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Women have the power: When motor efficiency makes the difference in older individuals of the sardinian blue zone

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ABSTRACT

This study was mainly aimed at exploring the effect of gender on the patterns of Physical Activty (PA) in older people living in an area of exceptional longevity, the so-called Sardinian Blue Zone. Furthermore, the study intended to investigate the nature of the relationships among PA metrics, cognitive measures, and age. One hundred and nine community-dwelling participants (M_{age} = 81.7 years old, SD = 8.1 years) completed a battery of cognitive tests (i.e., Mini-Mental State Examination and Trail Making Test) and were provided a wearable accelerometer to collect data for 7 consecutive days about amount and intensity of the performed PA on a daily basis. A series of Analyses of Covariance was conducted to examine the impact of gender on PA variables, whereas the global cognitive functioning measure was used as a covariate. Thus, it was found that women outperformed men in terms of a more active lifestyle, as indicated by the significantly reduced sedentary behavior and increased percentage of time spent in PA of moderate to vigorous intensity (MVPA). Moreover, significant associations were found among age, PA, and cognitive measures. Finally, global cognitive functioning was significantly associated with MVPA and overall accelerometric counts, as well as significant relationships were found between time spent in sedentary behavior and MVPA, accelerometric counts, speed of processing, and cognitive flexibility, respectively. Overall, these outcomes suggest that older individuals, especially women, exhibiting more preserved cognitive efficiency also reported superior levels of PA. Therefore, the promotion of a more active lifestyle is essential to achieve better functional and cognitive health in late adulthood.

1. Introduction

Although the continuous increase in life expectancy can be seen as an important achievement indicative of superior levels of well-being and improved conditions in the environment where human beings live, it also poses major challenges in terms of public health management. In fact, it is crucial that late adulthood, which is characterized by an unavoidable decline in most physiologic and cognitive functions, takes place in the best possible conditions, that is, preventing the occurrence of chronic diseases and physical disability while, at the same time, ensuring optimal social engagement and mental health [1]. In this context, a large body of literature highlights the pivotal role of physical activity (PA) as one of the most important determinants of successful aging. Indeed, practicing regular PA not only is safe for both healthy and frail older people but also reduces the risk of developing major cardiovascular and metabolic diseases, counteract sarcopenia by increasing muscular strength (thus ensuring independence in mobility and activities of daily living, ADL) and exerts a protective effect against cognitive impairment and neurodegenerative diseases [2,3].

Thus, it appears of interest to examine the influence of PA profiles among older people exhibiting optimal aging trajectories, like those living in the so-called Blue Zones (BZ). These are geographical areas that share the common feature of extreme longevity of its inhabitants and that have been located in the central-eastern part of Sardinia (Italy), peninsula of Nicoya (Costa Rica), Okinawa (Japan), and Ikaria (Greece) [4] A stream of research documented that physical health and perceived psychological well-being are significant determinants which contribute to the successful aging of older people living in the BZ (e.g., [5–8]). However, it must be noted that there is a scarcity of objectively assessed data on the amount and intensity of PA performed by older women and men living in the BZ. Thus far, studies have mainly been conducted by collecting data through the administration of self-report measures, which, in turn, are known to be prone to recall bias with poor reliability and validity [9]. Indeed, to our knowledge, the few studies that reported

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data obtained by objective instrumental measures performed using wearable inertial sensors have been conducted in the Sardinian BZ. They have documented that older individuals living in that area exhibited an active lifestyle, such that PA of moderate-to-vigorous intensity (i.e., those graded with a Metabolic Equivalent of Task MET in the range 3-6) and number of daily steps predicted self-reported depressive symptoms, while cognitive reserve mediated between them [10]. A further investigation showed that the average number of daily steps calculated for a sample of older people of the Sardinian BZ was a significant mediator in the relationship between cognitive reserve (assessed through a self-reported questionnaire) and global cognitive functioning (objectively assessed through the Mini-Mental State Examination by [11]) [12]. Extending this, the unique longitudinal study of which we are aware [13] revealed that perceived psychological well-being was associated with performance in a basic motor task like gait assessed by objectively measured speed, stride length, and cadence through a miniaturized inertial sensor located in the low-back. In addition, this investigation revealed that 2 years after the first assessment, older individuals reporting more cognitive complaints were also those characterized by a significant decline in gait performance. According to Pes et al. [14], the regular PA performed by older people living in the Sardinian BZ and the peculiar features of the environment (frequent walking for work or social activities in terrains characterized by steep and uneven surfaces.) seem responsible for the prolonged maintenance of adequate cardiovascular functioning.

