Title:
Association between gait speed and balance disorders in older adults from 12 high Andean Peruvian communities, 2013-2019

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Abstract

**Background:** Gait speed is associated with a higher prevalence of balance disorders in older adults residing at high altitudes. This study investigated this association in older adults from 12 high-altitude Andean Peruvian communities.

**Methods:** We performed a secondary data analysis from an analytical cross-sectional study of adults >60 years of age, residing in 12 high-altitude Andean Peruvian communities, enrolled between 2013 and 2019. The exposure and outcome variables were gait speed (categorized in tertiles), and balance disorders (defined as a functional reach value of ≤20.32 cm), respectively. We built generalized linear models of the Poisson family with a logarithmic link function and robust variances, and estimated crude prevalence ratios (cPR) and adjusted prevalence ratios (aPR) with 95% confidence intervals (CIs).

**Results:** We analyzed 418 older adults; 38.8% (n=162) were male, and the mean age was 73.2 ± 6.9 years. The mean gait speed and functional reach were 0.66 ± 0.24 m/s and 19.9 ± 6.48 cm, respectively. In the adjusted regression model, the intermediate (aPR=1.88; 95% CI: 1.39–2.55; p<0.001) and low (aPR=2.04; 95% CI: 1.51–2.76; p<0.001) tertiles of gait speed were associated with a higher prevalence of balance disorders.

**Conclusions:** The intermediate and low tertiles of gait speed were associated with a higher prevalence of balance disorders among older adult residents of 12 high-altitude Andean communities. We recommend further research on the behavior of this association to propose interventions for these vulnerable groups and reduce the impact of geriatric conditions.

**Keywords:** walking speed, gait speed, balance, older adults, high-altitude.
1. Introduction

Aging causes numerous physiological changes and increases the risk of chronic diseases. Additionally, it is associated with a general decline in mobility, which directly influences an older adult’s ability to walk by altering their gait (1,2). Gait speed is a vital sign in older adults. Alterations in gait speed can predict a variety of adverse outcomes, including functional dependence, frailty, cognitive impairment, falls, isolation, hospitalization, cardiovascular events, and mortality (3). In addition, functional degradation, which is typical of aging, can cause physical manifestations such as postural instability, muscle weakness, and increased sensory deficits (4,5), which can also cause alterations in the gait speed of older adults.

Gait execution requires the coordination of extremity movement, postural tone, and balance (6). Balance can be affected when sensory input from the eyes (presbyopia) (7), feet, or ankles (8) is impaired. Balance disorders have been reported in adults residing in high-altitude areas with hypobaric hypoxia (9). Hypoxia can influence the partial pressure of inspired, arterial, and alveolar oxygen in the integration between the central nervous system and sensorimotor function (9), leading to deterioration of neuromuscular coordination and changes in standing balance (10). This has resulted in a higher prevalence of balance disorders ranging from 3.3–21.5% (which increases with age) in older adults residing in high-altitude areas compared with those residing at sea level (11). In addition, permanent exposure to hypoxia causes a reduction in muscle mass (12), which can lead to other geriatric syndromes (13), sequencing balance disorders, and fatal outcomes such as mortality in older residents of high-altitude areas.

A previous systematic review evaluated the presence of balance disorders in a high-altitude population (9); however, no study has reported on people from the Andes. Moreover, the previous study populations were mainly young adults. Likewise, although gait speed is an important predictor and an effective and easy-to-apply measure for evaluating balance disorders, no study has evaluated this association in older adults at high altitudes or in the Andes, where older adults could have higher exposure to the chronic effects of altitude. Therefore, the present study investigated the association between gait speed and balance disorders in older adults from 12 high-altitude Andean communities in Peru between 2013 and 2019.
2. Materials and methods

2.1. Study design, population, and sample

2.1.1. Study design

This observational, cross-sectional, and analytical study used data from an open-access secondary database. The primary study paved the way for new research focused on geriatric syndromes present in the high-altitude Andean Peruvian population.

2.1.2. Population and sample

The primary study included 453 adults aged ≥60 years living in 12 high-altitude Andean communities (>1500 m above sea level [masl]) in the Peruvian highlands: Viñac (Lima), San Pedro de Chaná, Llupa, Macashca and Atipayán (Ancash), Ayahuanco (Ayacucho), Pampamarca (Huánuco), Chacapampa (Huancayo), Vilca (Huancavelica), Paucarcolla (Puno), and Leimebamba and La Jalca (Amazonas) evaluated between 2013 and 2019.

