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Gait speed in older adults: exploring the impact of functional, physical and social factors
Velocidad de la marcha en adultos mayores: explorando el impacto de factores funcionales, físicos y sociales

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Abstract. Purpose: With age there is a neuromuscular and cognitive decline that impacts on functional ability. One of the most characteristic and easily recognisable signs of this decline is a decrease in usual gait speed. For older adults, gait speed is a non-invasive indicator of health and functional status and is regarded as a vital sign. As it predicts various conditions later in life, measuring usual walking speed is crucial in the clinical setting. Therefore, analysing and determining the association between walking speed and the impact of functional and socio-economic variables may facilitate the prevention of associated health problems and the maintenance of physical function in older adults. This study aims to identify the key factors that influence walking speed in older adults, as well as to examine the influence of socio-economic status on walking speed. Methods: A total of 1253 older adults (89.5% women) with a mean age of 78.1 ± 5.8 voluntarily participated in this descriptive cross-sectional study, which examines the results of functional capacity tests and socioeconomic data in older adults. To assess physical function, SPPB tests (chair stand test, balance tests, gait speed test), manual grip strength, muscle quality index, and power were conducted, in addition to measuring body composition and socioeconomic status. Results: The final regression model showed that gait speed was significantly partially explained ($R^2=0.35$; $p<0.01$) by the socioeconomic environment, age, balance, and relative power. At the same time, belonging to a higher socio-economic environment is linked to lower relative power ($p<0.01$; $\eta 2=0.07$). Conclusions: Exploring the factors that affect walking speed in older adults, this study highlights that age, relative power and balance are significant determinants. These clinical markers provide crucial information for designing personalized and effective interventions to promote healthy aging.
Keywords: Frailty, gait speed, elderly, relative power, socioeconomic status.

Resumen. Objetivo: Con la edad, se produce un deterioro neuromuscular y cognitivo que afecta la capacidad funcional. Uno de los signos más característicos y fácilmente reconocibles de este deterioro es la disminución de la velocidad de marcha habitual. En los adultos mayores, la velocidad de la marcha es un indicador no invasivo del estado de salud y funcional, y se considera un signo vital. Dado que predice diversas condiciones en etapas posteriores de la vida, medir la velocidad de marcha habitual es crucial en el ámbito clínico. Por lo tanto, analizar y determinar la asociación entre la velocidad de la marcha y el impacto de las variables funcionales y socioeconómicas puede facilitar la prevención de problemas de salud asociados y el mantenimiento de la función física en los adultos mayores. Este estudio tiene como objetivo identificar los factores clave que influyen en la velocidad de marcha en adultos mayores, así como examinar la influencia del estado socioeconómico sobre la velocidad de marcha. Métodos: Un total de 1,253 adultos mayores (89.5% mujeres) con una edad media de 78.1 ± 5.8 años participaron voluntariamente en este estudio transversal descriptivo, que examina los resultados de pruebas de capacidad funcional y datos socioeconómicos en adultos mayores. Para evaluar la función física, se realizaron pruebas SPPB (prueba de levantarse de la silla, pruebas de equilibrio, prueba de velocidad de la marcha), fuerza manual, índice de calidad muscular y potencia, además de medir la composición corporal y el estado socioeconómico. Resultados: El modelo de regresión final mostró que la velocidad de la marcha fue explicada significativamente de forma parcial ($R2=0.35$; $p<0.01$) por el entorno socioeconómico, la edad, el equilibrio y la potencia relativa. Al mismo tiempo, pertenecer a un entorno socioeconómico más alto se asocia con una menor potencia relativa ($p<0.01$; $\eta 2=0.07$). Conclusiones: Este estudio destaca que la edad, la potencia relativa y el equilibrio son determinantes significativos de la velocidad de la marcha en los adultos mayores. Estos marcadores clínicos proporcionan información crucial para diseñar intervenciones personalizadas y efectivas que promuevan un envejecimiento saludable.
Palabras clave: Fragilidad, velocidad de la marcha, adulto mayor, potencia relativa, estatus socioeconómico.

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Introduction

The hallmark of aging is the gradual loss of physiological and physical abilities, which results in diminished function and increased mortality risk (López-Otín et al., 2023). Aging, even in healthy individuals, is associated with a progressive decline in muscular, neuronal, and cognitive function leading to deficits in functionality (Hortobágyi et al., 2015). Functional disability is a growing global problem that becomes more pronounced as we age (Hu et al., 2022; Navarrete-Villanueva et al., 2021). While the average trend shows declining health and function with age, individual experiences vary greatly (Rothermund et al., 2023). One of the most characteristic and easily recognizable signs of this decline is a decrease in usual walking speed (Abellan Van Kan et al., 2009; Andrews et al., 2023; Bohannon & Williams Andrews, 2011). This slowing of usual walking pace stands out as a significant indicator, potentially declining up to 16% per decade beginning at the age of 60 years (Hortobágyi et al., 2015).

Gait speed is considered a vital sign which serves as a non-invasive predictor of health and functional status in older adults (Middleton et al., 2015). Walking speed tests have become widely used in clinical and research contexts because of their sensitivity, validity, and reliability (Middleton et al., 2015). There are several walking speed tests with different distance ranges, one of the commonly employed tests for measuring gait speed is the 4m gait speed test (Hirabayashi et al., 2020; Lin et al., 2021). It has been demonstrated that the 4m gait speed is an important component of physical function related to sarcopenia and functional independence, serving as a significant predictor of frailty in older adults (Middleton et al., 2015; Navarrete-Villanueva et al., 2021).

