Research Square

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Changes in gait speed during hospitalization according to baseline gait speed in patients with heart failure

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Abstract

Purpose: Gait speed is an established prognostic marker in patients with heart failure (HF). However, whether improvement during hospitalization differs according to baseline gait speed remains unclear. This study investigated whether improvement differed across baseline gait speed levels.

Methods: This prospective cohort study included 538 patients with HF undergoing inpatient cardiac rehabilitation. Usual 10-m gait speed was assessed at baseline and discharge. Patients were classified into low (<0.67 m/s), middle (0.67 to <0.94 m/s), or high (≥0.94 m/s) group according to baseline gait speed. Improvement was defined as a ≥10% increase from baseline. Improvement proportions were compared using the chi-square test; magnitude of improvement and achievement of ≥0.98 m/s at discharge were also evaluated.

Results:

Overall, 55.4% of patients showed gait speed improvement, with improvement occurring in 73%, 57%, and 36% of the low, middle, and high groups, respectively (p <.001). The magnitude was greatest in the low group (+26.2%) and lowest in the high group (+6.4%). Conversely, achievement of a discharge gait speed ≥0.98 m/s was lowest in the low group (8.8%) and highest in the high group (91.1%). Patients with lower baseline gait speed were characterized by older age, greater comorbidity burden, poorer nutritional status, and lower physical function.

Conclusion: Patterns of gait speed improvement during hospitalization differed according to baseline gait speed. Patients with lower baseline gait speed were more likely to improve and showed greater improvement, but few achieved the prognostic threshold at discharge. Rehabilitation goals may need to be individualized according to baseline gait speed.

Key summary points

Aim: To determine whether gait speed improvement during hospitalization differs across baseline gait speed groups in patients with heart failure.

Findings: Patients with lower baseline gait speed more often showed improvement and greater relative gains, but rarely achieved the discharge gait speed threshold of 0.98 m/s.

Message: Baseline gait speed may help guide individualized rehabilitation goals during hospitalization.

Introduction

Heart failure (HF) is a global pandemic affecting more than 26 million people worldwide, with approximately one million hospitalizations attributable to HF each year [1]. In Japan, the number of patients with HF is expected to continue increasing, largely driven by population ageing [2]. Indeed,

registry data of patients with HF in Japan have shown a progressive increase in mean age over time, reaching 83 years in the most recent reports [3].

With the progression of population ageing, geriatric syndromes, including frailty, have become a major clinical concern in the management of HF. These conditions are highly prevalent among patients with HF and are increasingly recognized as having a substantial impact on clinical outcomes [4–6]. Therefore, there is a growing need to incorporate routine assessment and management of physical function into HF care.

Gait speed is commonly used to assess slowness, a key component of the physical frailty phenotype [7], and is associated with physical function and mortality in the general population [8]. Walking is an activity that places demands on multiple organ systems—including the cardiovascular, pulmonary, nervous, and musculoskeletal systems—and gait speed is considered a composite index that integratively reflects dysfunction across these systems [8]. In both the general population and in patients with HF, numerous studies have shown associations between gait speed and prognosis in patients with HF [9–11], and incorporating gait speed into established HF prognostic scores can enhance predictive accuracy [12]. Furthermore, changes in gait speed during hospitalization are also important in patients with HF, with greater improvements in gait speed being associated with better clinical outcomes [13].

However, most previous studies have examined improvements in gait speed during hospitalization in their overall study populations without stratifying patients according to baseline gait speed, and stratified analyses remain limited. Although the trajectory of improvement and clinical characteristics may differ among patients with varying levels of gait speed, this aspect has been insufficiently investigated. Further, there is no consensus on the definition of improvement in gait speed, which may contribute to variability in the interpretation of results. Therefore, stratifying patients by gait speed early in hospitalization may help anticipate gait speed improvement during hospitalization and guide targeted rehabilitation for those less likely to improve.

This study aimed to investigate whether improvement in gait speed during hospitalization differs according to baseline gait speed in patients with HF. We hypothesized that the proportion of patients with improvement would differ across groups stratified by baseline gait speed. By elucidating the characteristics of changes in gait speed according to baseline gait speed, this study is expected to contribute to the development of individualized rehabilitation strategies.

