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Original Research

Association between very high altitude and frailty syndrome in rural community residents of Junín Department, Peru

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Abstract

Introduction: Frailty syndrome represents a state of vulnerability that significantly affects the elderly. Chronic exposure to high altitudes may accelerate this process due to chronic hypoxia. Peru's aging population has increased from 5.7% in 1950 to 13.6% in 2023, with 42.6% residing in rural areas. This demographic shift has led to increased prevalence of geriatric syndromes, particularly frailty syndrome. The prevalence of frailty syndrome varies globally, ranging from 5.8% to 27% in European countries and 19.6% in Latin America and the Caribbean. In Peru, previous studies report prevalences between 7.7% and 27.8%, with high-altitude Andean communities showing higher rates. The study's purpose was to determine the association between very high altitude and frailty syndrome in rural community residents of Junín Department, Peru.

Methods: A cross-sectional study was conducted in 2023. A total of 393 participants aged ≥60 years residing in rural communities located at high altitudes (2500–3500 m above sea level (a.s.l.)) and very high altitudes (3500–5800 m a.s.l.) were evaluated. Frailty syndrome was assessed according to Fried's criteria: unintentional weight loss (≥4.5 kg in the past year), self-reported exhaustion, low physical activity measured by the Minnesota Leisure Time Activity Questionnaire (lowest quintile <383 kcal/week in men, <270 kcal/week in women), slow walking speed (adjusted for sex and height), and muscle weakness (grip strength below 20% of normal limit, adjusted for BMI and sex). Categories were defined as robust (0 criteria), prefrail (1–2 criteria), and frail (≥3 criteria). Non-probabilistic convenience sampling was used to select 14 population centers. Bivariate analysis and Poisson regression were performed to determine associations.

Results: The overall prevalence of frailty syndrome was 44.53% (n=175). Among the frail elderly, 80.6% (n=141) resided in very-high-altitude communities. A significant association was found between very high altitude and frailty (adjusted prevalence ratio=3.11, 95%CI 1.87–5.17, p<0.001). Associated factors included female sex (63.43% of frail versus 47.25% of non-frail, p=0.001), primary education or no formal education (94.28%), agricultural occupation (62.86% of frail versus 39.91% of non-frail, p=0.001), regular self-perceived health (58.86% of frail versus 47.25% of non-frail, p=0.001), and mild functional dependence (54.29%). Cognitive impairment was present in 73.14% of frail versus 15.60% of non-frail elderly (p=0.001). Moderate/severe physical limitation affected 58.86% of frail versus 20.64% of non-frail elderly (p=0.001).

Conclusion: There is a significant association between residing at very high altitudes and frailty syndrome in the elderly from Peruvian rural communities. Elderly residents at very high altitude have three times higher prevalence of frailty than residents at high altitudes. The findings suggest the need to implement specific preventive programs for this vulnerable population. Chronic exposure to hypobaric hypoxia at extreme altitudes may accelerate the depletion of physiological reserves, predisposing to frailty development. Future longitudinal studies are needed to establish causal relationships and clinical trials are needed to evaluate specific interventions for high-altitude populations.

Keywords

altitude, cognitive dysfunction, frailty, functional status, hypobaric hypoxia, elderly, Peru, physical performance, vulnerable populations.

Introduction

Population aging represents one of the most important challenges of the 21st century. In Peru, the elderly population has increased from 5.7% in 1950 to 13.6% in 2023, with 42.6% residing in rural areas[1]. This demographic change has led to an increase in the prevalence of geriatric syndromes, particularly frailty syndrome.

Frailty syndrome is characterized by a decrease in physiological reserve and resistance to stressors, resulting in greater vulnerability to adverse health-related events[2]. The criteria established by Fried include unintentional weight loss, exhaustion, low physical activity, slow gait, and muscle weakness (Hoogendijk et al[3]).