Predicting various conditions later in life, measuring usual walking speed is crucial. A walking speed that exceeds 1 m/s is typically considered normal among the elderly population without disabilities (Hainline et al., s. f.). Speeds below 0.6 m/s are predictive of adverse events, while a threshold below 0.8 to 1 m/s is commonly recognised as a reliable indicator of frailty (Castell et al., 2013; Cawthon et al., 2021). However, the walking speed generally used and associated with adverse health outcomes is less than 0.8 m/s (Abellan Van Kan et al., 2009; Studenski et al., 2011). Having a gait speed lower than 0.8m/s represents a risk factor for functional dependence, frailty, cognitive decline, falls, hospitalization, cardiovascular events, and all-cause mortality (Abellan Van Kan et al., 2009; Mª Lourdes et al., 2024; Middleton et al., 2015; Studenski et al., 2011). Furthermore, it is essential to recognize that these implications extend beyond individual health; slow walking also increases the financial cost of care, due to the greater need for long-term nursing home assistance (Lyons et al., 2016). While additionally contributing to the overall burden of morbidity, specific diseases, and geriatric deficits (Piotrowicz et al., 2023).

Consequently, there is a significant interest in identifying elements that influence reduced walking speed, aiming to enhance primary prevention and maintain functionality (Lara et al., 2024). Several factors that can affect gait speed can be categorized into four aspects: socio-cultural, gender and age, medical and psychological factors (Franz, 2016; Manjavong et al., 2023). Socio-cultural factors, such as economic status, industrialization level, population size, climate, cultural values, education, and feelings of loneliness, can influence gait speed, with more industrialized countries often exhibiting faster walking speeds (De Bartolo & Iosa, 2018). Furthermore, health and socioeconomic position take the form of a gradient, where more advantaged individuals show better health indicators and a higher walking speed (Malkowski et al., 2023; Radford, 2021). Second, there are gender differences, with men exhibiting swifter gait, while walking speed generally diminishes with age (Aboutorabi et al., 2016; Bohannon & Williams Andrews, 2011; Córdova-León et al., 2024; Frutos et al., 2022; Sialino et al., 2021). Additionally, individuals with elevated disease burdens, higher body mass indices (BMI), and increased levels of pain are more prone to experience slower gait speeds (Duan-Porter et al., 2019; Sialino et al., 2021). Beyond clinical aspects, psychological factors, like purpose in life or depression, might play a role in determining walking speed and its alterations over time (Sialino et al., 2021; Sutin et al., 2024).

Given the nature of walking speed as a clinical outcome influenced by numerous factors, understanding how each determinant impacts walking speed in older adults can aid in developing effective intervention programs. Despite previous research highlighting the roles of socioeconomic status, personal characteristics and functional factors, physical activity, and health conditions, the specific contributions of these factors to different walking speed profiles in a cohort of healthy older Spanish adults remain unclear. Our objective is to identify key factors that effectively differentiate between different walking speed profiles. Additionally, we seek to evaluate the influence of socioeconomic status on walking speed to provide comprehensive insights into the determinants of mobility among older adults.

However, the proportion in which each factor contributes to gait speed performance is not well established. Thus, this study aims to investigate the impact, separate and combined, of functional and strength variables, anthropometric and socioeconomic factors on gait speed of older adults using a multivariable regression models to determine which factors most significantly explain variations in walking speed. We hypothesize that functional and strength variables will have a more significant impact on gait speed compared to socioeconomic factors, and that socioeconomic status will also play a notable role in gait speed variations. To achieve this, we will use multivariable regression models to identify which factors most significantly explain variations in walking speed.This analysis will involve validating the model through k-fold cross-validation and evaluating performance with metrics such as root mean square error (RMSE) and R^2. Additionally, we will assess the influence of socioeconomic status on gait speed using one-way ANOVA, with significance set at $p < 0.05$. This approach will help identify key determinants and inform targeted intervention strategies for improving mobility in older adults.

Methods

Participants and Procedure

This descriptive cross-sectional study investigates dynamometric, anthropometric, and Short Physical Performance Battery (SPPB) test outcomes, including balance, gait speed test and chair stand test alongside socioeconomic index data. A group of 1253 participants (89.5% women), with more than 60 years old with a mean age of 78.1 ± 5.8 voluntarily participated in this descriptive cross-sectional study. Participants were selected through non-probabilistic convenience sampling from the "Health for the Elderly" program sponsored by the Bilbao City Council. Inclusion criteria for participants encompassed being aged 60 or older, currently enrolled in the "Health for the Elderly" program, and voluntarily participating, with the inability to walk independently serving as the exclusion criteria.

The subjects were examined by evaluators who went to the centres at the times specified by the programme. As this was a study with a large number of participants, auxiliary personnel were required for data collection. To avoid bias and ensure the quality of the data, personnel from the Higher Level Training Cycle in Teaching and Socio-sports

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Animation received specialized training from physical exercise professionals. This training covered the tests to be conducted as well as subsequent data collection procedures.

Measures and Material

Functional assessment: SPPB and Manual Grip Strength

The Short Physical Performance Battery (SPPB) is a widely utilized clinical functional assessment test known for its high reliability and validity (Santamaría-Peláez et al., 2023). The SPPB comprises three parts: balance assessment (in the standing, semi-tandem, and tandem positions), a 4-meter gait assessment (time taken to walk 4 meters at normal pace), and the five-repetition chair stand test (5STS) performed as quickly as possible (Guralnik et al., 1994). Scores range from zero to four for each component, with zero indicating the lowest score. Additionally, a composite score, ranging from zero to 12 points, is derived by summing the scores from the three components (Guralnik et al., 1994).

This test provides knowledge of the relationship between balance, strength and power of the lower body and is of vital importance to identify individuals at risk in old age, since deficits in these neuromuscular components are associated with an increased risk of injury and falls (Baltasar-Fernandez, Alcazar, Mañas, et al., 2021), closely related to gait speed (Kirk et al., 2023). Due to this, the following balance test results are collected. In the first position, the individual must stand with their feet together, side by side, for 10 seconds. The second position involves standing in a semi-tandem stance, with the side of the heel of one foot touching the big toe of the other foot for 10 seconds. Finally, the full tandem position is performed, standing with the heel of one foot in front and touching the toes of the other foot for 10 seconds, using the more comfortable foot in front.

