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Seasonality and objective physical activity and sedentary behaviour among older adults from four European countries

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Abstract

Objective: The present study aimed to explore the relationship between objective physical activity and sedentary behaviour with seasonality among a sample of older adults living in four European countries. Methods: A samples of 169 older adults living in Croatia, Greece, Portugal and Poland (mean age = 72.2±6.0, 68% female); had valid objective physical activity and sedentary behaviour data collected in different seasons of the year: spring and autumn/winter. Physical activity and sedentary behaviour were collected with accelerometers (ActiGraph, GT3X), during consecutive 7 days, in both moments. A valid record was defined as at least 3 days with 10 hours of wear time, and one weekend day. Analysis were run with IBM SPSS 28.0, using t-test, ANOVA, and binary logistic regressions. Results: Most older adults from the four countries involved in this study met the physical activity guidelines in spring and autumn/winter. No significant variations were found across seasons for sedentary behaviour, and physical activity both for light and vigorous intensity, regardeless of sex, country, education and Body Mass Index (BMI). A decline in moderate physical activity intensity from spring to autumn/winter was found for those with lower education and higher BMI. Conclusion: The promotion of physical activty must be considered in programs to promote healthy aging along the year, specially considering the moderate intensity and among those populations with higher BMI and less educational levels.
Key words: seasonality, physical activity, sedentary behaviour, health, elderly

Introduction

Physical activity plays a crucial role in maintaining overall health, well-being, and healthy aging (1). Physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure (2). Its regular practice improves cardiovascular health and helps reduce the risk of heart disease (3). Additionally, among other benefits, it positively impacts mental well-being by reducing symptoms of depression and anxiety (4, 5). Physical activity also aids in weight management and the prevention of obesity (6). Furthermore, active older people tend to benefit in relation to their coordination, prevention of falls, reducing isolation and maintaining social links (7, 8). On the other hand, a sedentary lifestyle and lack of physical activity can have detrimental effects on health. Physical inactivity and sedentary behaviours are associated with an increased risk of chronic diseases such as obesity, type 2 diabetes, cancer, and musculoskeletal disorders (9). Understanding the risks of physical inactivity highlights the importance of incorporating physical activity into daily routines.

Physical activity recommendations for older adults include engaging in at least 150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity aerobic activity per week, or a combination of both, along with muscle-strengthening exercises at least two days per week (10). Furthermore, older adults should do varied multicomponent physical activity focused on balance and strength training at moderate or greater intensity three or more days a week. However, adherence to these guidelines remains a challenge. Around a third of the world's population is estimated to be non-compliant with global physical activity recommendations, with levels of physical inactivity being higher in high-income countries and among older adults (11).

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Seasonality has emerged as a potential factor influencing physical activity levels. Seasonality refers to the cyclical changes in weather, daylight hours, and environmental conditions throughout the year (12). These changes can significantly influence people's behaviours and activities, including their engagement in physical activity (13). Several factors contribute to the seasonal variations in physical activity levels, such as temperature, precipitation and daylight.
Temperature is a critical factor affecting physical activity participation during different seasons. In colder months, individuals may be less inclined to engage in outdoor activities due to discomfort or concerns about exposure to cold weather-related risks. On the other hand, warmer temperatures during spring and summer can facilitate increased participation in outdoor activities, including walking, cycling, and sports (14). Even in young people, this association is found since playgrounds are usually outdoors and are where they usually engage in physical activity at school (15, 16).
Precipitation, such as rain or snow, can also impact physical activity engagement. Inclement weather conditions may limit opportunities for outdoor activities and lead to decreased motivation for physical activity (17). Safety concerns related to slippery surfaces or reduced visibility during precipitation can deter individuals from participating in outdoor physical activities.
Daylight availability plays a crucial role in shaping physical activity behaviours. During winter, shorter daylight hours can limit the time available for outdoor activities, particularly after work. The reduced exposure to natural light and the tendency to spend more indoors can impact individuals' mood and motivation for physical activity. Conversely, longer daylight hours in spring and summer provide more opportunities for outdoor activities and may positively influence participation (18).
Physical activity and seasonality seem to be closely interconnected, as the changing seasons can significantly impact individuals' engagement in physical activity. In brief, a recent systematic review focused on adults and older adults, evidence that in summer, compared to winter, physical activity levels tend to be higher (19). Other studies show that spring is the year's season with the highest level of physical activity. In this review, some studies compared seasons more favourable for physical activity, such as spring/summer vs. autumn/winter, finding statistically significant differences that favor the aforementioned season of the year. However, conducting further studies where the data is disaggregated by sex and other sociodemographic characteristics are needed (e.g. body mass index, education level), especially in the elderly population. Importantly, this study evidence that a very limited number of studies has been carried out in two or more countries, ranging out of the dichotomy summer/winter. The present work addressed some of the above-identified limitations identified in the existing evidence.
The influence of seasonality on physical activity has important implications for public health promotion. Understanding the influence of seasonality on physical activity patterns is crucial for developing effective strategies to promote year-round physical activity and mitigate the potential barriers posed by different seasons. Strategies targeting specific barriers associated with each season may help individuals maintain regular physical activity habits regardless of the weather or environmental conditions. Therefore, in the present study, we sought to explore the relationship between physical activity and seasonality, by discussing the factors influencing seasonal variations in physical activity and sedentary behaviour among the elderly population from four countries and the implications for public health promotion.

