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Use of Wearables in Frail Institutionalized Older Adults While Ambulating in Different Environments

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Abstract: (1) Prolonged life expectancy often leads to declining health, reduced physical activity, and dependence, especially in institutionalized elderly. Frailty, obesity, limited functionality, and cognitive impairment are common. Physical activity programs for this demographic can increase weekly energy expenditure and improve frailty. Understanding differences in walking indoors versus outdoors is crucial for tailored programs. This study aimed to compare time, energy expenditure, and perceived exertion in institutionalized elderly walking indoors versus outdoors. It also explored how body mass index and cognitive levels affected these factors. (2) Employing a cross-sectional descriptive observational approach, the study gathered data on height, weight, accelerometers, the modified Borg Scale, the Timed Up and Go test, and the Lobo Cognitive Mini-Exam from a sample of 30 institutionalized older adults. (3) Walking outdoors leads to shorter walking times, higher energy expenditure, and increased perceived effort. Overweight individuals expend more energy in both settings, while cognitive impairment does not significantly impact walking preferences. (4) The study concludes that indoor walking is preferable for frail elderly due to lower perceived exertion, but outdoor walking is recommended for overweight individuals. Cognitive status does not influence the choice of walking environment.

Keywords: older adults; walking; nursing homes; environment; perceived exertion; energy expenditure

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1. Introduction

Currently, we are observing an aging population and a trend towards increased life expectancy. According to the World Health Organization, by the year 2030, it is estimated that one in six people worldwide will be 60 years old or older [1]. However, this increase in longevity is not synonymous with an improvement in the quality of life, as aging is associated with health deterioration, decreased physical fitness, disability, and dependence [2]. These conditions accentuate the need to live in residential centers where necessary care can be provided. According to the Spanish National Institute of Statistics, in 2019, the occupancy rate in Spanish nursing homes was estimated at 86% [3]. Additionally, there is a high prevalence of institutionalized older adults with frailty [4]. Frailty is a medically complex syndrome characterized by a loss of strength and endurance, and a decrease in physiological function, increasing individual vulnerability to develop dependence or succumb to mortality [5]. Frailty has been shown to be a predictive factor in adverse health events, such as falls or limitations in activities of daily living [5].

In older individuals living in the community, the presence of frailty is associated with a decrease in physical activity, lower energy expenditure, and increased sedentary behavior [6], making physical activity a protective factor against this frailty syndrome [7,8]. Older adults spend around 6 h per day in sedentary activities [9]. As a result, after the age of 65, energy expenditure related to physical activity decreases [9,10], leading to poorer grip strength [11].

Related to energy expenditure is the resting metabolic rate, which can be used as an early identifier of functional health in the pre-frail and frail elderly population, where a higher resting metabolic rate is associated with a lower risk of health deterioration [12]. More active older adults tend to show better health indicators [9] and a higher prevention of potential issues related to low energy expenditure [11]. Some of these issues include metabolic syndrome, type 2 diabetes, obesity, and cardiovascular diseases [13].

In relation to physical activity and metabolic expenditure in older adults, the European Health Survey in Spain 2020 states that 68.35% of individuals aged 65 to 74 have overweight or obesity. This figure remains at 68.73% for adults between 75 and 84 years old, slightly decreasing to 58% in those aged 84 and above [3]. In institutionalized elderly individuals, there is a high prevalence of obesity accompanied by limitations in functional capacity and cognitive impairment [14], as a higher body mass index (BMI) could act as a risk factor for cognitive decline [15]. To prevent weight gain among the older population, engaging in physical activity is recommended and effective, as it increases total energy expenditure [16].

The participation of institutionalized older adults in physical activity programs leads to higher weekly energy expenditure [17] and contributes to improving frailty syndrome, gait parameters, cognitive function, and quality of life [18]. Between 60% and 80% of institutionalized older adults experience at least one fall per year, and they generally suffer two to three times more falls than healthy older adults without cognitive pathologies [19].

Maintenance and functional recovery programs in residential facilities include physical activity programs, where walking is a fundamental element, typically performed in a controlled indoor environment [17]. However, no research has been found that compares the benefits of walking in different environments, indoors or outdoors, in institutionalized older adults, nor the analysis of the impact of such activity based on individual or environmental characteristics. Therefore, the main objective of the study was to describe and evaluate differences in time, energy expenditure, and the perception of effort in institutionalized older adults while walking in a controlled residential environment and in an uncontrolled outdoor environment. Additionally, the study aimed to investigate whether body mass index or the cognitive level of the older adult influenced time, energy expenditure, and the perception of effort in both environments.