For the 4m gait speed test, the protocol established by the SPPB battery was followed. The test was explained along with instructions to perform it as they normally walk. Subsequently, in the prepared space, measured and marked with a 4-meter tape (Softee tape), the test was timed with a stopwatch.

Lastly, the 5STS test was performed. This test has demonstrated excellent intra- and inter-rater reliability, as well as consistency across successive repetitions, making it a reliable measurement tool for both experienced and novice raters (Bohannon & Williams Andrews, 2011; Teo et al., 2013). This test was chosen over the minimum chair height standing test because of its greater efficacy in patients with osteoarthritis (Reider & Gaul, 2016), a condition with a significant prevalence (70%) in individuals over the age of 65 years (Wilson et al., 1990). For the 5STS, a chair with a height of 49 cm and a stopwatch were used (Alcazar et al., 2018). First, the test and the procedure were explained to the participants, mentioning that the test measures leg strength and that they should perform the chair poses as quickly as possible, five times without stopping between repetitions. To begin, they should cross their arms over their chest and sit down so that their feet are on the floor; they should then stand up with their arms crossed over their chest and repeat until they have completed all five repetitions.

MGS was conducted utilizing a Camry EH101 electronic handheld dynamometer from Sensun Weighing Apparatus Group Ltd., located in Guandong, China. This dynamometer is recognized as medical equipment approved by the Spanish Agency of Medicines and Health Products. The testing protocol involved maintaining a standing position with the shoulder slightly abducted (approximately 10°), the elbow fully extended, and the forearm and hand positioned neutrally (*Fitness für Health: The ALPHA-FIT Test Battery for Adults Aged 18–69. Tester's Manual – ScienceOpen*, s. f.). Each participant underwent the test twice, and the higher of the two recorded values was considered for analysis.

Relative Power and Absolute Power

The mechanical power, the result of strength and speed, experiences a more pronounced decline compared to other muscle attributes such as muscle mass and strength (Siglinsky et al., 2015). Above the age of 70, relative power (normalized to body mass) decreases due to the loss of absolute power (both specific power and lean mass in the legs) (Alcazar et al., 2020). The 5STS test, explained in the previous section, is utilized to assess lower extremity muscle power in clinical or field environments (Ferrari et al., 2022). Based on the 5STS, both the absolute and relative power of the lower limbs were calculated (Baltasar-Fernandez, Alcazar, Losa-Reyna, et al., 2021). To calculate the mean absolute value, the equation developed by Alcazar et al., 2018 was applied, which considers performance in the 5STS (measured in time to complete five STS repetitions), body mass, body height, and chair height (Alcazar et al., 2018). To relativize the data, the result was divided by body weight.

Muscle Quality Index

Muscle Quality Index (MQI) is a useful indicator for assessing total muscle integrity (Mayrink Ivo et al., 2023). There is a remarkable diversity in the definitions and methods used to assess muscle quality in older adults (de Lucena Alves et al., 2023). In this study, muscle quality index was defined as handgrip strength (kg) divided by relative skeletal muscle mass (Barbat-Artigas et al., 2012; Chang et al., 2021).

Anthropometry

Currently, there are new perspectives on the association between anthropometry, functionality and mortality (Ceolin et al., 2024). Body composition variables were analyzed using segmental bioimpedance with the Tanita BC-601 Segment analyzer (Tanita Corp., Tokyo, Japan). This method provides information on weight (W), body fat percentage (fat %), and kilograms of muscle (Kg_Muscle). The Tanita BC-601 Segment is considered a reliable and non-invasive

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method that yields accurate measurements ($R^2 = 0.98$) (Yamada et al., 2021). Additionally, the Tanita HR 001 Leicester portable stadiometer was employed for height measurements.

Socioeconomic Environment

The socioeconomic and built environment of an area is interrelated with health data and directly influences the quality of life of the elderly (Ding & Gebel, 2012; Molero Jurado & Pérez Fuentes, 2011). There is a significant association between social frailty and functional limitations, cognitive impairment and depressive symptoms in older adults (Huang et al., 2024). This frailty can impact both intrinsic and functional capacity, key aspects for healthy aging.

The Euskadi 2021 socioeconomic deprivation index was constructed following the methodology used in the MEDEA project described in Dominguez-Berjon et al. (2008)(Domínguez-Berjón et al., 2008). This variable has been defined on the basis of the average personal income of the municipality of Bilbao by city neighborhoods, according to type of income (in euros) for the year 2021. Thus, 3 socioeconomic indexes have been extracted, defined as SI1 (low rent_<20.000 euros), SI2 (medium rent_20.000-30.000 euros) and SI3 (high rent >30.000 euros).(Eustat, s. f.)

Statistical Analysis

The data homogeneity of variance test was performed using Levene's test, and Kolmogorov–Smirnov, Cramer-von Mises, and Anderson-Darling tests were used to analyze the normal distribution of all continuous variables.

First, χ^2 Pearson test was performed to check possible dependencies between variables. If the previous analysis showed a significant association, Cramérs's V was set to establish the effect size (ES); thresholds or effects were: < 0.2 "small", $0.2 \leq 0.6$ "medium", and > 0.6 "large". A subsequent correspondence analysis was performed to determine the proximity relationship between the variables.

A correlation analysis was carried out with two objectives. First, we analysed whether there was a relationship between the quantitative variables and then determined the magnitude and action of this relationship (R2). Secondly, possible multicollinearity between independent quantitative variables was checked to avoid biases in the interpretation of future regression coefficients. Consequently, before performing the regression analyses, a correlation matrix between the independent variables was established. The probability of collinearity was correlated with a Pearson correlation coefficient > 0.8 (Shrestha, 2020; Vatcheva et al., 2016). Therefore, one of the variables was eliminated if a high correlation coefficient ($R^2 > 0.8$) was observed between them.

