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Body Mass Index, Physical Activity, and Physical Balance among Community-Dwelling Older Adults in A Rural Balinese Village: A Cross-Sectional Study

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ABSTRACT

Background: Population aging in Indonesia has been accompanied by a rising burden of falls among older adults, and rural villages carry much of this burden while having the least access to geriatric rehabilitation services. Impaired physical balance is a modifiable precursor of falling, yet nutritional status and habitual activity have rarely been examined together in rural Balinese communities. **Purpose:** To examine the relationship of body mass index and physical activity with physical balance among community-dwelling older adults in Gulingan Village, Mengwi Sub-district, Badung Regency, Bali, Indonesia. **Methods:** An analytical cross-sectional study was conducted between February and March 2026 among 248 older adults aged 60 years and over, recruited by purposive sampling from the village register of integrated health posts for older people. Nutritional status was expressed as body mass index calculated from measured weight and height, and classified with Asia-Pacific cut-off points. Habitual activity was measured with the Physical Activity Scale for the Elderly, and physical balance with the Timed Up and Go test. Associations were tested with the Spearman rank correlation. **Results:** Mean age was 71.60 years (standard deviation 7.46) and 134 respondents (54.0%) were women. Obesity class 1 was the most frequent nutritional category (85 respondents; 34.3%); 166 respondents (66.9%) had a low level of habitual activity; and 126 respondents (50.8%) were classified as high risk of falling. A higher body mass index category was associated with poorer physical balance ($r = 0.848$; $p < 0.001$), and a lower level of physical activity was likewise associated with poorer physical balance ($r = 0.725$; $p < 0.001$). **Conclusions:** Nutritional status and habitual activity were both strongly associated with physical balance in this rural older population, and both are modifiable. Nurses working in village settings should combine routine measurement of weight, height, and activity level with performance-based balance screening and cadre-delivered balance training within existing integrated health posts for older people.

KEYWORDS

Accidental falls, Physical activity, Body Mass Index, Exercise, Postural balance

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1. BACKGROUND

The global population is ageing at an unprecedented pace. People aged 60 years and over numbered approximately 1.4 billion in 2022 and are projected to reach 2.1 billion by 2050, with the steepest growth in low-

and middle-income countries (World Health Organization, 2022). Indonesia has entered the aging-population phase, with older people accounting for 11.75% of the national population (Badan Pusat Statistik, 2023). Bali has one of the country's highest proportions, at approximately 13.5%, reflecting improved life expectancy and sustained out-migration of younger adults from rural villages. This shift has substantially increased demand for community-based nursing to address the degenerative health problems of advanced age.

Among these problems, falls are one of the most consequential. A meta-analysis of 104 studies estimated the global prevalence of falls among older adults at 26.5% (Salari et al., 2022), and the World Health Organization (2021) identifies falls as the second leading cause of unintentional injury death worldwide. They precipitate fractures, restrictions in daily activities, loss of independence, and institutionalization. They are consistently associated with increased morbidity, health expenditure, and premature mortality (Montero-Odasso et al., 2022), while fear of falling compounds these consequences by further reducing activity (Xiong et al., 2024). In rural districts the consequences are amplified, because emergency transport is slower, rehabilitation services are concentrated in urban referral hospitals, and recovery depends heavily on family caregiving capacity. Evidence from West Java indicates that fall prevalence among rural Indonesian older adults is at least as high as among urban counterparts, despite the assumption that village life is protective (Nugraha et al., 2021).

Physical balance, the capacity to keep the centre of mass within the base of support during static postures and movement, is an integrated output of the visual, vestibular, proprioceptive, central nervous and musculoskeletal systems. Ageing degrades each subsystem: proprioceptive sensitivity declines, vestibular hair cells are lost, central processing and reaction time slow, and muscle mass, strength and power decrease (Gupta & Singla, 2024). Because balance is the final common pathway through which many age-related changes translate into falls, it is the principal screening target in fall-prevention programs. Unlike chronological age, several of its determinants are modifiable.