Methods

Study design and participants

We conducted a prospective cohort study of consecutive patients hospitalized for acute HF or worsening chronic HF at Hirakata Kohsai Hospital, Osaka, Japan, between May 2021 and June 2024. Those patients who underwent cardiac rehabilitation during hospitalization were included. Patients were excluded if they were unable to ambulate independently prior to admission, required ambulation

assistance during hospitalization, underwent rehabilitation for < 5 days, were transferred to another department, declined participation, or died during hospitalization. The sample size was determined by the number of eligible consecutive patients during the study period; no a priori sample size calculation was performed.

Ethical considerations

The research protocol was approved by the Ethics Committee of Hirakata Kohsai Hospital (Reference no. 2020-021). The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from all participants before enrolment.

Assessment of gait speed

Gait speed was assessed as the primary exposure variable in this study. Usual gait speed over a distance of 10 m was measured at two time points: at baseline, defined as the first gait speed assessment performed after independent indoor ambulation was permitted, and at discharge, defined as the time when discharge was determined. Gait speed was assessed by one of five physical therapists involved in cardiac rehabilitation using a standardized protocol, with the same therapist conducting both the baseline and discharge assessments for each patient. Patients were instructed to walk at their usual pace, beginning with a 2-m acceleration zone that preceded the 10-m measurement zone [14]. The use of walking aids, such as canes, was permitted during the test. Each patient performed two trials, and the faster of the two gait speeds was used for analysis. Gait speed measurement in older adults has been reported to show very high test-retest reliability, with an intraclass correlation coefficient exceeding 0.9 [15].

In previous studies, improvement in gait speed has sometimes been defined using absolute values, such as 0.1 m/s[16]; however, no consensus has been established. Moreover, when stratified by gait speed, the “weight” of improvement based on absolute values is likely to differ across strata. Therefore, in the present study, improvement was defined as a relative change from baseline. The rate of change in gait speed from baseline to discharge was calculated as follows: (gait speed at discharge − gait speed at baseline) / gait speed at baseline × 100. Patients were categorized into two groups: those with gait speed improvement (≥ 10% increase) and those without (< 10% increase), with the threshold defined a priori.

Other measurements

Clinical and demographic data were obtained from patients’ medical records. Demographic variables included baseline characteristics and comorbidities. Pre-admission functional status was assessed using the Barthel Index and Life-Space Assessment [17]. Clinical data collected at admission comprised echocardiographic parameters (left ventricular ejection fraction [LVEF] measured by the Simpson

method), New York Heart Association (NYHA) functional classification, and blood biochemistry values, including B-type natriuretic peptide, estimated glomerular filtration rate (eGFR), albumin, and haemoglobin levels. To assess nutrition, the Geriatric Nutritional Risk Index (GNRI) was calculated from serum albumin levels at admission, body weight, and ideal body weight, according to the following formula: GNRI = 14.89 × albumin (g/dL) + 41.7 × body weight (kg) / [height (m^2) × 22] [18]. Medication-related variables included discharge prescriptions and the duration of intravenous drug administration during hospitalization. Rehabilitation-related variables included the total number of rehabilitation days and total rehabilitation units during hospitalization. Functional assessments conducted by physical therapists were performed at baseline. In addition to gait speed, physical therapists assessed the patients with the Short Physical Performance Battery (SPPB)[19] and measurement of handgrip strength. Cognitive function was assessed using the Mini-Mental State Examination [20].

Statistical analysis

The proportion of patients with and without gait speed improvement in the overall cohort was described using descriptive statistics. Patients were stratified into three groups according to tertiles of baseline gait speed (low, middle, and high groups), and clinical characteristics were compared across the three groups. Trends across ordered groups were evaluated using the Jonckheere-Terpstra test for continuous variables and the Cochran-Armitage trend test for categorical variables.

Differences in the proportion of patients with gait speed improvement among the three groups, as well as according to the factors of age, sex, and presence of musculoskeletal disorders, were assessed using the chi-square test.

Achievement of a clinically meaningful gait speed was defined as a discharge gait speed of ≥ 0.98 m/s, a previously reported prognostic threshold in patients with HF [21]. The proportion of patients achieving this threshold was compared across baseline gait speed strata using the chi-square test.

Analyses included patients with gait speed measurements available at both baseline and discharge. Missing values for other variables were handled using available-case analysis for each variable, without imputation.

All statistical analyses were performed using JMP version 18.2.1 (SAS Institute Inc., Cary, NC, USA), and a two-sided p-value < 0.05 was considered statistically significant.

