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The 30-second chair stand test (CS30) as a predictor of exercise tolerance in elderly individuals (≥75 years) with stage A/B heart failure

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ABSTRACT

Background: In Japan, the number of very elderly individuals with heart failure (HF) is on the rise. One indicator of HF stage progression is a decrease in exercise tolerance (ET). While peak oxygen uptake (peak VO_2) determined by cardiopulmonary exercise testing (CPX) is the gold standard for ET assessment, the wide-scale applicability of CPX is constrained owing to expensive equipment and challenges in this population. The 30-second chair stand test (CS30), a simple and quick alternative, is widely used among community-dwelling elderly individuals. The objective of this study was to investigate whether CS30 is a predictor of ET in elderly individuals with stage A/B HF.

Methods: Of 748 outpatients aged 75 years and over who visited our center between March 2021 and December 2022, 493 patients (296 males and 197 females) were included in this study. CS30 was measured using a seat height of 40 cm, and peak VO_2 was assessed using CPX.

Results: The findings showed a statistically significant positive association between CS30 and peak VO_2 for both males and females (males: $\beta = 0.255$, 95 % CI = 0.102–0.407; females: $\beta = 0.282$, 95 % CI = 0.043–0.521). Receiver operating characteristic (ROC) analyses showed moderate accuracy of CS30 in predicting low ET in both sexes (males AUC = 0.740, 95 % CI = 0.640–0.841, $p < 0.001$; females AUC = 0.725, 95 % CI = 0.644–0.807, $p < 0.001$). The cut-off values of CS30 were established as 18 times for males and 16 times for females.

Conclusions: CS30 is a potentially convenient method for estimating current ET in older adults, providing a feasible alternative to CPX.

1. Introduction

The prevalence of heart failure (HF) among the elderly population in Japan is on the rise [1]. Current projections indicate that by 2030, the number of HF cases will reach approximately 1.3 million nationwide [2]. Among elderly patients, HF with preserved ejection fraction is the most common form of HF [3]. In addition, HF affects approximately 2 % of the Western population, with the prevalence increasing to 10 % in patients over the age of 75 years [4]. Notably, a significant proportion of those aged 75 and over in Japan (referred to as late-stage elderly individuals) concurrently suffer from sarcopenia and frailty [5,6]. Patients with HF also exhibit frailty, and the combination of HF and frailty is associated with symptom worsening, more frequent hospital admissions, and a higher mortality rate [1].

Abbreviations: ET, exercise tolerance; peak VO_2, peak oxygen uptake; CPX, cardiopulmonary exercise testing; CS30, 30-second chair stand test; LET, low ET; peak RER, peak respiratory exchange ratio; BMI, body mass index; NT-pro BNP, N-terminal pro-brain natriuretic peptide; Alb, albumin; eGFR, estimated glomerular filtration rate; Cr, creatinine; LVEF, left ventricular ejection fraction; E/e', early mitral inflow velocity/early mitral annulus velocity; LAD, left atrial dimension; KCL, Kihon checklist; SMI, skeletal muscle mass index; PhA, phase angle; SOC, stage of change for exercise behavior; GS, grip strength; OLST, one-leg standing time; AT, anaerobic threshold; VE Vs. VCO_2, minute ventilation/carbon dioxide output slope; ROC, receiver operating characteristic; AUC, area under the ROC curve.

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HF is recognized as a progressive chronic disease. Identifying the patient's current stage of HF is challenging. The American College of Cardiology Foundation/American Heart Association outlines the stages of HF: Stage A comprises individuals at high risk for developing HF but without structural heart disease or symptoms; Stage B involves the presence of structural heart disease but without overt signs or symptoms of HF; Stage C consists of the presence of structural heart disease with prior or current HF symptoms; and Stage D comprises refractory HF [7]. As patients transition from stages A/B to C/D, there is a marked decline in physical functioning [8]. Moreover, the onset of HF is correlated with reduced physical activity [9] and cognitive function [10] and is often associated with depression [11] and social isolation, among others [12]. Therefore, understanding the patient's current stage of HF is imperative. Furthermore, early identification of older patients with HF at Stages A or B is also crucial. It allows for timely intervention and management, which can help prevent the worsening of symptoms and improve the patient's quality of life.