Methods

Participants and study design

This prospective study, which involved the data collection in two moments among the same older adults, is part the "Interventions in the Elderly's Mobility Modes for Promotion of their Physical Activity and Fitness" (FITOLD) project. This project funded by the European Union [Grant Agreement No 622623-EPP-1-2020-1-DESPO- SCP] under the Erasmus+ Sport project involved academic and non-governamental partners from 7 seven countries, namely: Germany (coordinator), Croatia, Greece, Italy, Portugal, Poland, and Turkey. The FITOLD project took place between 2021-2023 and

the main purpose was to identify the factors associated with the physical activity and physical fitness of senior citizens (aged 60 or more years), living in countries where further studies involving the older population are less common and, therefore, needed.
Data was collected in six out of those seven countries (German partners did not collect data). However, in this study, only data from four countries (Portugal, Croatia, Poland, Greece) are used since a minimum of 30 persons per country with valid accelerometer in bothe moments was predefined as a minimum for these specifc analyses – i.e. a large sample in statistical terms (20).
In each country, older adults aged 60 years or more were randomly invited to participate in the study through the network of each partner (fitness clubs, senior universities, other community organisations working with the elderly, etc.). In addition to the age, the following selection criteria were considered: healthy or controlled heath situation; able to understand and maintain a conversation; walking ability without using a gait aid. For exclusion criteria, we have considered: not having a stable health situation; reduced physical or mental abilities that limit their participation; auditive or visual limitations; if they have fallen one or more times during the last year; living in collective residences; and decline to participate. After the approval from the ethics committee, the senior citizens were firs approached. The conditions of the research were presented in a friendly and personal environment. Written consent from senior citizens and approval on a brief screening of health risks for exercise was required for participation in the study.
In brief, from the four mentioned countries, a total of 676 (64.5% female; mean age 72.1·5.5; min 61, máx 96) participants answered the questionnaire (Croatia = 209, Greece = 203, Portugal = 94, Poland = 170). Of those, based on their self-reported availability to provide data on two distinct moments separated by several months, 239 senior citizens were selected and used the accelerometer in moment one. Among these, 202 had valid accelerometer data (criteria specified below). Finally, within all that used the accelerometer in moment 2, only 169 senior citizens had valid data on both moments and were, therefore, included in the current study.

Measures

Physical activity and sedentary behaviour data evaluation and accelerometry data collection

The ActiGraph wGT3X-BT triaxial accelerometer was used to estimate the time spent in all physical activity intensities, including sedentary behaviour (ActiGraph, GT3X model, Fort Walton Beach, FL). In this study, the GT3X was used on an elastic belt on the right side of the hip at the level of the iliac crest. The participants were advised to wear the belt with the activity monitor on the right side during all waking hours, excluding the time spent in the sauna, bath, shower, or in other water activities, under their clothes. Participants were informed to wear the device for seven consecutive days, including two weekends. The participanst were informed to record the timing and reasons for every occasion the device was removed in a registration form. The delivery of the accelerometers was made personally, following a protocol defined for the whole research group. The FMH team trained the researchers during a 3 hours recorded session, and continuous support was provided during the data collection.
Additionally, before the official data collection for the project, a pilot phase for using the accelerometer was established and implemented. Data was collected for 5-10 people, and the data was analysed. All data was analysed, and the project partners met to share their doubts and find solutions. This training phase was important since not all partners have worked before with these devices and methodologies for collecting data. Both the .agd and .gt3x files were stored with the participants' code as their file name during the download.
Regarding the data processing phase and checking for validity, the wear time validation and periods of at least 90 consecutive 0 counts were considered non-wear time. Each day with a wear time > 10 hours was considered a valid day (21). To be included in the analysis, the participants had to present at least three valid days (with at least one weekend day).

