RESEARCH ARTICLE

Exploration of the correlation between subjective and objective balance indicators in older adults with falls

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Abstract

Objective: To precisely determine the correlation between subjective and objective balance indicators among older adults having experienced falls.

Method: The cross-sectional, comparative study was conducted at the Geriatric Outpatient Clinic and Rehabilitation Department of Beijing Tongren Hospital, Capital Medical University, Beijing, China, from January 2022 to January 2023, and comprised elderly patients who were divided into falls group A and no-falls group B, based on whether the selected individuals had experienced one or more falls in the preceding year. The patients were subjected to the Short Physical Performance Battery and Computer Dynamic Posturography testing. Data was analysed using SPSS 22.

Results: Of the 266 patients, 131(49.2%) were in group A; 89(68%) males and 42(32%) females with mean age 81.38±7.30 years. There were 135(50.8%) patients in group B; 100(74%) males and 35(26%) females with mean age 79.66±8.26 years (p>0.05). SPPB,VIS, VEST, SOT-COM, EPE, MXE and DCL scores were lower in group A compared to group B (p<0.05).SPPB was positively correlated with SOT-COM (r=0.254, p<0.001), VIS (r=0.220, p<0.001), VEST (r=0.246, p<0.001), MVL (r=0.247, p<0.001), EPE (r=0.370, p<0.001), MXE (r=0.399, p<0.001), and DCL (r=0.233, p<0.001).Binary logistic regression confirmed VEST (OR: 1.019, 95%CI: 1.008-1.030, p<0.001) and MXE (OR: 1.041, 95%CI: 1.012-1.072, p=0.006) as independent positive predictors of SPPB.

Conclusion: Better physical function and improved visual/vestibular senses were found to be associated with lower fall risk in older adults. The integration of subjective and objective balance indicators could yield a more comprehensive and precise assessment.

Keywords: Aged, Accidental falls, Short Physical Performance Battery, Computerised dynamic posturography, Balance.

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Introduction

Older adults are prone to increased vulnerability to falls due to age-related factors, such as diminished muscle strength, delayed reaction times, impaired coordination, and reduced balance capabilities.[1] Falling is defined as an abrupt, involuntary and unintentional alteration in body position that leads to descending to the ground or a lower level, and also includes falls on the same surface.[2] The risk of falls among older individuals is strongly linked to their balance function. It is crucial to comprehend the balance capabilities of elderly individuals as it plays a significant role in fall-prevention. Balance refers to the body's capacity to sustain a specific posture and make automatic adjustments to maintain it when in motion or facing external pressures.[3] The human balance system is a complex control system that relies on receiving spatial information and proprioception through the sensory system. This information is then sent to the nervous system for processing, which, in turn, issues regulatory instructions. The motor system then acts on these instructions to maintain body balance. Any problem in the entire balance system that prevents older people from making timely physical adjustments can lead to falls. Hence, the assessment of balance function holds significance in the prevention of falls.

Various evaluation techniques exist for assessing balance capabilities. Subjective balance indicators do not require specialised medical equipment as they rely on observation or scale assessments. The Short Physical Performance Battery (SPPB)[4] was introduced in the 1990s as a thorough assessment tool for evaluating body functions, encompassing tests on standing balance, walking speed, and sit-to-stand test. These evaluations can offer a comprehensive overview of an individual's muscle strength, postural control and walking capabilities. In a longitudinal study spanning two years at a senior primary care facility, investigators observed a notable association between impaired performance on a sit-stand assessment among older adults and a heightened susceptibility to sustaining fall-related injuries in subsequent periods. The findings of the study revealed a substantial 111% increase in the likelihood of experiencing such injuries (odds ratio

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[OR]: 2.11),[5] encompassing fractures, joint dislocations and severe head trauma.[6] SPPB plays a crucial role in evaluating the physical capabilities and risks of falling in older adults, but differences in how assessors and participants understand and perform the test can result in discrepancies in the final clinical outcomes. Additionally, subjective assessment methods may not accurately identify the main areas of balance decline, leading to some limitations.