Results

Study population and characteristics

Of the 1397 consecutive patients hospitalized for HF during the study period, 1103 underwent cardiac rehabilitation. After applying the exclusion criteria, 538 patients were included in the analysis. The patient selection process is shown in Figure 1.

The baseline characteristics of the study population are presented in Table 1. The median age was 81.0 years, and 303 patients (56.3%) were male. The median gait speed was 0.80 m/s at baseline and 0.94 m/s at discharge. The median number of rehabilitation units per day was 2.0, and the median length of hospital stay was 16 days.

[Place Figure 1 here]

Gait speed improvement pattern

The proportion of patients (n = 538) who showed improvement in gait speed was 55.4% (n = 298). When stratified by tertiles of baseline gait speed, patients were categorized into three groups: low (<0.67 m/s), middle (0.67 to <0.94 m/s), and high (≥0.94 m/s) (Online Resource 1, Supplementary Fig. S1). The proportions of patients with gait speed improvement were 72.9% in the low group, 57.3% in the middle group, and 35.8% in the high group, indicating that a lower baseline gait speed was associated with a higher likelihood of improvement (p <.001) (Figure 2). In contrast, no significant differences were observed in the proportion of patients with gait speed improvement when stratified by age tertiles, sex, or the presence of musculoskeletal disease (Online Resource 1, Supplementary Fig. S2). The magnitude of gait speed improvement was greatest in the low group (26.2%), followed by the middle group (13.3%) and the high group (6.4%). In contrast, the proportion of patients achieving a discharge gait speed ≥0.98 m/s was lowest in the low group (8.8%) and highest in the high group (91.1%) (Figure 3).

[Place Figure 2, Figure3 here]

Clinical characteristics across baseline gait speed tertiles

Next, clinical characteristics were examined across increasing tertiles of baseline gait speed (from low to high) using trend analyses (Table 1). Regarding baseline characteristics, patients in the higher baseline gait speed tertiles were younger, and a higher proportion were male. Pre-admission functional status and life-space mobility were better in the higher tertiles, as reflected by higher Barthel Index and Life-Space Assessment scores. With respect to cardiac-related factors at admission, the higher tertiles had a higher prevalence of cardiomyopathy but lower LVEF and E/e' values and lower prevalences of valvular disease and HF with preserved ejection fraction (HFpEF). For comorbidities, patients in the higher tertiles had a lower prevalence of musculoskeletal disorders and lower Charlson Comorbidity Index scores. Laboratory findings showed that eGFR and haemoglobin levels were higher in the higher tertiles, as was nutritional status reflected by higher GNRI values. Baseline physical functions were also better in the higher tertiles, as indicated by greater handgrip strength and higher SPPB scores. Among in-hospital treatment-related factors, the duration of intravenous diuretic therapy was shorter in the higher tertiles, whereas the rate of concurrent prescription of the “Fantastic Four” at discharge among the patients with HF with reduced ejection fraction was higher in the higher tertiles. No significant trend was observed in the rehabilitation-related factors of number of rehabilitation units per day, but time to initiation of cardiac rehabilitation and length of hospital stay were shorter in the higher tertiles.

Discussion

Brief summary

This study provides novel insights into in-hospital changes in gait speed among patients with HF by stratifying patients according to baseline gait speed. First, the proportion of patients with gait speed improvement differed across baseline gait speed groups. Second, although the patients with lower baseline gait speed were more likely to improve and show greater magnitude of improvement, only 8.8% achieved the previously reported target gait speed at discharge. Furthermore, patients with lower baseline gait speed were characterized by older age, a greater comorbidity burden, poorer nutritional status and physical function, prolonged hospitalization, a higher prevalence of HFpEF and valvular disease, higher LVEF and E/e' values, and a lower prevalence of cardiomyopathy.

Comparison with previous studies

We found that 55.4% of the patients showed improvement in gait speed during hospitalization, which was higher than the proportion of those not improving. A previous study reported that 71.9% of patients with HF experienced improvement in gait speed during hospitalization [13], supporting our findings. However, the lower proportion of improvement observed in the present study may also be attributable to differences in patient characteristics between this and the previous study [13], including older age and a higher proportion of patients with HFpEF and NYHA functional class III or higher in our cohort.