Nutritional status, commonly operationalised as body mass index, is one such determinant. Excess body mass

displaces the centre of gravity anteriorly, increases the mechanical demand on the ankle and hip stabilisers and slows postural correction, all of which narrow the margin of stability. A meta-analysis concluded that obesity after age 60 increases both the risk and severity of falls (Neri et al., 2020), and a survey of 1,984 older adults in Shanghai found that overweight and obesity independently increased the odds of balance impairment (odds ratio 1.26) after adjustment for age, exercise, somatosensory function and vision (Xia et al., 2023). At the opposite extreme, a low body mass index frequently signals depletion of muscle mass and strength, and sarcopenia-related traits predict falling in cohort and Mendelian randomisation analyses (Yang et al., 2025). Their combination, sarcopenic obesity, is particularly detrimental because a heavier body must be stabilised by weaker effectors, carrying a higher likelihood of falls and fractures than either condition alone (Gandham et al., 2021). The relationship between body mass index and balance is therefore best understood as non-linear, with both tails conferring risk.

Habitual physical activity is the second modifiable determinant. Regular activity preserves muscle cross-sectional area and neuromuscular recruitment, maintains joint range of motion, sustains proprioceptive acuity and speeds postural responses. Exercise containing balance and functional training reduces the rate of falls in community-dwelling older adults by about one quarter, an effect confirmed in recent syntheses, and global guidance recommends multicomponent activity emphasising balance and strength on at least three days weekly (Sherrington et al., 2019; Wiedenmann et al., 2023; Yu et al., 2025; Bull et al., 2020). Conversely, inactivity accelerates muscle loss and deconditioning of postural reflexes and drives positive energy balance in later life. The two exposures are thus reciprocally reinforcing, and examining them together gives a more realistic account of balance impairment than either alone.

Existing Indonesian research has important limitations: studies have generally examined a single exposure in relation to balance, sample sizes have often been modest, and data have been collected predominantly in urban settings, nursing homes, or hospital-based physiotherapy units (Dharmawan et al., 2022; Fadila et al., 2024; Niswatin et al., 2021). Rural older adults differ materially. Their activity is largely occupational and domestic rather

than recreational, encompassing wet-rice cultivation, animal husbandry, market trading and customary ceremonies, patterns seldom captured by instruments designed for leisure-time exercise, and rural Balinese households have experienced a dietary shift towards refined carbohydrate and fried foods. Evidence from urban or institutional settings cannot be assumed to transfer to the village context in which most Indonesian community nurses practice.

Gulingan Village, in Mengwi Sub-district of Badung Regency, illustrates this gap. Its older population of approximately 650 has grown steadily without a matching improvement in functional status. Records from the village auxiliary health center for 2024 documented 25 older residents with recognized balance impairment and high fall risk, and approximately 15% of older residents across the sub-district reported limitations in daily activities attributable to reduced balance. A preliminary survey by the research team on 26 June 2025 among 12 older residents found all 12 at risk of falling, with six obese and six markedly inactive, suggesting that both exposures were prevalent but allowing no inference about their association with balance.

This study therefore examined the relationships of body mass index and physical activity with physical balance among community-dwelling older adults in Gulingan Village, hypothesizing that a more adverse body mass index category and a lower activity level would each be associated with poorer balance. Its contribution lies in examining both exposures concurrently, using directly measured anthropometry and a performance-based outcome, in a rural Balinese population underrepresented in the literature, to inform nurse-led screening and balance training delivered through existing village health posts.

2. METHODS

Design

This was a non-experimental, quantitative, descriptive-analytical study using a correlational cross-sectional design. Exposures and outcome were measured once per participant, without intervention or follow-up, because the aim was to quantify the strength and direction of association between two modifiable exposures and a functional outcome rather than to establish causation. Reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies.

