Nutritional Status in Patients Undergoing Phase II Cardiac Rehabilitation by Mini Nutritional Assessment

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Abstract

Background: Malnutrition impairs quality of life and prognosis of patients with cardiovascular disease. The Mini Nutritional Assessment (MNA) is a screening tool developed for the nutritional assessment of older adults. However, usefulness of MNA for patients undergoing cardiac rehabilitation (CR) has not been fully investigated.

Methods: From March 2017 to September 2019, the MNA-short form (MNA-SF) and the MNA total score in patients undergoing phase II CR at the Juntendo University Hospital were evaluated.

Results: A total of 336 patients (mean age 70.1 ± 11.4 years; males: 209) were analyzed. In the MNA-SF, 157 patients (47%) were found to be malnourished or at risk of malnutrition. In MNA total score, 168 patients (50%) were found to be malnourished or at risk of malnutrition. The MNA-SF < 12 group had significantly lower body mass index (BMI), hemoglobin level, low MNA scores for protein/water intake, self-evaluation of nutrition and health, and upper arm and calf circumferences compared to the MNA-SF ≥ 12 group. Assuming BMI < 18.5 as malnutrition, the sensitivity and specificity for malnutrition were 100% and 58.9% for MNA-SF, and 96.9% and 54.9% for MNA total score, respectively.

Conclusions: MNA is useful in screening for malnutrition in patients undergoing CR. Approximately 50% of them were determined to be malnourished or at risk of malnutrition, suggesting the need for detailed evaluation regarding their food intake and dietary intervention.

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Introduction

Cardiac rehabilitation (CR) is a comprehensive second prevention program that includes exercise therapy, coronary risk factor modification, disease management, and pharmacotherapy. This program aims to improve physical and psychological status and to reduce recurrence and death in patients with cardiovascular disease (CVD) [1]. A meta-analysis reported that CR is a cost-effective treatment that leads to significantly better quality-adjusted life-years than usual care in patients with coronary artery disease [2]. Recent studies have shown that frailty and sarcopenia caused by malnutrition or decreased activity in older adults are prognostic factors in heart failure patients [1, 3, 4]. To prevent the progression of frailty in patients with CVD, it is important to adopt comprehensive CR including appropriate nutritional and exercise therapy from early stage [5].

Malnutrition is highly prevalent in older adults undergoing rehabilitation [6, 7], and it is a risk factor for poor prognosis [8, 9]. The Mini Nutritional Assessment (MNA) is a widely used screening tool [10, 11] developed for the nutritional assessment of older adults [12, 13]. The MNA consists of six screening items and 12 assessment items, and the MNA total score is calculated from these 18 items [12, 13]. The six-item screening score, which is part of the MNA total score, is also used alone as the MNA-short form (MNA-SF) [14, 15]. Although there are several reports on the nutritional evaluation of patients undergoing CR using MNA-SF [14-16], there have been no reports on the MNA total score of Japanese patients undergoing CR. Therefore, we evaluated the nutritional status of CR patients using MNA-SF and MNA total score to examine the usefulness of them.