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For the quality control and harmonisation process, two different approaches were adopted. First a decentralised analysis was performed by each country on their data, using the methodology mentioned above for preliminary validation of the data. Then, a centralised reprocessing occurred with the highest data resolution using the methodology mentioned above. The accelerometer data processing was performed by the FMH team while using the Actilife software with specific standardised procedures. The epochs were set to 15 seconds during the download, and the biometric data was filled. Both the .agd and .gt3x files were stored with the participants code as their file name during the download.

The cutoff values used to define the intensity of physical activty and, therefore, to quantify the mean time in each intensity (sedentary, light, moderate or vigorous) were as follows: sedentary: < 100 counts·min- 1; light: 100-2019 counts·min-1; moderate: 2020-5998 counts·min-1 (corresponding to 3-5.9 METs); vigorous: ≥ 5999 counts·min-1 (corresponding to ≥ 6 METs) (21).

Sociodemographic variables

Country, sex (male/female), age (years), education, height (m) and weight (kg), were self-reported and collected as sociodemographic variables by using the questions of the European Social Survey (22). The education level of the participants was collected by using the question: "About how many years of education have you completed, whether full-time or part-time? The adapted answer options provided were: 1) up to 9 years, 2) 10-12 years, and 3) More than 12 years. The body mass index (BMI) was calculated using the formula: weight [kg] / height² [m²]. Cut-off values were defined following the WHO cut-offs: normal weight (18.5-24.9), overweight (25-29.9), obesity (30.0 and above) (23).

Seasonality

Data was collected at two different moments of the year. Moment 1 of data collection occurred between March 1st and May 15th (spring time). Moment 2 of data collection occurred several months later, between mid-October and mid-December (end of autumn/beginning of winter). Table 1 shows the weather by month in each country and climate classification.

Table 1. Weather by month in each country and climate classification (1991-2021).

Country	Season	Month	Average temperature (ºC)	Rainy days	Classification
Portugal (Lisbon)*	Spring	March	13.5	6	Hot-summer Mediterranean climate
		April	15.2	7	
	Autumn/Winter	Ocotober	18.7	7	
		November	14.6	8	
		December	12.3	7	
Croatia (Zagreb)	Spring	March	6.6	9	Warm humid continental climate
		April	11.8	11	
	Autumn/Winter	Ocotober	12	9	
		November	6.9	10	
		December	1.8	10	
Poland (Krakow)	Spring	March	3.5	12	Warm humid continental climate
		April	9.3	10	
	Autumn/Winter	Ocotober	9.7	9	
		November	5.1	10	

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		December	0.9	11	
Greece (Theassaloniki)	Spring	March	9.7	7	
		April	14.1	7	
	Autumn/Winter	Ocotober	16	5	Cold semi-arid climates
		November	10.9	6	
		December	5.5	6	

Notes: * nearest city from Grândola with available data; **source: https://en.climate-data.org, consulted on 14.6.2021

Data analysis

First, descriptive statistics were calculated for all variables under study (mean and percentages). For continuous variables, normality analysis was carried out using the Kolmogorov–Smirnov test and the homogeneity of variances using the Levene test. As this was a large sample, we invoked the central limit theorem in cases where some of the assumptions were violated. The relationship between physical activity intensity levels and time spent in sedentary behaviour (at the moment one and two) and gender, country, education level, and BMI was calculated using student t-tests and ANOVA. As there were some differences between the time spent in physical activity and sedentary behaviour in the two moments of data collection due to seasonality, we proceeded to calculate the difference between the two moments. We created a new variable that was the result of this difference. We then used this variable to see if there were differences according to gender, country, level of education and BMI, using student t-tests and ANOVA. For each of the moments, we intended to verify which sociodemographic characteristics most explained compliance with the recommendations for physical activity. For each moment, a binary logistic regression model was created. All analyses were performed using IBM SPSS 28.0, with a significance level of 0.05.

Results

The characteristics of the participants are shown in table 2. Most of the participants were women (68%), had more than 12 years of schooling (47.9%), were retired (91%), were overweight or obese (59.9%) and fulfilled the recommendations for physical activity both in spring (61.5%) and autumn/winter (50.9%).

Table 2. Sociodemographic and physical activity characteristics of the participants.

Variables	% OR M±SD
Age	72.2±6.0
Sex	
Male	32,0
Female	68,0
Country	
Croatia	24,9
Greece	21,3
Portugal	34,9
Poland	18,9
Education	
Up to 9 years	24,9
10-12 years	27,2
More than 12 years	47,9
Occupation	

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Employed	4,5
Retired	91,0
Doing housework	1,3
Other	2,6
BMI	26.7±3.8
BMI	
Normal weight	40,1
Overweight	44,3
Obese	15,6
Physical ativity guidelines	
Do not achieve_1	38,5
Achieve_1	61,5
Do not achieve_2	49.1
Achieve_2	50.9

Notes: Variables ending in "1" are referent to spring time; Variables ending in "2" are referent to autumn/winter time; M, mean; SD, standard deviation.