The prevalence of frailty syndrome varies globally, ranging from 5.8% to 27% in European countries[4], and 19.6% in Latin America and the Caribbean[5]. In Peru, previous studies report prevalences between 7.7% and 27.8%, with high-altitude Andean communities showing higher rates[6].

Chronic exposure to high altitudes (>2500 m a.s.l.) generates complex physiological adaptations due to chronic hypobaric hypoxia[6,7]. These changes include compensatory hyperventilation, erythrocytosis, pulmonary hypertension, and increased pulmonary arterial pressure[8]. In the elderly, these adaptive processes may accelerate the depletion of physiological reserves, predisposing them to frailty development.

International studies have demonstrated an association between altitude and frailty. In Qinghai Province, China, elderly people residing at 4700 m a.s.l. presented a 61.7% prevalence of frailty[9]. However, there is limited evidence about this association in South American Andean populations.

Junín Department, located in the central Peruvian Andes, has rural communities distributed across various altitudinal ranges, from 2500 m to more than 4000 m a.s.l. Previous studies in the region have reported frailty prevalences of 30% in Apata (3340 m a.s.l.) and 72.1% in Chaglla, Huánuco (3000 m a.s.l.)[2,10].

The objective of this research was to determine the association between very high altitude and frailty syndrome in rural community residents of Junín Department, Peru, in 2023.

Methods

Study design

An observational, analytical, prospective, cross-sectional study was conducted between January and December 2023. The target population consisted of participants aged ≥60 years residing in rural communities of Junín Department 2500–5800 m a.s.l. According to the 2017 census, this region had 41,978 elderly residents in rural areas[11]. Sample size was calculated according to the formula for finite populations with a 95% confidence interval (CI), 5% maximum error, and 50% expected prevalence, resulting in a sample size of 381 participants, adjusted to 400 considering 5% losses.

Inclusion criteria were participants ≥60 years, residence ≥6 months in the study area, and the capacity to provide informed consent. Exclusion criteria included severe mental illness (schizophrenia, severe dementia), lower limb amputation, severe motor disability, recent hospitalization, and an inability to communicate in Spanish.

For community selection, non-probabilistic convenience sampling was implemented, selecting 14 population centers distributed as:

- high altitude (2500–3500 m a.s.l.): six communities (*n*=198)
- very high altitude (3500–5800 m a.s.l.): eight communities (*n*=195).

Data collection

Altitude was categorized as high (2500–3500 m a.s.l.) and very high (3500–5800 m a.s.l.)[12]. Frailty syndrome was evaluated using Fried's criteria[13]:

- unintentional weight loss: ≥4.5 kg in the past year
- self-reported exhaustion: evaluated with two questions: 'During the last week, have you felt that everything you did required effort?' or 'During the last 7 days, did you feel you couldn't get up to walk?'
- low physical activity: measured using the Minnesota Leisure Time Activity Questionnaire[14], considering frailty when in the lowest quintile (<383 kcal/week in men, <270 kcal/week in women)
- slow walking speed: measured according to the time taken to walk 4.6 m, considered frailty when in the lowest quintile, adjusted for sex and height
- muscle weakness: measured according to grip strength, considered a criterion when below 20% of the normal limit, adjusted for BMI and sex[13,14] (Table 1).

Final categories were robust (0 criteria), prefrail (1–2 criteria), and frail (≥3 criteria)[4].

Additionally, sociodemographic variables (age, sex, education level, occupation) and clinical variables were measured, including:

- self-perceived health: addresses cognitive and descriptive aspects of oneself regarding physical, social, and emotional health[15]. Classified as excellent, very good, good, regular or poor
- functional dependence: using the Barthel index, which is scored in increments of five points[16]. Classified as total dependence (<20 points), severe dependence (20–35 points), moderate dependence (40–55 points), mild dependence (60–95 points), and independent (100 points)
- cognitive impairment: evaluated with Pfeiffer's Short Portable Mental Status Questionnaire[17], consisting of nine questions, and counting errors obtained
- depressive symptoms: the Yesavage Depression Scale[18] (abbreviated five-item version), classified as presence of depressive symptoms (score ≥2) and absence of depressive symptoms (score <2)
- physical performance: evaluated with the Short Physical Performance Battery[19,20], consisting of three tests: balance, walking speed, and ability to stand up and sit down from a chair. Results classified as severe limitation (0–4 points), moderate limitation (5–6 points), mild limitation (7–9 points), and minimal limitation (10–12 points).