Overall, the current investigation intended to shed light on the characteristics of PA profiles for optimal aging. Specifically, the main goal of this study was to explore the impact of gender on a series of PA metrics. These measures were calculated based on body accelerations which were collected through a clinically validated wearable accelerometer on a sample of older individuals living in the Sardinian BZ. In addition, this investigation intended to examine the nature of the relationships among the PA variables, age, global cognitive efficiency, speed of processing, and cognitive flexibility.

Bearing in mind that this is an exploratory study, the following hypotheses have been proposed:

1) men and women exhibit different patterns of PA [15,16];
2) significant associations were expected between objectively assessed global cognitive functioning and several motor parameters (e.g., [12, 17]);
3) age was expected to be negatively associated both with motor and cognitive efficiency (e.g., [18–21]).

2. Method

2.1. Participants

One hundred and nine 65-100-year-old individuals living in the Sardinian BZ (Italy), 61 females and 48 males, took voluntary part in this study. To be recruited, the following criteria had to be satisfied: (1) participants had not to exhibit severe signs of cognitive decline, that is, they had to report a score $\geq$ 20/30 on the Mini-Mental State Examination (MMSE, [11]); (2) participants had to be community-dwellers, therefore they had to reside in their home and not being institutionalized; (3) in line with previous studies (e.g., [13]) participants had to be born in the Sardinian BZ and to be a descendant of people living in those areas for at least two previous generations; (4) participants had to be functional healthy, that is, they were not affected by neurologic or musculoskeletal condition able to severely affect basic motor functions (i.e., postural control and gait). Gender was equally distributed across participants (χ^2= 1.55, df= 1, p= .213).

2.2. Materials

Each participant was asked to complete the following tasks:

The MMSE [11] was used to evaluate global cognitive functioning, since it encompasses different tasks assessing distinct cognitive processes, such as spatiotemporal orientation, short-term memory, and long-term memory (maximum total score= 30). As suggested by Magni et al. [19], scores were adjusted for years of education and age (maximum score= 30). A score < 20 was used to identify participants with suspected cognitive decline.

Part A of the Trail Making Test (TMT-A, [22]) was designed to evaluate the speed of processing, number sequencing, and visual scanning skills. Specifically, to perform this task, participants had to connect 25 encircled numbers located in a scattered fashion on a white sheet, as fast as possible. The time (i.e., total number of seconds) necessary to perform this task was used as the dependent measure.

In addition, Part B of the Trail Making Test [22] was proposed as a measure of cognitive flexibility. To carry out this task, the examinee had to track a line to connect a series of numbers and letters in consecutive order as fast as possible, starting with the number 1, then switching to the letter A, then connecting A with the number 2, and so on. The final score was the result of the subtraction of the time necessary to execute the task Part A from the time necessary to perform Part B (i.e., TMT-B-A).

Moreover, patterns of PA were objectively assessed for 7 consecutive days using a clinically validated accelerometer (Actigraph GT3X, Actigraph Co., USA) previously employed in similar studies on older adults [15,23]. Participants were asked to wear the device on their non-dominant wrists 24 h/day and to perform their usual daily activities removing it only for personal hygiene or other water-based activities. At the end of the monitoring period, the raw data (i.e., three-axial accelerations collected in 60 s epochs at 30 Hz frequency) were processed using the dedicated software provided by the manufacturer (Actilife v6.13.3 Acticorp Co., USA). In particular, the following metrics were considered:

- Accelerometric counts per minute (CPM), based on the Vector Magnitude (VM, square root of the sum of the squared accelerations in the x, y, and z axes);
- Percentage of time spent while performing PA of different intensity. To this aim, data was segmented into three classes which were defined according to the associated value of metabolic equivalent (MET) as follows: sedentary behavior (SB, 0–1.5 MET), light intensity PA (LPA, 1.5–3 MET) and moderate-to-vigorous PA (MVPA, 3-6 MET). Such classification was performed by using the cut points for accelerometric counts proposed by Migueles et al. [24]. A certain day was considered valid (and thus included in the results) only if the wear time was at least 16 h.