Computer Dynamic Posturography (CDP) serves as a valuable assessment method for evaluating both static and dynamic balance capabilities. This technique involves the utilisation of precise equipment and computer technology to acquire objective balance indicators.[7] CDP includes the Sensory Organisation Test (SOT), which can quantitatively assess the vestibular, visual and proprioceptive abilities of older individuals.[8] SOT generates an overall score known as the SOT-Composite (SOT-COM) by combining these abilities. Additionally, CDP features the Limits of Stability (LOS) test, which assesses reaction time, movement speed and range of motion (ROM) during physical activity.[9] These evaluations provide an objective assessment of balance capacity and have reliability, sensitivity and specificity in their outcomes.

The current study was planned to precisely determine the correlation between subjective and objective balance indicators among older adults having experienced falls.

Patients and Methods

The cross-sectional, comparative study was conducted at the Geriatric Outpatient Clinic and Rehabilitation Department of Beijing Tongren Hospital, Capital Medical University, Beijing, China, from January 2022 to January 2023, and comprised elderly patients who were divided into falls group A and no-falls group B, based on whether the selected individuals had experienced one or more falls in the preceding year. The two groups were matched in terms of gender and age. All the patients were aged 60 years or older, able to walk independently for 30 meters, and willing to participate in the study. Patients with acute cardiac, pulmonary or renal conditions, severe neurological or psychiatric disorders, vestibular system dysfunction, or those who had used sedatives or psychotropic medications within the preceding 72 hours were excluded.

After approval from the institutional ethics review committee, the sample size was calculated using a power analysis with G*Power 3.1 software.[10] Informed consent was obtained from all the participants.

Baseline data collected included age, gender, height and weight. Body mass index (BMI) was determined by dividing weight in kilogrammes by height in meters-squared. Medical records were reviewed to identify any existing health conditions or diseases, and to calculate the age-adjusted Charlson Comorbidity Index (aCCI).[11] Polypharmacy was defined as the use of five or more medications.

The SPPB consists of three parts: standing balance, walking speed, and five sit-stand tests.[4] Standing balance includes three standing positions: with feet-together stand, with semi-tandem stand, and with full-tandem stand. For the first and second posture, if the older adults can maintain them for >10 seconds, they receive 1 point, Otherwise, no points is awarded. For the third posture, if they can maintain it for >10 seconds, they receive 2 points. If they maintain it between 3 and 9.99 seconds, they receive 1 point. Otherwise, no points is awarded. The maximum score for balance standing is 4 points.[4]

For walking speed assessment, the subjects are required to walk along a straight line at their usual pace for 6 meters, and record the time taken from passing the second metre to the fifth metre. Those who finish within 4.82 seconds receive 4 points, those who finish between 4.83 and 6.20 seconds receive 3 points, those who finish between 6.21 and 8.70 seconds receive 2 points, and those who take >8.71 seconds receive 1 point. Participants who cannot complete the walking test, receive no point. The maximum possible score for walking speed is 4 points.[4]

For the sit-to-stand tests, a stable chair is chosen with a backrest and a height of 44cm. Individuals are asked to perform 5 sit-to-stand movements as fast as possible. Achieving completion in <11.19 seconds earns 4 points, between 11.20 and 13.69 seconds earns 3 points, between 13.70 and 16.69 seconds earns 2 points, between 16.70 and 60 seconds earns 1 point, and no points are given for completion in >60 seconds. The full score for the five sit-stand tests is 4 points. The maximum score for SPPB is 12 points, with score ≥10 indicating normal physical function.[4]

CDP was conducted for objective balance function assessments[7] using the NeuroCom's EquiTest.[12] CDP includes SOT,[13] which involves somatosensory (SOM), vision (VIS) and vestibular (VEST) scores, followed by the calculation of SOT-COM based on the weighted average scores of all branches. Additionally, LOS test[14] includes reaction time (RT), movement velocity (MVL), endpoint excursion (EPE), maximum excursion (MXE), and directional control (DCL).

