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Berg Balance Scale score is a valuable predictor of all-cause mortality among acute decompensated heart failure patients

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ABSTRACT

OBJECTIVE To investigate possible associations between physical function assessment scales, such as Short Physical Performance Battery (SPPB) and Berg Balance Scale (BBS), with all-cause mortality in acute decompensated heart failure (ADHF) patients.

METHODS A total of 108 ADHF patients were analyzed from October 2020 to October 2022, and followed up to May 2023. The association between baseline clinical characteristics and all-cause mortality was analyzed by univariate Cox regression analysis, while for SPPB and BBS, univariate Cox regression analysis was followed by receiver operating characteristic curves, in which the area under the curve represented their predictive accuracy for all-cause mortality. Incremental predictive values for both physical function assessments were measured by calculating net reclassification index and integrated discrimination improvement scores. Optimal cut-off value for BBS was then identified using restricted cubic spline plots, and survival differences below and above that cut-off were compared using Kaplan-Meier survival curves and the log-rank test. The clinical utility of BBS was measured using decision curve analysis.

RESULTS For baseline characteristics, age, female, blood urea nitrogen, as well as statins, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, or angiotensin receptor-neprilysin inhibitors, were predictive for all-cause mortality for ADHF patients. With respect to SPPB and BBS, higher scores were associated with lower all-cause mortality rates for both assessments; similar area under the curves were measured for both (0.774 for SPPB and 0.776 for BBS). Furthermore, BBS ≤ 36.5 was associated with significantly higher mortality, which was still applicable even adjusting for confounding factors; BBS was also found to have great clinical utility under decision curve analysis.

CONCLUSIONS BBS or SPPB could be used as tools to assess physical function in ageing ADHF patients, as well as prognosticate on all-cause mortality. Moreover, prioritizing the improvement of balance capabilities of ADHF patients in cardiac rehabilitation regimens could aid in lowering mortality risk.

Heart failure (HF) is a serious disease, characterized by significant decreases in cardiac pumping function, resulting in insufficient cardiac output to meet bodily tissue and organ metabolic demands.[1] Its incidence has been increasing, along with global population aging and concomitant rises in cardiovascular disease (CVD) occurrence. Additionally, it has a substantial negative impact on patient quality of life and life expectancy, with a 5-year survival rate of 50%, and a 10-year survival rate of only 10%.[2] As a result, identifying effective indicators among HF patients, especially acute decompensated HF (ADHF) which are able to predict the occurrence of all-cause mortality, is crucial for enabling effective clinical diagnosis and treatment.

Assessing HF clinical prognoses has long been a key medical research area, and numerous patient characteristics have been identified as being able to serve as predictive indicators for all-cause mortality in HF patients, ranging from blood pressure variability, peak oxygen consumption, along with quality of life and simple physical fitness assessment scales.[1,3] However, some traditional assessment tools analyzing these characteristics, such as the cardiopulmonary exercise test (CPET),[4] despite their widespread usage, possess the drawbacks of being expensive and incapable of evaluating ADHF patients. Therefore, assessment approaches able to analyze a wider range of patient indicators, such as the 6-minute walk test, Short Physical Performance Battery (SPPB), and the Berg Balance Scale (BBS), have gained more interest for potentially predicting HF all-cause mortality.[1,5,6] In particular, SPPB has been integrated into the standard protocol for evaluating CVD risk, owing to its robust reproducibility and minimal intrusiveness.[7] Indeed, measuring the physical capabilities of individuals could serve as a major predictive factor for both overall and CVD-specific mortality risk.[8]