2. Materials and Methods

A descriptive cross-sectional observational study was conducted, following the recommendations established by the STROBE statement [20].

The study received approval from the ethics committee of the Rey Juan Carlos University, with internal registration number ref: 2502202205622, in accordance with the ethical principles for medical research involving human subjects outlined in the Declaration of Helsinki, adopted at the 18th World Medical Association General Assembly (Helsinki, Finland, June 1964) and its subsequent revisions [21]. After recruiting participants and informing them about the study process, benefits, and potential risks, all subjects in the sample signed informed consent.

2.1. Participants and Assessment Instruments

The sample consisted of older adults from residential centers affiliated with the Grupo Asistencial NJ company, located in the province of Zamora, Spain. The participant sample was obtained through a non-probabilistic convenience sampling strategy.

To determine the appropriate sample size, G*Power software (version 3.1.7) was used, obtaining a sample size of 25 subjects, calculated with an effect size of 0.6, a statistical power of 0.8, and a type I error rate of 0.05 for the comparison of matched pairs of means. Allowing for 10% of possible sample losses, the final sample size was 28 subjects.

Inclusion criteria were as follows: being a resident of the assistance centers affiliated with Grupo Asistencial NJ; being 60 years of age or older; and being independent for walking with or without assistive devices. Exclusion criteria included: having experienced 3 or more falls in the last year; wheelchair users; and non-acceptance and failure to sign the informed consent form.

Height and weight data for each participant were collected from the weekly reports of the nursing service at the residence. This information was used to calculate the BMI using the formula weight in kilograms divided by the square of height in meters. To categorize the sample, individuals with a BMI less than 24.9 were considered to have normal weight, while those with a BMI greater than or equal to 25 were classified as overweight [22].

To record the time taken to complete the routes and energy expenditure, measured in METs, ActiGraph wGT3X-BT accelerometers were used, programmed at a frequency of 30 Hz. The ActiGraph wGT3X-BT captures and records high-resolution information about human activity through a 3-axis accelerometer [23]. In recent years, the ActiGraph accelerometer has been the most widely used in research and has consistently demonstrated good validity and reliability in many studies [24]. The ActiLife 6 software was used for processing accelerometer data.

The Modified Borg Scale, used since the 1980s, is a visual analog scale that allows for the graphical assessment of the subjective perception of physical exertion. It consists of a range from 0 to 10, where 0 corresponds to "nothing at all" and 10 to "very, very strong" or "very, very heavy", referring to the exercise or physical work that the subject perceives as the most strenuous [25].

The Timed Up and Go (TUG) test has been widely used to assess older adults and is also utilized as a predictor of falls [26,27]. The test measures the time it takes for subjects to rise from a chair, walk a distance of three meters, turn, return to the chair, and sit back down [28]. A score of less than 10 s predicts a low risk of falls, between 10 and 20 s indicates frailty, and when it exceeds 20 s, the elderly individual is considered to have a high risk of falls [28,29]. In a recent study, the TUG test showed a sensitivity of 76.2% and a specificity of 89.8% [27].

The Mini-Examen Cognoscitivo de Lobo (MEC) is the adapted and validated Spanish version of the Mini-Mental Status Examination by Folstein, a standard instrument for assessing cognitive function. The items that compose it explore five cognitive areas: orientation, fixation, concentration and calculation, memory, and language and construction. In this study, the 35-point version was used as it is the most well-known. This scale has a cutoff point for geriatric patients at 23/24, with a sensitivity of 89.8% and a specificity of 83.9% for this point, indicating that below this score, there is some type of cognitive impairment [30]. Individuals without cognitive impairment were those with a score equal to or greater than 24, while all those with a score lower than 24 were included as individuals with cognitive impairment [30].

2.2. Procedure

Data collection took place between March and April of 2022 by an occupational therapist. The individual assessment of each participant occurred on three different days, thus avoiding an overload on the subjects, and all data were collected in individual booklets designed for this study. Assessments were conducted in the afternoon, under similar conditions of rest, nutrition, and hydration. The MEC was administered in an interview format, while the TUG and the Borg scale were administered according to the protocol described in the previous section.