Tables 3a and 3b shows the relationship between sociodemographic characteristics with sedentary behaviour and different intensity levels of physical activity in spring and in autumn/winter. There were no differences between men and women in the time spent in sedentary behaviour or the different intensity levels of physical activity in the two moments of the year. As for countries, in spring and in autumn/winter, Poland was the country where participants spent significantly more time in sedentary behaviour compared to other countries. Only in the spring differences were noted in the average time spent in light physical activity, with Portugal being the country with the highest value (230.9 minutes, 95% CI: 213.4, 248.5). Regarding education, participants with higher levels of education spent significantly more time in sedentary behaviour both in spring (543.3, 95% CI: 528.0, 558.5) and in autumn/winter (583.1, 95% CI: 565.9, 600.3). BMI was not correlated with time spent in sedentary behaviour and physical activity in the summer. However, in winter, those who were obese practised significantly less moderate physical activity and moderate to vigorous physical activity.

Table 4a and 4b present the time variation in sedentary behaviour and physical activity in spring and autumn/winter. It was found that there are no differences in terms of sex and country. As for education, the less educated showed the greatest variation in moderate physical activity and moderate to vigorous physical activity. From spring to autumn/winter, there was a decrease in physical activity. When comparing participants concerning BMI, the obese showed the greatest change (decreased) in moderate physical activity and moderate to vigorous physical activity when compared to those who had normal weight or overweight.

Table 3a. Relationship between participant's sex and country with sedentary behaviour and different intensity levels of physical activity in spring and in autumn/winter (minutes day)

Variables	Sex			Country				
	Male	Female	p-value	Croatia	Greece	Portugal	Poland	p-value
Sedentary beahviour_1 (m/day)	517.4 (495.6, 539.2)	525.0 (511.3, 538.7)	0,546	**531.0 (509.1, 552.8)**	**507.7 (478.2, 537.1)**	**501.4 (482.4, 520.4)**	**567.5 (548.3, 586.8)**	**<0.001**

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Light PA_1 (m/day)	204.9 (192.1, 217.8)	214.0 (202.5, 225.4)	0,344	**215.0 (198.0, 231.9)**	**185.5 (170.6, 200.3)**	**230.9 (213.4, 248.5)**	**198.2 (183.2, 213.2)**	**<0.001**
Moderate PA_1 (m/day)	37.0 (28.3, 45.7)	31.4 (26.7, 36.1)	0,217	33.5 (26.9, 40.1)	33.5 (20.6, 46.3)	32.9 (25.6, 40.2)	32.9 (25.1, 40.7)	0,999
Vigorous PA_1 (m/day)	0.7 (0.0, 1.3)	0.3 (0.0, 0.6)	0,242	0.1 (0.0, 0.1)	1.0 (0.0, 2.1)	0.2 (0.0, 0.4)	0.6 (-0.4, 1.5)	0,090
Total MVPA_1 (m/day)	37.7 (28.6, 46.8)	31.7 (26.9, 36.5)	0,203	33.6 (27.0, 40.2)	34.5 (21.0, 48.0)	33.1 (25.8, 40.5)	33.4 (25.0, 41.9)	0,997
Sedentary behaviour_2 (m/day)	574.0 (551.8, 596.1)	558.5 (543.7, 573.2)	0,243	**560.5 (537.5, 583.5)**	**566.0 (537.0, 594.9)**	**545.1 (525.2, 565.1)**	**598.1 (568.8, 627.4)**	**0,026**
Light PA_2 (m/day)	203.2 (189.4, 216.9)	215.5 (204.7, 226.3)	0,184	213.8 (199.1, 228.5)	200.6 (179.9, 221.2)	220.8 (204.1, 237.4)	204.1 (188.2, 220.0)	0,310
Moderate PA_2 (m/day)	31.5 (24.1, 39.0)	28.1 (24.1, 32.2)	0,385	30.1 (23.7, 36.5)	27.2 (19.9, 34.5)	28.3 (21.0, 35.6)	32.0 (24.0, 39.9)	0,843
Vigorous PA_2 (m/day)	0.2 (0.0, 0.3)	0.2 (0.0, 0.4)	0,924	**0.1 (0.0, 0.1)**	**0.6 (0.0, 1.1)**	**0.1 (0.0, 0.3)**	**0.1 (0.0, 0.1)**	**0,024**
Total MVPA_2 (m/day)	31.7 (24.2, 39.2)	28.3 (24.2, 32.4)	0,390	30.2 (23.8, 36.6)	27.8 (20.2, 35.3)	28.4 (21.1, 35.7)	32.0 (24.1, 40.0)	0,875

Note: Variables ending in "_1" are referent to spring time; Variables ending in "_2" are referent to autumn/winter time; BMI, body mass index; MVPA moderate-to-vigorous physical activity; PA, physical activity; m/day, minutes per day.