Following this initial test, the regression model took into account nearly all independent variables. The explanatory variables: MGS, MQI vs. right MGS, weight vs. BMI, relative vs. mean power, squat vs. mean power, squat vs. relative power, SPPB vs four meters walking, and SPPB vs. squat showed a high correlation ($R^2 > 0.8$). Thus, left MGS, MQI, weight, mean power, squat and four meters walking variables were removed. For the final regression model the best explanatory independent variables were selected using a stepwise regression approach based on the Ordinary Least Squares (OLS), for performing this analyzes R's package olsrr (Hebbali, 2024) was used.

After completing these preliminary tests, we set up a multiple regression model with gait speed as the dependent variable. Simultaneously, the interaction between categorical (socioeconomic environment) and other quantitative variables was considered for the regression model. The interaction is a combination of variables, creating a new one that has a significantly larger effect on the dependent variable than the sum of individual independent variables alone.

For internal validation, a k-fold cross-validation (10 folds and five repetitions) was performed. Internal validation was performed to reduce possible overfitting of the model (Bullock et al., 2021).

The R package dplyr was used to identify possible outliers and improve the fitting of the regression model (Wickham et al., 2022). Outlier data in the multiple regression model were identified and removed when the absolute value of the studentized residual (SRE) was ≥ 3. After this analysis, a final sample of 1209 participants was considered for the final regression model.

The Shapiro-Wilk test was used to check the normal distribution of the residuals in the regression model. In turn, the homoscedasticity of the regression model was checked using the Breusch-Pagan test.

The model performance was assessed using the root mean square error (RMSE) and R^2. The RMSE is the error of the model reported in the outcome units (i.e., min:s).

After the regression analysis, whether the categorical variable (Socioeconomic environment) was taken into account as a predictive variable, a subsequent one-way ANOVA was set to determine different significations of gait speed and socioeconomic belonging group. When the ANOVA test showed significant differences between factors, partial eta squared ($\eta 2$) was used as a measure of ES, using the reference values of small ($\eta 2 = .01$), medium ($\eta 2 = .06$), and large ($\eta 2 = .14$). A subsequent post-hoc Holm's test was performed to compare potential differences between the factors. For significant differences, Cohen's d was used as a measure of ES, using the reference values of small ($d = .2$), medium ($d = .5$) and large ($d = .8$) for interpreting them, as suggested by Cohen (Ellis, 2010).

In all statistical analyses, the significance level was set at $p < 0.05$. Statistical analysis was conducted using R software 4.2.2 (Team, R. C, 2022) and RStudio version 2022.12.0.353 (Rstudio Team, 2022)(Rstudio Team, 2022).

After previous statistical analyses, 1209 participants were included in the power analysis. To establish the ES and power in the future linear multiple regression, post-hoc power analysis was performed using the G*Power software. The power analysis was performed based on R^2=0.35 and considering seven predictors (see the Results section, Table 2). Statistical analyses established a medium ES (f^2= 0.54) at a power of 99% and an α of 0.05.

Results

The descriptive characteristics of the participants are presented in Table 1. First, the total number of participants (n:1253) in the study is shown. The participants are then divided by gender, indicating the number of females (n:1121) and males (n:132). Additionally, the participants are segmented based on their socioeconomic index, with segment 1 representing the highest values. Finally, the remaining results are presented according to the established segmentation.

Table 1.
Mean values by sex and socioeconomic index of the physical and functional parameters analyzed (n = 1,253).

Total	Sex	Soc_Index	BMI	Muscle	Fat	MGS	gait speed m/s	gait speed 4m	M_Pow	Rel_Pow	MQI	5STS	SPPB	Balance
N= 1,253 Aged: 78.1 (5.78)	Women (N=1121) Aged: 78.0 (5.85)	1 (N=65) Aged: 80.0 (5.9)	28.3 (5.1)	39.4 (5.0)	38.0 (5.3)	19.7 (5.3)	0.92 (0.2)	4.53 (1.0)	109 (37.2)	1.62 (0.5)	1.21 (0.3)	17.0 (5.8)	9.26 (1.5)	3.69 (0.6)
		2 (N=373) Aged: 78.9 (5.9)	27.7 (3.8)	37.9 (3.9)	38.0 (5.3)	19.6 (5.3)	0.99 (0.2)	4.31 (1.2)	111 (41.7)	1.69 (0.5)	1.22 (0.3)	15.7 (4.9)	9.51 (1.7)	3.63 (0.7)
		3 (N=683) Aged: 77.4 (5.6)	28.9 (4.1)	38.2 (4.0)	39.3 (5.4)	19.2 (4.8)	0.98 (0.2)	4.37 (1.2)	120 (37.6)	1.79 (0.4)	1.17 (0.3)	14.1 (3.8)	9.87 (1.6)	3.71 (0.6)
	Men (N=132) Aged:78.9 (5.18)	1 (N=1) Aged: 79.0 (-)	31.0 (-)	53.0 (-)	30.0 (-)	20.0 (-)	1.01 (-)	3.97 (-)	102 (-)	1.28 (-)	1.01 (-)	22.1 (-)	8.00 (-)	3.00 (-)
		2 (N=55) Aged: 80.0 (5.0)	27.9 (3.6)	49.3 (6.5)	31.3 (7.9)	31.4 (6.5)	1.07 (0.2)	4.03 (1.2)	161 (56.6)	2.14 (0.6)	1.72 (0.3)	14.5 (3.5)	9.87 (1.5)	3.71 (0.7)
		3 (N=76) Aged: 78.1 (5.1)	28.3 (3.0)	49.8 (5.6)	31.5 (4.6)	32.8 (6.9)	1.04 (0.2)	4.09 (1.1)	176 (56.0)	2.28 (0.5)	1.79 (0.3)	13.6 (3.3)	10.30 (1.4)	3.82 (0.5)

Data presented as mean (SD). BMI (Body Mass Index_weight (kg)/ [height (m)]^2 ;Muscle (kg); Fat (%); MGS (kg); gait speed m/s; gait speed 4m (s); M_Pow (Mean Power_(weight*0,9*9,81*(height*0,5-0,49))/(5STS*0,1); Rel_Pow (Relative Power_Mean Power/weight); MQI (Musque Quality Index_MGS (kg)/relative skeletal muscle mass; 5STS (five-repetition chair stand test in second); SPPB (Short Physical Performance Battery in points 0-12); Balance (In points 0-4).