Materials and Methods

Subjects

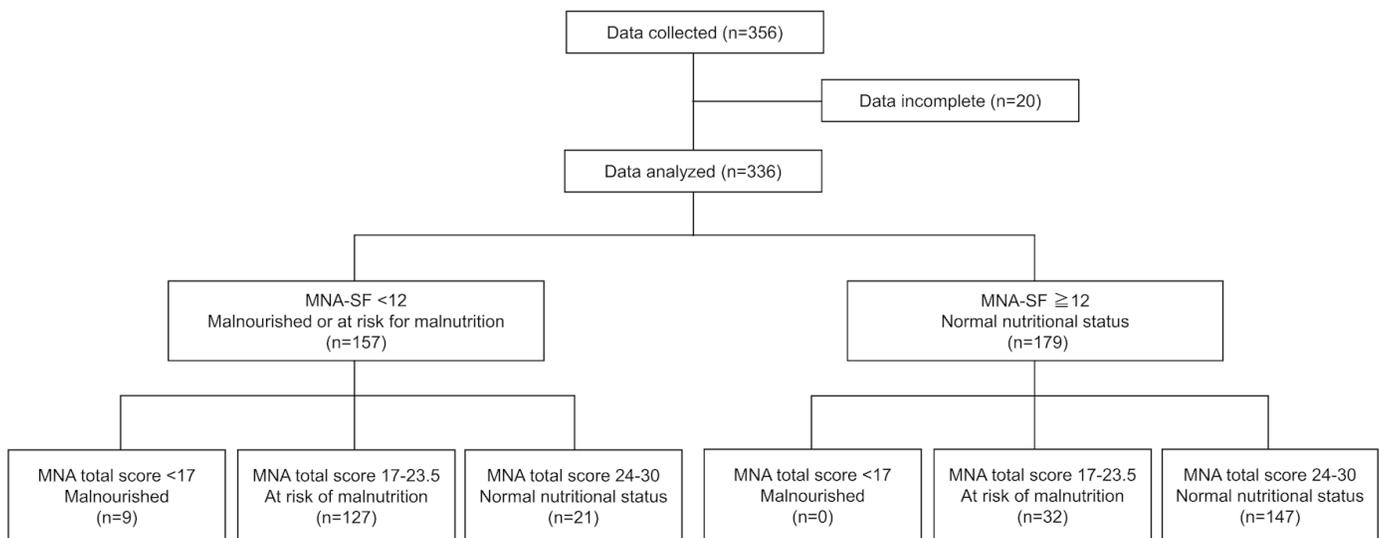This study recruited 356 patients undergoing phase II CR at

Figure 1. Study flow. CR: cardiac rehabilitation, MNA: Mini Nutritional Assessment; SF: short form.

Juntendo University Hospital from March 2017 to September 2019. This study included inpatients with stable cardiac function and those who had participated in early phase II CR.

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and in compliance with the ethical guidelines for medical research involving human subjects. The protocol for this study was approved by the Ethics Committee of Juntendo University Hospital (17-307). Written consent to participate in the study was obtained from the participants.

Methods

This is a retrospective study that evaluated nutritional status using MNA in patients undergoing CR. In this study, we assumed that body mass index (BMI) < 18.5 as malnutrition [1], and we evaluated: 1) correlation between MNA-SF and MNA total score and BMI; 2) the screening accuracy of MNA-SF and MNA total score for malnutrition; 3) patient characteristics between MNA-SF categories; and 4) equivalence of MNA-SF for MNA total score. BMI was measured using a body composition analyzer (TANITA, MC 780A, Tokyo, Japan) at the beginning of CR in hospitalized patients with stable cardiac function. Study flow is shown in Figure 1. To evaluate the screening accuracy for malnutrition, the area under the curve (AUC) in the receiver operating characteristic (ROC) analysis and the sensitivity and specificity for the MNA-SF with a cut-off value of 12 and the MNA total score with a cut-off value of 24 were calculated. Patient characteristics, score of each item of MNA and results of MNA-SF and MNA total score were compared between the MNA-SF categories. We calculated the sensitivity and specificity of the MNA-SF category for the MNA total score category. The cut-off value of the MNA-SF score for the MNA total score category was calculated from the actual data in this study. In addition, patient background was analyzed for those whose MNA-SF and MNA total score judgment were inconsistent.

MNA

The MNA total score consists of 18 items as follows (maximum score 30): 1) food intake; 2) weight loss; 3) mobility; 4) psychological stress; 5) neuropsychological problems; 6) BMI; 7) living independently; 8) number of medications; 9) skin ulcers; 10) number of meals; 11) protein intake; 12) fruit or vegetables intake; 13) fluid intake; 14) mode of feeding; 15) self-assessment of nutritional status; 16) self-assessment of health status; 17) mid-arm circumference; and 18) calf circumference [12, 13]. MNA-SF is scored on items 1) to 6) (maximum score 14). For MNA-SF, 12 - 14 points indicate a normal nutritional status, 8 - 11 points indicate at risk of malnutrition, and 7 points or less indicate malnourishment, whereas for MNA total score, these are attributed to 24 - 30, 17 - 23.5, and < 17 points, respectively. The MNA total score is usually calculated for patients with MNA-SF score < 12 [12, 13]; however, in this study, the MNA total score was calculated for all patients. The MNA-SF and MNA total score were evaluated at the beginning of phase II CR.