With respect to BBS, the ability of an individual to balance oneself refers to them being able to maintain physical stability. This capability decreases among HF patients, which could increase sarcopenia, falling, and cardiovascular mortality risks. The key organs responsible for determining and maintaining bodily balance are the vestibular organs in the inner ear, and their dysfunction, observed in diseases like cancer, have been associated with increased mortality. In fact, Medina, *et al.*[9] found that all-cause mortality increased by 31%, CVD mortality by 59%, and cancer mortality by 39% when vestibular dysfunction was present; this positive association between vestibular dysfunction and increased CVD mortality was also supported by a systemic review by Newman-Toker, *et al.*[10] Therefore, BBS, which assesses body balance capability, could serve as a potential measurement for predicting all-cause mortality among HF patients. Indeed, considering that out of the multiple factors associated with all-cause mortality in HF patients, dysfunctionality in the balance system is a significant one, examining the association between balance indices and all-cause mortality is of great importance.[1,3,11] In this study, we aimed to assess the applicability of physical functional indices, such as SPPB and BBS, for predicting all-cause mortality in ADHF patients.

METHODS

Study Population

This study was a retrospective one, which enrolled 140 ADHF patients admitted to the Department of Cardiac Rehabilitation of Shanghai Tongji Hospital from October 2020 to October 2022. ADHF was diagnosed based on the 2022 American Heart Association/American College of Cardiology/Heart Failure Society of America guidelines for heart failure management.[12] All patients provided written informed consent. Inclusion criteria were as follows: (1) patients with assessment test data already available; or (2) able to participate in the physical fitness assessment tests, while the exclusion criterion was being lost to follow up. After applying inclusion and exclusion criteria, a total of 108 eligible patients were enrolled in this study (Figure 1).

The study was registered in the Chinese Clinical Trial Registry (Registration number: ChiCTR-TNRC-08000235) and approved by the Ethics Committee of Tongji Hospital, Tongji University (Approval number: LL(H)-08-04). Patient clinical characteristic data at baseline were collected upon admission, both electronically and via one-on-one administration of a standardized testing questionnaire, which was constructed based on protocols from Rosero, *et al.*[5] and Newman-Toker, *et al.*[10]

Assessment of Activities of Daily Living, Physical Performance, and Balance

Assessment of activities of daily living is most commonly measured using the Barthel index,[13] in which the rehabilitation practitioner observes and records the ability of the HF patient to care for oneself by conducting daily living activities, such as eating. Each daily living activity was scored on a 0–15 scale, and the total score for Barthel index was out of 100, in which 0 represented total dependence on others to aid in daily living activities, and 100 total independence.[14]

To assess physical performance, SPPB was used,[15] which included four aspects of standing balance, such as a patient standing in a line, with heels together and toes spread apart, and their ability to maintain balance for as long as

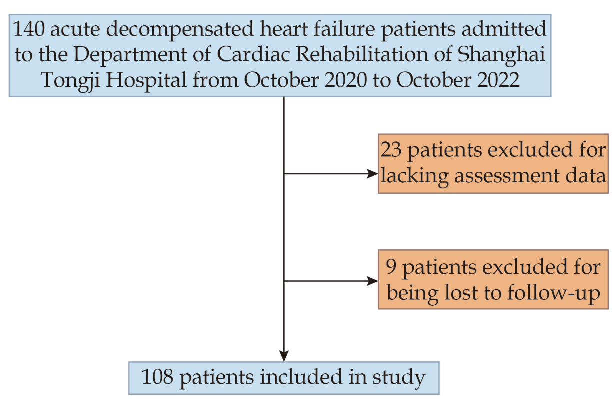


Figure 1 Flow chart of patients recruitment for the study.

possible without any support was measured, as well as stride, sit-to-stand, and time taken for each action. Scores for each test were recorded,[16] ranging from 0–12, in which higher values indicated higher physical functionality.[17]

Balance ability was assessed using BBS,[18] in which a trained evaluator instructs the patient to complete a series of maneuvers, such as turning around and looking over their shoulder, for a total of 14 maneuvers; they are scored based on their completeness, ranging from 0 (unable to complete) to 4 (independent completion), yielding a total score between 0–56.[19] Higher scores indicated greater balance capabilities for the patient.[20]

Follow-up

Patient follow-up was conducted by telephone every 3 months, from November 2022 to either the time of patient death, or until the study cut-off time of May 2023, in order to gather information on whether all-cause mortality had occurred.