2.3. Procedure

Written informed consent was mandatory to take part in the study and had to be provided before the start of the experimental session. First, participants had to individually complete the MMSE and Trail Making Test (i.e., both Part A and Part B) in a quiet room of their house. After that, each respondent was invited to wear the accelerometer. After one week, the examiner recontacted the examinee to collect the device, download the raw accelerometric data on a PC, and process them as previously described.

2.4. Statistics

The data were analyzed using IBM SPSS Statistics version 24 (SPSS Inc., Chicago, IL, USA) a. Statistical significance was set to p-values < .05. Descriptive statistical analyses were carried out to shed light on the characteristics (e.g., age, marital status, educational attainment) of the participants. A series of Analyses of the Covariance (ANCOVAs) was conducted to examine the impact of gender on the PA parameters,

whereas the global cognitive functioning evaluated through the MMSE was used as the covariate. Furthermore, Pearson product-moment correlations were calculated to examine the nature of the associations between cognitive and motor measures.

3. Results

First, response distributions relative to the cognitive and PA measures were examined to verify whether normality was achieved, and if necessary, data were transformed (e.g., log transformation) to achieve normality. Then, the descriptive statistics summarizing the socio-demographic characteristics of the examinees were performed. These findings are reported below in Table 1.

In addition, a series of ANCOVAs was carried out to test the impact of gender on the PA metrics, whereas the effect of the MMSE score was controlled for. The main effect of gender was found as regards the percentage of time spent in SB [$F(1,106)= 11.805$, $p= .001$, $\eta^2= .10$], LPA [$F(1,106)= 10.443$, $p= .002$, $\eta^2= .09$] and MVPA [$F(1,106)= 7.341$, $p= .008$, $\eta^2= .06$] as well in terms of VM [$F(1,106)= 10.042$, $p= .002$, $\eta^2= .09$] and VM-CPM [$F(1,106)= 13.365$, $p < .0001$, $\eta^2= .11$] ones. The significant effect of the covariate was found only when the MVPA [$F(1,106)= 4.93$, $p= .029$, $\eta^2= .04$] and VM-CPM [$F(1,106)= 4.837$, $p= .03$, $\eta^2= .04$] were evaluated. In contrast, the impact of the MMSE score was not found when VM [$F(1,106)= 3.597$, $p= .06$], SB [$F(1,106)= 3.709$, $p= .06$], and LPA [$F(1,106)= 1.936$, $p= .17$] were assessed. Overall, women exhibited a PA pattern indicative of a more active lifestyle than men. That is, the PA of women was mainly characterized by a significantly reduced percentage of time spent in SB (71.4 % vs. 78.4 %, $p= .001$) and a higher engagement in MVPA (6.3 % vs. 4.0 %, $p= .008$). Table 2 summarizes the values of the PA metrics exhibited by both groups, while Fig. 1 reports the hourly trend for the VM-CPM.

Finally, Pearson's product-moment correlation indexes were calculated between motor and cognitive measures. Table 3 illustrates these outcomes.

4. Discussion

The main purpose of the present study was to explore the role played by gender on a series of objectively assessed PA metrics examined in a sample of older participants living in the Sardinian BZ. A further goal was to investigate the nature of the associations among the PA variables, age, and some cognitive measures (i.e., global cognitive functioning, cognitive flexibility, and speed of processing). To the best of our knowledge, this is the first study in which PA patterns are examined in older men and women residing in areas characterized by the extreme longevity of its inhabitants, such as the Sardinian BZ. Moreover, the current investigation is one of the few in which PA was assessed through objective measures since, to date, studies conducted in the BZs mainly evaluated the lifestyle of their older inhabitants through diaries and recall questionnaires (e.g., for a review, see [25]).