In the primary study, non-probabilistic census-type sampling was used in each urban/rural community, achieving an approximate inclusion of 95% of older adult inhabitants in most of these communities.

2.2. Procedures

Participants were approached at their homes with the help of a guide from the area, and individuals who voluntarily agreed to participate in the study signed the informed consent form. Information on sociodemographic data, medical history (falls, polypharmacy, comorbidities, consumption of tobacco and alcohol), anthropometric measurements (weight and height), physical performance test procedures (gait speed), functional assessment (the Barthel index and Edmonton questionnaire), and mental assessments, including depressive symptoms, were collected by medical students and physicians previously trained in data evaluation by a geriatrician. For participants who did not understand Spanish, their relatives were requested to translate the questions for data collection.

2.3. Variables:

2.3.1. Outcome variable:

*Balance disorders*

Balance was evaluated using the functional reach test performed on a flat surface. The older adults were instructed to lean forward without moving their feet or touching the wall and without losing balance. The maximum reach with the first attempt was recorded in centimeters, considering the best of two attempts. For the analysis, the numerical variable was divided according to a cutoff point of 20.32 cm, and then categorized into two strata to prepare a score according to the presence of balance disorders. We defined the presence and absence of balance disorders as values ≤20.32 cm and ≥20.32 cm, respectively (14,15).

2.3.2. Exposure variables:

*Gait speed*
Gait speed was measured using a test included in the Short Physical Performance Battery (SPPB), which evaluates physical performance. Participants were instructed to initiate a marked 4-meter walk, and the time spent at a normal daily pace was measured using the best of two attempts. Scoring was based on time: 4 points for <4.82 s, 3 points for 4.82–6.20 s, 2 points for 6.21–8.7 s, 1 point for >8.7 s, and 0 points for participants unable to complete the test. The numeric variable was divided into four categories to define gait speed. Tertiles were generated based on this numerical variable (16,17).

### 2.3.3. Other variables

#### Sociodemographic characteristics

The self-reported sociodemographic characteristics evaluated include sex (female or male), age (<70 years, 71–80 years, or >80 years), marital status (single, married, or widowed/divorced), educational level (no education/incomplete primary, completed primary, or completed secondary), living alone (yes or no), working (yes or no), and altitude (masl). The collected information was corroborated using the participants’ national identity documents.

#### Medical and personal history

The following self-reported variables were included: tobacco use (yes or no), alcohol use (yes or no), polypharmacy (defined as the regular use of ≥5 drugs under medical prescription), falls in the last year (none or at least one), and comorbidities (arterial hypertension [yes or no], type 2 diabetes mellitus [yes or no], chronic obstructive pulmonary disease [yes or no], and lower back pain [yes or no]). Body mass index (BMI) was calculated using the following formula: weight in kg/ height in meters squared.

#### Neuropsychiatric evaluation

To assess depressive symptoms, we used the five-item Spanish version of the Geriatric Depression Scale (GDS) put forth by Yesavage (18,19), with scores ≥2 indicating depressive symptoms (20).

To assess cognitive impairment, we used the 10-question Pfeiffer questionnaire, which categorized participants based on the number of their error responses as follows: no cognitive impairment (0–2 errors), mild cognitive impairment (3–4 errors), and moderate cognitive impairment (5–7 errors) (21).

#### Functional evaluation and geriatric syndromes

We used the Barthel Index to assess the presence or absence of disabilities in older adults. The Barthel Index is a questionnaire that assesses 10 basic activities of daily living. Its scores range from 0 to 100, with scores <100 indicating the presence of disability (22). In addition, we used two questions from the Edmonton Questionnaire: 1) social support: When you need help, can you count on someone who is willing and able to meet your needs? (always or sometimes/never), and 2) urinary incontinence: Do you have a problem with losing control of urine when you do not want to? (yes or no) (23).
2.4 Statistical analysis

We analyzed the data using Stata/SE, version 17.0 (StataCorp, TX, US). We present the descriptive results of the numerical variables as means and standard deviations, as well as medians with their respective interquartile ranges, depending on the normality distribution of the variables. Similarly, we summarized the categorical variables using relative and absolute frequencies. We used Pearson's chi-square or Fisher's exact tests to compare categorical variables. In addition, we used the Student's t-test or Mann–Whitney U-test to compare differences in numerical variables between groups based on the presence or absence of balance disorders. We applied analysis of variance (ANOVA) or the Kruskal–Wallis test to compare the differences in numerical variables between the groups of tertiles according to gait speed.