Gait speed has been widely reported as a strong prognostic factor in patients with HF [9], and greater improvements in gait speed have been associated with better outcomes [13]. However, few studies have examined improvement rates and goal attainment after stratifying patients based on baseline physical function. Although our patients with lower baseline gait speed were more likely to improve, the proportion of those achieving a clinically meaningful gait speed at discharge was lower. One possible explanation might be that the patients with lower baseline gait speed in the present study exhibited greater frailty, as reflected by their older age, poorer nutritional status, lower physical and cognitive function, and higher prevalence of musculoskeletal disorders. Their low baseline gait speed may partly explain why, despite showing the greatest magnitude of gait speed improvement during hospitalization, most patients did not reach the clinically meaningful gait speed threshold by discharge. These patients may represent a subgroup with substantial room for further recovery through continued rehabilitation beyond the acute hospitalization period. Previous studies have shown that physical function can be improved through rehabilitation programmes initiated during hospitalization and continued after discharge [22], comprehensive outpatient cardiac rehabilitation [23], tele-rehabilitation [24], and multidisciplinary cardiac rehabilitation in convalescent rehabilitation hospitals [25].

Despite previous reports, no significant differences in gait speed improvement were observed according to age, sex, or musculoskeletal disease, although these factors have previously been associated with gait speed and mobility limitation [26, 27]. Instead, baseline gait speed clearly differentiated the likelihood of gait speed improvement during hospitalization.

The precise mechanisms underlying differences in clinical characteristics across gait speed strata remain unclear. Reduced physical function is considered to reflect diminished physiological reserve, which may increase vulnerability to clinical deterioration and rehospitalization [28]. Patients with lower gait speed were older, had a higher burden of comorbidities, poorer nutritional status, lower cognitive and physical function, and longer hospital stays. They also required longer durations of intravenous diuretic therapy, suggesting delayed clinical recovery during hospitalization. Patients with lower baseline gait speed exhibited multidimensional functional impairments and greater vulnerability, suggesting that baseline gait speed assessed early in hospitalization may serve as a comprehensive indicator of overall physical condition in patients with HF.

Clinical implications

Assessment of baseline gait speed may help classify patients according to their expected recovery trajectory during hospitalization. Patients with low baseline gait speed frequently improved during hospitalization but rarely achieved the prognostic gait speed threshold at discharge, suggesting that rehabilitation goals may need to be individualized according to baseline functional status. In contrast, patients with high baseline gait speed showed limited improvement, which may partly reflect a ceiling effect. Notably, only approximately half of the patients with intermediate baseline gait speed experienced improvement despite having greater potential to achieve a clinically meaningful gait speed. Previous studies have identified age, renal dysfunction, and baseline gait speed as predictors of functional improvement after rehabilitation in analyses of overall cohorts [13, 29, 30]. However, factors associated with non-improvement within each baseline gait speed stratum remain unclear. Future studies should clarify such factors, particularly among patients with intermediate baseline gait speed, and determine whether rehabilitation strategies tailored to baseline gait speed can improve functional recovery.

Strengths and limitations

This study has several strengths. Gait speed was prospectively assessed using a standardized protocol at baseline and discharge. Furthermore, stratifying patients according to baseline gait speed allowed us to characterize differences in the proportion and magnitude of improvement and in the achievement of a prognostic gait speed threshold.

However, several limitations should be acknowledged. First, this was a single-centre observational study and therefore may be subject to selection bias. Second, the associations and trends across the ordered groups were evaluated using univariable analyses, and potential confounding factors and interactions among covariates were not fully accounted for. Therefore, the observed findings should be interpreted as descriptive and exploratory in nature. Furthermore, this study was designed to describe gait speed improvement patterns according to baseline gait speed rather than to identify independent determinants of improvement. Investigation of factors associated with gait speed improvement within each baseline gait speed subgroup would require substantially larger sample sizes and should be addressed in future studies. Third, the study population was limited to patients able to undergo gait assessment during

hospitalization, and those with more severe conditions who could not be evaluated were excluded. Therefore, the generalizability of these findings to all patients with HF may be limited. Fourth, detailed factors that may influence improvement and goal attainment in gait speed, such as daily physical activity levels, were not fully assessed.

Conclusion

In this study, patterns of gait speed improvement during hospitalization differed according to baseline gait speed in the patients with HF, suggesting that baseline gait speed may be useful for characterizing recovery trajectories. Our findings identified the need for future studies to clarify factors associated with non-improvement within each baseline gait speed subgroup and to determine whether subgroup-specific rehabilitation strategies can improve functional recovery.

