

Association between anxiety symptoms and risk of falls in older adults residing in a high-altitude Peruvian Andean district: a secondary analysis of the Aunqui-Andes study

Asociación entre los síntomas ansiosos y el riesgo de caídas en adultos mayores residentes de un distrito andino peruano de gran altitud: análisis secundario del estudio Aunqui-Andes

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ABSTRACT

Objectives: This study aimed to evaluate the association between anxiety symptoms and risk of falls in older adults residing in the district of Totos, Ayacucho, Peru, in 2022. **Methods:** We conducted a secondary analysis of an analytical cross-sectional study. A total of 272 community-dwelling older adults aged ≥ 60 years were included. Participants with severe cognitive impairment (Pfeiffer score ≥ 8), dependence for ambulation, or incomplete data were excluded. Anxiety symptoms were assessed using the GAD-2 scale (score ≥ 3). Risk of falls was evaluated using the functional reach test (≤ 20.32 cm indicating increased risk). Crude (cPR) and adjusted prevalence ratios (aPR) with 95% confidence intervals (95%CI) were estimated using Poisson regression with robust variance. The adjusted model included sex, age, employment status, use of prescription eyeglasses, polypharmacy, frailty, and history of falls in the past year. **Results:** The prevalence of anxiety symptoms was 58.1% and the prevalence of risk of falls was 57.4%. In the crude analysis, older adults with anxiety symptoms had a higher prevalence of risk of falls (cPR = 1.32; 95% CI: 1.06 – 1.66; $p = 0.014$). After adjustment, the association was no longer statistically significant (aPR = 1.08; 95% CI: 0.86 – 1.36; $p = 0.491$). **Conclusions:** In older adults residing in a high-Andean rural district, anxiety symptoms were not significantly associated with risk of falls after adjustment for relevant covariates. These findings suggest that fall risk in high-altitude settings may be driven primarily by physical and functional factors, highlighting the importance of comprehensive geriatric assessment in rural Andean populations.

Keywords: Geriatric assessment; GAD-2; Postural balance; Altitude; Peru (Source: MeSH NLM).

RESUMEN

Objetivo: Evaluar la asociación entre los síntomas ansiosos y el riesgo de caídas en adultos mayores residentes en el distrito de Totos, Ayacucho, Perú, en 2022. **Materiales y métodos:** Análisis secundario de un estudio transversal analítico. Se incluyeron 272 adultos mayores de 60 años o más residentes en Totos, Ayacucho, Perú. Se excluyeron participantes con deterioro cognitivo severo (Pfeiffer ≥ 8), dependencia para la deambulación o datos incompletos. Los síntomas ansiosos se evaluaron con la escala GAD-2 (puntuación ≥ 3) y el riesgo de caídas mediante la prueba de alcance funcional ($\leq 20,32$ cm). Se estimaron RPc y RPa con IC95% mediante regresión de Poisson con varianzas robustas. El modelo ajustado incluyó sexo, edad, situación laboral, uso de anteojos, polifarmacia, fragilidad y antecedente de caídas en el último año. **Resultados:** La prevalencia de síntomas ansiosos fue 58,1% y la de riesgo de caídas 57,4%. En el análisis crudo, los adultos mayores con síntomas ansiosos presentaron mayor riesgo de caídas (RPc = 1,32; IC 95%: 1,06 – 1,66; $p = 0,014$). Tras el ajuste, la asociación dejó de ser significativa (RPa = 1,08; IC 95%: 0,86 – 1,36; $p = 0,491$). **Conclusiones:** Los síntomas ansiosos no se asociaron significativamente con el riesgo de caídas tras el ajuste por confusores relevantes. Estos hallazgos sugieren que el riesgo de caídas en contextos altoandinos podría estar determinado principalmente por factores físicos y funcionales, lo que subraya la importancia de una evaluación geriátrica integral en poblaciones rurales andinas.

Palabras clave: Evaluación geriátrica; GAD-2; Equilibrio postural; Altitud; Perú (fuente: DeCS Bireme).



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INTRODUCTION

Falls in older adults represent a major public health problem due to their high frequency and the serious consequences they can cause. The World Health Organization (WHO) defines a fall as any event in which a person unintentionally ends up on the ground [1]. Approximately 30% of adults aged 65 years or older experience at least one fall per year, and these events can lead to fractures, prolonged hospitalizations, loss of independence, fear of falling again, and reduced social participation [2,3]. Falls rarely have a single cause; physical, psychological, and environmental factors all contribute to their occurrence, particularly in older adults who already face multiple health problems [4,5].