Data was analysed using SPSS 22. Data normality of continuous variables was checked using the Shapiro-Wilk test. Those with normal distribution were presented as mean±standard deviation, while variables with non-normal distribution were summarised as median with interquartile range (IQR). Student's t-test was used for normally distributed variables when comparing continuous variables between the two groups, and Mann-Whitney U test was used for non-normally distributed variables. Categorical variables were expressed as frequencies and percentages, and analysed using the Pearson chi-squared test. The occurrence rate of falls was treated as a binary categorical variable. Binary logistic regression was used for assessing the correlation between balance indicators and falls. Odds ratios (ORs) and 95% confidence intervals (CIs) were also calculated. Spearman correlation was used to analyse the correlation between subjective and objective balance indicators. Furthermore, using SPPB as a binary dependent variable (SPPB≥10), binary logistic regression was used for analysing the correlation between balance indicators. A receiver operating characteristic (ROC) curve was generated to analyse the correlation involving VEST, MXE and SPPB. P<0.05 was considered statistically significant.

Results

Of the 266 patients, 131(49.2%) were in group A; 89(68%) males and 42(32%) females with mean age 81.38±7.30 years. There were 135(50.8%) patients in group B; 100(74%) males and 35(26%) females with mean age 79.66±8.26 years (*p*>0.05) (Table 1).

Group A patients had poorer SPPB score compared to those in group B (p<0.05). Additionally, VIS, VEST, SOT-COM, EPE, MXE and DCL scores were lower in group A compared to group B (*p*<0.05). However, there was no significant difference between the groups in terms of SOM, RT and MVL (Table 2).

After adjusting for age, gender, BMI, history of multiple medications, and aCCI, SPPB (OR: 0.748; 95%CI: 0.631-0.888, *p*=0.001), VIS (OR: 0.965; 95%CI: 0.934-0.997, *p*=0.031) and VEST (OR: 0.959, 95% CI: 0.944-0.974, *p*<0.001) scores had a negative correlation with the incidence of falls.

SPPB was positively correlated with SOT-COM (*r*=0.254, *p*<0.001), VIS (*r*=0.220, *p*<0.001), VEST (*r*=0.246, *p*<0.001), MVL (*r*=0.247, *p*<0.001), EPE (*r*=0.370, *p*<0.001), MXE (*r*=0.399, *p*<0.001), and DCL (*r*=0.233, *p*<0.001).

Binary logistic regression analysis showed that after adjusting for age, gender, BMI, history of multiple medications, and aCCI, VEST (OR: 1.019, 95%CI: 1.008-1.030, *p*<0.001) and MXE (OR: 1.041, 95%CI: 1.012-1.072, *p*=0.006) had a positive correlation with SPPB.

With respect to ROC curve, the area under the curve (AUC) was 0.637 (95%CI:0.569, 0.705) for VEST, with sensitivity

Table-1: Intergroup comparison of baseline characteristics (n=266).

	Non-Falls Group (135 Cases)	Falls Group (131 Cases)	|X²/T/Z|	*p*-value
Age (years)	79.66±8.26	81.38±7.30	1.804	0.072
Gender (male, %)	100(74.07)	89(67.94)	1.217	0.270
BMI	23.95±2.90	23.70±3.34	0.664	0.507
aCCI	5.44±1.38	6.19±1.61	4.071	<0.001*
Hypertension (Yes, %)	95(70.37)	90(69.77)	0.011	0.915
Coronary heart disease (Yes, %)	46(34.07)	70(54.26)	10.916	0.001*
Diabetes (Yes, %)	46(34.07)	59(45.74)	3.746	0.053
Cerebrovascular disease (Yes, %)	11(8.15)	15(11.63)	0.900	0.343
Chronic kidney disease (Yes, %)	11(8.15)	15(11.63)	0.900	0.343
Multiple medication history (≥5, %)	53(39.26)	88(68.22)	22.230	<0.001*

aCCI: Age-adjusted Charlson Comorbidity Index, BMI: Body mass index; *$p<0.05$. Statistical tests: Student's t-test (a) for normally distributed continuous variables, and Pearson chi-squared test (b) for categorical variables.

Table-2: Intergroup comparison of balance indicators.