Sample and setting

The study was conducted in Gulingan Village, Mengwi Sub-district, Badung Regency, Bali Province, Indonesia, between February and March 2026. The village is a rural administrative unit served by one auxiliary health center and integrated health posts for older people, which convene monthly in each customary hamlet. The accessible population comprised 650 residents aged 60 years and over who were registered at these posts.

Participants were recruited by purposive sampling. Inclusion criteria were age 60 years or older, permanent village residence, ability to stand and walk 10 meters independently, with or without a walking aid, ability to communicate in Indonesian or Balinese, and willingness to provide consent. Exclusion criteria were acute musculoskeletal injury or lower-limb fracture within six months, amputation or fixed lower-limb deformity preventing height measurement, stroke with residual hemiparesis or another progressive neurological disorder, severe uncorrected visual or vestibular impairment, cognitive impairment preventing two-step instruction-following, and wheelchair use or dependence in transfers.

Sample size was determined using the Slovin formula with a 5% margin of error, yielding $n = 650 / (1 + 650 \times 0.05^2) = 247.6$, rounded to 248 respondents; a post hoc Fisher transformation confirmed greater than 99% power to detect a two-sided correlation of 0.25 at alpha = 0.05. All 248 participants completed every measurement, with no missing data.

Variables

The independent variables were body mass index and physical activity. Body mass index was calculated as measured weight in kilograms divided by the square of measured height in metres and classified with the Asia-Pacific cut-off points adopted by the Indonesian Ministry of Health into five ordered categories: underweight (below 18.5), normal weight (18.5–22.9), overweight (23.0–24.9), obesity class one (25.0–29.9) and obesity class two (30.0 or above). Physical activity was classified into two ordered categories, adequate and low, using the median total score of the Physical Activity Scale for the Elderly in this population as the cut-off.

The dependent variable was physical balance, operationalised as Timed Up and Go performance and classified with the original functional mobility bands into three

ordered categories: full independence (under 10 seconds), low risk of falling (10–19 seconds) and high risk of falling (20 seconds or more) (Podsiadlo & Richardson, 1991). Age, sex, education, occupation and self-reported chronic illness were recorded as descriptive characteristics.

Instruments

Three instruments were used. A structured demographic form recorded age, sex, education, occupation and chronic illness. Weight was measured with a calibrated digital scale accurate to 0.1 kilogram, participants in light clothing and no footwear, and standing height with a wall-mounted stadiometer accurate to 0.1 centimeter, head in the Frankfort horizontal plane; both were measured twice, and the mean was used.

Habitual activity was assessed using the Physical Activity Scale for the Elderly, a 12-item instrument that quantifies leisure, household, and occupational activity over the preceding 7 days, with higher weighted scores indicating greater activity. The original instrument showed test-retest reliability of 0.75 and construct validity against motion-sensor counts and physiological measures (Washburn et al., 1993), and a regionally adapted Malay-language version has acceptable validity and reliability in a neighboring South-East Asian setting (Ismail et al., 2015). The scale was forward- and back-translated into Indonesian and administered via interview to accommodate limited literacy; no formally validated Indonesian version was available, which is addressed in the limitations section.

Physical balance was assessed using the Timed Up and Go test, in which the participant rises from a standard armchair with a 46-centimeter seat height, walks three meters at a comfortable pace, turns, walks back, and sits down (Podsiadlo & Richardson, 1991). Timing began on the command to start and ended when the participant was again seated with the back against the chair. One practice trial was allowed, two timed trials were performed with a two-minute rest, and the faster time recorded. A researcher walked beside each participant to guard against falls; the test used a level, non-slip indoor surface, with habitual footwear and any walking aids.