Statistical Analysis

Baseline clinical characteristics for non-normally distributed measures are presented as medians (interquartile range), and for counting variables, they were expressed as counts (percentages), and compared by the Pearson's chi-squared test or Fisher's exact probability test, if they were categorical unordered variables, such as gender.

The relationships between various scales to assess physical functioning, baseline patient characteristics and all-cause mortality were analyzed by univariate Cox regression analysis, whose results were expressed as hazard ratios (HR) with 95% CI, and factors predictive for all-cause mortality were identified. Subsequently, multivariable Cox regression analysis was conducted to further evaluate and confirm the associations between various physical function scales and all-cause mortality.[21]

To assess their predictive capabilities, HRs were converted to odds ratios (ORs) using the Cox proportional hazards regression model, and receiver operating characteristic curves constructed; the area under the curve were quantified, serving as a measure of the predictive accuracy of those factors. Their incremental predictive values were then measured by calculating net reclassification index and integrated discrimination improvement scores.[22] For BBS, the optimal cut-off value was identified using restricted cubic spline plots, and survival differences between groups were compared using Kaplan-Meier survival curves and the log-rank test. Decision curve analysis was performed to illustrate the contribution of BBS to the predictive value of the model. All statistical tests were two-tailed, and analyses were conducted using SPSS 22.0 (SPSS Inc., IBM, Armonk, NY, USA). *P*-value < 0.05 was statistically significant.

RESULTS

Identification of Baseline Characteristics Associated with Higher Mortality in ADHF Patients

Table 1 shows baseline patient characteristics, in which among the 108 patients, 69 patients were female, with median age of 85 (79.00–88.75) years, left ventricular ejection fraction of 63.0% (54.5%–67.6%), and follow-up period of 473.7 days. Additionally, the maximum follow-up period was 1015.2 days, and 55 deaths occurred over the study period, yielding a mortality rate of 50.93%.

We identified, based on univariate Cox regression analysis, that the baseline characteristics of age, female, blood urea nitrogen, as well as statins, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, or angiotensin receptor-neprilysin inhibitors, were predictive for all-cause mortality for ADHF patients (Table 1).

Better Physical Functional Assessment Scores Are Associated with Higher Survival Rates

We then assessed patient physical functioning within 4–7 days of admission, using Barthel index, SPPB, and BBS scores, as shown in Table 2. We found that out of those three assessment scores, only SPPB and BBS were significantly correlated with all-cause HF mortality under univariate Cox regression analysis. Similarly, after adjustment for potential confounders, both the SPPB and BBS continued to be identified as significant predictors of all-cause mortality (Table 2). The predictive capabilities of SPPB and BBS were then assessed using receiver operating characteristic curve analysis, in which both scores, either alone or in combination, shared similar area under the curves: 0.774 (0.686–0.863) for SPPB, 0.776 (0.687–0.865) for BBS, and 0.775 (0.687–0.864) for SPPB + BBS (Figure 2). Therefore, both higher SPPB and BBS scores were associated with higher survival rates for ADHF patients. The lack of significant differences between BBS alone, or in combination with SPPB, for accurately predicting all-cause mortality was also demonstrated by integrated discrimination improvement and net reclassification index having values < 0.

Table 1 Baseline characteristics and univariate Cox regression analysis of their associations with all-cause acute decompensated heart failure mortality of 108 patients.