Table 3b. Relationship between participant's education and BMI with sedentary behaviour and different intensity levels of physical activity in spring and in autumn/winter (minutes/day)

Variables	Education				BMI categories			
	≤ 9 years	10-12 years	> 12 years	p-value	Normal weight	Overweight	Obese	p-value
Sedentary beahviour_1 (m/day)	**488.3 (463.7, 512.8)**	**517.5 (495.5, 539.4)**	**543.3 (528.0, 558.5)**	**<0.001**	526.5 (508.5, 544.5)	524.3 (506.8, 541.8)	511.6 (478.2, 545.1)	0,691
Light PA_1 (m/day)	227.4 (206.9, 247.9)	213.3 (194.5, 232.1)	201.3 (190.8, 211.9)	0,056	203.9 (191.9, 216.0)	217.0 (203.3, 230.8)	206.5 (178.3, 234.7)	0,380
Moderate PA_1 (m/day)	39.0 (26.8, 51.3)	28.7 (22.0, 35.5)	32.7 (27.8, 37.6)	0,212	35.9 (29.8, 42.1)	31.1 (25.6, 36.7)	31.2 (14.5, 47.9)	0,554
Vigorous PA_1(m/day)	0.6 (0.0, 1.2)	0.1 (0.0, 0.2)	0.5 (0.0, 1.0)	0,382	0.6 (0.0, 1.3)	0.1 (0.1, 0.2)	0.7 (-0.2, 1.7)	0,186
Total MVPA_1 (m/day)	39.6 (26.9, 52.3)	28.8 (22.1, 35.6)	33.2 (28.1, 38.3)	0,205	36.5 (30.1, 42.9)	31.2 (25.7, 36.8)	31.9 (14.4, 49.5)	0,527
Sedentary behaviour_2 (m/day)	**536.7 (510.3, 563.1)**	**553.2 (531.5, 574.9)**	**583.1 (565.9, 600.3)**	**0,005**	559.5 (539.4, 579.6)	573.5 (554.5, 592.4)	547.9 (519.0, 576.7)	0,323
Light PA_2 (m/day)	216.4 (196.1, 236.8)	222.2 (206.2, 238.3)	203.0 (191.6, 214.4)	0,145	202.6 (189.6, 215.6)	213.2 (200.0, 226.4)	224.3 (200.8, 247.8)	0,214
Moderate PA_2 (m/day)	26.3 (17.5, 35.0)	32.3 (24.9, 39.6)	29.0 (24.4, 33.5)	0,494	**37.1 (30.1, 44.1)**	**25.9 (21.7, 30.1)**	**16.2 (11.3, 21.2)**	**<0.001**
Vigorous PA_2 (m/day)	0.2 (0.0, 0.4)	0.2 (0.0, 0.5)	0.2 (0.0, 0.4)	0,875	0.2 (0.0, 0.4)	0.2 (0.0, 0.4)	0.1 (0.0, 0.2)	0,829

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Total MVPA_2 (m/day)	26.4 (17.6, 35.2)	32.5 (25.1, 39.9)	29.2 (24.6, 33.8)	0,489	**37.3 (30.2, 44.3)**	**26.1 (21.9, 30.4)**	**16.3 (11.4, 21.3)**	**<0.001**

Note: Variables ending in "1" are referent to spring time; Variables ending in "2" are referent to autumn/winter time; BMI, body mass index; MVPA moderate-to-vigorous physical activity; PA, physical activity; m/day, minutes per day.