Data collection

Data were collected on scheduled health post days and, for those unable to attend, during home visits with the village cadre. The two data collectors were

registered nurses who completed a one-day standardization session covering anthropometric technique, administration of the activity scale, and conduct of the timed test, with supervised practice until the procedures were performed identically. Each participant received a verbal and written explanation, provided written informed consent or a witnessed thumbprint, then completed the demographic interview, anthropometric measurements, activity scale interview, and timed balance test in that fixed order, which took approximately 25 minutes. All sessions ran between 08.00 and 11.00 to limit diurnal variation. Forms were checked the same day, entered into a password-protected spreadsheet by one researcher, and independently verified by a second researcher.

Data analysis

Analysis used statistical software for the social sciences, version 26. Univariate analysis described age as mean, standard deviation, minimum and maximum, and sex and the three categorical variables as frequencies and percentages. Because both exposures and the outcome were ordinal, the bivariate association was examined using the nonparametric Spearman rank correlation, interpreted as very weak (0.00–0.199), weak (0.20–0.399), moderate (0.40–0.599), strong (0.60–0.799), or very strong (0.80–1.000). Both exposures were coded in ascending order of adversity, and the outcome in ascending order of fall risk, so a positive coefficient indicates that a more adverse exposure category is associated with poorer balance. Significance was set at a two-sided alpha of 0.05.

Ethical consideration

The protocol was reviewed and approved by the Health Research Ethics Committee of STIKES Bina Usada Bali (approval number: 023/EA/KEPK-BUB-2026). Written permission was obtained from the Head of Gulingan Village and the Head of the Auxiliary Health Center. Participants received information about the purpose, procedures, duration, potential discomfort, and voluntary nature of the study in Indonesian or Balinese before providing written informed consent. They were told they could withdraw at any time without consequences to their access to health services. Anonymity was maintained by coding each record, and data were stored on a password-protected device accessible only to the research team. The principal foreseeable risk was a fall during the balance

test, mitigated by researcher accompaniment, a non-slip surface and use of habitual walking aids. Participants at high risk received individual education on home hazard reduction and were referred to the auxiliary health center. The study adhered to the Declaration of Helsinki.

3. RESULTS

All participants provided complete data (Table 1). Mean age was 71.60 years (standard deviation 7.46), ranging from 60 to 84 years, indicating that most respondents belonged to the old-old group. Women slightly outnumbered men, 134 (54.0%) against 114 (46.0%).

Table 1. Characteristics of the respondents (n = 248)

Characteristic	Mean	SD	Minimum	Maximum
Age (years)	71.60	7.46	60	84
Sex	**f**		**%**	
Male	114		46.0	
Female	134		54.0	

The distribution of exposures and outcomes is shown in Table 2. Nutritional status was adverse in most respondents. Only 68 respondents (27.4%) were of normal weight, whereas 164 (66.1%) were above the normal range, with obesity class one the most frequent category (85; 34.3%), followed by overweight (45; 18.1%) and obesity class two (34; 13.7%). Sixteen respondents (6.5%) were underweight, the smallest category.

Habitual activity was low in two-thirds of the sample: 166 respondents (66.9%) had a low activity level, while 82 (33.1%) were in the adequate category. Physical balance showed a correspondingly unfavorable pattern: 126 respondents (50.8%) were at high risk of falling, 55 (22.2%) at low risk, and only 67 (27.0%) achieved full independence, with 181 respondents (73.0%) showing some degree of balance impairment (Table 2).

Table 2. Distribution of body mass index, physical activity and physical balance (n = 248)

Variable and category	Frequency (f)	Percentage (%)
Body mass index		
Underweight (< 18.5)	16	6.5
Normal weight (18.5–22.9)	68	27.4
Overweight (23.0–24.9)	45	18.1
Obesity class one (25.0–29.9)	85	34.3
Obesity class two (≥ 30.0)	34	13.7
Physical activity		
Adequate	82	33.1
Low	166	66.9
Physical balance		
Full independence (< 10 seconds)	67	27.0
Low risk of falling (10–19 seconds)	55	22.2
High risk of falling (≥ 20 seconds)	126	50.8

The bivariate analysis is presented in Table 3. The Spearman rank correlation showed a significant association between body mass index category and physical balance ($r = 0.848$; $p < 0.001$). The magnitude places this association in the very strong range, and its positive direction indicates that respondents in more adverse body mass index categories tended to fall into more adverse balance categories.