Identifying the current stage of HF in patients and the role of exercise tolerance in this process is challenging. Recent advancements have highlighted the importance of functional testing to detect hemodynamic abnormalities during exercise [3]. In fact, the main clinical characteristic of HF with preserved ejection fraction is exercise intolerance, defined as an impaired ability to perform physical activity and to reach the expected age-related level of exercise duration [13,14]. Exercise intolerance in patients with HF is associated with a poor quality of life and a higher incidence of hospitalization [15]. These findings underscore the importance of gaining an understanding of the patient's HF stage to provide therapy such as exercise training to help prevent exercise intolerance.

Studies have shown that exercise training can improve the cardiac health of older patients. For instance, findings from the ARISTOS-HF trial indicate that exercise training leads to an improvement in peak oxygen uptake (peak VO_2) and left ventricular ejection fraction (LVEF) in patients with HF [16]. In addition, exercise training can enhance beta adrenergic receptor responsiveness, which can play a role in the reported clinical improvement of cardiovascular health in older individuals [17]. A study that included 13,612 cardiac patients who took part in a cardiac rehabilitation program showed that improvements in exercise capacity could be observed in old age (85 years) [18].

A variety of methods can be used to identify older patients with HF. For instance, molecular methods can be used to detect older patients with HF, exercise intolerance, and frailty. A recent study has demonstrated that microRNA-181c levels are significantly increased in frail older patients with HF and diabetes mellitus [19]. However, noninvasive methods to identify exercise intolerance in older individuals with HF are preferred because they reduce discomfort and risk for the patient.

Exercise tolerance (ET) is a method that can potentially track the progression of HF stages. ET is defined as the ability to perform physical activity and to achieve the expected exercise duration for a given age. Among the parameters used to measure ET, peak VO_2 is considered the gold standard. This parameter is a powerful and independent predictor of cardiovascular risk, surpassing classical risk factors [20,21].

Peak VO_2 can be assessed by cardiopulmonary exercise testing (CPX) using either gas exchange analysis or determination of blood lactate concentration. A peak VO_2 less than 80 % of the reference value signifies decreased ET [22]. However, CPX is not always feasible; its equipment is expensive, and many late-stage elderly individuals have motor impairment, making tests involving activities such as pedaling and walking challenging.

A study in older patients with type 2 diabetes showed a significant correlation between peak VO_2 during incremental sit-to-stand exercises and that during the cycle ergometer test [23]. The 30-second chair stand test (CS30), which is one of the sit-to-stand indicators, measures the number of sit-to-stand repetitions performed in 30 s [24]. This test is widely used for assessing community-dwelling older adults owing to its simplicity, speed, and lack of equipment required [25]. Research has also shown a moderate correlation between CS30 and relative peak VO_2 in women with breast cancer [26], further highlighting its utility in assessing ET. However, a knowledge gap exists regarding the relationship between CS30 and ET in stage A/B HF in late-stage elderly individuals. Identifying a clear cut-off point of low ET (LET) using a simple test such as CS30 could offer a useful alternative to estimate ET in the elderly population.

The objective of this study is to investigate whether CS30 is a predictor of ET in late–stage elderly individuals with stage A/B HF.

2. Methods

This was a single-center, cross-sectional, observational study. A total of 748 consecutive outpatients aged 75 years old and over visited our center between March 2021 and December 2022. Of these, 493 patients (296 males and 197 females) were enrolled in the study. Exclusion criteria were as follows: (i) those already enrolled in the study, (ii) previous hospitalization owing to HF, (iii) history of valvular disease surgery, (iv) palpitations as the sole symptom, (v) presence of a cardiac pacemaker, (vi) certification for long-term care insurance, including patients with stroke, severe musculoskeletal disorders, and Parkinson's disease, (vii) peak respiratory exchange ratio (peak RER) ≤ 1.0 [22], and (viii) missing data. Notably, patients with respiratory diseases were not explicitly excluded and could be included in the study cohort. Written informed consent was obtained from all participants prior to their inclusion in the study. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee.

2.1. Measurements

2.1.1. Demographic and clinical characteristics

Data were collected from patient medical records. The survey items included age, sex, height, weight, body mass index (BMI), presence or absence of heart disease, diagnosis, lifestyle-related conditions (diabetes, hypertension, and dyslipidemia), history of outpatient cardiac rehabilitation visits, and residence form. In addition, blood tests were performed to determine levels of N-terminal pro-brain natriuretic peptide (NT-pro BNP), albumin (Alb), estimated glomerular filtration rate (eGFR), and creatinine (Cr). Data on cardiac function were derived from cardiac ultrasonography, including measurements for LVEF, early mitral inflow velocity/early mitral annulus velocity (E/e'), and left atrial dimension (LAD). Participants were surveyed on their exercise habits and were asked to complete the Kihon checklist (KCL) [27].