Declarations

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors declare that they have no conflicts of interest related to this study.

Clinical trial number

Not applicable.

Ethics approval

The research protocol was approved by the Ethics Committee of Hirakata Kohsai Hospital (Osaka, Japan; Reference no. 2020-021). The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from all participants before enrolment.

Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used ChatGPT (OpenAI) to assist with English-language editing and sentence refinement. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Authors' contributions: CRediT

Atsushi Ogi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft. Kotaro Iwatsu: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. Yuji Kanejima: Methodology, Writing – review & editing. Kodai Ishihara: Methodology, Writing – review & editing. Kazuhisa Tsurumoto: Writing – review & editing. Yusuke Kawamura: Writing – review & editing. Konoka Yasunaga: Writing – review & editing. Hiroki Sasaki: Data curation, Investigation, Writing – review & editing. Ubuka Nakahira: Investigation, Writing – review & editing. Tsutomu Ikeda: Data curation, Investigation, Writing – review & editing. Minato Nakazawa: Formal analysis, Writing – review & editing. Ryoko Fujita: Resources, Writing – review & editing. Takeshi Kimura: Resources, Writing – review & editing. Kazuhiro P. Izawa: Supervision, Funding acquisition, Project administration, Writing – review & editing.

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Figures

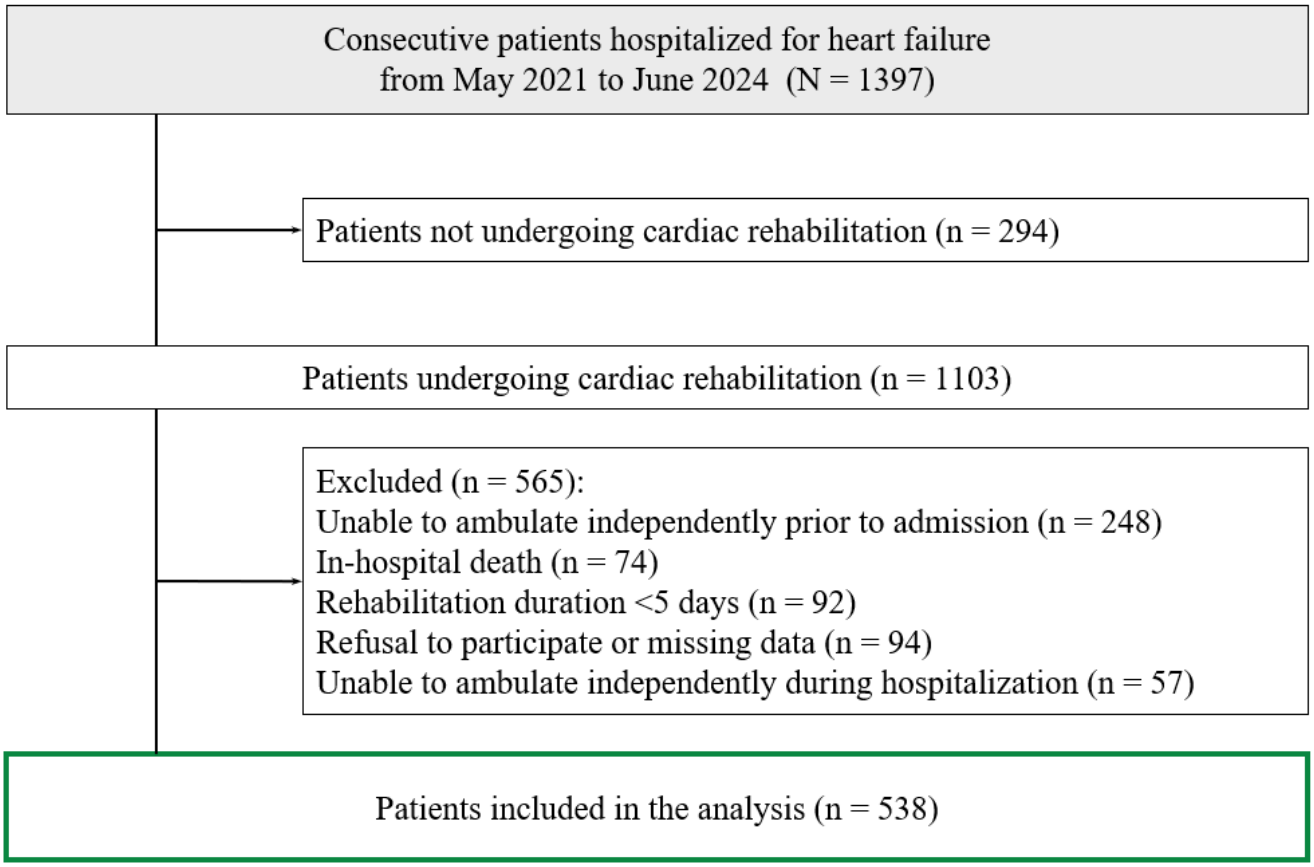


Figure 1

Patient flow diagram.

Alt text: Patient flow diagram shows that 538 of 1397 patients hospitalized with heart failure were included after exclusions based on rehabilitation participation, ambulatory status, death, rehabilitation duration, and missing data.

Fig. 2

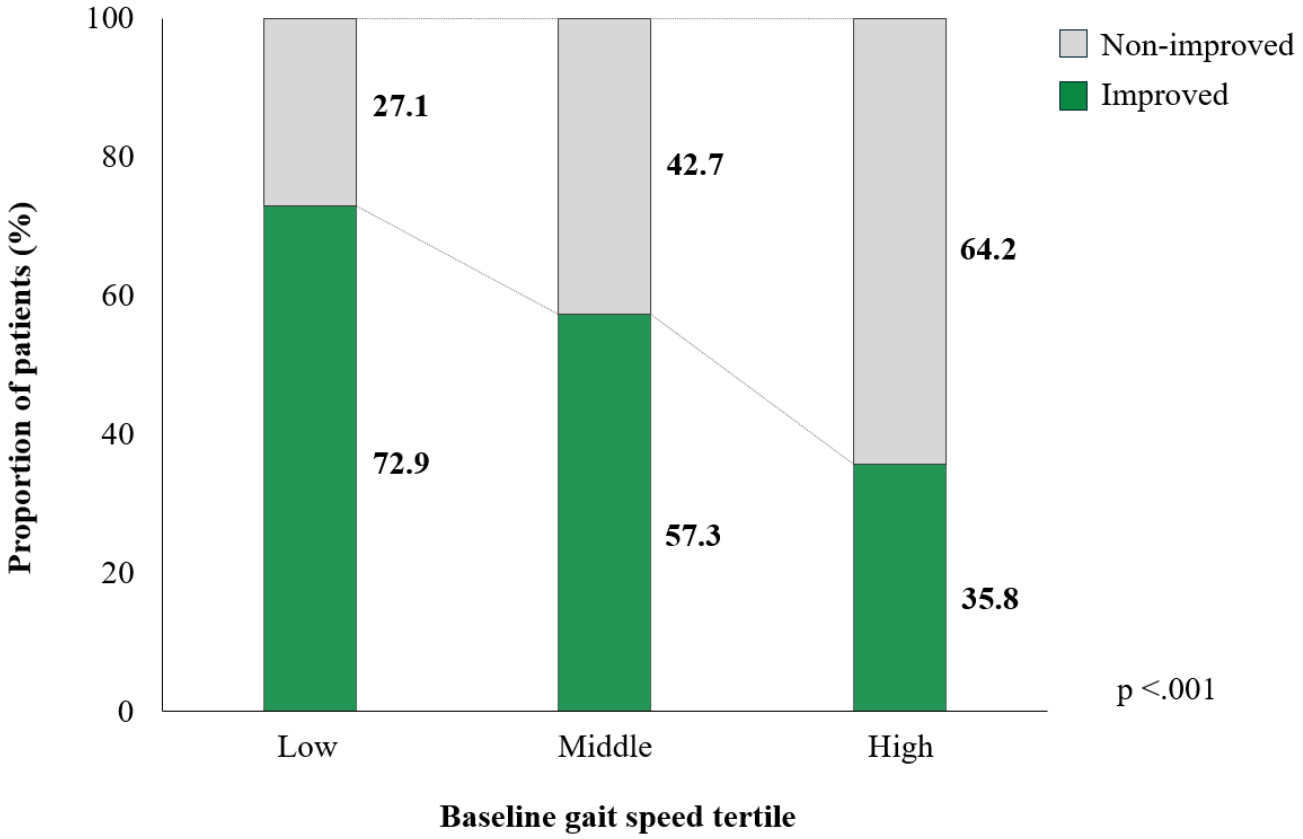


Figure 2

Gait speed improvement according to baseline tertiles.