	Non-Falls Group (135 Cases)	Falls Group (131 Cases)	|X²/T/Z|	*p*-value
Subjective balance indicators				
SPPB (score)	9.93±2.07	8.24±2.41	6.121	<0.001*
Stand balance (score)	4(3,4)	3(2,4)	4.471	<0.001*
Walking speed (m/s)	0.91±0.23	0.76±0.23	5.105	<0.001*
five sit-stand test (s)	12.54±4.04	17.02±11.00	4.382	<0.001*
Objective balance indicators				
SOM (score)	96.89±3.68	95.87±5.53	1.763	0.079
VIS (score)	78.92±9.29	66.05±18.49	7.137	<0.001*
VEST (score)	70(60,80)	30(5,65)	8.036	<0.001*
SOT-COM (score)	74.78±8.36	57.77±15.99	10.821	<0.001*
RT (s)	0.89±0.27	0.96±0.30	1.737	0.084
MVL (degree/s)	2.96±0.78	2.79±0.69	1.818	0.070
EPE (%)	54.37±10.17	50.66±10.05	2.968	0.003*
MXE (%)	69.12±10.99	65.80±12.31	2.306	0.022*
DCL (%)	70.79±9.74	65.78±12.08	3.684	<0.001*

SPPB: Short Physical Performance Battery, SOM: Somatosensory, VIS: Vision, VEST: Vestibular, SOT-COM: Sensory Organisation Test Composite, RT: Reaction time, MVL: Movement velocity, EPE: Endpoint excursion, MXE: Maximum excursion, DCL: Directional control; *$p<0.05$. Statistical tests: Student's t-test for normally distributed continuous variables, Mann-Whitney U test (Z value) for non-normally distributed variables.

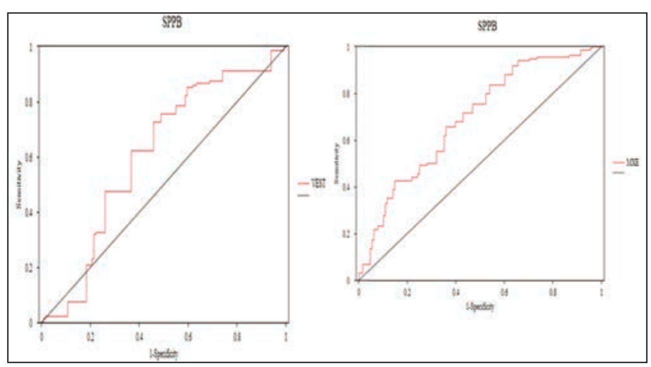

Figure: Correlation among VEST, MXE and SPPB. The area under the curve (AUC) was 0.637 (95%CI:0.569, 0.705) for VEST, with a sensitivity of 0.726 and a specificity of 0.542. The AUC was 0.698 (95%CI:0.634, 0.761) for MXE, with a sensitivity of 0.662 and a specificity of 0.632.

SPPB: Short Physical Performance Battery; Vest: Vestibular; MXE: Maximum excursion.

0.726 and specificity 0.542, while the AUC was 0.698 (95%CI:0.634, 0.761) for MXE score, with sensitivity 0.662 and specificity 0.632 (Figure).

Discussion

The occurrence of falls in older adults worldwide, specifically those aged 65 and older, varies 28-35%, with higher rates of 32-42% seen in individuals aged 70 and above.[15] Falls not only decrease life expectancy, but can also cause fractures, dislocations, traumatic brain injuries, soft tissue injuries, and other health issues, resulting in disabilities and limitations for elderly individuals. This significantly affects their age-related ability.[16] Falls are influenced by multiple risk factors, with the balance function being a key factor. Therefore, it is essential to conduct a precise evaluation of the balance function in older adults. Subjective assessment techniques are convenient and fast, but lack standardisation, while objective methods are precise, but difficult to expand. The current study sought to merge these two approaches to investigate correlations, with the aim of enhancing the reliability of subjective assessments with the more robust objective support for future widespread use.