Overall, current findings extend previous evidence on the factors contributing to the successful aging of the older population. Indeed, relative to the first goal, the obtained data clearly indicate that men and women living in the Sardinian BZ exhibit different patterns of PA. In particular, the significant differences found in the average daily accelerometric counts (i.e., a metric employed as a proxy for the total volume of PA regardless of its intensity, [26,27]) suggest that generally speaking, women are characterized by a more active lifestyle in comparison with men. Looking more in detail at the PA segmentation in terms of different intensities, our results indicate that women are characterized by reduced SB and an increased percentage of time spent in LPA and MVPA. In this regard, the findings here presented are substantially consistent with those of several previous studies performed across Europe [15,23,26,28,29], United Kingdom [30], USA [31], and Japan [32] on individuals of similar age using wearable accelerometers. Of particular interest appears the fact that women are indeed much more engaged in PA of moderate to vigorous intensity than men (+60%). These findings are consistent with previous studies reporting that older adults who perform satisfactory levels of MVPA are likely to exhibit better performances in muscular strength, gait, and functional mobility [33–35] and, as such, they are at lower risk of disability.

The sex-related differences in PA patterns have been usually explained by sociocultural factors, drawbacks in the PA assessment (i.e., inability to correctly estimate the intensity of activities mostly performed by men or women), and an underestimation of the actual impact of certain daily activities (such as household activities, grocery shopping, children care, etc.) in which women are typically more engaged than men. In the case of the present study, it is necessary to consider the specific socioeconomic features of the Sardinian BZ, which is mostly composed of small rural villages whose economic activities are mainly farming, shepherd work, and agriculture [7,36]. Such activities are typically managed by men while women, mostly for cultural reasons, are more engaged in household activities (eg, food preparation, housework, garden maintenance, etc.) which, in turn, are performed, for the entire life as long as physical and cognitive performance allows it. Thus, once systematic working activities of men cease, the leisure/hobby activities that replace job engagement determine a reduced physical effort. In contrast, women substantially keep unaltered their daily routine and the associated PA patterns.

The present study also sheds light on the relationship among age, PA patterns, and some cognitive functions in older individuals aging well like those of the Sardinian BZ. Indeed, following Cohen [37] and consistent with previous evidence (e.g., [20,21]), large significant positive associations were found between age and time spent completing Part A and Part B of the Trail Making test. That is, advanced age was associated with a reduction in the speed of processing and cognitive flexibility of the participants. Similarly, as expected [19], a moderate negative relationship was found between age and the MMSE score, suggesting the detrimental effect of aging on the global cognitive functioning of older individuals. Moreover, in line with previous findings (e.g., [17]), low to moderate significant associations were found between the intensity of the performed PA (in particular SB and MVPA) and the efficiency of the speed of processing and shifting functions. This evidence implies that those who were more sedentary were also less prone

Table 1
Socio-demographic information relative to the sample of older individuals enrolled for the current study. M refers to the mean score, whereas SD denotes standard deviation scores. MMSE indicated the Mini-Mental State Examination score.

		χ^2	df	p
n	109			
gender		1.55	1	0.213
Men	48			
women	61			
age range (years)	65-100			
Age (years)	M= 81.7 (SD= 8.1)			
MMSE (corrected)	M= 25.9 (SD= 2.06)			
MMSE (range)	20-30			
Education (years of formal schooling)	M= 6.3 (SD= 3.8)			
Marital Status		2.064	1	0.151
Single or Widowed	47			
Married	62			
Reading		0.743	1	0.389
YES	50			
NO	59			
Gardening		0.083	1	0.774
YES	56			
NO	53			

Table 2
Means (i.e., M), Standard Deviations (i.e., SD) of the physical activity metrics derived on the basis of the accelerations recorded by the Actigraph (i.e., SB, sedentary behavior, LPA light intensity physical activity, MVPA moderate-to-vigorous physical activity, VM Vector Magnitude, VM-CPM, Vector Magnitude Counts per Minute).