Blood biochemistry test

The estimated glomerular filtration rate was calculated based on serum creatinine (Cre), sex, and age [17]. Blood biochemical tests were conducted for serum hemoglobin (Hb), Cre, low-density lipoprotein cholesterol, triglycerides, high-density protein cholesterol, hemoglobin A1c (HbA1c), and C-reactive protein (CRP) at the beginning of CR.

Statistical analysis

Descriptive statistics were expressed as n (%) and mean ± standard deviation (SD). The Spearman's rank correlation coefficient was used to evaluate the correlation between MNA-

Table 1. Patient Characteristics

	Total (N = 336)	MNA-SF < 12 (N = 157)	MNA-SF ≥ 12 (N = 179)	P
Age (years), mean ± SD	70.1 ± 11.4	70.3 ± 11.9	70.0 ± 11.0	0.44
Sex (male), n (%)	209 (62.2%)	97 (61.8%)	112 (62.6%)	0.88
CVD at the beginning for CR, n (%)				
Open heart surgery	151 (44.9%)	67 (42.7%)	84 (46.9%)	0.06
Chronic heart failure	119 (35.4%)	65 (41.4%)	54 (30.2%)	
Other	66 (19.6%)	25 (15.9%)	41 (22.9%)	
Acute coronary syndrome, n (%)	33 (9.8%)	19 (12.1%)	14 (7.8%)	0.18
BMI, mean ± SD	23.1 ± 4.1	21.5 ± 3.9	24.4 ± 3.7	< 0.05
Hemoglobin (g/dL), mean ± SD	12.8 ± 1.9	12.3 ± 1.9	13.2 ± 1.8	< 0.05
Creatinine (mg/dL), mean ± SD	1.3 ± 1.8	1.4 ± 1.9	1.2 ± 1.6	0.07
eGFR (mL/min/1.73 m^2), mean ± SD	60.8 ± 23.5	58.0 ± 24.8	63.2 ± 22.0	0.06
TG (mg/dL), mean ± SD	115.0 ± 56.5	116.2 ± 59.1	114 ± 54.7	0.88
LDL-C (mg/dL), mean ± SD	98.0 ± 28.7	97.9 ± 30.4	98.2 ± 27.3	0.65
HDL-C (mg/dL), mean ± SD	52.6 ± 15.8	50.8 ± 15.4	54.2 ± 16.1	0.07
HbA1c (%), mean ± SD	6.0 ± 0.8	6.0 ± 0.9	6.0 ± 0.6	0.19
CRP (mg/dL), mean ± SD	0.6 ± 1.6	0.6 ± 1.7	0.5 ± 1.4	0.75

P: Wilcoxon rank sum test or χ^2 test. CR: cardiac rehabilitation; BMI: body mass index; CVD: cardiovascular disease; eGFR: estimated glomerular filtration rate; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; MNA: Mini Nutritional Assessment; SF: short form; TG: triglyceride; CRP: C-reactive protein; HbA1c: hemoglobin A1c; SD: standard deviation.

SF and MNA total score and BMI. The χ^2 test was used to compare categorical variables, and the Wilcoxon rank sum test was used to compare continuous variables. The significance level was set to < 0.05 on both sides. The cut-off values of MNA-SF for MNA total score categories and AUC of ROC curve were calculated in a ROC analysis. Sensitivity and specificity were calculated for the accuracy of judgment for various cut-off values. Statistical analysis was performed using JMP ver. 16.2.0 (SAS Institute Inc., Cary, NC, USA).

Results

Patient characteristics

In a total of 356 patients, 20 patients were excluded because of incomplete data; therefore, 336 patients were included in the analysis (Fig. 1). The age of the patients was 70.1 ± 11.4 years, and 209 (62.2%) of them were male (Table 1). CVD at beginning of CR were post-open-heart surgery for 151 patients (44.9%), chronic heart failure for 119 patients (35.4%), and other for 66 patients (19.6%). Acute coronary syndrome (ACS) was present in 33 patients (9.8%). There were 157 and 179 patients in the MNA-SF < 12 group and MNA-SF ≥ 12 group, respectively. The proportion of ACS was relatively higher in the MNA-SF < 12 group compared to the MNA-SF ≥ 12 group (12.1% vs. 7.8%), but there was no significant difference between the groups. BMI and Hb levels were significantly lower in the MNA-SF < 12 group than in the ≥ 12 group, but there were no significant differences in other patient characteristics.