Pearson's χ^2 test showed a significant association between SPPB and Socioeconomic Environment (χ^2 (16) = 33.4, p = 0.007; Cramer's V = 0.115). The subsequent correspondence analysis revealed a tendency to achieve higher SPPB scores in low socioeconomic environments (Figure 1). Nevertheless, this relationship must be interpreted cautiously because of the small effect size.

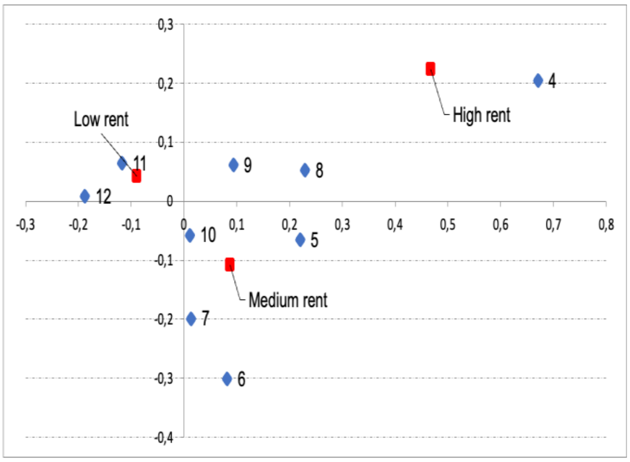

Figure 1. Correspondence analysis between SPPB scores and socioeconomic environments.

Correlation analysis revealed several significant relationships between the quantitative variables (Figure 2). As expected, certain variables displayed very high relationships ($R^2 > 0.8$) (i.e., MGS, MQI vs. right MGS, weight vs. BMI, relative vs. mean power, squat vs. mean power, squat vs. relative power, SPPB vs four meters walking, and SPPB vs. squat) (Figure 2). Therefore, the regression analysis only considered the following independent variables: MGS, BMI, relative power, socioeconomic environment, fat %, kilograms of muscle, SPPB, and the interaction between socioeconomic environment and all anterior quantitative independent variables.

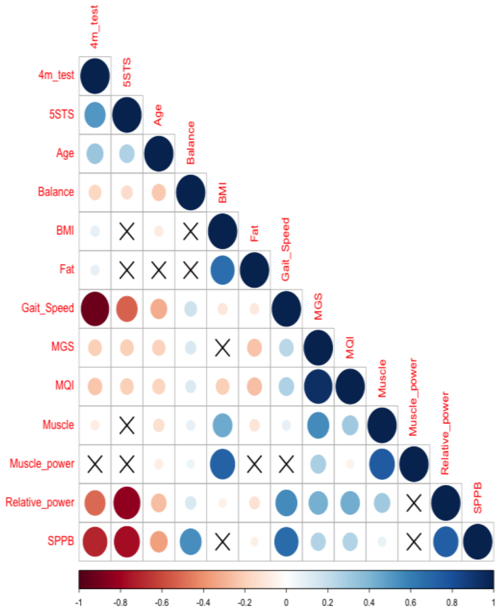

Figure 2. Correlation analysis between the quantitative variables. Note. For better understanding, the non-significant correlations were not provided on the figure (they were shown as "X"). The magnitude of the circle was in accordance with R^2, as explained in the legend.

After OLS regression, five independent variables (socioeconomic environment, age, balance, relative power, and socioeconomic environment*relative power) were used to predict gait speed. The final regression model showed in Table 2 (R^2 =0.35, 95%CI 0.31-0.39, RMSE= 0.18 $m.s^{-1}$; p<0.001). Although some independent variables that constructed the model were not significant, the recommended

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stepwise regression was included in the final model to improve prediction and decrease the RMSE.

Table 2.
Regression results using gait speed as the criterion.

Predictor	b	STD. Error	t- value	p-value
Intercept	0.98	0.12	8.35	<0.001
Soc_Index (middle)	0.02	0.08	0.29	0.77
Soc_Index (low)	0.09	0.08	1.14	0.25
Age	-0.01	0.00	-7.07	<0.001
Relative_Power	0.23	0.05	5.17	<0.001
Balance	0.03	0.01	3.25	0.001
Soc_Index (middle)*Rel_Pow	0.01	0.05	0.23	0.82
Soc_Index (low)*Rel_Pow	-0.05	0.05	-1.08	0.28

Note. A significant b-weight indicates the beta-weight and semi-partial correlation are also significant. b represents unstandardized regression weights. beta indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. r represents the zero-order correlation. LL and UL indicate the lower and upper limits of a confidence interval, respectively.

The proposed model met the criteria for homoscedasticity and showed no multicollinearity; however, the residuals were not normally distributed. Therefore, transformation and standardization of the independent variables were performed to achieve a normal distribution. However, the resulting regression did not meet the normality criterion. For this reason, the final model was based on a generalized linear model (GLM).

After the generalized regression model was established, its internal validation was verified using a cross-validation model. The results were nearly identical to those of the proposed model (R^2=0.37, RMSE=0.18 m.s^{-1}). Thus, there is a lack of evidence for the possible overfitting of the proposed generalized linear model.

Subsequently, and based on previous regression analysis, a one-factor ANOVA was conducted to establish possible differences in relative power based on the Socioeconomic Environment of belonging. There was a significant difference between these two variables (p < 0.001; η2=0.07). Post-hoc analysis showed that the higher income group was related to lower relative power than the lower income group (p=0.03; *d*=-0.37), and the lower-income group displayed a significantly higher power than the middle-income group (p=0.03; *d*=-0.17) (Figure 3).