Variable	Women group		Men group			η^2
	M	*SD*	*M*	*SD*	p	
SB	0.714421	0.113	0.784606	0.099	.001	0.10
LPA	0.222387	0.076	0.175652	0.074	.002	0.09
MVPA	0.063497	0.052	0.039748	0.035	.008	0.06
VM	13664044.86	6928819.97	9806100.08	5616182.92	.002	0.09
VM-CPM	1652.601	616.94	1256.03	507.793	<.0001	0.11

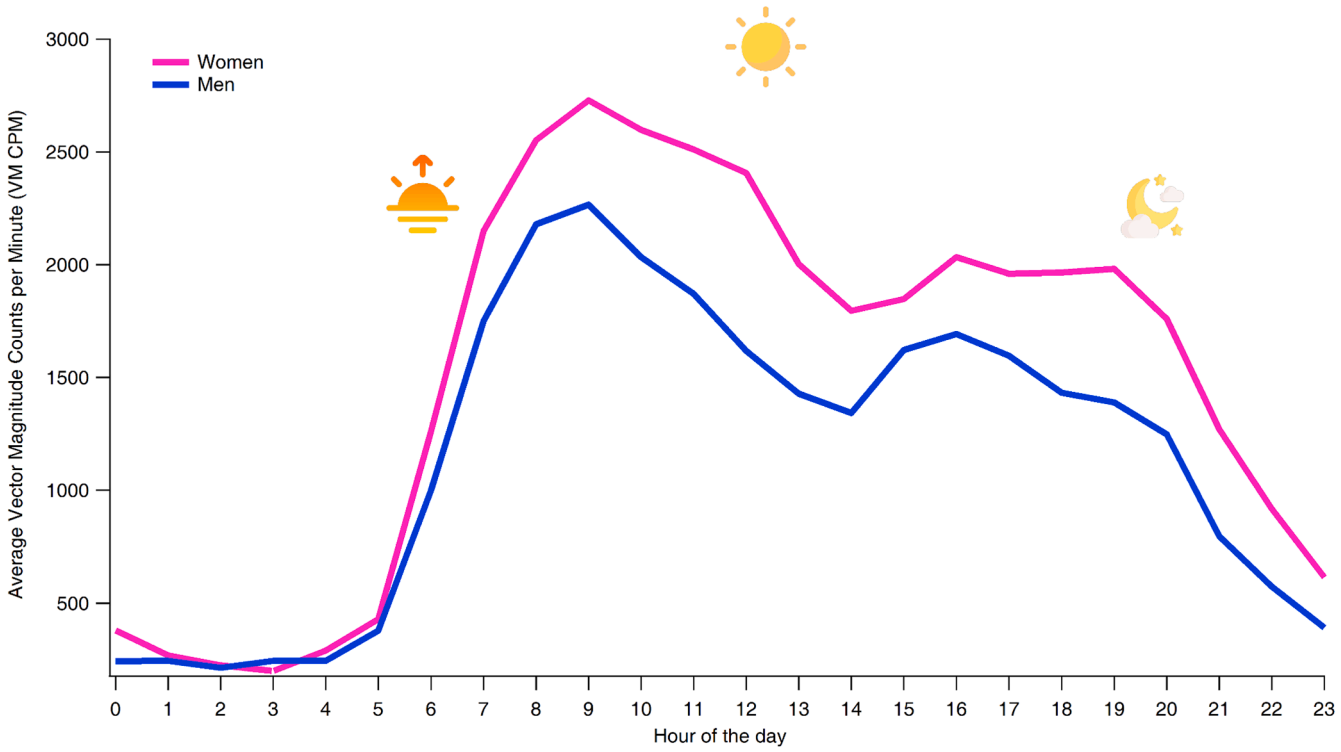

Fig. 1. Hourly trend of VM-CPM for men and women. Data represent the mean value across 7 consecutive days of observation.