Alt text: Stacked bar chart shows gait speed improvement in 72.9 percent, 57.3 percent, and 35.8 percent of the low, middle, and high baseline gait speed groups, respectively.

Fig. 3

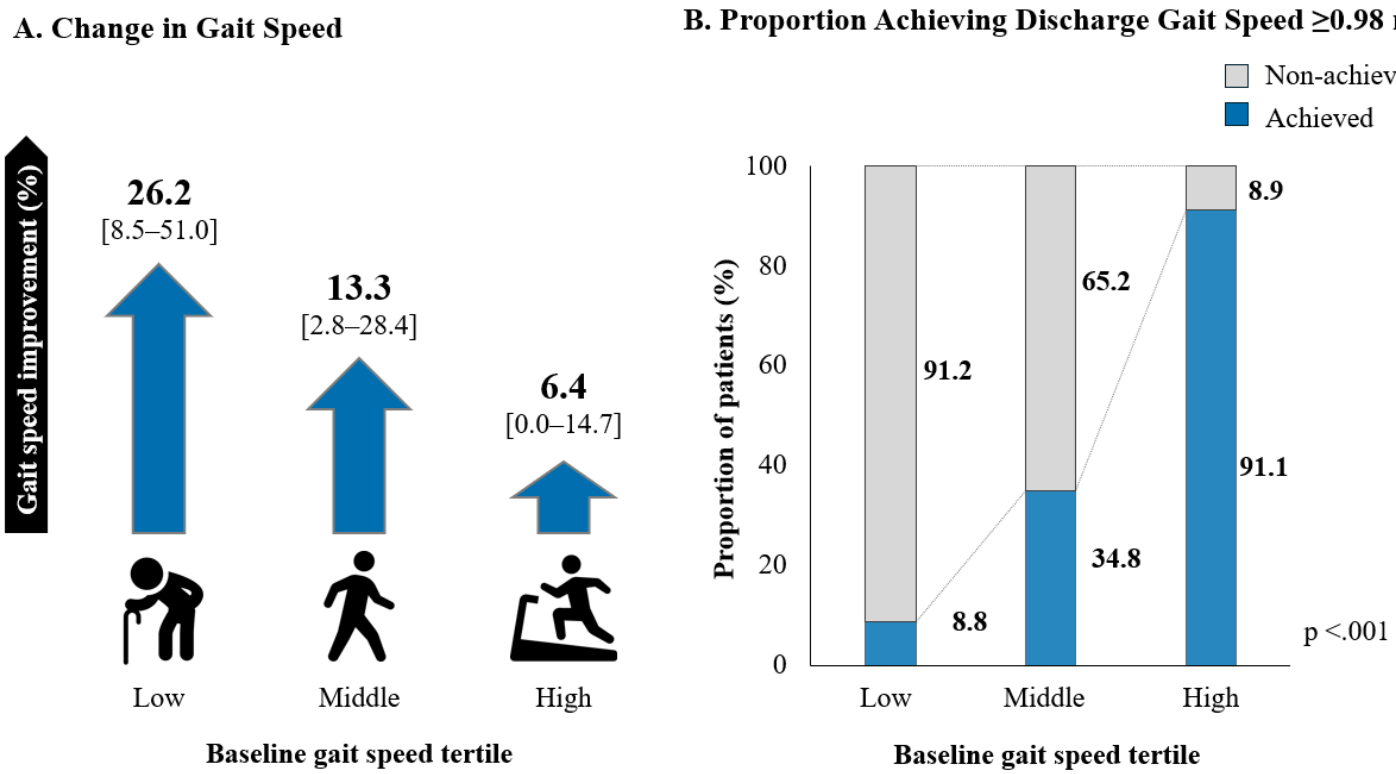


Figure 3

Gait speed improvement and achievement of target discharge gait speed. (A) Percentage improvement in gait speed from baseline to discharge across the three baseline groups. (B) Proportion of patients achieving a discharge gait speed of ≥ 0.98 m/s in each group.

Alt text: Panel A shows that the greatest percentage of gait speed improvement occurred in the low baseline group. Panel B shows increasing achievement of at least 0.98 metres per second across the groups.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GraphicalAbstract.png
- SupplementaryFigures.pptx