One such psychological factor is anxiety, which has been identified as an independent predictor of fear of falling and activity restriction in older adults [6]. The American Psychiatric Association recognizes that anxiety disorders substantially interfere with daily functioning, affecting the person's ability to manage fear and excessive worry [7]. Stress, adverse experiences, and limited social support have been associated with higher rates of anxiety in this age group [8,9] and, when untreated, anxiety can contribute to greater dependence, disability, and excessive use of health services [10,11]. Its relationship with fall risk is explained through specific pathways, including restriction of physical activity due to fear of movement, which accelerates deconditioning, amplification of dizziness and postural instability, and reduced attentional resources available for walking due to the cognitive load of worry [12]. In high-Andean communities, where geographic isolation and limited access to medical care are common, anxiety may go undetected and untreated for extended periods [5].

Living at high altitude adds physiological and structural conditions that can independently increase the risk of falls. Experimental exposure to hypobaric hypoxia has been shown to impair balance by disrupting the cerebral integration of visual, vestibular, and proprioceptive signals [13], although the extent to which these effects apply to lifelong high-altitude residents remains unclear, and previous studies in high-altitude Peruvian communities have reported high prevalences of balance impairment and low physical performance in older adults [14,15]. Structural conditions further contribute to fall risk. Food insecurity may reduce muscle mass and strength, compromising postural stability; limited access to healthcare hinders the treatment of comorbidities such as sarcopenia and osteoarthritis; and the high prevalence of poverty restricts access to safe environments and support networks that act as protective factors [5,16]. It should be noted, however, that individuals who are lifelong residents of high-altitude communities may develop physiological and genetic adaptations to chronic hypoxia that could

attenuate some of these effects compared with those observed under acute or short-term exposure conditions.

Despite the global relevance of fall prevention, the association between psychological factors such as anxiety and fall risk in contexts of chronic hypoxia, physical frailty, and rural poverty has not been systematically evaluated. Most available studies have been conducted in urban settings or at sea level, where the physiological profile and determinants of fall risk differ considerably from those of high-Andean communities [14,16]. The aim of this study was to evaluate the association between anxiety symptoms and risk of falls in older adults residing in a high-Andean district of Ayacucho, Peru, in 2022.

METHODS

Study design, population, and sample

A secondary analysis of data from an analytical cross-sectional study was conducted in the district of Totos, province of Cangallo, Ayacucho region, Peru, during August 2022. The district is located at a mean altitude of 3,286 meters above sea level, with a mean annual temperature of 9.2°C and approximately 97 km from Huamanga, the regional capital. According to the 2017 National Census, the district had 3,009 inhabitants, of whom approximately 11% were older adults. The present analysis is based on data from the Aunqui-Andes study, the primary study conducted in this district [5]. The district is characterized by a predominantly rural, Quechua-speaking population with high rates of poverty, limited access to healthcare services, and low educational attainment, conditions that contribute to the vulnerability of its older adult population.

The primary study conducted a complete census of older adults aged 60 years or older residing in nine populated centers of the district, identifying and assessing 292 eligible individuals: Huanupampa, Ramón Castilla, Chuymay, Totos, Veracruz, Quiñasi, Lloqllasqa, Chacabamba, and Totospampa. For this secondary analysis, 272 participants with complete data for all variables of interest were included. The remaining 20 were excluded for not meeting the selection criteria: 11 had severe cognitive impairment (Pfeiffer score ≥ 8 ; as this level of impairment compromises the ability to provide reliable self-report and to participate meaningfully in assessments requiring comprehension and cooperation), 5 had functional dependence for ambulation, and 4 had incomplete information on study variables.

With 272 participants, a prevalence of fall risk of 57.4%, 80% power, and a two-sided α of 0.05, the study had sufficient power to detect a prevalence ratio of ≥ 1.30 or ≤ 0.68 . The observed crude prevalence ratio of 1.32 marginally exceeds this threshold; however, the adjusted

prevalence ratio of 1.08 falls below it, suggesting that the study may have had limited power to detect associations of smaller magnitude after adjustment. This report follows the STROBE recommendations for observational studies.