2.1.2. Body composition

Bioelectrical impedance analysis was performed using a body composition analyzer (InBody-s10, InBody Japan). Participants were seated with electrodes attached to their extremities. The parameters evaluated were muscle mass, skeletal muscle mass index (SMI), and phase angle (PhA). PhA expresses the cell membrane's resistance and is thought to reflect the cell's physiological function [28]. SMI is obtained by summing the muscle mass of the limbs and then dividing by the height squared (kg/m^2); this is also used as a diagnostic criterion for sarcopenia [29].

2.1.3. Frailty

Frailty was evaluated using the KCL, a binary self-administered questionnaire comprising 25 items across seven domains: instrumental activities of daily living, exercise, nutrition, oral health, confinement, cognition, and depression [27]. Because the KCL's total score is considered useful for frailty evaluation, this study used the total score for analysis.

2.1.4. Exercise habits

The presence or absence of exercise habits was determined using the

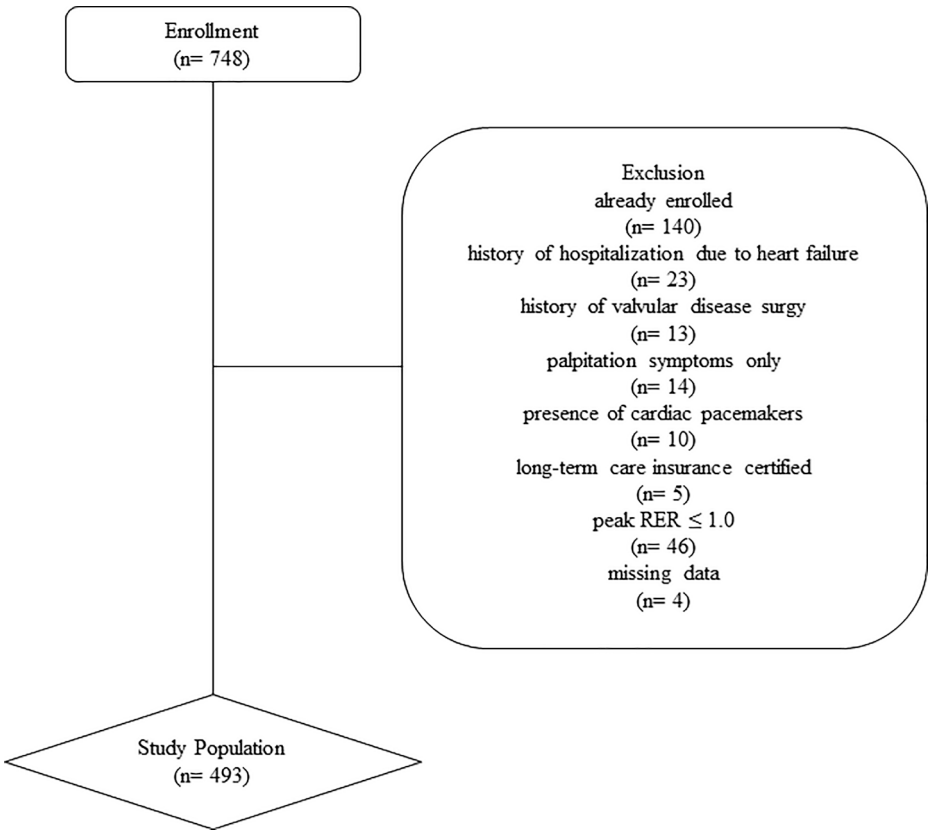

Fig. 1. Flow chart of study population selection.peak RER: peak respiratory exchange ratio.

five-item Stage of Change for Exercise Behavior (SOC). This scale comprises items that measure past and present motor behaviors and the state of readiness for motor behavior [30]. The contents of the scale's items are as follows: (1) "I am not currently exercising. I have no intention of doing so in the future" (pre-reflection period), (2) "I am not currently exercising, but I plan to start in the near future (within 6 months)" (contemplation period), (3) "I am currently exercising, but not regularly" (preparatory period), (4) "I am currently exercising regularly for ≤ 6 months" (execution period), and (5) "I am currently exercising regularly" (exercising for 20–30 min or more at a time at least 2–3 times a week). In this study, (1) and (2) were categorized as having no exercise habits and (3)–(5) were categorized as having exercise habits.