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Table 4a. Variation of sedentary behaviour and physical activity between spring and autumn/winter, by sex and country characteristics (minutes/day|)

	Sex			Country				
	Male	Female	p-value	Croatia	Greece	Portugal	Poland	p-value
Sedentary behaviour (m/day)	56.6 (35.5, 77.6)	33.5 (18.7, 48.2)	0,078	29.6 (12.5, 46.6)	58.3 (17.9, 98.7)	43.8 (26.3, 61.3)	30.6 (4.8, 56.4)	0,365
Light PA (m/day)	-1.7 (-15.9, 12.4)	1.6 (-7.4, 10.5)	0,686	-1.2 (-15.4, 13.1)	15.1 (-8.9, 39.1)	-10.1 (-19.9, -0.4)	5.9 (-8.8, 20.6)	0,096
Moderate PA (m/day)	-5.5 (-12.5, 1.5)	-3.3 (-7.9, 1.4)	0,596	-3.4 (-7.7, 0.9)	-6.2 (-21.9, 9.4)	-4.6 (-9.0, -0.3)	-0.9 (-7.0, 5.2)	0,850
Vigorous PA (m/day)	-0.5 (-1.2, 0.2)	-0.1 (-0.4, 0.2)	0,264	0.0 (0.0, 0.1)	-0.5 (-1.7, 0.7)	-0.1 (-0.3, 0.1)	-0.5 (-1.4, 0.5)	0,565
Total MVPA (m/day)	-6.0 (-13.3, 1.4)	-3.4 (-8.2, 1.5)	0,553	-3.4 (-7.7, 0.9)	-6.7 (-23.1, 9.7)	-4.7 (-9.1, -0.3)	-1.4 (-8.0, 5.2)	0,865

Note: PA, physical activity, MVPA moderate-to-vigorous physical activity; m/day, minutes per day.

Table 4b. Variation of sedentary behaviour and physical activity between spring and autumn/winter, by education and BMI categories (minutes/day)

	Education				BMI categories			
	≤ 9 years	10-12 years	> 12 years	p-value	Normal weight	Overweight	Obese	p-value
Sedentary behaviour (m/day)	48.4 (26.6, 70.3)	35.8 (12.0, 59.5)	39.8 (21.2, 58.5)	0,750	33.0 (14.2, 51.8)	49.2 (30.0, 68.3)	36.2 (4.3, 68.1)	0,468
Light PA (m/day)	-11.0 (-23.0, 1.1)	8.9 (-7.5, 25.4)	1.7 (-9.4, 12.8)	0,162	-1.3 (-13.2, 10.6)	-3.8 (-14.6, 6.9)	17.8 (-6.0, 41.6)	0,149
Moderate PA (m/day)	-12.8 (-24.3, -1.3)	3.6 (-2.8, 9.9)	-3.7 (-7.7, 0.3)	**0,010**	1.2 (-3.8, 6.2)	-5.2 (-10.0, -0.4)	-15.0 (-31.8, 1.9)	**0,020**
Vigorous PA (m/day)	-0.4 (-1.0, 0.2)	0.2 (-0.2, 0.5)	-0.3 (-0.9, 0.2)	0,340	-0.4 (-1.1, 0.3)	0.1 (-0.1, 0.3)	-0.6 (-1.6, 0.3)	0,182
Total MVPA (m/day)	-13.2 (-25.2, -1.2)	3.7 (-2.8, 10.2)	-4.0 (-8.2, 0.2)	**0,011**	0.8 (-4.6, 6.1)	-5.1 (-10.0, -0.2)	-15.6 (-33.3, 2.1)	**0,026**

Note: BMI, body mass index; MVPA moderate-to-vigorous physical activity; PA, physical activity; m/day, minutes per day.

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Table 5 shows the sociodemographic factors that explain compliance with physical activity recommendations. In summer (OR = 0.92, 95% CI: 0.86, 0.97) and winter (OR = 0.91, 95% CI: 0.86, 0.97), age was negatively associated with compliance with physical activity recommendations. Similarly, also in summer (OR = 0.90, 95% CI: 0.82, 0.99) and winter (OR = 0.84, 95% CI: 0.75, 0.93), BMI was inversely associated with compliance with the physical activity recommendations.

Table 5. Comparison of the sample between the two assessment moments

	Spring (moment 1) OR (95% CI)	p-value	Autumn/Winter (moment 2) OR (95% CI)	p-value
Age	0.92 (0.86, 0.97)	**0,004**	0.91 (0.86, 0.97)	**0,003**
Sex				
Male	1.00 (ref.)		1.00 (ref.)	
Female	0.69 (0.32, 1.51)	0,357	0.77 (0.36, 1.65)	0,504
Country				
Croatia	1.00 (ref.)		1.00 (ref.)	
Greece	0.38 (0.13, 1.11)	0,078	0.43 (0.15, 1.23)	1,116
Portugal	0.53 (0.19, 1.50)	0,232	0.64 (0.23, 1.79)	0,390
Poland	0.54 (0.18, 1.66)	0,282	0.94 (0.32, 2.73)	0,911
Education				
≤ 9 years	1.00 (ref.)		1.00 (ref.)	
10-12 years	0.37 (0.13, 1.08)	0,069	1.36 (0.47, 3.94)	0,571
> 12 years	0.81 (0.29, 2.30)	0,692	0.69 (0.24, 1.99)	0,498
BMI	0.90 (0.82, 0.99)	**0,037**	0.84 (0.75, 0.93)	**<0.001**

Note: BMI, body mass index. CI, confidence intervals.