Patient characteristics	Baseline data	Univariate Cox regression analysis	
		HR (95% CI)	*P*-value
Age, yrs	85 (79.000–88.750)	1.066 (1.026–1.107)	0.001
Female gender	69 (63.900%)	0.538 (0.297–0.974)	0.041
Cardiac function class	108 (100.000%)	1.240 (0.786–1.958)	0.355
II	14 (12.963%)		
III	73 (65.593%)		
IV	21 (19.444%)		
White blood cells, U/µL	6.835 (5.440–8.570)	0.983 (0.877–1.102)	0.767
Hemoglobin, mg/dL	119.5 (101.000–134.000)	0.991 (0.981–1.001)	0.093
C-reactive protein, mg/L	5.055 (1.523–18.480)	1.004 (0.999–1.010)	0.118
Cardiac troponin I, ng/L	0.027 (0.015–0.051)	1.050 (0.635–1.736)	0.851
Blood urea nitrogen, mmol/L	10.015 (7.753–13.238)	1.058 (1.012–1.105)	0.013
Creatinine, µmol/L	113 (88.000–151.750)	1.003 (0.999–1.008)	0.134
Cholesterol, mmol/L	3.770 (3.095–4.633)	1.122 (0.882–1.426)	0.349
Triglycerides, mmol/L	1.010 (0.810–1.368)	0.651 (0.354–1.197)	0.167
High-density lipoprotein cholesterol, mmol/L	1.085 (0.890–1.280)	1.696 (0.715–4.020)	0.230
Low-density lipoprotein cholesterol, mmol/L	1.010 (0.810–1.368)	1.135 (0.825–1.562)	0.436
Serum potassium, mmol/L	3.950 (3.450–4.200)	1.079 (0.652–1.784)	0.768
Serum sodium, mmol/L	140.850 (138–142.675)	0.976 (0.899–1.060)	0.567
Serum chloride, mmol/L	103.300 (100.525–106.375)	0.962 (0.910–1.018)	0.178
Left ventricular ejection fraction	63.0% (54.5%–67.6%)	1.463 (0.273–7.842)	0.657
Serum iron, µmol/L	9.000 (5.650–11.900)	0.958 (0.911–1.006)	0.086
Complications & Medications			
Diabetes mellitus	33 (30.560%)	0.762 (0.421–1.380)	0.370
Atrial fibrillation	59 (54.630%)	0.719 (0.423–1.221)	0.222
Pacemaker	17 (15.740%)	1.434 (0.740–2.780)	0.286
Stents	18 (16.670%)	0.778 (0.367–1.648)	0.512
Coronary artery bypass grafting	6 (5.560%)	0.282 (0.039–2.039)	0.210
Statin	89 (82.410%)	0.486 (0.265–0.893)	0.020
Beta-blocker	68 (62.960%)	0.761 (0.443–1.307)	0.322
Angiotensin-converting enzyme inhibitors/Angiotensin II receptor blockers/Angiotensin receptor-neprilysin inhibitors	50 (46.300%)	0.410 (0.233–0.722)	0.002
Calcium channel blocker	29 (26.850%)	0.791 (0.424–1.475)	0.460

Data are presented as *n* (%) or median (interquartile range).

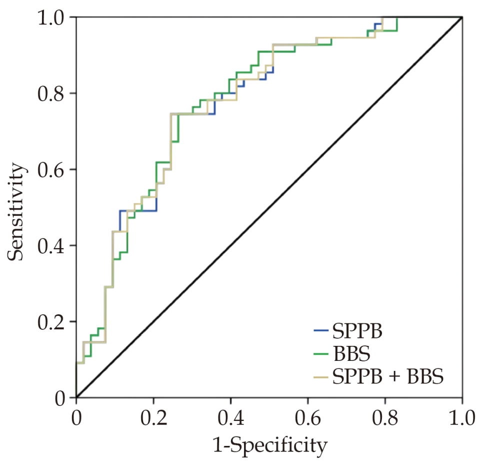
BBS Scores ≤ 36.5 Were Associated with Higher All-cause Mortality in ADHF Patients