Procedures

Data collection was carried out through scheduled visits to the populated centers of the district. Participants were recruited through local radio broadcasts, and access to each community was coordinated with community leaders and the district's social development office. Health center staff and the research team received prior training from the principal investigator on technical, ethical, and methodological aspects related to instrument administration and data management. All necessary materials and instruments were transported to the communities in advance.

Assessments were conducted individually with each participant. To ensure effective communication, the team included staff from Ayacucho with proficiency in both Spanish and the Chanka variant of Quechua, the predominant language in the district. All older adults who met the selection criteria and voluntarily agreed to participate were enrolled after receiving a clear explanation of the informed consent process and signing it. Assessments were conducted independently of the healthcare provided by the district health center, which was explicitly communicated to participants upon enrollment.

Outcome variable: risk of falls

Risk of falls was assessed using the functional reach test, performed on a flat surface. Each participant was instructed to lean forward without moving their feet or touching the wall, while maintaining balance. The maximum reach distance in centimeters was recorded, considering the best of two attempts. A cut-off of 20.32 cm was established. Values ≤ 20.32 cm indicated the presence of fall risk, and values > 20.32 cm indicated its absence [15,17]. This test is a functional indicator of fall risk, as it assesses components related to balance and postural stability, although it does not measure the actual occurrence of falls.

Exposure variable: anxiety symptoms

Anxiety symptoms were assessed using the GAD-2 (Generalized Anxiety Disorder-2), an abbreviated version of the GAD-7. The GAD-2 consists of two items exploring the frequency of feeling anxious or nervous and being unable to control worry over the past two weeks. A score

≥ 3 points was considered a positive result for anxiety symptoms [18]. It is important to note that the GAD-2 is a screening tool and not a clinical diagnostic instrument; it only allows for the identification of the possible presence of anxiety symptoms in the assessed sample. Furthermore, the questionnaire has not been specifically validated in Quechua-speaking populations.

Other variables

Sociodemographic characteristics

The following variables were collected through self-report: age (60–69, 70–79, ≥ 80 years), sex (male, female), marital status (single, married or cohabiting, widowed or divorced), living alone (yes, no), educational level (no education/incomplete primary, complete primary/incomplete secondary, complete secondary, technical or university education), and employment status (employed, unemployed).

Medical history and medication use

The following were assessed by self-report: use of prescription eyeglasses (yes, no) and polypharmacy, defined as the concurrent use of three or more medications at the time of assessment (yes, no) [19]. Comorbidities assessed included: hypertension, type 2 diabetes mellitus, arthritis or osteoarthritis, chronic low back pain, and osteoporosis, all evaluated by self-report and summarized as a variable with three categories (0, 1, and 2 or more). Body mass index (BMI) was calculated from body weight in kilograms and height in meters, and reported in kg/m^2 .

Frailty

Frailty was assessed using the Fried phenotype criteria, comprising five components [20]. Weight loss was evaluated through the question: Have you recently noticed that your clothes feel looser? An affirmative response defined the presence of this criterion [21]. Exhaustion was defined as an affirmative response to two or more of the following items from the Center for Epidemiologic Studies Depression Scale (CES-D): a) Do you feel full of energy?, b) Do you feel that you can't get going?, and c) Do you feel that everything you do is an effort? [22]. Slowness was defined as having gait speed in the slowest 20th percentile over four meters, adjusted for sex and height, or an inability to complete the test [23]. Low physical activity was assessed using the Physical Activity Scale for the Elderly (PASE), with a score below 64 for men and below 52 for women indicating low physical activity [24,25]. Weakness was defined as having grip strength in the lowest 20th

percentile, estimated within each combination of sex and BMI quartile [23]. Older adults meeting three or more criteria were classified as frail [20].

Cognitive impairment

Cognitive impairment was assessed using the Short Portable Mental Status Questionnaire (SPMSQ), a 10-item instrument evaluating orientation, memory, and calculation. Scoring is based on the number of errors. Cognitive impairment was defined as 3 or more errors, with adjustment for the participant's educational level: one additional error was allowed for those with no formal education or incomplete primary schooling, and one error was discounted for those with higher education [26].

Depressive symptoms

Depressive symptoms were assessed using the 5-item Geriatric Depression Scale (GDS-5), an abbreviated version of Yesavage's original scale. Each item is answered yes or no, with a total score ranging from 0 to 5. A score of 2 or more was considered a positive result for depressive symptoms [27].