2.1.5. Motor function

Motor function was investigated via three parameters: grip strength (GS), CS30, and one-leg standing time (OLST). GS was measured using a grip dynamometer (K. K. 5401; Takei Kiki Kogyo Co., Ltd.). Each participant was verbally encouraged to perform grip strength tasks, twice on each side in the elbow joint extension position in a standing position; the highest average values were recorded [29]. For the CS30, participants began seated on a 40-cm-high chair with both legs shoulder-width apart and arms crossed in front of the chest. Participants were then instructed to stand and sit repeatedly for 30 s with their arms crossed [24]. The number of times a person completed the stand-to-sit sequence within 30 s was recorded. The OLST measured the time spent from side to side with one leg raised, hands on hips, eyes open, and posture maintained.

2.1.6. Exercise tolerance

ET was measured using a bicycle ergometer (Strength Ergo 8; Mitsubishi Electric Engineering Co., Ltd.) with a progressively increasing load. The targeted speed was 40–60 rpm, with an exercise duration of approximately 8–12 min, tailored to the participant's age and physical function status. Exhaled gas was analyzed using a gas metabolism monitor (Cpex-1). Continuous monitoring of heart rate, ST-T changes, and arrhythmias was performed using a 12-lead electrocardiogram, and blood pressure was recorded every minute. The test would conclude if there were signs that met the discontinuation criteria of the exercise stress test or if oxygen uptake remained stagnant despite an increase in load intensity. Parameters assessed included peak VO_2, anaerobic threshold (AT), minute ventilation/carbon dioxide output (VE vs. VCO_2) slope, minimum VE/ VCO_2, and peak RER.

2.2. Statistical analyses

The Shapiro–Wilk test was used to confirm that the primary CS30 outcome variable could be analyzed as a normally distributed variable. CS30 was not significantly skewed ($p = 0.81$), thus confirming the choice of linear regression tests as appropriate. Data are expressed as mean ± standard deviation. All statistical analyses were performed using IBM SPSS Statistics (version 25), and the threshold for significance was set at 5 %.

In univariable linear regression analysis, CS30 served as the dependent variable and peak VO_2 as the independent variable. In multivariable linear regression analysis, variables exhibiting absolute values of the correlation coefficients of 0.3 or more in the Pearson correlation analysis (age, PhA, OLST, GS, and KCL for males and OLST, peak RER, KCL, and LVEF for females) were selected as adjusting explanatory variables. Variables showing multicollinearity (%AT and %peak VO_2 for males and %AT, %peak VO_2 and AT for females) were excluded from this analysis. The correlation magnitude was classified as follows: 0.0–0.3 as a weak or negligible correlation, 0.3–0.5 as a slightly stronger correlation, 0.5–0.7 as a moderately strong correlation, 0.7–0.9 as a strong correlation, and 0.9–1.0 as an extremely strong correlation [31].

Multivariable linear regression analysis was conducted by forced entry. Univariable linear regression analysis was conducted to evaluate

Table 1
Demographic and clinical characteristics of participants.