A significant association was likewise found between physical activity and physical balance ($r = 0.725$; $p < 0.001$). This coefficient falls in the strong range, and its positive direction indicates that respondents with lower habitual activity tended to have poorer balance. The null hypothesis was rejected for both associations.

Table 3. Spearman rank correlation of body mass index and physical activity with physical balance (n = 248)

Independent variable	n	r	p	Interpretation
Body mass index	248	0.848	< 0.001***	Very strong, positive
Physical activity	248	0.725	< 0.001***	Strong, positive

4. DISCUSSION

This study examined the relationships between body mass index and physical activity and physical balance among 248 community-dwelling older adults in a rural Balinese village. Three findings warrant discussion: the high prevalence of adverse nutritional status, low activity, and impaired balance; the very strong association between body mass index and balance; and the strong association between habitual activity and balance.

Interpreted together, these findings describe a population in which two modifiable exposures cluster in the same individuals and track closely with a functional outcome. The reading is not that body mass index or activity level each independently determines balance, which a bivariate design cannot establish, but that a rural older population carrying a high burden of adiposity and inactivity also carries a high burden of measurable balance impairment, and that all three characteristics can be identified with equipment already available at a village health post. The value of rural community nursing, therefore, lies less in the size of the coefficients than in what they identify as screenable and actionable.

Profile of the respondents

The mean age of 71.60 years places most respondents in the old-old group. Reduction in type two muscle fiber cross-

sectional area, redistribution of adipose tissue towards the trunk, declining basal metabolic rate, and slowed central processing occur concurrently in this age band and jointly compromise energy balance and postural control (Dharmawan et al., 2022). The predominance of women, at 54.0%, is consistent with national age-sex structures and relevant to interpretation: women accumulate proportionally more fat and less lean mass than men of equivalent body mass index. They are more susceptible to postmenopausal loss of bone and muscle, so that an identical body mass index can conceal a less favorable composition and a smaller strength reserve. Indonesian evidence confirms that sex, age, and body mass index are jointly related to physical fitness in later life (Oktriani et al., 2020), and rural Balinese women concentrate daily activity in low-intensity domestic and ceremonial tasks, contributing little to the muscle power that protects against falls.

The nutritional profile of this population is striking. Almost two-thirds of respondents were above the normal range, and 47.9% met the criteria for obesity, substantially higher than the 33.3% reported by Fadila et al. (2024) in a rural Javanese setting. This is consistent with the nutrition transition across rural Indonesia, in which the mechanization of agricultural work and the greater availability of energy-dense processed foods have simultaneously reduced energy expenditure and increased intake. The finding challenges the assumption, still common in Indonesian community nursing practice, that undernutrition is the dominant nutritional problem among rural older adults; here, the reverse was true: only 6.5% were underweight, so screening protocols focused exclusively on weight loss will miss most nutritionally vulnerable residents.

The activity profile was equally unfavorable, with 66.9% having a low level of habitual activity. Reduced activity in later life is driven by declining muscle strength and endurance, joint pain and other chronic conditions, and environmental and social factors such as unsafe walking surfaces, absence of organized exercise opportunities, and cultural expectations that older adults should rest; fear of falling, highly prevalent in this age group, is a further and self-reinforcing barrier (Xiong et al., 2024). Withdrawal from agricultural labor without structured replacement activity plausibly results in a drop in energy expenditure that is not matched by a reduction in intake, linking the activity finding directly to the nutritional one.