Falls in the past year

History of falls was assessed by self-report through the question: Have you experienced a fall in the past year? A positive classification was assigned if the participant reported at least one fall in the 12 months prior to the assessment (yes, no) [5].

Functional disability

Functional disability was assessed using the Barthel Index, an instrument that measures the older adult's ability to independently perform ten basic activities of daily living, such as eating, bathing, dressing, transferring, and controlling sphincters. The total score ranges from 0 to 100 points. A score below 100 was classified as functional disability [28].

Statistical analysis

Data were imported into Stata/SE v17.0 (StataCorp, College Station, TX, USA) for analysis. Categorical variables were described using absolute and relative frequencies, and continuous variables using means and standard deviations. Normality of continuous variables was assessed using histograms, quantile plots, and comparison of measures of central tendency and dispersion.

Bivariate analysis was performed using Pearson's chi-square test or Fisher's exact test for categorical variables, according to the fulfillment of assumptions. For the comparison of continuous variables between two groups, the independent-samples Student's t-test was used; when assumptions were not met, the Mann-Whitney U test was applied. Homogeneity of variances was assessed with Levene's test.

For the multivariable analysis, a generalized linear model of the Poisson family with a logarithmic link function and robust variance was constructed, from which crude (cPR) and adjusted prevalence ratios (aPR) with their respective 95% confidence intervals (95% CI) were estimated. The adjusted model included the following covariates, selected based on their reported association with both variables in the literature: sex, age, employment status, use of prescription eyeglasses, polypharmacy, frailty and history of falls in the past year [5,14]. Multicollinearity between covariates was assessed using the variance inflation factor (VIF), with a threshold of 3 used to identify relevant collinearity; all VIF values were below this threshold. A p-value <0.05 was considered statistically significant.

Ethical Aspects

The primary study was approved by the Institutional Research Ethics Committee of Universidad Científica del Sur (registration code: 005-2022-PRO99). The present secondary analysis was exempted by the same committee, as it did not involve direct contact with participants. The database was formally requested from the investigators of the primary study. In the primary study, written informed consent was obtained from all participants; in the case of individuals without formal education, consent was provided by a legal guardian or authorized representative.

RESULTS

Descriptive and bivariate analysis according to the prevalence of anxiety symptoms

Of the 292 older adults assessed in the primary study, 272 were included in the present analysis after excluding 11 with severe cognitive impairment, 5 with functional dependence for ambulation, and 4 with incomplete data. A sample of 272 older adults residing in a high-Andean community was analyzed, with a mean age of 75.0 years (SD: 8.6). Of these, 59.9% (n=163) were women and the vast majority (83.1%) had not completed primary education. At the time of assessment, 48.9% were employed, 37.9% lived alone, and 62.1% were married or cohabiting.

Table 1. Descriptive and bivariate analysis according to the prevalence of anxiety symptoms in older adults residing in a high-Andean district of Ayacucho, Peru (n=272).

