased screen exposure during the evening may affect circadian rhythm regulation and contribute to sleep-related problems, including reduced sleep quality and shorter duration, since the wavelength of light emitted by screens can suppress melatonin production during the evening period [10]. For this reason, recommendations suggest limiting daily recreational screen time to approximately two hours [26]. Future studies should further explore the relationships between sedentary evening behavior, screen use, and sleep outcomes in older adults.

In sex-stratified analyses, no statistically significant differences in SB measured by either wearable or LASA-SBQ were observed on weekdays or weekends among older adults. Although variability was limited, the weekday afternoon and evening periods showed a trend toward higher Fitbit-estimated SB among women than among men. The lower SB observed during the morning period may be related to the concentration of activities requiring greater energy expenditure earlier in the day (e.g., daily activities, group activities, aerobic exercise, water aerobics, and dance). On weekends, the evening period showed a trend toward higher Fitbit-estimated SB among women compared with men, which, as previously discussed, may be influenced by preferences for specific television programming on those days.

In summary, social, cultural, and biological factors influence SB. According to the literature, women tend to engage more frequently in sedentary domestic activities, such as sewing and handicrafts (often performed as a source of income by the Brazilian population), as well as leisure activities such as watching television, reading, using mobile phones, and socializing. In general, women receive less encouragement to engage in outdoor physical activities and experience greater functional disability in older age compared with men[32]. Consequently, reductions in muscle mass, a higher prevalence of joint pain, and frailty impair mobility, leading to functional limitations and activity restriction, which in turn increase the likelihood of adopting sedentary behaviors [33].

The literature indicates that excessive time spent in sedentary activities, such as watching television or using social media, has a significant negative impact on older adults' health [34], affecting sleep quality [35], increasing the risk of dementia [36], and contributing to balance impairments, obesity, cardiovascular diseases, and other noncommunicable chronic diseases (NCDs) [37], in addition to promoting frailty [36]. Strategies aimed at interrupting SB should therefore be

encouraged, even though light physical activities (LPA), as these can provide clinical benefits, particularly with respect to evening SB [38]. Furthermore, recent evidence indicates that even small increases in daily physical activity may provide meaningful health benefits. Replacing sedentary time with brief periods of moderate-to-vigorous physical activity, even for approximately five minutes per day, has been associated with a lower risk of mortality, reinforcing the potential benefits of small and achievable increases in daily movement[39].

Studies have shown that such interruptions, including transitions from sitting to standing, positively affect cardiometabolic health, including improvements in glycemic control [40]. Unlike movements that maintain a seated posture, active interruptions do not need to involve structured exercise but should aim to break up prolonged sedentary periods [41, 42]. These findings highlight the need for interventions that promote regular breaks in SB, especially in this population. For example, active breaks, engaging in light physical activity before rest periods, and raising awareness of the risks of prolonged SB may be effective measures to minimize the negative impacts of this emerging health behavior[43]. Furthermore, to support the maintenance of recommended activity levels, population-targeted interventions should be grounded in public health policies that consider both development and implementation aspects [38].

To date, no studies have proposed specific metrics for developing an initial algorithm to measure SB using data from wearable devices. The main challenge in creating such metrics lies in the lack of detailed information in the literature regarding the architecture of algorithms used for data capture by accelerometers [44].

Given the importance of objectively assessing SB, the integration of wearable devices with the SSM platform may provide valuable information on daily sedentary time and its temporal patterns in older adults. An important methodological limitation concerns the indirect estimation of sedentary time using movement-related metrics from the Fitbit Inspire 2. Although this approach enables the characterization of daily movement patterns in free-living conditions, it does not directly distinguish sitting or reclining from quiet standing. Consequently, periods of standing without recorded movement may have been classified as sedentary, potentially overestimating sedentary time. Furthermore, the proprietary nature of Fitbit's data-processing algorithms limits transparency regarding the derivation of activity metrics. Therefore, the absolute estimates should be interpreted cautiously and should not be considered equivalent to posture-based measurements of sedentary behavior. The central objective is to mitigate the harms associated with excessive sedentary time among older adults.

5 CONCLUSION

This study demonstrated that older adults spend a high amount of time in sedentary behavior, particularly in the evening, even while taking a relatively high number of daily steps, which remains insufficient to meet the WHO recommendations for physical activity. The weak and non-significant correlation between questionnaire-based and wearable-derived estimates highlights the methodological differences between these assessment approaches and the importance of considering their distinct measurement characteristics when interpreting SB. Considering these findings, the need to develop targeted interventions to reduce sedentary behavior and promote practices that support healthy aging is reinforced.

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