Half of the respondents were at high risk of falling, and 73.0% showed some balance impairment, considerably higher than the 26.5% global prevalence of falling reported by Salari et al. (2022) or the 16.5% rural prevalence reported for West Java by Nugraha et al. (2021). Part of this difference reflects the definition of outcome, since the timed test assesses current mobility performance rather than fall history, thereby identifying risk before a fall occurs. Part reflects the sample's older age structure. The magnitude of impairment in a population living independently is nonetheless clinically important. It indicates a substantial unmet need for balance assessment. In these figures, roughly three in four older residents attending a village health post would meet the criteria for referral, which is as much a service-planning problem as a clinical one.

Body mass index and physical balance

A very strong positive association was found between body mass index category and physical balance, with a correlation coefficient of 0.848. The direction of this association is mechanistically plausible. Excess body mass shifts the center of gravity forward and upward relative to the base of support. Hence, a smaller angular displacement suffices to move the center of mass beyond the limits of stability. Greater trunk mass increases the torque that ankle and hip strategies must generate to arrest a perturbation. At the same time, fat accumulation around the thighs and abdomen restricts trunk excursion during recovery steps, and altered plantar pressure distribution degrades cutaneous feedback from the sole. Neri et al. (2020) confirmed that obesity after age 60 is associated with an increased risk and severity of fall-related injuries, and Xia et al. (2023) showed that overweight and obesity remained independently associated with balance impairment after adjustment for age, exercise, somatosensory function, and vision.

The relationship is further mediated by body composition rather than by body mass alone. Aging brings progressive loss of muscle mass and strength, defining sarcopenia (Cruz-Jentoft et al., 2019), and cohort and Mendelian randomization evidence implicate sarcopenia-related traits, such as low grip strength and slow gait speed, in falls (Yang et al., 2025). Where muscle loss coexists with excess adiposity, sarcopenic obesity imposes greater load on a weaker postural apparatus (Batsis & Villareal, 2018) and carries a higher likelihood

of falls and fractures than either condition alone affecting roughly one in ten non-hospitalized older adults, it is plausibly common where obesity is prevalent and activity is low (Gandham et al., 2021; Luo et al., 2024). The same mechanism explains poor balance in the small, underweight group: there, a low body mass index reflects depleted muscle mass and functional reserve rather than favorable composition. Niswatin et al. (2021) similarly concluded that a body mass index outside the normal range in either direction is accompanied by reduced muscle mass and a higher risk of balance disturbance. The present findings are also consistent with Balinese evidence: Dharmawan et al. (2022) reported a significant association between body mass index and dynamic balance, measured with the same timed test, among older members of a retired civil servants' association in Denpasar; Putra et al. (2023) found body mass index to be related to postural balance in a Denpasar neighbourhood; and Putra et al. (2023) documented the same relationship in the semi-rural Balinese village of Batubulan. The association therefore appears reproducible across Balinese settings rather than specific to Gulingan.

The coefficient nevertheless exceeds that of comparable research, in which correlations between body mass index and balance have typically been moderate and adjusted odds ratios modest (Xia et al., 2023). Several methodological features probably contribute. Both variables were analyzed as ordered categories rather than continuous measurements, and categorizing two correlated continuous variables using cut-off points partly determined by function can inflate a rank correlation. Measurements were also taken by a small team in a single village with a relatively homogeneous lifestyle, reducing the random variation that would attenuate a coefficient in a more heterogeneous sample. Because a rank correlation on ordinal categories cannot separate the contribution of body mass index from that of the collinear activity variable, this coefficient should be read as evidence of a robust association within this population, not as a generalizable independent effect size.

Physical activity and physical balance

Habitual physical activity was strongly associated with physical balance (r = 0.725), indicating that respondents with lower activity levels performed worse on the timed test. Physical activity acts on almost every component of postural control. Weight-bearing activity maintains muscle cross-

sectional area and, more importantly for fall prevention, muscle power, the capacity to generate force rapidly that determines whether a recovery step can be executed in time. Regular movement preserves ankle range of motion, essential to the ankle strategy for correcting small perturbations, and maintains proprioceptive acuity through repeated loading; conversely, somatosensory dysfunction and poor vision are among the strongest independent correlates of balance impairment in large community samples (Xia et al., 2023).