Variables	Total (n = 272)	No anxiety symptoms (n = 114)	Anxiety symptoms (n = 158)	P value
	n (%)	n (%)	n (%)	
Sex				<0.001
Female	163 (59.9)	51 (44.7)	112 (70.9)	
Male	109 (40.1)	63 (55.3)	46 (29.1)	
Age (years), mean (SD)	75.0 (8.6)	74.0 (8.1)	75.7 (8.9)	0.106 [‡]
60–69 years	81 (29.8)	38 (33.3)	43 (27.2)	0.544
70–79 years	97 (35.7)	38 (33.3)	59 (37.3)	
≥80 years	94 (34.6)	38 (33.3)	56 (35.4)	
Marital status				0.500
Single	16 (5.9)	7 (6.1)	9 (5.7)	
Married or cohabiting	169 (62.1)	75 (65.8)	94 (59.5)	
Widowed or divorced	87 (32.0)	32 (28.1)	55 (34.8)	
Educational level				0.146 [*]
No education/Incomplete primary	226 (83.1)	90 (78.9)	136 (86.1)	
Complete primary/Incomplete secondary	28 (10.3)	14 (12.3)	14 (8.9)	
Complete secondary	12 (4.4)	5 (4.4)	7 (4.4)	
Technical or university education	6 (2.2)	5 (4.4)	1 (0.6)	
Lives alone				0.190
No	169 (62.1)	76 (66.7)	93 (58.9)	
Yes	103 (37.9)	38 (33.3)	65 (41.1)	
Employment status				0.023
Unemployed	139 (51.1)	49 (43.0)	90 (57.0)	
Employed	133 (48.9)	65 (57.0)	68 (43.0)	
Comorbidities				0.027
0	140 (51.5)	69 (60.5)	71 (44.9)	
1	75 (27.6)	28 (24.6)	47 (29.7)	
2 or more	57 (21.0)	17 (14.9)	40 (25.3)	
Use of prescription eyeglasses				0.511
No	202 (74.3)	87 (76.3)	115 (72.8)	
Yes	70 (25.7)	27 (23.7)	43 (27.2)	
BMI (kg/m ²), mean (SD)	25.9 (3.7)	25.8 (3.7)	26.0 (3.7)	0.714 [‡]
Polypharmacy				0.057
No	247 (90.8)	108 (94.7)	139 (88.0)	
Yes	25 (9.2)	6 (5.3)	19 (12.0)	
Low physical activity				0.209
No	254 (93.4)	109 (95.6)	145 (91.8)	
Yes	18 (6.6)	5 (4.4)	13 (8.2)	
Frailty (Fried phenotype)				0.019
No	218 (80.1)	99 (86.8)	119 (75.3)	
Yes	54 (19.9)	15 (13.2)	39 (24.7)	
Cognitive impairment (SPMSQ)				0.017
No	77 (28.3)	41 (36.0)	36 (22.8)	
Yes	195 (71.7)	73 (64.0)	122 (77.2)	
Depressive symptoms (GDS-5)				<0.001
No	116 (42.6)	66 (57.9)	50 (31.6)	
Yes	156 (57.4)	48 (42.1)	108 (68.4)	
Falls in the past year				<0.001
No	141 (51.8)	77 (67.5)	64 (40.5)	
Yes	131 (48.2)	37 (32.5)	94 (59.5)	
Functional disability (Barthel)				<0.001
No	133 (48.9)	73 (64.0)	60 (38.0)	
Yes	139 (51.1)	41 (36.0)	98 (62.0)	
Risk of falls				0.010
No	116 (42.6)	59 (51.8)	57 (36.1)	
Yes	156 (57.4)	55 (48.2)	101 (63.9)	

BMI: body mass index; SPMSQ: Short Portable Mental Status Questionnaire; GDS-5: Geriatric Depression Scale, 5-item version.

* Fisher's exact test. ‡ Student's t-test for independent samples.

Regarding comorbidities, 14.7% had hypertension, 5.9% had type 2 diabetes mellitus, and 11.8% had arthritis or osteoarthritis. Frailty according to the Fried phenotype was present in 19.9%, cognitive impairment in 71.7%, and functional disability according to the Barthel Index in 51.1%. Depressive symptoms were present in 57.4%, and 48.2% reported at least one fall in the past year.

The prevalence of anxiety symptoms was 58.1% (n=158). A higher frequency of anxiety symptoms was observed in women (70.9% vs. 29.1%; $p<0.001$), in unemployed individuals (57.0% vs. 43.0%; $p=0.023$), in those with two or more comorbidities (25.3%; $p=0.027$), in those with frailty (24.7% vs. 13.2%; $p=0.019$), cognitive impairment (77.2% vs. 22.8%; $p=0.017$), depressive symptoms (68.4%; $p<0.001$), falls in the past year (59.5%; $p<0.001$), and functional disability (62.0%; $p<0.001$). No statistically significant differences were found by age group, marital status, educational level, use of prescription eyeglasses, BMI, polypharmacy, or low physical activity. The full descriptive and bivariate analysis according to the prevalence of anxiety symptoms is presented in Table 1.

Bivariate analysis according to the prevalence of risk of falls

The prevalence of risk of falls was 57.4% (n=156). Mean age was significantly higher among those with fall risk 77.4 years (SD: 8.7) compared with those without (71.7 years (SD: 7.2); $p<0.001$). Fall risk increased progressively with age: 18.6% in the 60–69 age group, 37.8% in the 70–79 group, and 43.6% in those aged 80 years or older ($p<0.001$).