Table 3
Pearson's correlations calculated among PA parameters, Mini-Mental State Examination (i.e., MMSE), speed of processing (i.e., Part A of the Trail Making Test, that is, TMT-A), and cognitive flexibility (i.e., Part B-Part A of the Trail Making Test, that is, TMT-B-A) measures.

	1		2		3		4		5		6		7		8		9
1. Age	—																
2. SB	0.323	***	—														
3. LPA	-0.195	*	-0.940	***	—												
4. MVPA	-0.448	***	-0.821	***	0.576	***	—										
5. VM	-0.352	***	-0.798	***	0.665	***	0.795	***	—								
6. VM-CPM	-0.352	***	-0.970	***	0.854	***	0.890	***	0.841	***	—						
7. MMSE	-0.314	***	-0.170		0.127		0.193	*	0.163		0.191	*	—				
8. TMT-A	0.652	***	0.213	*	-0.101		-0.346	***	-0.241	*	-0.228	*	-0.404	***	—		
9. TMT-B-A	0.623	***	0.265	**	-0.168		-0.359	***	-0.267	**	-0.273	**	-0.127		0.567	***	—

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$

to be fast in processing stimuli and were less flexible in managing their daily tasks and difficulties, exhibiting a more rigid modality of thinking. Altogether, as already pointed out elsewhere [38], the associations between PA measures and cognitive functions of our participants reflect the fact that the brain regions engaged in higher-order cognitive processes (e.g., prefrontal cortex, hippocampus) are also involved in performing basic motor tasks such as balance and walking (e.g., [39]). On the other hand, it is noteworthy that the overall cognitive state, as assessed by the MMSE score, was found significantly correlated only with the percentage of time spent in MVPA, but not SB or LPA. This was not surprising as also previous studies typically observed a stronger link between cognitive performance and daily time spent in MVPA, while this was not true when considering lower intensity PA or even the overall amunt of performed PA regardless its intensity [40-43]. Although this phenomenon has not been fully explained yet, it has been hypothesized that PA of higher intensity increases cardiac output, thus positively affecting cerebral perfusion, which is one of the mechanisms suggested to be essential for preserving cognitive function [44,45].

In summary, following Baltes and Baltes [46], it seems plausible to assume that the maintenance of an active lifestyle in the Sardinian BZ prolongs the optimal motor and cognitive functioning of its inhabitants. This speculation is consistent with previous studies which pointed out that cognitively healthy older people living in the BZs are regularly engaged in PA of moderate intensity (e.g., walking, gardening), and are relatively independent in managing their daily activities [6–8,47]. From an applied perspective the current evidence is quite crucial for the independence of older people in daily life since there is evidence that executive functioning mediates between a measure of muscular strength (i.e., evaluated in terms of hand-grip strength) and ADLs skills in late adulthood [48]. In line with this, it has also been found that muscular strength, functional mobility, and global cognitive function predict problem-focused coping in late adulthood [49], an ability that is essential to face age-related functional and cognitive changes characterizing the last decades of life.

Finally, it is necessary to discuss some research limitations. The paucity of psychological tools administered to evaluate cognitive efficiency, the sample size, the characteristics of the participants (e.g., being community-dwellers, living in a BZ), and the lack of longitudinal data limit the generalizability of the current findings. Therefore, future research should overcome the limit of the current investigation, involving wider samples of participants recruited in further BZs and elsewhere. Moreover, individuals should be longitudinally tested in terms of motor and cognitive functions (e.g., assessing further executive functions such as planning, updating, and inhibition, and proficiency in specific motor tasks associated with ADL, to appreciate the developmental changes associated with their aging.

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Research ethics and research participant consent

The study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. The protocol used in the current study was approved by the Ethics Committee of the research institution. Written informed consent was given by all participants prior to participation.

CRediT authorship contribution statement

Massimiliano Pau: Writing – original draft, Methodology, Conceptualization. **Benedetta Brandas:** Investigation, Data curation. **Maria Chiara Fastame:** Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors report there are no competing interests to declare.

Data availability

The data that has been used is confidential.

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