On the first day, the MEC and TUG tests were administered in the described order, while on the second and third days, participants undertook the route in the controlled residential environment and the uncontrolled outdoor environment, respectively. Before both routes, subjects were fitted with accelerometers on their hips, as there is less bias and greater accuracy in estimating energy expenditure when the accelerometer is worn on the hip compared to the wrist [31–33] or ankle [33]. The hip is also the most commonly used location for placing accelerometers in studies involving older adults [31]. After completing the routes, the Borg Scale was administered.

The route in the controlled residential environment took place on the ground floor of the residential center, while the route in the uncontrolled outdoor environment was conducted in a park near the residential center. Both routes covered a distance of 200 m and did not include obstacles such as steps, stairs, changes in elevation, or sharp turns. The two routes had the same changes in direction, incline, and difficulty. The indoor and outdoor routes, as well as the time of day they were conducted, were the same for all participants. All participants were instructed to walk as they normally would. Images of the two environments can be seen in the Supplementary Material, where Figure S1 shows the controlled residential environment and Figure S2 the uncontrolled outdoor environment.

2.3. Statistical Analysis

The statistical analysis of the variables was conducted using the IBM SPSS Statistics software for Windows, Version 27.0 (Copyright© 2013 IBM SPSS Corp., Armonk, NY, USA).

Descriptive analyses were conducted, expressing quantitative variables with mean and standard deviation, and qualitative variables with frequencies. Normal distribution analysis of the variables was assessed using the Shapiro–Wilk test. The Wilcoxon signed-rank test was employed for non-parametric paired sample comparisons, the Student's *t*-test for parametric paired sample comparisons, and the Mann–Whitney U test for independent sample comparisons. Cohen's d statistic was used to estimate the effect size magnitude of differences between groups. The following values were considered regarding the effect size magnitude: values near d = 0.20 suggest a small difference, those close to d = 0.5 suggest a moderate difference, and starting from d = 0.8, the difference can be considered large. The statistical significance threshold was set at $p < 0.05$.

3. Results

The total sample consisted of 30 institutionalized older adults, and their sociodemographic data are reflected in Table 1. Considering the cutoff points of the TUG assessment test, nearly all participants exhibited frailty, and consequently, a risk of falls. The total sample was grouped based on BMI and cognitive level.

Table 1. Sociodemographic data of the total sample (n = 30).

		Participants (n = 30)
Age		78.90 ± 9.08
Sex		
	Men (%)	15 (50)
	Women (%)	15 (50)
Height (cm)		160.43 ± 7.76
Weight (kg)		70.16 ± 12.82
Timed Up and Go		15.01 ± 3.19
	Low fall risk (%)	1 (3.3)
	Frailty/Risk of falling (%)	28 (93.3)
	High risk of falling (%)	1 (3.3)
Body Mass Index		27.19 ± 4.22
	Normal weight (%)	8 (26.7)
	Overweight (%)	22 (73.3)
Mini-examen Cognoscitivo de Lobo		24.27 ± 5.17
	No cognitive impairment (%)	11 (36.7)
	With cognitive impairment (%)	19 (63.3)

Table 2 and Figure 1 display the differences between the results of time, energy expenditure, and perceived exertion in a controlled environment and an uncontrolled environment, along with the magnitude of these differences, calculated using the effect size.

Table 2. Comparison of time, energy expenditure, and perceived exertion during ambulation in a controlled and uncontrolled environment (n = 30).

	Controlled Residential Environment	Uncontrolled External Environment	Test Statistic	*p*-Value	d-Cohen
Time (min)	5.75 ± 1.38	5.01 ± 1.12	−2.707	0.007 *	0.589
MET	1.42 ± 0.68	2.24 ± 1.28	−4.268	<0.001 *	0.800
Borg Scale	6.13 ± 1.01	6.97 ± 1.10	−4.291	<0.001 *	0.795

Data expressed in M ± SD; * $p < 0.05$; MET = energy expenditure.