A higher prevalence of fall risk was observed in women (69.2% vs. 30.8%; $p<0.001$), in widowed or divorced older adults (39.7%; $p=0.004$), in unemployed individuals (62.2%; $p<0.001$), and in those with lower educational levels ($p=0.006$). From a clinical standpoint, fall risk was significantly higher in those with low physical activity (10.3% vs. 1.7%; $p=0.005$), polypharmacy (12.2% vs. 5.2%; $p=0.048$), frailty (28.2% vs. 8.6%; $p<0.001$), cognitive impairment (79.5%; $p<0.001$), prior falls (54.5%; $p=0.015$), and functional disability (57.7%; $p=0.012$). No significant differences were found for comorbidities, use of prescription eyeglasses, BMI, or depressive symptoms. In the bivariate analysis, anxiety symptoms were associated with a higher risk of falls (64.7% vs. 35.3%; $p=0.010$). The full bivariate analysis according to fall risk is presented in Table 2.

Crude and adjusted prevalence ratios estimating the association between anxiety symptoms and risk of falls

In the crude Poisson regression model, older adults with anxiety symptoms had a prevalence ratio of 1.32 (95%

CI: 1.06 – 1.66; $p=0.014$) for fall risk compared with those without anxiety symptoms. However, after adjusting for sex, age group, employment status, use of prescription eyeglasses, polypharmacy, frailty, and history of falls in the past year the association was no longer statistically significant (aPR=1.08; 95% CI: 0.86 – 1.36; $p=0.491$) (Table 3).

DISCUSSION

Main findings

This study found no statistically significant association between anxiety symptoms and risk of falls in older adults residing in a high-Andean community in Peru, after adjusting for sociodemographic, clinical, and functional variables. This finding is noteworthy because, in the crude analysis, anxiety symptoms were associated with a higher risk of falls, though this association lost magnitude and statistical significance after including covariates such as sex and age. To our knowledge, this is one of the first studies to evaluate this association in a rural high-Andean population in Peru, a context that differs substantially from those in which most previous studies have been conducted.

Comparison with previous studies

The association between anxiety symptoms and risk of falls has been described in previous studies. A meta-analysis including 25 international studies found that the presence of anxiety was associated with a higher risk of recurrent falls in older adults [29]. Similarly, a systematic review of 27 studies concluded that fall-related concerns, a frequent manifestation of anxiety, were associated with poorer postural stability, lower gait confidence, and greater restriction of social participation [30]. It should be noted, however, that these studies used self-reported or recurrent fall events as their outcome, whereas the present study assessed balance-derived fall risk using the functional reach test, an objective measure of postural stability, which constitutes a functional proxy for fall risk rather than a direct measure of fall occurrence. Direct comparisons should therefore be interpreted with caution.

In rural settings, Liu, in a cross-sectional study conducted exclusively in robust, non-frail older adults, found no direct association between anxiety and fear of falling, suggesting that this fear may be more strongly determined by prior fall experiences or subjective perception of balance than by anxiety itself [31]. This distinction is relevant to the present study, in which one out of five of participants were classified as frail, and the functional profile of the sample may therefore differ from that of Liu's population.

Table 2. Descriptive and bivariate analysis according to the prevalence of risk of falls in older adults residing in a high-Andean district of Ayacucho, Peru (n=272).