We further investigated the association between different BBS scores and all-cause HF mortality, in which a non-linear relationship was present, as observed by restricted cubic spline analysis (Figure 3A). There, the lowest mortality risk was found at BBS = 36.5–40; mortality was higher at BBS < 36.5, as well, to a lesser extent, BBS > 40. It should be note that both patients with BBS ≤ 36.5 and > 36.5 had decreases in survival rates over time under Kaplan-Meier survival analysis, but those rates were significantly lower in the former group versus the latter, with the gap between the two groups increasing throughout the follow-up period (Figure 3B, $P < 0.001$). This difference was also present even after adjusting the Kaplan-Meier survival curves for confounding factors, and comparing them in

Table 2 Cox proportional hazard analysis of physical function assessment scores with all-cause mortality in acute decompensated heart failure patients.

	Score	Univariate Cox regression analysis		Multivariate Cox regression analysis	
		HR (95% CI)	*P*-value	Adjusted HR (95% CI)	*P*-value
Barthel index	80 (60–95)	0.985 (0.976–0.994)	0.002	0.991 (0.979–1.002)	0.117
SPPB	3.500 (1–7)	0.862 (0.795–0.935)	< 0.001	0.905 (0.820–1.000)	0.049
BBS	35 (18.000–44.750)	0.971 (0.956–0.985)	< 0.001	0.978 (0.960–0.996)	0.020

Multivariate Cox regression analysis: adjusted for age, gender, hemoglobin, blood urea nitrogen, serum iron, statin and angiotensin-converting enzyme inhibitors/angiotensin II receptor blockers/angiotensin receptor-neprilysin inhibitors. BBS: Berg Balance Scale; SPPB: Short Physical Performance Battery.



	C-statistics (95% CI)	SE	*P*-value		NRI	IDI
SPPB	0.774 (0.686−0.863)	0.045	Reference		Reference	Reference
BBS	0.776 (0.687−0.865)	0.045	0.975	Reference	−0.297 (*P* = 0.118)	−0.001(*P* = 0.864)
SPPB + BBS	0.775 (0.687−0.864)	0.045	0.988	0.988	−0.206 (*P* = 0.278)	0.000 (*P* = 0.752)

NRI: net reclassification index IDI: integrated discrimination improvement

Figure 2 Receiver operating characteristic curves for the predictive capabilities of SPPB, BBS, and SPPB + BBS for all-cause acute decompensated heart failure mortality, as well as confirmation by net reclassification index and integrated discrimination improvement. BBS: Berg Balance Scale; SPPB: Short Physical Performance Battery.

the log-rank test (Figure 3C, $P < 0.001$). Lastly, decision curve analysis found that BBS scores had great clinical utility for identifying HF patients with higher mortality risk, particularly when the probability was between 0.1–0.4 (Figure 3D).

DISCUSSION

In this study, we analyzed ADHF patients and explored the relationship between multiple physical function assessment scales and all-cause mortality. Previous studies have found that resting heart rate,[23–26] peak oxygen uptake, and other indicators are associated with differing HF prognoses.[23,24] However, these studies only analyzed stable HF patients, while our study examined ADHF patients, which otherwise would have been excluded from trials, such as the CPET. In fact, this study is the first to systematically compare the relationship between different physical functional scales with ADHF prognoses. We identified multiple patient characteristics, such as age, female, blood urea nitrogen, as well as statins, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, or angiotensin receptor-neprilysin inhibitors, being predictive for all-cause mortality in ADHF patient. Moreover, we observed that higher scores in physical functional assessment scales, such as SPPB, were significantly associated with better HF prognoses, in the form of higher survival rates, which were in accordance with findings from previous studies.[14,26] Such a positive correlation was also present for BBS; in particular, the lowest mortality risk was found at BBS = 36.5–40. All of these findings were still applicable even after adjusting for confounders, highlighting that BBS was a highly accurate predictor for all-cause ADHF mortality, with great clinical utility under decision curve analysis.