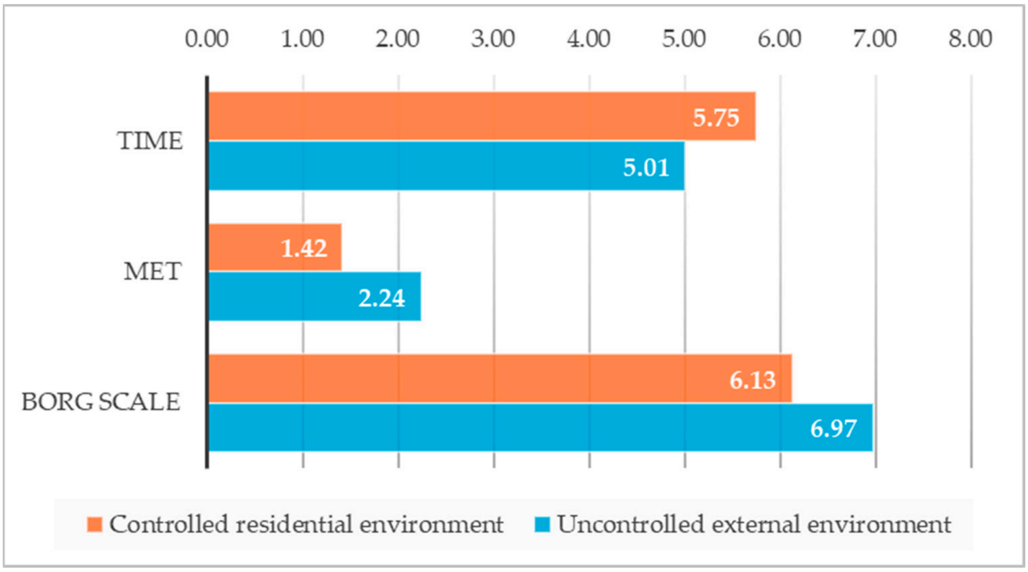

Figure 1. Graph comparing time, energy expenditure, and perceived exertion during ambulation in a controlled and uncontrolled environment (n = 30). Data expressed as mean; MET = energy expenditure; time data expressed in minutes.

These results reveal that participants take less time and exhibit higher energy expenditure, as well as a greater perception of effort, when walking in the uncontrolled outdoor environment compared to walking in the controlled residential environment. There are significant differences in all three variables ($p < 0.05$) and a large effect size for energy expenditure and perceived exertion ($d \geq 0.8$).

When grouping the sample based on BMI, older adults with normal weight (n = 8) had a mean BMI of 21.81 ± 1.64, while those overweight (n = 22) had a mean BMI of 29.15 ± 2.95. The mean differences between groups in time, energy expenditure, and perceived exertion in each environment, along with the magnitude of these differences calculated through effect size, are shown in Table 3 and Figure 2.

Among participants with normal weight and those overweight, statistically significant differences are observed in energy expenditure ($p < 0.05$) when walking in a controlled residential environment and an uncontrolled outdoor environment. In both environments, overweight older adults show higher energy expenditure compared to those with normal weight, with their energy expenditure being higher in the uncontrolled external environment. The effect size is moderate for energy expenditure in the controlled residential environment (d = 0.5–0.7) and large for energy expenditure in the uncontrolled outdoor environment ($d \geq 0.8$).

Table 3. Comparison of time, energy expenditure, and perceived exertion during ambulation in a controlled and uncontrolled environment among institutionalised frail older adults based on their BMI (n = 30).

		Normal Weight (n = 8)	Overweight (n = 22)	*p*-Value	d-Cohen
Controlled residential environment					
	Time (min)	5.44 ± 1.01	5.86 ± 1.49	0.557	0.329
	MET	1.14 ± 0.29	1.52 ± 0.75	0.044 *	0.668
	Borg Scale	6.00 ± 0.93	6.18 ± 1.05	0.622	0.181
Uncontrolled external environment					
	Time (min)	5.11 ± 0.68	4.97 ± 1.26	0.172	0.138
	MET	1.31 ± 0.40	2.58 ± 1.32	0.009 *	1.302
	Borg Scale	6.63 ± 1.06	7.09 ± 1.11	0.342	0.424

Data expressed in M ± SD; * $p < 0.05$; MET = energy expenditure.