Variables	Total (n = 272)	No risk of falls (n = 116)	Risk of falls (n = 156)	P value
	n (%)	n (%)	n (%)	
Anxiety symptoms				0.010
No	114 (41.9)	59 (50.9)	55 (35.3)	
Yes	158 (58.1)	57 (49.1)	101 (64.7)	
Sex				<0.001
Female	163 (59.9)	55 (47.4)	108 (69.2)	
Male	109 (40.1)	61 (52.6)	48 (30.8)	
Age (years), mean (SD)	75.0 (8.6)	71.7 (7.2)	77.4 (8.7)	<0.001 [‡]
60–69 years	81 (29.8)	52 (44.8)	29 (18.6)	<0.001
70–79 years	97 (35.7)	38 (32.8)	59 (37.8)	
≥80 years	94 (34.6)	26 (22.4)	68 (43.6)	
Marital status				0.004
Single	16 (5.9)	6 (5.2)	10 (6.4)	
Married or cohabiting	169 (62.1)	85 (73.3)	84 (53.8)	
Widowed or divorced	87 (32.0)	25 (21.6)	62 (39.7)	
Educational level				0.006*
No education/Incomplete primary	226 (83.1)	86 (74.1)	140 (89.7)	
Complete primary/Incomplete secondary	28 (10.3)	18 (15.5)	10 (6.4)	
Complete secondary	12 (4.4)	7 (6.0)	5 (3.2)	
Technical or university education	6 (2.2)	5 (4.3)	1 (0.6)	
Lives alone				0.213
No	169 (62.1)	77 (66.4)	92 (59.0)	
Yes	103 (37.9)	39 (33.6)	64 (41.0)	
Employment status				<0.001
Unemployed	139 (51.1)	42 (36.2)	97 (62.2)	
Employed	133 (48.9)	74 (63.8)	59 (37.8)	
Comorbidities				0.784
0	140 (51.5)	61 (52.6)	79 (50.6)	
1	75 (27.6)	33 (28.4)	42 (26.9)	
2 or more	57 (21.0)	22 (19.0)	35 (22.4)	
Use of prescription eyeglasses				0.547
No	202 (74.3)	84 (72.4)	118 (75.6)	
Yes	70 (25.7)	32 (27.6)	38 (24.4)	
BMI (kg/m ²), mean (SD)	25.9 (3.7)	25.8 (3.5)	25.9 (3.9)	0.814 [‡]
Polypharmacy				0.048
No	247 (90.8)	110 (94.8)	137 (87.8)	
Yes	25 (9.2)	6 (5.2)	19 (12.2)	
Low physical activity				0.005
No	254 (93.4)	114 (98.3)	140 (89.7)	
Yes	18 (6.6)	2 (1.7)	16 (10.3)	
Frailty (Fried phenotype)				<0.001
No	218 (80.1)	106 (91.4)	112 (71.8)	
Yes	54 (19.9)	10 (8.6)	44 (28.2)	
Cognitive impairment (SPMSQ)				<0.001
No	77 (28.3)	45 (38.8)	32 (20.5)	
Yes	195 (71.7)	71 (61.2)	124 (79.5)	
Depressive symptoms (GDS-5)				0.715
No	116 (42.6)	48 (41.4)	68 (43.6)	
Yes	156 (57.4)	68 (58.6)	88 (56.4)	
Falls in the past year				0.015
No	141 (51.8)	70 (60.3)	71 (45.5)	
Yes	131 (48.2)	46 (39.7)	85 (54.5)	
Functional disability (Barthel)				0.012
No	133 (48.9)	67 (57.8)	66 (42.3)	
Yes	139 (51.1)	49 (42.2)	90 (57.7)	

BMI: body mass index; SPMSQ: Short Portable Mental Status Questionnaire; GDS-5: Geriatric Depression Scale, 5-item version.

* Fisher's exact test. ‡ Student's t-test for independent samples.

Table 3. Crude and adjusted Poisson regression models estimating the association between anxiety symptoms and risk of falls in older adults residing in a high-Andean district of Ayacucho, Peru (n=272).

Variables	Crude model			Adjusted model*		
	cPR	95% CI	P value	aPR	95% CI	P value
Anxiety symptoms						
No		Reference			Reference	
Yes	1.32	1.06 – 1.66	0.014	1.08	0.86 – 1.36	0.491

cPR: Crude prevalence ratio; aPR: Adjusted prevalence ratio; 95% CI: 95% confidence interval.

*Adjusted for sex, age group, employment status, use of prescription eyeglasses, polypharmacy, frailty, and history of falls in the past year.

Interpretation of the results

The absence of an association can be explained from different perspectives. First, it is likely that in rural high-Andean communities, fall risk is determined primarily by physical and functional factors such as frailty, muscle weakness, or sarcopenia, rather than by emotional symptoms. Previous studies in Peruvian Andean communities have reported high prevalences of balance impairment and low physical performance associated with chronic hypoxia and the conditions of life at altitude [14,15], and when controlling for frailty, which integrates into a single construct muscle weakness, slowness of gait, exhaustion, weight loss, and low physical activity [20], the accumulated functional burden may be large enough to eclipse the independent contribution of anxiety symptoms.

From a physiological perspective, chronic hypobaric hypoxia reduces serotonin synthesis by decreasing the activity of tryptophan hydroxylase, an oxygen-dependent enzyme, which has been associated with greater vulnerability to anxiety and depressive symptoms in altitude populations [32]. However, the participants in this study are high-Andean natives with decades of physiological and genetic adaptation, whose neurobiological response to chronic hypoxia differs substantially from that described in models of acute exposure [13], making it impossible to directly extrapolate those mechanisms to this sample.