MNA

The results of MNA-SF and MNA total score are shown in Table 2. In all patients, MNA-SF showed 21 patients (6.3%) of malnourished, 136 patients (40.5%) of at risk of malnutrition, and 179 patients (53.3%) of normal nutritional status, with the MNA total score of nine (2.7%), 159 (47.3%) and 168 (50.0%), respectively. Of the 157 patients with MNA-SF < 12, nine patients (5.7%) were malnourished, 127 patients (80.9%) were at risk of malnutrition, and 21 patients (13.4%) were normal nutritional status according to the MNA total score. Similarly, in 179 patients with MNA-SF ≥ 12, malnourished was not observed, 32 patients (17.9%) were at risk of malnutrition, and 147 patients (82.1%) were normal nutritional status by the MNA total score. Compared to the MNA-SF ≥ 12 group, the MNA-SF < 12 group presented significantly lower scores on the MNA assessment for protein intake, water intake, self-assessment of nutritional and health status, upper arm circumference, and calf circumference.

Screening accuracy of MNA-SF and MNA total score for malnutrition

Correlations between MNA-SF and MNA total score and BMI are shown in Figure 2. Both MNA-SF and MNA total score were significantly positively correlated with BMI (r = 0.446, P < 0.001 and r = 0.496, P < 0.001, respectively). ROC analysis showed that AUC of MNA-SF for malnutrition (BMI < 18.5) was 0.811, and the sensitivity of MNA-SF with cut-off value

Table 2. MNA Results

Number	Total (N = 336)	MNA-SF < 12 (N = 157)	MNA-SF ≥ 12 (N = 179)	P
MNA				
Screening items: MNA-SF				
A. Has food intake declined over the past 3 months due to loss of appetite, digestive problems, chewing or swallowing difficulties?	1.8 ± 0.5	1.7 ± 0.6	1.9 ± 0.3	< 0.05
B. Weight loss during the last 3 months?	2.1 ± 1.1	1.5 ± 1.2	2.7 ± 0.6	< 0.05
C. Mobility	1.9 ± 0.3	1.9 ± 0.3	2.0 ± 0.2	< 0.05
D. Has suffered psychological stress or acute disease in the past 3 months?	1.4 ± 0.9	0.9 ± 1.0	1.8 ± 0.6	< 0.05
E. Neuropsychological problems	2.0 ± 0.2	1.9 ± 0.3	2.0 ± 0.0	< 0.05
F. BMI	2.1 ± 1.1	1.5 ± 1.1	2.6 ± 0.7	< 0.05
MNA-SF category				
Normal nutritional status: 12 - 14 points	179 (53.3%)	0 (0%)	179 (100%)	< 0.05
At risk of malnutrition: 8 - 11 points	136 (40.5%)	136 (86.6%)	0 (0%)	
Malnourished: 0 - 7 points	21 (6.3%)	21 (13.4%)	0 (0%)	
MNA assessment items				
G. Lives independently	0.9 ± 0.4	0.9 ± 0.4	0.8 ± 0.4	0.93
H. Takes more than four prescription drugs per day	0.2 ± 0.4	0.1 ± 0.4	0.2 ± 0.4	0.11
I. Pressure sores or skin ulcers	0.7 ± 0.5	0.6 ± 0.5	0.7 ± 0.5	0.24
J. How many full meals does the patient eat daily?	1.9 ± 0.3	2.0 ± 0.2	1.9 ± 0.3	< 0.05
K. Selected consumption markers for protein intake	0.8 ± 0.3	0.7 ± 0.3	0.8 ± 0.3	< 0.05
L. Consumes two or more servings of fruit or vegetables	0.8 ± 0.4	0.8 ± 0.4	0.9 ± 0.4	0.4
M. How much fluid is consumed per day?	0.7 ± 0.3	0.7 ± 0.3	0.8 ± 0.3	< 0.05
N. Mode of feeding	1.9 ± 0.3	1.9 ± 0.3	2.0 ± 0.3	0.59
O. Self-assessment of nutritional status	1.7 ± 0.5	1.6 ± 0.6	1.8 ± 0.4	< 0.05
P. In comparison with other people of the same age, how does the patient consider his/her health status?	0.9 ± 0.7	0.8 ± 0.7	0.9 ± 0.7	< 0.05
Q. Mid-arm circumference in cm	0.9 ± 0.3	0.8 ± 0.4	1.0 ± 0.1	< 0.05
R. Calf circumference in cm	0.8 ± 0.4	0.7 ± 0.5	0.9 ± 0.3	< 0.05
MNA total score categories				
Normal nutritional status: 24 - 30 points	168 (50.0%)	21 (13.4%)	147 (82.1%)	< 0.05
At risk of malnutrition: 17 - 23.5 points	159 (47.3%)	127 (80.9%)	32 (17.9%)	
Malnourished: < 17 points	9 (2.7%)	9 (5.7%)	0 (0%)	