We constructed two generalized linear models (crude and adjusted) of the Poisson family with a logarithmic link function and robust variances to evaluate the association between gait speed tertiles and balance disorders in the older adult participants. We estimated the crude prevalence ratios (cPRs) and adjusted prevalence ratios (aPRs) using their respective 95% confidence intervals (CIs). We developed an adjusted model based on an epidemiological criterion, incorporating variables whose associations with the exposure and outcome variables have been described in the literature and were not observed in the causal pathway. We conducted an additional analysis using a linear regression model to estimate crude and adjusted beta ($\beta$) coefficients to assess the association between gait speed tertiles and functional reach.

2.5 Ethics approval and consent to participate

The Institutional Research Ethics Committee (IREC) of the Universidad Científica del Sur evaluated and approved our use of the secondary data (632-2020-PRE15). The primary study was approved by the IREC of the Naval Medical Center (Memorandum No. 49). Informed consent was obtained from all participants, and the integrity of the older adults was not violated, data confidentiality was maintained.
3. Results

Descriptive and bivariate analysis according to gait speed tertiles
We analyzed 418 older adults residing in 12 high-altitude Andean communities in Peru. Of these, 256 (61.3%) were women, and the mean age was 73.2 ± 6.9 years. The mean gait speed was 0.66 ± 0.24 m/s and functional reach was 19.91 ± 6.48. Table 1 shows the characteristics of the study population according to gait speed tertiles in geriatric adults.

Descriptive and bivariate analysis according to the presence of balance disorders
The gait speed (p<0.001), marital status (p=0.008), altitude (p=0.014), tobacco use (p=0.002), alcohol use (p<0.001), polypharmacy (p=0.001), BMI (p=0.002), social support (p=0.018), cognitive impairment (p<0.001), disability (p=0.001), and falls in the last year (p<0.001) differed significantly based on the presence of balance disorders (Table 2).

Descriptive analysis of gait speed and balance disorders
The mean gait speeds for the higher, intermediate, and lower tertiles were 0.95 ± 0.18 m/s, 0.56 ± 0.07 m/s, and 0.46 ± 0.04 m/s, respectively. Furthermore, the mean functional reach measurements in the groups without and with balance disorders were 25.0 ± 4.42 cm and 14.6 ± 3.25 cm, respectively. The median gait speeds were 0.95 m/s, 0.53 m/s, and 0.47 m/s for the high, medium, and low tertiles, respectively. Additionally, the median functional reach measurements in the groups without and with balance disorders were 24 cm and 15 cm, respectively. Table S1 presents the descriptive characteristics of the primary variables. The mean gait speeds were 0.61 m/s for women and 0.70 m/s for men. Regarding age groups, the mean gait speed was 0.66 m/s for those <71 years, 0.64 m/s for individuals aged 71–80 years, and 0.61 m/s for those >80 years of age. The mean functional reach measurements for women and men were 19.51 cm and 20.74 cm, respectively. Additionally, the mean functional reach measurements according to age group were 20.35 cm, 19.82 cm, and 19.54 cm for participants <71 years, 71–80 years, and >80 years, respectively (Table S2).

Crude and adjusted prevalence ratios to estimate the association between gait speed tertiles and balance disorders
The crude Poisson regression model showed that the intermediate (cPR =1.81; 95% CI: 1.32–2.47; p<0.001) and low tertiles (cPR =2.35 95% CI: 1.78–3.14; p<0.001) of gait speed increased the probability of presenting with a balance disorder. In the adjusted model, the intermediate (aPR=1.88; 95% CI: 1.39–2.55; p<0.001) and low tertiles (aPR=2.04; 95% CI: 1.51–2.76; p<0.001) were adjusted for confounding variables such as sex, age, educational level, living alone, work, comorbidities, neurocognitive disorder, depressive symptomatology, and disability (Table 3).