Currently, to improve HF prognoses, cardiac rehabilitation and tailored pharmacological regimes have been recommended. In particular, cardiac rehabilitation has become a key part of HF rehabilitation, being recommended as a class IA treatment.[12] However, current cardiac rehabilitation regimens for HF emphasize aerobic, resistance, and respiratory training, while balance training is mainly overlooked, which is a significant omission, as fall occurrence among ageing individuals is significant, at 14.7%–34% per year among Chinese people, and reaching as high as 30%–60% among Caucasians > 65 years.[27] Therefore, emphasizing balance training could aid in furthering the effectiveness of cardiac rehabilitation for improving HF prognoses, as a good sense of balance and proprioception is essential for effective exercise training, which would, in turn,

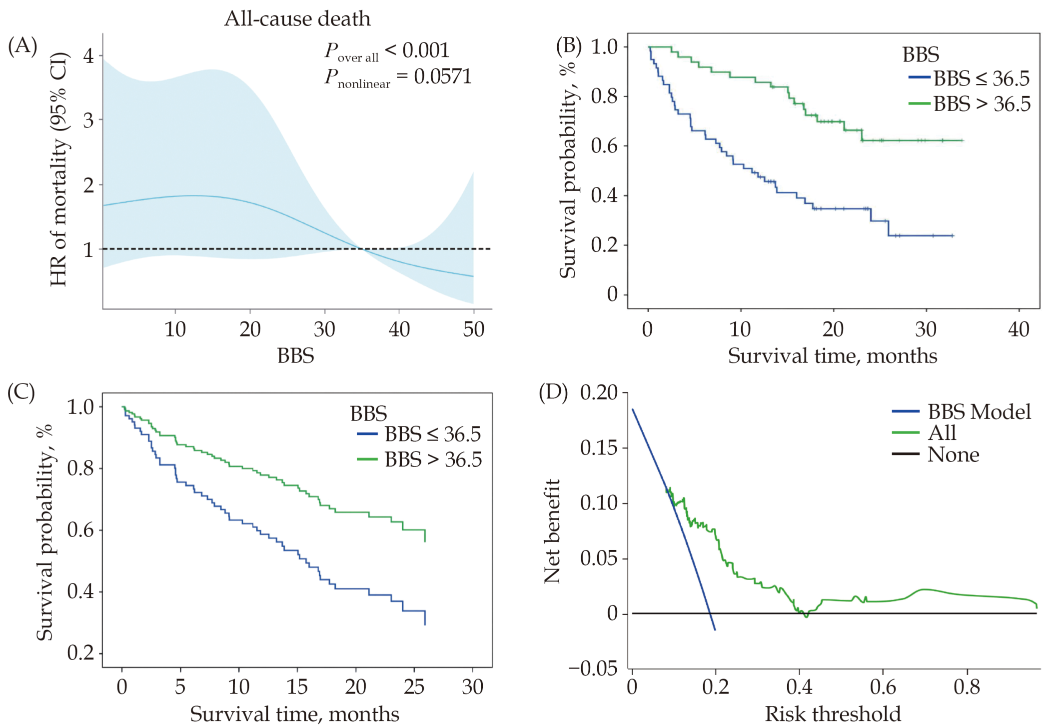


Figure 3 BBS ≤ 36.5 were associated with higher all-cause mortality in acute decompensated heart failure patients. (A): Restricted cubic spline analysis of the relationship between BBS scores and all-cause acute decompensated heart failure mortality, where the lowest mortality was present for BBS = 36.5–40. Kaplan-Meier survival analysis of survival rates between patients with BBS ≤ 36.5 versus > 36.5; (B): before and (C): after adjusting for the confounding factors of sex, age, hemoglobin, blood urea nitrogen, statins, angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers; and (D): decision curve analysis of BBS. BBS: Berg Balance Scale.

improve oxygen uptake and muscle strength. Previous studies, though, have used crude measurements to measure balance capacity, meaning that it was not able to be definitively quantified, or analyzed to identify its effects on HF prognoses. One such study was conducted in Japan, where a close relationship was observed between one-legged standing balance time with other physical fitness and mortality measurements.[28] Additionally, Medina, *et al.*[9] found a relationship between BBS and cancer prognoses, based on the National Health and Nutrition Examination Survey database. However, both studies were limited by their usage of public databases that were lacking laboratory test data. By contrast, our study remedied this omission by providing laboratory test data, as well as examining the relationship between laboratory indicators, and physical assessment scores, with HF prognoses.