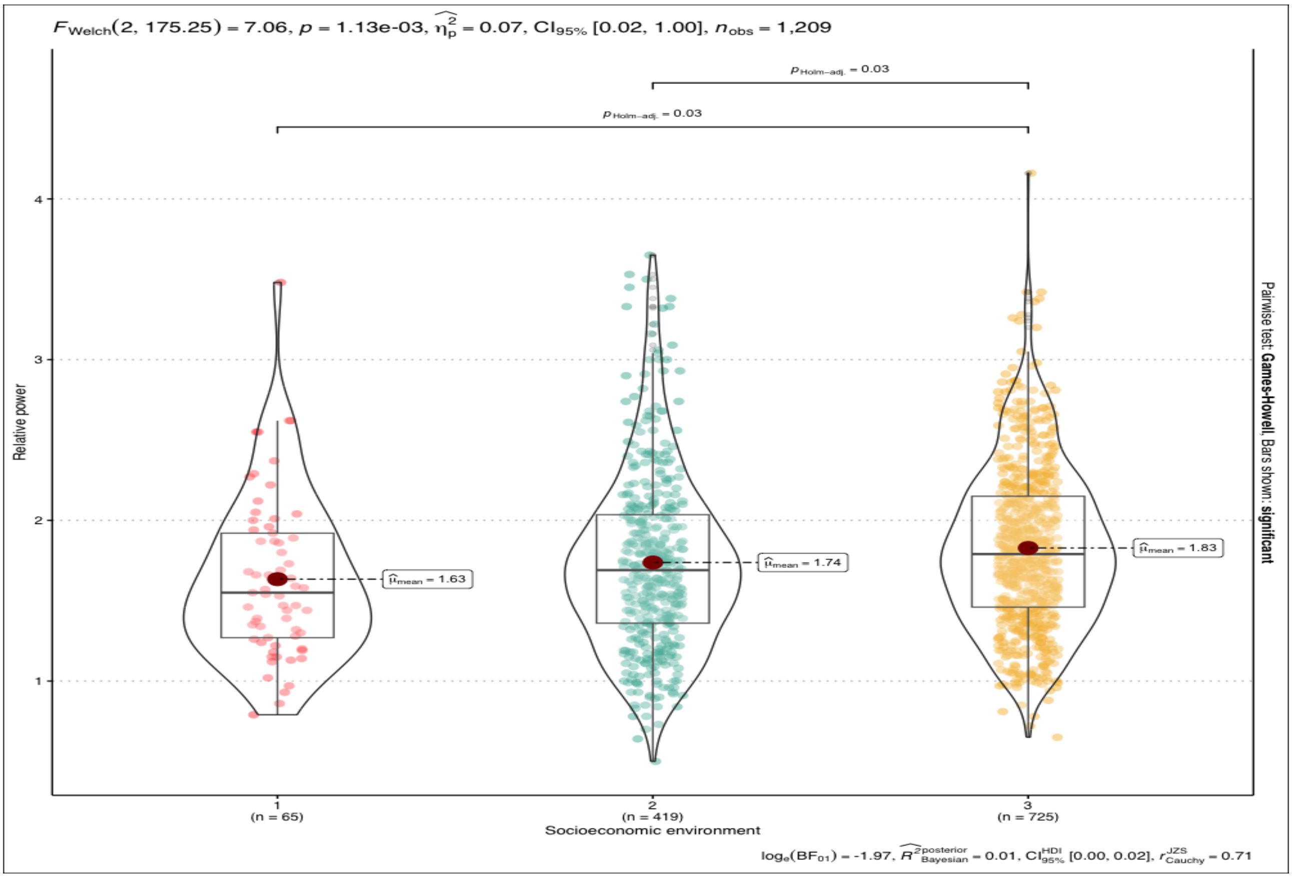

Figure 3. One-factor ANOVA to establish possible differences in relative power as a function of the socioeconomic environment to which they belong.

Discussion

This study examined the determinants of gait speed in a population of older adults from the Spanish locality of Bilbao, focusing not only on the predictive capacity of the regression model but also on exploring the interactions among variables related to gait speed. It is important to note that, while the predictive capacity of the regression model was limited, our main objective was to better understand the underlying mechanisms influencing this health marker, aiming to identify relationships among the different variables.

The impact of age on gait speed is noteworthy. In the presented regression model, a significant negative association is evident between the coefficient of age and gait speed, highlighting the impact of aging on gait speed. Specifically, there is an average decrease of 0.01 m/s for each additional year of age in older adults. These findings are consistent with the existing literature on the progressive decline in muscular, neuronal, and cognitive functions impacting the reduction of gait speed with age (Abellan Van Kan et al., 2009; Andrews et al., 2023; Bohannon & Williams Andrews, 2011). In line with the results obtained, a previous study has identified the reduction in gait speed as a significant indicator of these age-related changes, suggesting a potential reduction of 16% per decade from the age of 60 (Hortobágyi et al., 2015).

On the other hand, as for power, regression analysis highlighted it as a significant predictor of gait speed in our sample. We found that a one unit increase in relative power was associated with a 0.23 m/s increase in walking speed on average. Power, especially in the legs, plays an important role in gait speed and overall mobility in older people (Baltasar-Fernandez, Alcazar, Mañas, et al., 2021; Cuoco et al., 2004). As gait speed increases, an increase in both power and mechanical work of the lower limb joints is required (da Silva et al., 2020).