All information was collected in a structured form designed by the authors.

Table 1: Classification of grip strength or weakness

BMI (kg/m^2)	Grip strength (kg)	
	Men	Women
≤24	≤29	≤17
24.1–26	≤30	≤17.3
26.1–28	≤30	≤18
>28	≤32	≤21

BMI, body mass index.

Statistical analysis

Data were processed in Statistical Package for the Social Sciences v27 (IBM Corp; https://www.ibm.com/products/spss-statistics). Descriptive analysis was performed with measures of central tendency and dispersion for quantitative variables, and frequencies for categorical variables. Bivariate analysis used χ^2 or Fisher's exact test for categorical variables, and Student's *t*-test or ANOVA for continuous variables. Crude and adjusted prevalence ratios (PR) were calculated using Poisson regression with 95%CI. A *p*-value ≤0.05 was considered statistically significant.

Ethics approval

The study was approved by the Ethics Committee of Universidad Continental (Official Letter No. 0128-2022-VI-UC). All participants signed informed consent. Data confidentiality and anonymity were maintained.

Results

Sample characteristics

A total of 393 elderly individuals were evaluated, with a mean age of 72.8±8.4 years. Of these, 54.45% (*n*=214) were women. Distribution by altitude showed 50.38% (*n*=198) resided at high altitude and 49.62% (*n*=195) at very high altitude.

Regarding education level, 47.07% (*n*=185) had primary education and 31.30% (*n*=123) had no formal education. The predominant occupation was agriculture (50.13%, *n*=197), followed by homemaker (15.27%, *n*=60) and commerce (11.70%, *n*=46).

Prevalence of frailty syndrome

The overall prevalence of frailty syndrome was 44.53% (*n*=175). Distribution by groups was non-frail 55.47% (*n*=218) and frail 44.53% (*n*=175).

Of the total frail elderly, 80.6% (*n*=141) resided in very-high-altitude communities, while only 19.4% (*n*=34) lived at high altitude.

In the bivariate analysis evaluating sociodemographic characteristics and frailty:

- female sex: 63.43% of frail versus 47.25% of non-frail (p=0.001)
- no formal education: 49.14% of frail versus 16.97% of non-frail (p=0.001)
- agricultural occupation: 62.86% of frail versus 39.91% of non-frail (p=0.001)
- regular self-perceived health: 58.86% of frail versus 47.25% of non-frail (p=0.001)
- functional dependence (any degree): 72.0% of frail versus 35.32% of non-frail (p=0.001)
- cognitive impairment: 73.14% of frail versus 15.60% of non-frail (p=0.001)
- moderate/severe physical limitation: 58.86% of frail versus 20.64% of non-frail (p=0.001).

In the crude analysis between altitude and frailty, elderly residents at very high altitude presented 4.21 times higher prevalence of frailty than residents at high altitude (PR 4.21, 95%CI 3.06–5.78, p<0.001) (Table 2).

In the adjusted analysis, after adjustment for sociodemographic and clinical variables, the association remained significant (adjusted PR 3.11, 95%CI 1.87–5.17, p<0.001).

Stratified analysis by altitude showed that in:

- very-high-altitude communities: frailty prevalence 72.3%, with significant association with regular self-perceived health (p=0.001), functional dependence (p=0.001), cognitive impairment (p=0.001), and limited physical performance (p=0.001)
- high-altitude communities: frailty prevalence 17.2%, with similar associated factors but of lesser magnitude (Table 3).