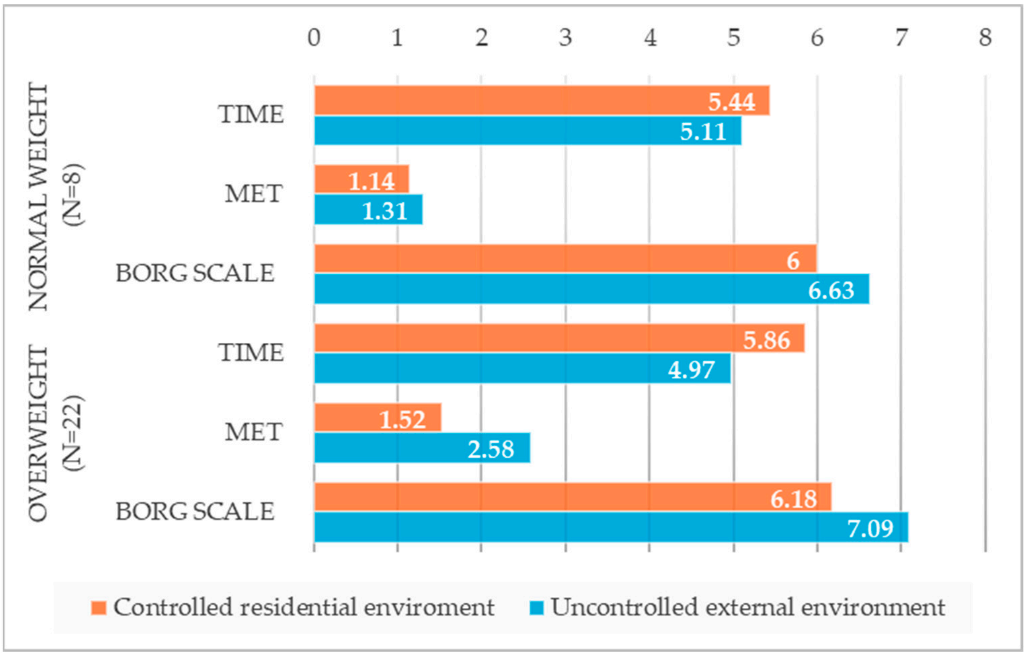

Figure 2. Graph comparing time, energy expenditure, and perceived exertion during ambulation in a controlled and uncontrolled environment among institutionalised frail older adults based on their BMI (n = 30). Data expressed as mean; MET = energy expenditure; time data expressed in minutes.

When grouping older adults by their scores on the MEC, those without cognitive impairment (n = 11) had a mean score of 30.18 ± 2.68, while those with cognitive impairment (n = 19) had a mean score of 20.84 ± 2.29. Table 4 presents the mean differences in variables between both groups, as well as the effect size of these differences.

No statistically significant differences are observed in time, energy expenditure, or perceived exertion among institutionalized older adults with and without cognitive impairment when walking in a controlled residential environment and an uncontrolled outdoor environment.

Table 4. Comparison of time, energy expenditure, and perceived exertion during ambulation in a controlled and uncontrolled environment among institutionalised older adults based on their cognitive status (n = 30).

		Without Cognitive Impairment (n = 11)	**With Cognitive Impairment (n = 19)**	***p*-Value**	**d-Cohen**
Controlled residential environment					
	Time (min)	5.30 ± 1.17	6.01 ± 1.45	0.181	0.539
	MET	1.76 ± 0.95	1.22 ± 0.36	0.111	0.752
	Borg Scale	6.09 ± 1.22	6.16 ± 0.90	0.701	0.065
Uncontrolled external environment					
	Time (min)	4.81 ± 0.61	5.13 ± 1.33	0.713	0.309
	MET	2.57 ± 1.29	2.05 ± 1.26	0.162	0.408
	Borg Scale	6.91 ± 1.30	7.00 ± 1.00	0.688	0.08

Data expressed in M ± SD; MET = energy expenditure.

4. Discussion

We found that institutionalized older adults take less time, exhibit higher energy expenditure, and report greater perceived exertion when walking in the uncontrolled outdoor environment versus a controlled residential environment. Additionally, we observed higher energy expenditure in participants with overweight, and no significant differences were found in any of the three study variables when dividing the sample based on cognitive level.

Studies such as that of Runzer-Colmenares et al. [34] show that frail older adults are slower in walking compared to those without frailty. By including the variable environment, previous research in the literature has studied walking in two different environments, specifically in a laboratory and in a free-living environment [35–37]. However, our study provides information on the influence of the environment in institutionalized frail older adults during walking, including results on variables such as energy expenditure and perceived exertion.

The study by Kuntapun et al. [35] indicates that participants used a faster walking speed in the free-living environment compared to the laboratory environment. This result aligns with the findings of the present study, where participants took less time to complete the walk in the outdoor environment, as a higher walking speed corresponds to completing the activity in less time. However, Brodie et al. [36] reported a lower cadence during walking in the free-living environment, which corresponds to more time spent on the activity. These authors focused their studies on gait analysis in older adults living in the community, not institutionalized, while our findings center on the energy expenditure associated with walking and the perceived exertion of frail institutionalized older adults.