N (%)	All n = 493	SD	Male n = 296 (60.0)	SD	Female n = 197 (40.0)	SD
Age (years)	79	3	79	3	80	3
Height (m)	1.58	8.4	1.63	5.7	1.50	5.0
Body weight (kg)	58.7	9.8	63.2	8.6	51.9	7.2
BMI (kg/m^2)	23.2	2.9	23.5	2.7	22.9	3.1
Stage of heart failure						
Stage A	128		48 (16.2)		80 (40.6)	
Stage B	365		248 (83.8)		117 (59.4)	
Heart disease						
Angina pectoris	239		162 (54.7)		77 (39.1)	
Myocardial infarction	58		48 (16.2)		10 (5.1)	
Arrhythmia	69		38 (12.8)		31 (15.7)	
Cardiomyopathy	2		0 (0.0)		2 (1.0)	
History of rehabilitation visits	91		62 (20.9)		29 (14.7)	
Diabetes	113		81 (27.4)		32 (16.2)	
Hypertension	312		188 (63.5)		124 (62.9)	
Dyslipidemia	294		186 (62.8)		108 (54.8)	
Exercise habits	136		94 (31.8)		42 (21.3)	
Residence form						
Living alone	408		270 (91.2)		138 (70.1)	
Not living alone	81		23 (7.8)		58 (29.4)	
Muscle mass (kg)	41.4	7.6	46.0	5.5	34.1	3.8
SMI (kg/m^2)	7.1	1.3	7.7	1.2	6.1	0.8
PhA (°)	5.1	0.8	5.4	0.8	4.7	0.7
NT-proBNP (pg/mL)	409.3	760.2	327.6	542.8	539.1	1005.3
Alb (g/dL)	4.1	0.3	4.1	0.3	4.1	0.2
eGFR (mL/min/1.73 m^2)	55.2	18.1	54.7	18.7	56.0	17.1
Cr (mg/dL)	0.92	0.23	0.99	0.22	0.81	0.21
LAD (mm)	32.0	14.6	32.5	14.2	31.1	15.2
E/E' (mm)	11.7	4.1	11.3	4.1	12.2	4.0
LVEF (%)	63.8	9.9	62.8	10.1	65.3	9.4
OLST (sec)	34.5	20.9	35.4	21.4	33.1	20.0
GS (kg)	28.1	7.4	32.7	5.7	21.2	3.4
CS30 (times)	19.9	5.3	20.3	5.4	19.1	5.0
AT (mL/min/kg)	14.0	5.1	14.4	2.6	12.8	2.3
%AT	101.4	19.2	107.2	18.8	92.6	16.2
peak VO_2 (mL/min/kg)	20.0	4.3	21.4	4.2	18.0	3.7
%peak VO_2	97.9	20.5	103.0	20.5	90.3	17.9
VE vs. VCO_2 slope	27.8	5.5	27.3	5.1	28.4	5.9
minimum VE/VCO_2	30.7	4.8	30.3	4.7	31.3	4.8
peak RER	1.16	0.08	1.16	0.08	1.14	0.08
KCL (point)	4.6	3.4	4.0	3.1	5.6	3.6

Data are shown as mean, SD, or n (%).
Alb: albumin, AT: anaerobic threshold, BMI: body mass index, Cr: creatinine, CS30: 30-Second Chair Stand Test, E/e′: early mitral inflow velocity/early mitral annulus velocity, eGFR: estimated glomerular filtration rate, GS: grip strength, KCL: Kihon checklist, LAD: left atrial dimension, LVEF: left ventricular ejection fraction, minimum VE vs. CO_2: minimum ventilation/carbon dioxide output, NT-pro BNP: N-terminal pro-brain natriuretic peptide, OLST: One-leg standing time, peak RER: peak respiratory exchange ratio, peak VO_2: peak oxygen uptake, PhA: phase angle, SD: standard deviation, SMI: skeletal muscle mass index, VE Vs. VCO_2 slope: minute ventilation/carbon dioxide output.

Table 2
Pearson correlation analysis for the relationship between CS30 and measured items.

	Male		Female	
Independent Variable	r	P-value	r	P-value
Age (years)	−0.300	<0.001	−0.168	0.019
Body weight (kg)	−0.064	0.278	−0.211	0.003
BMI (kg/m^2)	−0.015	0.796	−0.085	0.236
Muscle mass (kg)	0.038	0.536	−0.194	0.011
SMI (kg/m^2)	0.074	0.227	−0.097	0.208
PhA (°)	0.370	<0.001	0.241	0.001
E/e' (mm)	−0.035	0.619	0.012	0.892
LVEF (%)	−0.111	0.148	−0.334	<0.001
OLST (sec)	0.435	<0.001	0.337	<0.001
GS (kg)	0.303	<0.001	0.217	0.002
AT (mL/min/kg)	0.081	0.170	0.397	<0.001
%AT	0.309	<0.001	0.390	<0.001
Peak VO_2 (mL/min/kg)	0.408	<0.001	0.406	<0.001
%peak VO_2	0.322	<0.001	0.395	<0.001
VE vs. VCO_2 slope	−0.114	0.052	−0.123	0.086
minimum VE/VCO_2	−0.097	0.099	−0.126	0.080
peak RER	0.185	0.001	0.326	<0.001
KCL (point)	−0.410	<0.001	−0.338	<0.001