Weakness in balance may limit patient mobility and increase sedentary time,[9] in turn increasing obesity and CVD, which could ultimately lead to higher mortality risk. Although our study demonstrates a robust association between balance impairment and increased all-cause mortality, the observational design precludes definitive causal inferences. However, the pathophysiological plausibility of this relationship is supported by mechanistic evidence: (1) vestibular dysfunction, linked to HF-induced hypoperfusion of the inner ear, may concurrently exacerbate balance disorders and increase cardiovascular mortality via autonomic dysregulation;[29–31] (2) balance deficits directly contribute to reduced physical activity, accelerating sarcopenia and frailty, which are established mortality risk factors in HF.[9,27] Therefore, when weaker balance is identified, targeted balance training could potentially interrupt this vicious cycle.

As for physical function assessments, SPPB is a simple and rapid tool, which entails standing balance, gait speed, and stepping tests, yielding a final score that reflects the overall exercise capacity of an individual; these scores are negatively correlated with all-cause mortality in HF patients.[15,25] Another assessment is BBS, which measures the ability of a patient to perform daily activities without risk of falling, by analyzing their balance and mobility capabilities. Such measurements are important for HF patients, as balance and mobility impairments could lead to complications that increase all-cause mortality risk, such as fatal falls. We found that both SPPB and BBS, alone or in combination, provide a comprehensive view for predicting all-cause mortality in ADHF patients. This integrated approach accounts for physical performance, balance and mobility, providing clinicians with a more accurate method to assess ADHF patient overall health and prognosis, and subsequently enable the development of personalized treatment plans to reduce all-cause mortality risk.

LIMITATIONS

There are a number of limitations to this study, one of which being its retrospective nature, as well as lacking data on cardiovascular mortality and unassisted grip strength. Owing to limited sample size, we prioritized adjustment for established confounders but acknowledge residual confounding from unmeasured factors (including the New York Heart Association functional classification). Therefore, future research will involve prospective analyses, with larger patient sample sizes; these patients should be categorized into different groups for analysis, based on their HF type/stage, thereby allowing the development of a more generalized predictive model for ADHF prognoses. Additionally, other balance scales, aside from BBS, would be also applied, such as the Tinetti Balance Assessment Scale. Furthermore, further endeavors need to focus on the underlying mechanisms linking HF mortality with balance weaknesses, as well as possible associations with other pathologies, such as vestibular dysfunction. Critically, as a retrospective observational study, our findings cannot establish a causal link between balance improvement and reduced mortality. While the pathophysiological rationale supports the biological plausibility of this relationship, confirmation requires prospective interventional studies specifically evaluating the impact of balance training on survival outcomes in ADHF patients.

CONCLUSIONS

In this study, we identified an association between balance disorders and elevated all-cause mortality risk, among ADHF patients. We found that higher scores in physical functional assessment scales, such as SPPB, significantly correlated with increased HF survival. More importantly, in BBS, which measures balance capability, scores > 36.5 was associated with lower ADHF mortality. Therefore, BBS or SPPB could be used as tools to assess physical function in ADHF patients unable to undergo CPET, as well as prognosticate on all-cause mortality. Additionally, given the strong association between balance impairment and elevated mortality, emphazing balance training in cardiac rehabilitation could be a strategic approach to potentially mitigate mortality risk, though future intervention trials are needed to confirm causality.

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