Pakozdi et al. [38] did not find statistically significant differences in total daily energy expenditure between institutionalized and non-institutionalized older adults. The association between age and energy expenditure during walking has been demonstrated, with an increase in energy expenditure in this activity, particularly in those aged over 65 [39]. However, there are no studies that analyze differences in energy expenditure associated with walking in controlled indoor and uncontrolled outdoor environments in the older population. According to our findings, there are significant differences in energy expenditure between walking in the controlled and uncontrolled environments. Casal [40] used MEC and the Barthel Index in institutionalized older adults and found that higher functional capacity leads to greater energy expenditure. In our research, we add additional information by analyzing and comparing energy expenditure in two distinct environments, where higher energy expenditure is observed when walking in the uncontrolled outdoor environment compared to the controlled residential environment. We believe that these data can provide important information to improve current residential physical activity programs by indicating whether walking activities should take place indoors or outdoors depending on the characteristics of the resident.

During moderate-intensity walking, Kossi et al. [33] found significant differences in perceived exertion, measured with the Borg Scale, between young adults and older adults. They also concluded that assessing perceived exertion is recommended to estimate exercise intensity in older adults. The results of the present study contribute to the understanding that frail institutionalized older adults exhibit differences in perceived exertion when walking in a controlled residential environment compared to an uncontrolled outdoor environment, experiencing greater effort when walking in the uncontrolled outdoor environment. When analyzing the study variables considering the sample's grouping by BMI, the results show statistically significant differences in energy expenditure. As expected, individuals with overweight have higher energy expenditure than those with normal weight, both in the controlled residential environment and the uncontrolled outdoor environment. A recent review [41] supports that energy expenditure is generally higher in overweight and obese individuals compared to individuals within the normal range for age, height, and sex. Similarly to our results, Galloway et al. [42] found that overweight adults showed higher total energy expenditure when walking compared to normal-weight adults, regardless of the pace. However, our results do not show differences between overweight and normal-weight older adults in the time it took to complete both walks or in perceived exertion. This aligns with the work by Galloway et al. [42], where they did not find significant differences in speed between normal-weight and overweight adults during a self-selected walking pace. This result is similar to what is presented in the current study, as speed and time during walking are related, and our study adds novelty by observing these results in frail institutionalized older adults. However, our study is the only one that focuses on perceived exertion, comparing it by BMI groups and in two different environments. The lack of significant differences in perceived exertion between overweight and normal-weight older adults when walking in a controlled residential environment and an uncontrolled outdoor environment may be due to the small overall sample size and the difference in size in each of the groups.

When grouping the sample based on cognitive level, our data show that there are no statistically significant differences in time, energy expenditure, or perceived exertion among institutionalized older adults with and without cognitive impairment when walking in a controlled residential environment and an uncontrolled outdoor environment. These findings complement those presented in the study by Dixe et al. [43], who also did not find statistically significant differences in walking speed, mobility capacity, and functional balance when comparing institutionalized older adults with and without cognitive impairment.

The limitations of this study include the small sample size, the fact that the sample is from the same region, and the convenience sampling method, which could hinder the generalization of the results. For future studies, larger and more diverse samples from various locations across the country should be considered. Additionally, expanding the sample to include both frail and non-frail elderly individuals would provide a more comprehensive understanding of the relationships studied.

5. Conclusions

The physical activity of walking is more suitable to being conducted indoors for frail institutionalized elderly individuals, as it shows lower perception of effort and energy expenditure. When dealing with a frail and institutionalized elderly individual who also has overweight, it is recommended that this walking activity be carried out in an uncontrolled outdoor environment.

The cognitive status of older adults does not influence the decision to choose between conducting the physical activity of walking indoors or outdoors.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app14125158/s1, Figure S1: Controlled residential environment; Figure S2. Uncontrolled outdoor environment.

Author Contributions: Conceptualization, Ó.G.-G. and M.P.-d.-H.-T.; methodology, Ó.G.-G. and M.P.-d.-H.-T.; formal analysis, S.S.-T. and P.O.-B.; investigation, Ó.G.-G., L.H.-H. and P.S.-H.-B.; data curation, Ó.G.-G. and P.S.-H.-B.; writing—original draft preparation, P.O.-B., L.H.-H. and R.M.M.-P.; writing—review and editing, M.P.-d.-H.-T., L.H.-H. and S.S.-T.; supervision, P.O.-B. and R.M.M.-P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Research Ethics Committee of the Universidad Rey Juan Carlos with internal registration number 2502202205622, for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy reasons.

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Conflicts of Interest: The authors declare that they have no competing interests.

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