In this sense, and in relation to power and age, a decrease in the power of the plantar flexors has been observed, which is linked to a significant functional limitation in the gait of older adults as these muscles are critical for forward propulsion and the initiation of foot swing (Aboutorabi et al., 2016; DeVita & Hortobagyi, 2000; Franz, 2016; Gill et al., 2022). This results in a decrease in ankle power (Aboutorabi et al., 2016; DeVita & Hortobagyi, 2000; Morfis & Gkaraveli, 2021). Additionally, decreases in knee power are observed in older subjects (Aboutorabi et al., 2016; DeVita & Hortobagyi, 2000). These reductions in plantar flexor power lead to a redistribution of power generation towards more proximal leg muscles, increasing hip extensor and/or flexor strength. This effect may represent a neuromuscular compensation that counteracts distal weakness and allows for slower gait production (Aboutorabi et al., 2016; Franz, 2016; Kerrigan et al., 1998). Similar patterns have also been identified in populations with pathologies, such as traumatic brain injuries, which compensate for decreased ankle power by relying more on hip muscles (Gill et al., 2022). This suggests that a portion of age-related gait speed reduction may be biomechanically mediated, through increases in proximal muscle recruitment compensating for reductions in plantar flexor power generation during push-off.

The role of balance in gait speed in older adults is essential, as evidenced by the results of our regression model. Notably, the positive coefficient associated with balance in the model suggests that better balance is related to higher walking speeds. This underscores the importance of addressing balance deficits in interventions aimed at improving mobility in older adults (Alizadehsaravi et al., 2022; WEI et al., 2023). Balance is essential for the majority of activities of daily living and stability during ambulation. It has a multicomponent nature in which it integrates information from the sensory and musculoskeletal systems. Balance control in older adults involves a combination of factors, such as muscle strength, proprioception, vestibular function and tactile sensitivity, which contribute to maintaining stability and preventing falls (Osoba et al., 2019; Wang & Fu, 2022). During the aging process the systems that contribute to stabilization tend to deteriorate (Halvarsson et al., 2015; Osoba et al., 2019; Wang & Fu, 2022), leading to a decline in balance and an increased risk of falling. This loss of balance and fear of falling can lead to a reduction in step length and increased time spent in the support phase of the gait cycle, resulting in a slower walking speed. This compensatory strategy is adopted in order to maintain a more stable state during gait (Aboutorabi et al., 2016; Halvarsson et al., 2015; Osoba et al., 2019).

In exploring the relationship between socioeconomic status and health indicators, particularly walking speed, the results offer an intriguing insight. The results reveal that socioeconomic status does not show a significant direct association with walking speed. However, the association between physical functionality, measured by the SPPB, and socioeconomic environment suggests a tendency towards better performance in lower-income settings, albeit with a small effect size. Additionally, ANOVA revealed significant differences in relative power based on socioeconomic environment, indicating a trend towards better values in lower-income groups. These findings present a contrast to the broader literature, where higher income and education levels are commonly associated with better functional and health outcomes (Malkowski et al., 2023; Noppert et al., 2018; Shankar et al., 2010; Stringhini et al., 2018). Socioeconomic disadvantages are typically linked to earlier declines in physical functionality and greater risk of non-communicable diseases (Shankar et al., 2010; Stringhini et al., 2018). However, the observed variation in this Bilbao-based sample suggests that local factors, such as urban design and resource distribution, may play a pivotal role in shaping these outcomes.

One hypothesis is that the city's topography contributes to these differences. For instance, neighborhoods with lower socioeconomic status, often situated at higher altitudes or with hilly terrain, may present greater mobility challenges (topographic map, 2024). However, these environmental obstacles might paradoxically promote the maintenance of functional capacities over time due to increased physical activity levels associated with navigating such environments (Maharana & Nsoesie, 2018). This urban design factor could explain why lower-income participants in Bilbao exhibit relatively better functional performance than might be expected based on their socioeconomic status alone. Moreover, various studies suggest that prevention strategies aimed at addressing unfavorable socioeconomic circumstances, along with common risk factors for non-communicable diseases, could be crucial for promoting healthy aging (Caballero-Mora et al., 2020; De la Cámara et al., 2020; Stringhini et al., 2018). For example,

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participation in community programs could mitigate the disparities observed in physical functionality among different socioeconomic groups, and it is noteworthy that these participants are part of a specific program, such as the "Health for the Elderly" program sponsored by the Bilbao City Council(Shankar et al., 2010; Stringhini et al., 2018).

Upon further analysis, we observed that MGS and MQI were not included in the final regression model. These two variables showed a high correlation with each other but ultimately did not reveal clinical significance within the model. This could be attributed to the fact that, while grip strength is a widely used indicator of overall muscle strength (Bohannon et al., 2012; Cruz-Jentoft et al., 2010; Delinocente et al., 2021), its ability to reflect specific lower limb muscle strength is debatable (Ogawa et al., 2022; Tatangelo et al., 2022; Yeung et al., 2018). In the literature, MGS has been highlighted as a relevant indicator for detecting slow gait speeds (<0.8m/s) (Alley et al., 2014; Duchowny et al., 2017; Lin et al., 2021); however, this relationship is attenuated in populations with faster gaits (Busch et al., 2015; Fragala et al., 2016), such as ours. The connection between MGS and gait speed may vary depending on various factors, such as the level of physical activity and the general health of the population studied (Yeung et al., 2018). For example, the presence of severe MGS weakness affects gait speed, although the relationship between MGS and gait speed is less evident in stronger individuals (Buchner et al., 1996; Fragala et al., 2016). Additionally, studies have shown that a higher level of daily physical activity was significantly associated with higher knee extension strength (KES), but not with MGS, in community-dwelling older adults (Ikenaga et al., 2014; Samuel & Rowe, 2012). Lastly, it is important to note that the effect of decreased limb mobility and reduced physical activity associated with aging, coupled with the predominant role of the upper limb in daily activities, results in a more pronounced deterioration of lower limb strength compared to the upper limb (Nogueira et al., 2013; Tatangelo et al., 2022). This difference in decline rates could also be a hypothesis to explain the contradictory results. Therefore, since lower limbs are particularly crucial for gait speed, the importance of considering strength measures that may be more related to this specific motor function such as the KNE test or power test is emphasized (Tatangelo et al., 2022; Yeung et al., 2018).