In high-Andean communities, older adults often have strong family and community networks that may attenuate the effect of anxiety and reduce the avoidance behaviors that in other contexts contribute to fall risk [5,16]. In addition, the GAD-2 has not been validated in Quechua-speaking populations with low educational levels, so some culturally specific manifestations of anxiety may not be captured by the instrument, potentially underestimating the true prevalence and attenuating the magnitude of the observed association [18].

Notably, depressive symptoms were not associated with fall risk in the bivariate analysis, despite their high co-occurrence with anxiety symptoms in this sample. This suggests that the crude association between anxiety and fall risk may be driven specifically by anxiety-related mechanisms, such as fear of movement and avoidance

behavior, rather than by the broader affective burden shared with depression.

Public health implications

The findings of this study have concrete implications for the design of fall prevention strategies in rural high-Andean communities. The absence of a significant association between anxiety symptoms and fall risk does not diminish the importance of addressing mental health in this population, but it does point to the need to prioritize interventions focused on physical and functional strengthening, frailty management, and treatment of the most prevalent musculoskeletal comorbidities [33]. These findings suggest that preventive strategies in these communities must be contextualized and cannot be directly transferred from studies conducted in urban or sea-level settings [5,16]. This data may be useful for guiding differentiated geriatric policies and for justifying the development of longitudinal research to clarify the direction and magnitude of the association between psychological and functional factors in older adults living at high altitude.

Strengths and limitations

One of the main strengths of this study is the use of internationally validated instruments to measure both the exposure and the outcome, ensuring comparability of results with other studies. Another relevant strength is that the study provides evidence in a rural high-Andean population that is underrepresented in the literature on falls and mental health in older adults. Among the limitations, the cross-sectional design does not allow for establishing causality between the variables analyzed. The use of self-report for variables such as anxiety symptoms may have introduced recall or social desirability bias. As a secondary analysis, some variables of interest such as psychotropic medication use or the presence of depression could not be included in the adjusted model, limiting control for residual confounding. The minimum detectable effect size calculation, presented in the Methods section, suggests that the study may have had limited power to detect associations of smaller

magnitude after adjustment, which should be considered when interpreting the null finding in the adjusted model. The restriction of the sample to older adults from a single district limits the generalizability of the results to other high-Andean communities with different geographical, cultural, or socioeconomic characteristics. As the primary study employed a census-based design, the findings are representative of the eligible population of Totos but should be interpreted with caution when extrapolated to other settings. Additionally, the functional reach test provides an objective measure of postural balance and has been validated as a predictor of future falls; however, it does not capture the actual occurrence of fall events. Finally, the GAD-2 has not been validated in Quechua-speaking populations with low educational levels. Non-differential misclassification of anxiety symptoms, equally likely among those with and without fall risk, would bias the prevalence ratio toward 1.0, potentially contributing to the null finding in the adjusted model. Additionally, culturally specific expressions of distress in Andean populations, such as somatic symptoms, may not be captured by this instrument, likely underestimating the true prevalence of anxiety symptoms. Validation studies of the GAD-2 in Quechua-speaking older adults are warranted. The 20.32 cm functional reach cut-off has not been formally validated in high-altitude populations, though it has been previously used in the same geographic context [15].

This study found no statistically significant association between anxiety symptoms and risk of falls in older adults residing in a high-Andean district of Peru. Although an association was observed in the crude analysis, it was attenuated after controlling for sex, age, and functional factors. The absence of a significant association does not imply that mental health is irrelevant to the functional status of older adults, but rather underscores the need to address these variables within their specific geographical and cultural context. Longitudinal studies with instruments validated in Quechua-speaking populations and larger samples are needed to confirm these findings and to contribute to the design of culturally adapted preventive interventions aimed at preserving the quality of life of this population.

Author contributions

RRLG: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. PAPP: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. LST: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. DUP: Conceptualization, Methodology, Formal analysis,

Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration. RCM: Methodology, Writing – original draft, Writing – review & editing. FMRC: Resources, Data curation, Writing – review & editing. JFP: Resources, Data curation, Writing – review & editing.

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Conflicts of interest statement

The authors have no conflicts of interest to declare.

Generative Artificial Intelligence use statement

During the preparation of this work, the authors used Claude for the purpose of translating specific terms within the manuscript into English. After using this tool, the authors reviewed and carefully edited the content as needed; they agree with the final results and take full responsibility for the content of the publication.

Data availability statement

The datasets utilized and analyzed in the present study are accessible upon reasonable request to the corresponding author.

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