Conversely, inactivity initiates a self-reinforcing cycle: disuse accelerates the loss of muscle mass and power, reducing confidence in walking, which further reduces activity, leading to additional deconditioning and weight gain. Fear of falling is a central link in this cycle (Xiong et al., 2024). The high prevalence of both low activity and obesity here suggests the cycle is already established in the village. The findings align with those of Xia et al. (2023), who found regular exercise to be independently associated with better performance across every balance domain assessed in a sample of 1,984 older adults, and with Fadila et al. (2024), who reported a significant relationship between activity level and body mass index among rural Indonesian older adults, reinforcing the interdependence of the two exposures examined here.

The most important implication of this finding is that the association is modifiable. Exercise incorporating balance and functional training reduces the rate of falls among community-dwelling older adults by approximately 23%, with the largest effects when the balance challenge is high, and the program is sustained for at least 3 hours weekly (Sherrington et al., 2019). Recent syntheses confirm improved balance function and reduced falls across modalities. Multicomponent and balance-focused programs among the most effective in network comparisons and indicate that frequency and total duration are the prescription variables most closely related to risk reduction (Yu et al., 2025; Wiedenmann et al., 2023; Zhu et al., 2025). Indonesian evidence concurs: Faidah et al. (2020) demonstrated in a Balinese sample that balance training improved body balance and reduced fall risk, and Shalahuddin et al. (2022) reached the same conclusion in a review of Indonesian exercise interventions. Clinical guidance for community-dwelling older adults likewise recommends exercise as the single intervention with the strongest evidence base, combined with medication

review and correction of vision and home hazards (Ganz & Latham, 2020). Notably, this evidence is strongest for community-dwelling populations such as the present one. At the same time, effectiveness in residential aged care is less certain (Dyer et al., 2023), reinforcing the value of intervening early while older residents still live independently in the village.

Implications for rural community nursing practice

The findings translate into three recommendations for nurses in rural village settings. First, the measurement of weight and height and the calculation of body mass index should become a standing element of every health post session rather than an occasional activity, with interpretation identifying risk at both extremes of the distribution rather than at the low end alone. Where resources permit, adding waist circumference or a simple grip-strength measure would help distinguish sarcopenic obesity from uncomplicated adiposity and sharpen referral decisions, since grip strength is the entry point of the current consensus definition of sarcopenia (Cruz-Jentoft et al., 2019) and sarcopenic obesity is the phenotype most strongly linked to falls and fractures (Gandham et al., 2021).

Second, the Timed Up and Go test suits routine use here: it needs only a chair, a three-meter walkway, and a stopwatch, takes under two minutes, and yields a category cadres can act on. Incorporating it into periodic screening would allow detection of the 73.0% of residents with balance impairment before, rather than after, a first fall. However, it should serve as a screening trigger rather than a stand-alone diagnostic test, since its predictive accuracy in isolation is limited (Barry et al., 2014).

Third, and most importantly, screening must be linked to intervention. A nurse-supervised, cadre-delivered balance and strengthening program at the health post, delivered at least three times weekly and adapted locally through familiar movement patterns from customary and ceremonial activity, would address the activity and balance deficits simultaneously and match the dose parameters associated with greatest risk reduction (Zhu et al., 2025). Family involvement is essential in the Balinese extended household, where adult children and grandchildren shape both diet and daily routine. Home hazard assessment, footwear advice, medication review where indicated, and referral for visual assessment, complete a package feasible within existing village health structures and consistent with

both international guidance and clinical recommendations for community-dwelling older adults (Montero-Odasso et al., 2022; Ganz & Latham, 2020).