As with the MGS, when calculating the MQI using the MGS indicator, no relationships were found in this context either. In this research, MQI was assessed indirectly by employing the approach suggested by Barbat-Artigas et al. (2012) and Chang et al. (2021) (Barbat-Artigas et al., 2012; Chang et al., 2021), MGS/ skeletal muscle mass. The optimal method for quantifying MQI is unclear and varies in cost, complexity and availability and this formula provides an accessible one (Heymsfield et al., 2015). Results from other research suggest that assessing MQI through MGS could serve as a reliable indicator of upper body functional abilities among older individuals but may not be an ideal indicator for the lower extremity (Felicio et al., 2014; Nascimento et al., 2020; Yeung et al., 2018). The inclusion of a muscle quality indicator more tailored to the specific characteristics of the legs or the general body could provide a more complete and accurate understanding of the relationship between gait speed and muscle quality.

The findings of this study provide valuable insights into the factors influencing gait speed in older adults. A key contribution of this research is its potential application in clinical practice, specifically addressing these influential factors. The most important consideration for exercise prescription is that it must be individualized, taking into account not only functional capacity and tolerance but also risk factors and medical history (Izquierdo et al., 2021; Izquierdo & Cadore, 2024). By focusing on the most significant variables identified and aligning with recent studies, the optimal training approach would involve a multicomponent program (generally including various combinations of strength, power, gait, balance, and functional training) (Izquierdo & Cadore, 2024). In this case, the program should include power and balance exercises as key components to effectively enhance gait speed.

Power training is a type of muscle training that combines force production with speed. It is considered a subcategory of strength training. While strength training focuses on the ability to overcome resistance, power training emphasizes overcoming that resistance as quickly as possible (Izquierdo et al., 2021). Age-related power loss occurs before strength and muscle mass decline, primarily due to a reduction in the size of type II fibers, atrophy of remaining fibers, or changes in neural recruitment (Chodzko-Zajko et al., 2009; Izquierdo et al., 2021). These findings justify the inclusion of power training as a key component of concurrent training approaches. For optimal power training, concentric contractions should be performed rapidly, followed by a slower eccentric phase, always avoiding reaching concentric failure. Power is optimized using loads that represent 30-45% of the one-repetition maximum (1RM) for upper limbs and 60-70% 1RM for lower limbs. Heavy loads during resistance training can simultaneously improve muscle strength and power in older adults. However, for frail individuals or those with reduced force production capacity, moderate loads (40-60% 1RM) have also been shown to provide benefits (Izquierdo et al., 2021; Izquierdo & Cadore, 2024).

As for the balance and gait training, progressions should involve increasing difficulty of the exercise as they tolerate it, just as with strength and power training, when a load is no longer challenging enough they adapt. To achieve this there are different strategies such as narrowing or disruption of the base of support, proprioceptive or visual decrease, dual tasking… (Izquierdo & Cadore, 2024).

For the strengths of this study, it benefits from a large sample size, which enhances its representativeness and provides valuable insights into improving gait interventions for older adults. The results fill a gap in the literature, offering guidance for more effective public health strategies. As for

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the limitations, the study's reliance on convenience sampling and the non-representative gender distribution may affect the generalizability of the findings. Additionally, the use of postal codes alone for socioeconomic status limits our understanding of the reasons behind variations in gait speed compared to other current studies. Furthermore, including a more tailored muscle quality indicator could yield a more comprehensive understanding of the relationship between gait speed and muscle quality. Another limitation of the study is the absence of a specific measure for lower limb strength, such as the KNE test, which could have provided a more precise assessment of this particular motor function.

Conclusion

This study explored factors influencing gait speed in older adults. Age was a significant predictor of gait speed decline, in line with age-related declines in neuromuscular and cognitive function. Lower limb power emerged as an important marker, hypothesising that declines in plantar flexor power affect gait propulsion. In addition, better balance was associated with higher walking speeds, highlighting the importance of balance interventions for mobility.

Although socioeconomic status did not directly impact gait speed, low-income settings showed better physical functioning, possibly due to greater physical activity in challenging environments. Further studies on the involvement of MGS and indirect muscle quality are needed to validate their usefulness as reliable indicators of lower limb specific muscle strength and quality in older adults and determinants of gait speed. In general, understanding the determinants of gait speed is essential to promote healthy aging to maintain individual functional capacity. These determinants, such as power and balance, provide valuable information on the functionality of older adults, which will enable more effective and personalised interventions to be designed to promote healthy aging in clinical practice.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethics approval

The data collection of the study was approved by the University of Deusto Ethics Committee (reference # ETK-32/18–19) and written informed consent was obtained from each participant prior to study.

Consent for publication

All authors have seen and approved the final manuscript, and agree to its submission to the Journal of Frailty & Aging.

Availability of data

Data available from corresponding author on reasonable request with approval from data custodian at University of Deusto.

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Author contributions

Study concepts: N.V. and X.R. Data acquisition: X.R. Quality control of data and algorithms: I.M. Data analysis and interpretation: N.V., X.R. and I.M. Statistical analysis: I.M. Manuscript preparation: N.V., X.R and I.M. Manuscript editing: N.V, X.R., I.M., A.M-Z and B.G-Z. Manuscript review: N.V, X.R., I.M., A.M-Z and B.G-Z. All authors read and approved the final manuscript.

List of abbreviations:

Manual Grip Strength (MGS), Short Physical Performance Battery (SPPB), Five-repetition Chair Stand Test (5STS), Muscle Quality Index (MQI), Body Mass Indices (BMI), Ordinary Least Squares (OLS), Studentized Residual (SRE), Root Mean Square Error (RMSE), Generalized Linear Model (GLM), Analysis of Variance (ANOVA).

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