Discussion

The present study analysed the impat of seasonality on objective physical activity and sedentary behaviour, and explored how the potential sociodemographic factors related to sex, education level, BMI and country may affect this relationship. Overall, it was found that more than half of the older adults in the present study meet the physical activity guidelines, with age and BMI being significantly and inversely related to this outcome. Sedentary beahviour, light PA and vigorous PA did not varied from spring to autumn/winter, regardless of sex, age, BMI or country. A significant decline between seasons was identified for moderate and moderate-to-vigorous physical activity but only for those with lower education levels and with obesity. No changes were found in these PA intensity levels based on sex or country.

Physical activity is important for a healthy aging and has many psgyical, mental and social benefits for older adults (1). Epidemioligcal studies estimate that, worldwide, among adult and older adults populations about 70% meet the physical activity guidelines, and that physical activity is normally lower in older age groups and among women (24, 25) . Most of this conclusions, however, tend to be made using self-reported data of national representative samples, which differs from out methodology. Sun et al. (26), conducted a systematic review, where he analysed the physical activty in older people either by using self-reported or objective measurements. The authors conclude that the percentage of older adults meeting the physical activity guidelines ranged from 2.4% to 83.0%. If we look only it those studies that used objective data for measuring PA, such as in our study, the range across studies goes from 1.8 % (in a study conducted in UK, France and Italy), to 87% in Sweeden. In Portugal, a study that used a representative sample of the population, analysed the physical activity levels with acellerometers and found that 35% of those aged older than 64 yr (men = 46%, women = 29%) reached the PA recommendation 30 min/day. The differences in the

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methods to collect data (self-reported; objective; criteria used to transform the data), the population characteristics (age, health status), the country, moments of data colletion, make it diffuclt to do direct comparisons across studies (27). However, by using objective measures, we found that the older people involved in this study were classified mainly has physically active, regardless of their sex and country, which is a positive indicator.

Several studies have explored the correlates of physical activity among the population (25, 28). For the older adults population, Sallis et al. (28) concluded that the evidence of positive associations of younger age and male sex with higher physical activity is mixed. In our study, we had tdifferent results from the literature by stating that in spring and in autumn/winter, there were no difereences in physical activity at any intensity based on sex, which is a positive finding. Importantly, BMI was inversely related to moderate intensity physical activity and moderate-to-vigorous physical activity, specially in autumn/winter. This means that individuals with worst body compostion are a group at risk for reducing their moderate intensity and moderate-to-vigorous physical activity during this moments of the year, and most be considered for interventions. Given the additional challlenges posed by the winter (reduced day light; slippery surfaces; rain; etc), promoting indoor activities for this group might be needed and of value, since they are the ones who might benefit the most for the physical activity increase in terms of healthy aging. Indeed, almost 60% of our older adult participants had overwight or obesity, which is of concern since they tend to do less physical activity (25, 29), and face many other health and social consequences.

At the country level, the participants from Poland presented the higher levels of sedentary behaviour, either in spring and in autumn/winter. The Polish sample of older adults spent almost 10 hours per day of their waking time in sedentary behaviour. Among the countries, involved in the study, in the autumn/winter Poland present the most challenging conditions (cold, snow, daylight, etc). This finding is of concern because exposure to high amounts of sedentary behaviour significantly increases the risk of all-cause mortality, cardiovascular disease, type 2 diabetes and other health conditions (30). Despite being lower, the older adults of other countries also presented concerning levels of sedentary behaviour, all above 8 hours per day. From a practical point of view, it is important to have programs in order to help older people to reduce the time they spent in sedentary bahviour and increase their light intensity physical activity by moving more. The WHO (31) recommendation that every movement counts and that it is important to limit the amount of time spent being sedentary should be emphaised and promoted near the population. Furthemore, it should be highlighted that replacing sedentary beahviour by light intensity physical activity performed in daily routines (e.g. walk around, climb stairs) can benefit their health, as well as activities done in other intensities, based on the individual capability (31). In the present study, the individuals with a higher educational level presented more time in sedentary behaviour in spring and autumn/winter. This findig suggests that among the older people, special attention most be given to those with higher educational levels. We can especultate that this might be because this group have additional acess and make use of technologies, as well as literacy and digital literacy, and might do less house related labour work.