Table 2: Bivariate analysis between frailty syndrome and health-related variables (n=393)

Variable	Classification	Non-frail *n* (%)	Frail *n* (%)	*p*-value
Self-perceived health	Excellent	3 (1.38)	0 (0.00)	0.001
	Very good	21 (9.63)	4 (2.29)	
	Good	80 (36.70)	41 (23.43)	
	Regular	103 (47.25)	103 (58.86)	
	Poor	11 (5.05)	27 (15.43)	
Healthcare seeking behavior	Health facility	171 (78.44)	143 (81.71)	0.710
	Self-medication	8 (3.67)	6 (3.43)	
	Traditional medicine	39 (17.89)	26 (14.86)	
Body mass index	Underweight	10 (4.59)	7 (4.00)	0.426
	Normal	117 (53.67)	110 (62.86)	
	Overweight	73 (33.49)	46 (26.29)	
	Obesity grade 1	14 (6.42)	11 (6.29)	
	Obesity grade 2	2 (0.92)	1 (0.57)	
	Obesity grade 3	2 (0.92)	0 (0.00)	
Functional dependence	Independent	141 (64.68)	49 (28.00)	0.001
	Mild dependence	62 (28.44)	95 (54.29)	
	Moderate dependence	13 (5.96)	25 (14.29)	
	Severe dependence	2 (0.92)	6 (3.43)	
Depressive symptoms	Absence	194 (88.99)	136 (77.71)	0.002
	Presence	24 (11.01)	39 (22.29)	
Physical performance	Minimal limitation	37 (16.97)	0 (0.00)	0.001
	Mild limitation	136 (62.39)	72 (41.14)	
	Moderate limitation	39 (17.89)	81 (46.29)	
	Severe limitation	6 (2.75)	22 (12.57)	
Cognitive impairment	Intact intellectual functioning	184 (84.40)	47 (26.86)	0.001
	Mild intellectual impairment	25 (11.47)	71 (40.57)	
	Moderate intellectual impairment	5 (2.29)	40 (22.86)	
	Severe intellectual impairment	4 (1.83)	17 (9.71)	
Altitude (m a.s.l.)	2500–3500 (high)	164 (75.23)	34 (19.43)	0.001
	3500–5800 (very high)	54 (24.77)	141 (80.57)	

a.s.l., above sea level.

Table 3: Poisson regression analysis to quantify the association between altitude, frailty syndrome and other covariates (n=393)

Classification	Crude model prevalence ratio (95%CI)	Adjusted model† prevalence ratio (95%CI)
2500–3500 m a.s.l. (high)	Reference	Reference
3500–5800 m a.s.l. (very high)	4.21 (3.06–5.78)	3.11 (1.87–5.17)

† Model adjusted for altitude, province, district, population center, sex, age, education level, occupation, self-perceived health, healthcare seeking behavior, body mass index, functional dependence, depressive symptoms, physical performance and cognitive impairment.
a.s.l., above sea level. CI, confidence interval.

Discussion

Currently, there are few studies that have evaluated frailty syndrome in high-altitude communities. The present investigation found an important prevalence of frail elderly.

Similarly, this work showed that elderly individuals residing at an altitude of 3500–5800 m a.s.l. in communities of Junín Department, Peru, had a higher frailty prevalence than communities located at 2500–3500 m a.s.l., a significant association being found in both cases. This finding agrees with what was found in Qinghai Province, China, where people living at very high altitudes for long periods experience negative impacts on their health, as they are exposed to low barometric pressure and limited oxygen, generating greater exhaustion when performing daily activities; additionally, most frail elderly people found live at an altitude of 4700 m a.s.l. Thus, an association was found between altitude and frailty syndrome[9].

Regarding sociodemographic characteristics, a predominance of frail elderly females was found, with a significant association. This finding is similar to studies conducted in the Peruvian departments of Huánuco, Ayacucho, and Cusco, which evaluated elderly residents of localities at 3000, 3286, and 3399 m a.s.l., respectively, and showed a significant association between female sex and frailty syndrome[2,21,22].