In this study, the SPPB was employed as the subjective measure of balance, and the comparison revealed significantly lower SPPB scores in the group that experienced falls compared to the group that did not experienced a fall. Univariate analysis revealed a significant association between SPPB scores and falls, indicating a negative correlation, implying that older individuals with better physical function were less likely to fall. As age increases, older individuals undergo gradual changes in physical function, particularly in their walking patterns and speed. Gait speed is also considered a crucial indicator for predicting the risk of falls among residents in nursing homes. A prospective study conducted over 12 months in German nursing homes found that greater variability in gait and posture correlated with higher fall risks.[17] A meta-analysis also found that even for patients with Parkinson's disease or cognitive impairments, assessing physical function and providing exercise guidance can help prevent falls. This may be because exercise training can help improve body coordination, balance capabilities, and muscle strength, thereby reducing the risk of falls.[18] Therefore, it is recommended to conduct regular SPPB tests on elderly individuals to promptly identify those at high risk of falling, and to implement appropriate intervention measures.

CDP utilises computer technology for quantitative analysis to assess objective balance indicator.[9] The current study indicated that the fall group had lower scores in VIS and VEST perception compared to the non-fall group. Additionally, MVL, EPE, MXE and DCL were significantly lower in the fall group, indicating significant decline in movement speed, distance, amplitude and self-control abilities among older patients with falls. Further regression analysis identified VIS and VEST perception as independent correlates of falls in older adults. Based on the results of the European Health Aging and Retirement Study, individuals with impaired vision, regardless of hearing status, have a higher risk of falls compared to those maintaining good vision and hearing. Specifically, individuals with impaired vision alone face a 19% increased risk of falls, while those with impairments in both vision and hearing experience a 33% increased risk. This indicates that visual impairment significantly contributes to the risk of falls among elderly individuals, and having dual impairments in vision and hearing further exacerbates this risk.[19]The vestibular system is crucial for maintaining balance in both static and moving conditions, and approximately 50% of older people aged 60 and above experience vestibular dysfunction.[20] With age, the number of sensory cells and nerve fibres in the vestibular organs and vestibular central pathways of elderly people gradually decreases. These sensory cells and nerve fibres are crucial for maintaining body balance and spatial orientation, and their reduction directly affects the balance sense and stability of elderly individuals.[21] However, this process is relatively slow and easily overlooked by the older adults. Previous studies have found that early implementation of vestibular rehabilitation training for the older people can help improve their balance ability and enhance physical coordination, thus significantly reducing the risk of falls due to balance disorders.[22,23]

The correlation analysis in the current study between the two assessment methods found that SPPB was positively correlated with SOT-COM, VIS, VEST, MVL, MXE and DCL. Further binary logistic regression based on whether SPPB function was good (SPPB≥10) revealed that SPPB was independently correlated with VEST sensation and MXE. Good vestibular sensation provided individuals with accurate body position and movement information, aiding the brain in better controlling body movements and maintaining balance. Muscle strength, joint flexibility and body control were associated with MXE. Stable organism function relies on good muscle strength and coordination across various body parts. Both are important indicators for maintaining balance function. The independent positive correlation between SPPB and these two factors indicated that elderly individuals with good physical function tended to have higher balance ability, both in terms of VEST sensation and stability during dynamic activities. The SPPB is relatively simple to administer, suitable for community and outpatient settings, and is an effective assessment tool for observing balance abilities in older adults. Due to its correlation with VEST and MXE, future evaluations of these functions may be conducted using the SPPB for follow-up assessments. Both subjective and objective balance indicators have their strengths and limitations. Through their combined application, they complement each other, providing more comprehensive and accurate assessment results. This aids in developing more personalised treatment plans and follow-up services for such individuals.

The current study has limitations. The sample size was restricted to a single geographical region, which may limit the generalisability of the findings. Additionally, the cross-sectional design prevented causal inferences. Future longitudinal studies involving diverse populations are necessary to validate the current findings.

Conclusion

Better physical function led to better visual and vestibular senses, leading to a lower risk of falls. Older individuals with higher physical function tended to exhibit improved balance capabilities in both vestibular perception and stability during dynamic activities. The integration of subjective and objective balance indicators could yield a more comprehensive and precise assessment.

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Author Contribution:

YC, BL, JZ, QL, HY & MQ: Concept, design, data acquisition, analysis, interpretation, drafting, revision, final approval and agreement to be accountable for all aspects of the work.