Regarding the impact of seasonality on physical activity and sedentary behaviour, contrary to the main findings in the literature (19), no variations have been between spring and autumn/winter on sedentary beahviour, light physical activity and vigorous physical activity. Most studies that used accelerometers or other objective measures for similar outcomes, tend to focus on the differences between spring/summer and winter. The physical activity levels tend to be higher in spring or summer and lower on winter (19, 32). For example, seasonality impacted physical activity variation in studies conducted in Japan, UK and US (26). A similar finding emerged in a study conducted in Poland (33), but in a population with spinal cord injury. Despite this is a trend, in the literature there are also several examples of studies conducted in European contex where the physical activity and/or sedentary behaviour did not varied with seasonality(34, 35) (. Again, direct comparisons across studies are difficult because the charcteristics of the seasonality, of the sample (e.g. older adults

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with who had heart failure; etc), and methods of data collection and process are rather distinct. Indeed, the reduction of vigorous physical activity was not expected since the values are residual in both moments.

In our study, however, variations were only found for moderate intensity physical activity and moderate to vigorous physical activity among the lower educational group and those with higher BMI. If we have addressed the potential explatations for those with higher BMI, we can speculate that the other group with lower education level, during the spiring, can often be outdoors doing more home or labour-reated work. When imposed with the different condititons due to seasonality, this group might have been forced to redcue significantly their moderate physical activity levels. An education campaign targeting this group, has the whole population, about the diverse opportunities to be and keep being active during winter, when the outdoor conditions are challenging, might be important to promote an healthy lifestyle and aging.

The present work has some limitaions and strengths. As stregnths we highlight: (1) the use of a large sample of older adults from four European countries, that are not usually represented in the literature concerning this specifc theme; (2) the use of a piloted and standard methodology to collect objective physical activity and sedentary behaviour data, allowing valid and reliable assessments regarding duration, frequency and intensity; (3) the innovative approach to explore the association of seasonality with diverse physical activity intensity levels and sedentary behaviour, in addition to physical activity prevalence; (4) the focus on less often studies seasons by focusin on spring and in the transition of autumn to witner. As for the limitations, we identify: (1) the samples were not representative and, therefore, the generalization of this findings are limited; (2) the removal of the samples from the Italy (did not reach 30 participants with valida data in two moments) and Turkey (data and partners coleagues were affected by the 2023 earthquakes); (3) lost of participants between both moments was controlled but occurred; (4) The collection of objective seasonality indicators exactly in the weeks where the data collection occurred in each country could help to strengthen the discussion.

Conclusion

Most older adults from the four countries involved in this study met the physical activity guidelines to benefit their health either in spring and autumn/winter. Older people with higher age and obesity should be targeted interventions for increasing physical activity. No variations were found across seasons for sedentary behaviour, light and vigorous intensities physical activity. The prevetion of decline in moderate physical activity from spring to autumn/winter most be considered in programs to promote healthy aging, specially anong those with higher BMI and less educational levels.

Author’s contribution

Conceptualization, João Martins, Houshmand Masoum, Melika Mehriar and Marija Rakovac; Data curation, Vânia Brandão-Loureiro, Margarida Gomes, Melika Mehriar and Marta Tomczyk; Funding acquisition, Houshmand Masoum; Methodology, João Martins, Houshmand Masoum, Vânia Brandão-Loureiro, Margarida Gomes, Fortunata Ratinho, Melika Mehriar, Marija Rakovac, Davor Sentija, Andrzej Bahr, Marta Tomczyk, Maria Pirina, Giannangelo Boccuzzi, Birol Çağan, Ahmet Dal, Athanasios Papageorgiou, Soultana Smaga, Georgios Parisopoulos, Georgios Patsaka, Ioannis Meimaridis and Nuno Loureiro; Project administration, Melika Mehriar; Supervision, Houshmand Masoum; Writing – original draft, João Martins and Tiago Ribeiro; Writing – review & editing, Vânia Brandão-Loureiro, Margarida Gomes, Fortunata Ratinho, Tiago Ribeiro, Melika Mehriar, Marija Rakovac, Davor Sentija, Andrzej Bahr, Marta Tomczyk, Wojciech Dynowski, Roberto Solinas, Donatella Coradduzza, Maria Pirina, Giannangelo Boccuzzi, Birol Çağan, Ahmet Dal, Athanasios Papageorgiou, Soultana Smaga, Georgios Parisopoulos, Georgios Patsaka, Ioannis Meimaridis and Nuno Loureiro.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Faculty of Human Kinetics (nº22/2021) for studies involving humans.

Informed Consent Statement

Any research article describing a study involving humans should contain this statement. Please add "Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

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