Correlation analysis dependent variable: CS30, independent variable: age, body weight, BMI, muscle mass, SMI, PhA, E/e', LVEF, OLST, GS, AT, %AT, peak VO_2, %peak VO_2, VE vs VCO_2 slope, minimum VE/VCO_2, peak RER, KCL.
BMI: body mass index, CS30: 30-Second Chair Stand Test, E/e′: early mitral inflow velocity/early mitral annulus velocity, GS: grip strength, KCL: Kihon checklist, LVEF: left ventricular ejection fraction, minimum VE Vs. VCO_2: minimum ventilation/carbon dioxide output, OLST: One-Leg Standing Time, peak RER: peak respiratory exchange ratio, Peak VO_2: peak oxygen uptake, PhA: phase angle, SMI: skeletal muscle mass index, VE vs. VCO_2 slope: minute ventilation/carbon dioxide output.

the association between CS30 as the dependent variable and each measured item as the independent variable.

The unpaired two-tailed *t*-test was used to examine differences in CS30 values between groups with peak VO_2 less than 80 % (LET) and those with peak VO_2 more than 80 % (non-LET) for each sex separately. Moreover, the receiver operating characteristic (ROC) curve and the area under the ROC curve (AUC) were used to determine the cut–off values of CS30 indicative of LET presence. An AUC greater than 0.9 was considered to demonstrate high accuracy, 0.7–0.9 indicated moderate accuracy, 0.5–0.7 suggested low accuracy, and 0.5 corresponded to a chance result [32]. These cut-off values were determined using the Youden index.

3. Results

Of the 1848 outpatients, 748 were aged 75 years or older. From this cohort, 255 participants were excluded, resulting in 493 participants (296 males and 197 females) enrolled in the present study (Fig. 1). The demographic and clinical characteristics of the participants are summarized in Table 1. Male participants achieved a mean CS30 score of 20.3 ± 5.4 times, while female participants achieved a mean CS30 score of 19.1 ± 5.0 times. The mean peak VO_2 was 21.4 ± 4.2 and 18.0 ± 3.7 mL/min/kg for males and females, respectively.

Table 2 presents the results for the relationship between CS30 as the dependent variable and the measured items as the independent variables. Items with a Pearson correlation coefficient of ± 0.3 or more (indicating at least a low positive or negative correlation) included age, PhA, OLST, GS, and KCL for males and OLST, peak RER, KCL, and LVEF for females.

The associations between peak VO_2 and CS30 are provided in Table 3. Every 1 unit increase in peak VO_2 in males and in females was significantly associated with an increase in CS30 of 0.532 units (95 % CI = 0.394–0.669) and 0.551 (95 % CI = 0.375–0.726), in the unadjusted models (univariable linear regression analysis), respectively. After

Table 3
Multivariable linear mean regression analysis on CS30.

	Univariable (unadjusted) regression				Multivariable (adjusted) regression			
		95% CI				95% CI		
	β	Lower	Upper	P-value	β	Lower	Upper	P-value
Males								
peak VO_2	0.532	0.394	0.669	<0.001	0.255	0.102	0.407	0.001
Age (years)	-0.470	-0.643	-0.297	<0.001	-0.117	-0.290	0.056	0.184
PhA (°)	2.693	1.894	3.491	<0.001	1.113	0.278	1.947	0.009
OLST (sec)	0.110	0.084	0.137	<0.001	0.063	0.034	0.091	<0.001
GS (kg)	0.290	0.184	0.395	<0.001	-0.008	-0.117	0.101	0.885
KCL (point)	-0.721	-0.911	-0.532	<0.001	-0.454	-0.649	-0.259	<0.001
Females								
peak VO_2	0.551	0.375	0.726	<0.001	0.282	0.043	0.521	0.021
OLST (sec)	0.083	0.050	0.116	<0.001	0.058	0.013	0.104	0.013
peak RER	19.815	11.668	27.961	<0.001	9.070	-4.873	23.011	0.200
KCL (point)	-0.462	-0.650	-0.274	<0.001	-0.296	-0.548	-0.045	0.021
Age (years)	-0.269	-0.492	-0.045	0.019	0.093	-0.194	0.381	0.524
LVEF (%)	-0.005	-0.008	-0.003	<0.001	-0.010	-0.001	-0.000	<0.001

Multivariable linear mean regression analysis dependent variable: CS30, independent variable: peak VO_2.
CI: confidence interval, CS30: 30-Second Chair Stand Test, GS: grip strength, KCL: Kihon checklist, OLST: One-Leg Standing Time, peak RER: peak respiratory exchange ratio, peak VO_2: peak oxygen uptake, PhA: phase angle.