Operationally, these elements form one screening sequence within the existing monthly session: measure weight and height and classify body mass index; administer the timed test and record the category; refer high-risk residents to the auxiliary health center while enrolling everyone with any degree of impairment in the balance and strengthening group. Because cadres already perform weighing, the added burden is about 2 minutes per resident, which is realistic given rural staffing.

Strengths and limitations

The principal strengths are a comparatively large single-village sample, no missing data, directly measured rather than self-reported anthropometry, a performance-based balance outcome, and prior standardization of the two assessors.

Several limitations must nevertheless temper interpretation. First, the cross-sectional design establishes association but not temporal sequence: it is equally plausible that impaired balance restricts activity and thereby promotes weight gain as that excess weight impairs balance, and the two processes probably operate together. Second, purposive sampling in a single village limits generalisability, and requiring participants to walk ten meters independently excluded the most functionally impaired residents, so the true burden of impairment is likely underestimated. Third, the analysis was bivariate; confounders, including age, sex, chronic disease, medication use, visual acuity, fear of falling, and previous falls, were not adjusted for, and the two exposures were not mutually adjusted despite their strong interrelation. Fourth, treating both exposures and the outcome as ordinal categories discards information and may have inflated the coefficients compared with the analysis of continuous measurements. Fifth, the three-band classification of the timed test is more conservative than the 13.5-second screening threshold commonly used in fall-risk research, so the proportion at elevated risk may be understated; conversely, the test has limited accuracy in predicting future falls when used alone (Barry et al., 2014). Sixth, the activity scale, which relies on a seven-day recall, was administered in an Indonesian translation for which formal validation data are not yet published, and was not designed for the occupational and ceremonial activity

patterns of rural Bali; its internal consistency was not quantified in this sample. Finally, body mass index cannot distinguish fat mass from lean mass, a particular weakness where sarcopenic obesity is common.

Future research should use a prospective cohort design with verified fall outcomes, apply multivariable ordinal regression, analyze both exposures as continuous variables to examine the expected non-linear relationship, measure body composition directly, validate an Indonesian version of the activity scale for rural populations, and test a nurse-led balance intervention experimentally in the village setting.

5. CONCLUSIONS

Among 248 community-dwelling older adults in a rural Balinese village, adverse nutritional status, low habitual activity, and impaired physical balance were all highly prevalent: 66.1% were above the normal body mass index range, with obesity class one most frequent at 34.3%; 66.9% had low physical activity; and 50.8% were at high risk of falling. Body mass index category was very strongly associated with physical balance ($r = 0.848$; $p < 0.001$) and physical activity strongly so ($r = 0.725$; $p < 0.001$), with more adverse exposure categories corresponding to poorer balance in both cases. Because both exposures are modifiable, these findings support routine integration of body mass index measurement and performance-based balance screening into the monthly integrated health post sessions already operating in rural Indonesian villages, coupled with a nurse-supervised balance and strengthening program and family-oriented nutrition education.

These conclusions must be read within the limits of the design. The cross-sectional structure establishes association only and cannot determine whether adiposity and inactivity precede balance impairment or follow from it; the analysis was bivariate and unadjusted so that neither exposure can be assigned an independent effect; the ordinal treatment of exposures and outcome probably inflated the coefficients; and purposive sampling in one village restricts generalisability. The correlations reported here should therefore be treated as descriptive of this population rather than as transferable effect sizes, and confirmation is required in prospective, multivariable, and multi-site studies before any causal claim is made.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of the study. PWKP: collected the data and drafted the manuscript. NKMG: supervised the study, performed the statistical analysis and critically revised the manuscript. MBA: contributed to the methodology and revised the manuscript. All authors read and approved the final version.

CONFLICT OF INTEREST

The authors have no competing interests associated with the material presented in this paper.

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DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

DECLARATION OF USE OF AI

During the preparation of this work, the authors used Grammarly to assist with language and grammar editing. The authors take full responsibility for reviewing, verifying, and revising all AI-assisted output, and for ensuring the accuracy, validity, originality, and integrity of the manuscript's content.

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