Regarding education level, most frail elderly residents at altitude had no formal education. Research conducted in Cusco Department, located at 3399 m a.s.l., found a similar result in determining higher frailty incidence in elderly with low education levels, being significant (p=0.009)[21]. This could be because the elderly from rural areas with lower education levels have less access to health information sources, and thus lack knowledge about healthy lifestyle habits[6].

Likewise, this research demonstrated that most frail elderly residents at altitude had regular self-perception of their health, this being statistically significant. This finding agrees with reports from Cusco Department, where a significant association was found between poor self-perceived health and frailty syndrome[22]. Similarly, in a study conducted in the rural community of Pelotas, Brazil, located at 429 m a.s.l., an association was found between poor self-perceived health and frailty syndrome (p<0.01), representing 64.8% (n=230) of their sample[23]. This finding could be because regular self-perceived health of a frail elderly person leads to worsening of their health status, as they limit themselves when performing physical activities and following an adequate diet[23].

There is a close relationship between presenting some degree of functional dependence and frailty syndrome, since dependent patients show decreased physical strength, slow gait, and a low level of physical activity[2]; a high percentage of frail elderly were found to have some degree of functional dependence. This agrees with Carrasco et al, who, in 2017, when determining the degree of functional dependence in 400 Mexican elderly people, discovered that 49% (n=197) of subjects were dependent, reflected in a significant association between frailty and functional dependence (p<0.001)[24].

It was determined that most frail elderly residents have some degree of cognitive impairment. This result is similar to that reported in research conducted in the Colombian Andes, which suggested that cognitive impairment is associated with frailty[25]. Similarly, Llano et al, when evaluating elderly individuals from a rural Brazilian community, found that 89.32% had cognitive deficit related to external, behavioral, environmental, and social factors[23], which could be because frailty and cognitive impairment share underlying biological factors such as molecular and cellular damage generated by aging, thus forming part of the frailty phenotype, generating functional alteration, decreased quality of life, and dependence[23].

Regarding physical performance, frail elderly individuals were found to have some degree of physical limitation, with moderate limitation being most representative, followed by mild limitation. This is controversial because a study by Ayamamani et al in rural communities of Áncash Department, Atipayán (3345 m a.s.l.) and Santa (6 m a.s.l.), identified that elderly residents located a few meters above sea level had a two-fold higher risk of poor physical performance than elderly residents living at altitude. Additionally, evaluated elderly people showed better performance in balance, speed, and chair stand tests[26]. In the present investigation, a considerable percentage of participants showed mild limitation, this being statistically significant.

Strengths and limitations

One of the main limitations of this study is the cross-sectional study design, since the measured associations cannot establish causality. Likewise, we believe that it would have been important to include other variables such as socioeconomic status, availability of basic services, access to healthcare services, and relevant biochemical markers that could provide information about the participant's cardiovascular and metabolic health status, such as interleukin-6, which has been associated with the development of frailty. However, this study was conducted by a multidisciplinary team that included geriatric physicians with extensive experience in both research and clinical practice. It also addressed a topic relevant at the local and international level, since it proposes research questions that have not been extensively addressed previously.

Conclusion

There is a significant association between residing at very high altitudes (3500–5800 m a.s.l.) and frailty syndrome in elderly people from Andean rural communities. Elderly residents at very high altitudes present three times higher prevalence of frailty than residents at high altitudes.

Associated factors include female sex, low education level, agricultural occupation, regular self-perceived health, functional dependence, cognitive impairment, and physical limitation. These findings highlight the particular vulnerability of Andean populations and the urgent need to implement preventive and specific management programs for this population.

Longitudinal studies are required to establish causal relationships, and clinical trials are required to evaluate specific interventions in high-altitude populations.

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Conflicts of interest

The authors declare no conflicts of interest.

AI disclosure statement

No artificial intelligence was used in the preparation of this work. The original Spanish text and the English translation were done by the researchers. All authors agree with the final version of the manuscript at the end of the revision.

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