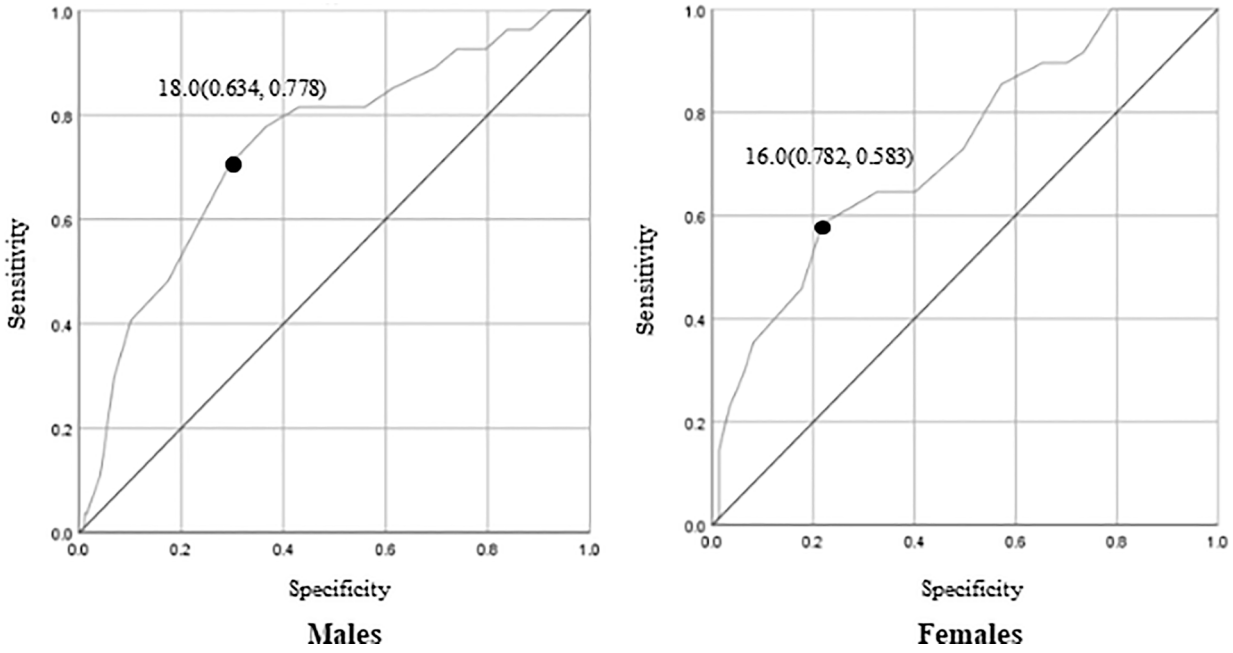

Fig. 2. Receiver operating characteristic (ROC) curve and area under the ROC curve (AUC) of CS30 to detect low exercise tolerance (LET) in males (left) and females (right).

adjustment for confounders, every 1 unit increase in peak VO_2 in males was significantly associated with a 0.255 unit increase in CS30 (95 % CI = 0.102–0.407, p = 0.001), adjusting for age, PhA, OLST, GS and KCL. For females, every 1 unit increase in peak VO_2 was significantly associated with a 0.282 unit increase in CS30 (95 % CI = 0.043–0.521, p = 0.021), adjusting for OLST, peak RER, KCL, LVEF, and age. Age was only associated with CS30 in males.

The values of CS30 in the LET and non-LET groups were then compared. The LET group included 27 male (9.0 %) and 48 female (24.0 %) participants. According to unpaired two-tailed t-tests, the mean CS30 scores for males were 16.5 times in the LET group and 20.7 times in the non-LET group (p < 0.001). In females, mean CS30 scores were 16.2 times in the LET group and 20.1 times in the non-LET group (p < 0.001).

The ability of CS30 to detect LET is presented in Fig. 2. The results demonstrated a moderate accuracy of CS30 in predicting LET in both male (AUC = 0.740, 95 % CI = 0.640–0.841, p < 0.001) and female (AUC = 0.725, 95 % CI = 0.644–0.807, p < 0.001) participants. The identified cut-off values of CS30 to distinguish LET from non-LET were 18 times in male participants and 16 times in female participants.