Crude and adjusted betas coefficients to estimate the association between gait speed tertiles and functional reach
The crude linear regression model showed that the low gait speed tertile was significantly associated with decreased functional reach ($\beta = -2.04$; 95% CI: -3.54 to -0.54; $p=0.008$), compared with the high gait speed tertile. After adjusting for potential confounders, this association remained significant (adjusted $\beta = -2.21$; 95% CI: -3.70 to -0.72; $p=0.004$). Conversely, the intermediate tertile showed non-significant associations in both crude ($\beta = -0.81$; 95% CI: -0.68 to 2.31; $p=0.286$) and adjusted models (adjusted $\beta = 1.19$; 95% CI: -0.28 to 2.66; $p=0.112$) (Table S3).
4. Discussion

We evaluated 418 older adults, 48.8% of whom had balance disorders. Our results showed that older adults from 12 high-altitude Andean communities with an intermediate or low gait speed had the greatest probability of also presenting with a balance disorder. The prevalence rates of slow gait speed and balance disorders were 34.2% and 48.8%, respectively. In previous studies of older adults who did not reside at high altitudes, the prevalence rates of slow gait speed (10.2–41%) and balance disorders (3.3–21.5%) were similar and even lower than those observed in our study (11,24–29). However, most studies evaluated outcomes such as falls (8,30) or mortality (31,32) and did not investigate the possible association between slow gait speed and balance disorders.

Gait speed and balance disorders are associated with residential altitude in older adults. A systematic review found that hypobaric hypoxia, a characteristic of residents in high-altitude areas, could cause an up to 2.4-fold alteration in standing balance(9), which may explain the increased prevalence of balance disorders in the present study, unlike the prevalence rates reported in older adults who did not reside in high-altitude areas. Another study found that balance disorders may be reduced by improving the functional capacity in older adults (33). However, exposure to high altitude is associated with decreased exercise capacity (34), making it more difficult for older adults to regain their functional capacity. Regarding gait speed, a study on older adults exposed to normal baric hypoxia found that acute exposure did not affect gait patterns (35), contrary to our findings on the chronicity of exposure, type of hypoxia, and gait speed patterns in older adults.

Previous studies have reported that older adults living at high altitudes present with some balance disorders (9), indicating that the loss of balance is influenced by hypobaric hypoxia in populations living in high-altitude Andean areas (9), due to alterations in visual, proprioceptive, vestibular, and motor cortex functions (36,37). Hypobaric hypoxia not only affects the somatosensory region but also inhibits the activation of muscle mechanoreceptors (38,39). However, under conditions of moderate hypoxia, falls may be reduced, and balance disorders may not develop in older adults (33,40).

Reduced gait speed may contribute to the early identification of functional deficiencies in vulnerable older adults, thereby reducing survival in this population(41,42). To date, no studies have evaluated the association between decreased gait speed and impaired balance in older adults. However, decreased gait speed reflects altered musculoskeletal system function, which serves as an early predictor of disability, cognitive deterioration, and risk of falls in older adults (43,44). Balance disorders are associated with the risk of falling in older adults, caused by loss of balance (45). Treatments aiming to improve gait speed and muscle strength improve balance, prevent falls, and reduce morbidity and mortality among older adults(46,47). We observed an association between lower gait speed and the presence of balance disorders in...
the present study, a finding not previously described in geriatric populations in high-altitude Andean areas, but which correlates with hypotheses of previous studies.

Age-related anatomical and functional changes in neuromuscular function, perception, and cognitive systems impair gait control and balance (48). Impairments in gait and balance are particularly important in older adults because they contribute to the risk of injuries and falls and jeopardize their independence (49), thereby underscoring the importance of early evaluation. Although electronic walkways, force plates, and body sensors can be used to assess gait and balance (50), high-altitude Andean rural localities in Peru have no access to these instruments. Thus, more accessible instruments are used instead, including the SPPB for the evaluation of gait speed and the functional reach test for the evaluation of balance disorders.

The present study has some limitations. First, the study population included only Peruvians from 12 high-altitude Andean communities; thus, extrapolation to the remaining Peruvian population may be limited. Second, the cross-sectional study design did not allow the assessment of causality between balance disorders and gait speed. Third, some variables included in the study were collected through self-reporting; therefore, information bias may have affected the results. Fourth, some variables such as alcohol consumption could not be measured because of the low educational level of the population. However, the main variables of the study were performance-based measures, which are useful, easy to administer, and have good diagnostic performance (41). Fifth, some of the included variables had missing values; however, the percentage of these variables did not exceed 20%; thus, they could be included in the analysis.

Conclusions

Our study results demonstrated that the intermediate and low tertiles of gait speed are associated with a higher prevalence of balance disorders in older adult residents of 12 high-altitude Andean communities in Peru. Given the lack of studies evaluating this association, research is necessary to further investigate this association in different high-altitude Andean communities, as well as in age groups with various comorbidities, to develop possible interventions in these vulnerable groups and reduce the impact of geriatric conditions.