4. Discussion

This study aimed to investigate whether CS30 serves as a predictor of ET in late-stage elderly individuals with stage A/B HF. The results demonstrated that CS30 was independently associated with peak VO_2 in these participants.

Previous studies have reported various results on the association between the sit-to-stand test and peak VO_2. Modest increases in peak VO2 have been linked to better outcomes in patients with HF. Studies have shown that the sit-to-stand test with 10 repetitions was positively correlated with peak VO_2 in older females [33]. Moreover, peak VO_2

during incremental sit-to-stand exercises showed a positive relationship with the cycle ergometer test in older patients with type 2 diabetes [23], and CS30 displayed a moderate correlation with peak VO_2 among women with breast cancer [26]. Similarly, correlations have been observed between a 1-minute sit-to-stand test and peak VO_2 in a 6-minute gait test in patients with chronic obstructive pulmonary disease [34]. The present study found that CS30 moderately correlated with peak VO_2 in both males and females. The results of this study support the findings of the aforementioned studies. Interestingly, in the present study, peak VO_2 was independently associated with CS30, suggesting that a higher CS30 indicates a higher peak VO_2. Patients with HF experience a slower increase in oxygen uptake rate at the start of exercise, which correlates with the peak VO_2 [35]. Thus, the oxygen uptake rate escalation likely influenced CS30 in our study. Given that reduced oxygen availability in the skeletal muscles of patients with HF is a major limiting factor in ET [36], CS30 is considered a useful method for evaluating skeletal muscle function.

In addition, our findings showed that the LET group had a significantly lower CS30 than the non-LET group. Moreover, ROC analysis revealed that CS30 exhibited moderate accuracy in predicting LET while indicating the best cut-off values of CS30. One study showed that CS30 scores of less than 17 times in males and 15 times in females were indicative of sarcopenia [37], and a *meta*-analysis of CS30 estimated a cut-off value of 18.5 times for individuals in their seventies [25]. In the present study, the cut-off values for LET were 18 times in males and 16 times in females; these were mid-way between the sarcopenia criteria and the base value of age. Gradual muscle loss is commonly observed in older adults, and it has been reported that muscle loss in older adults is exacerbated by HF [38]. A systematic review of sarcopenia in HF showed a pooled prevalence of sarcopenia in patients with HF of 34 % [39]. Consequently, our derived cut-off values are considered to have significant validity and are predictors of LET.

Strategies involving exercise and nutritional therapy for sarcopenia have been reported to improve leg muscle strength, quality of life, and the 6-minute walk distance [40]. Nonetheless, the evidence supporting this is lacking; therefore, it is necessary to intervene before the onset of sarcopenia.

5. Study limitations

There are some limitations to this study. First, this was a single-center study with a limited sample size, and careful consideration is required as to whether it reflects the broader population. Second, participant selection was limited to those capable of performing the CS30 and CPX, which may have introduced selection bias. Thus, the study's findings might overestimate the true association. Third, the study did not investigate symptoms or oral medications in detail, and some participants might have had pre-existing HF and respiratory diseases, which were not accounted for. These pre-existing diseases might have introduced confounding bias such that there might have been an overestimation of the findings (positive confounding). Fourth, peak VO_2 was not measured during the CS30, and variables such as maximum blood pressure, maximum heart rate, and the Borg rating of perceived exertion were not collected. These variables might have produced a better isolation of the association between the CS30 and peak VO_2. In addition, this was a cross-sectional study and therefore cannot refer to causal relationships. The crossover design cannot determine how the CS30 changes as HF progresses beyond the A/B stages. Finally, the CS30 was conducted one time for each participant. This is a potential limitation of the assessment, particularly in the absence of test–retest reliability statistics.

6. Conclusion

Although peak VO_2 measured by CPX has been recognized as the gold standard for evaluating ET, the practical challenges posed by CPX, including its cost and inconvenience, cannot be ignored. The findings of this study suggest that the CS30 may offer a feasible alternative to cardiopulmonary exercise testing to estimate the actual ET, and consequently, assess the progression of HF in late-stage elderly individuals. We anticipate that this index will be useful for a larger segment of the elderly population in the future.

CRediT authorship contribution statement

Taku Kobayashi: Writing – original draft. **Takatoshi Iwasaki:** Investigation. **Hiroko Kurata:** Investigation. **Akira Nikaido:** Investigation. **Yoshiki Hata:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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