P: Wilcoxon rank sum test or χ^2 test. MNA: mini nutritional assessment; SF: short form.

of 12 for malnutrition was 100.0%, with a specificity of 58.9% (Fig. 3a). Similarly, AUC of MNA total score for malnutrition was 0.838, and the sensitivity and specificity of the MNA total score with cut-off value of 24 were 96.9% and 54.9%, respectively (Fig. 3b).

Validity of cut-off values for MNA-SF

The ROC analysis of the MNA-SF score for the MNA total score < 24 (malnourished or at risk of malnutrition) indicated that AUC was 0.904 and the cutoff of MNA-SF score was 12,

which was consistent with the commonly used cut-off value (Fig. 4). The MNA-SF with cut-off value of 12 presented a sensitivity of 81.0% and specificity of 87.5% for the MNA total score < 24 (Fig. 4).

Discrepancies between MNA-SF and MNA total score

The MNA-SF < 12 group included 21 patients (13.4%) with MNA total score ≥ 24, whereas the MNA-SF ≥ 12 group included 32 patients (17.9%) with MNA total score < 24 (Table 3). In the MNA-SF < 12 group, compared to the patients with
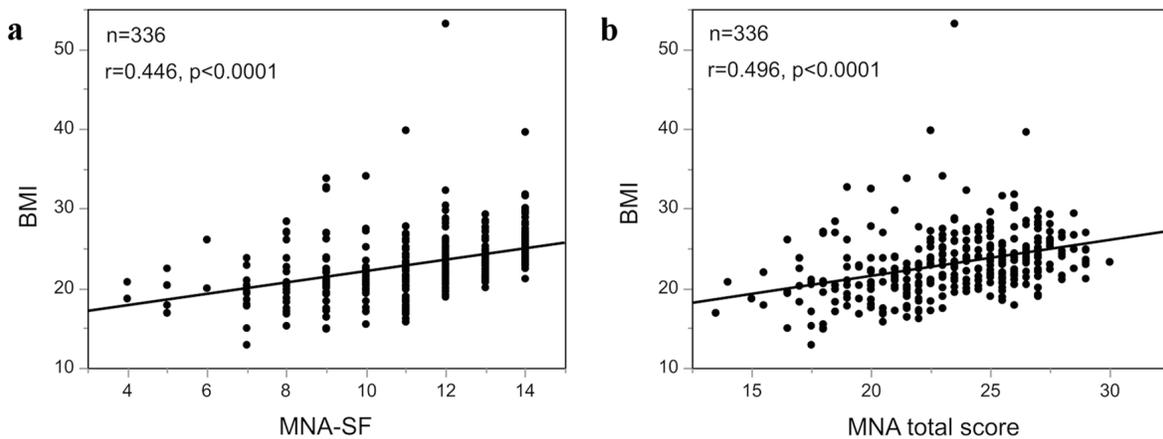
Figure 2. Correlation between MNA-SF and MNA total score and BMI. (a) Correlation between MNA-SF and BMI. (b) Correlation between MNA total score and BMI. MNA: Mini Nutritional Assessment; SF: short form; BMI: body mass index.

MNA total score < 24, patients with MNA total score ≥ 24 presented significantly higher male proportion and Hb levels and significantly lower CRP levels, with no significant differences in other parameters. In the MNA-SF ≥ 12 group, compared to patients with MNA total score ≥ 24, patients with MNA total score < 24 presented significantly lower BMI, and there were no significant differences in other parameters.

Discussion

The nutritional status of 336 patients undergoing CR was evaluated by the MNA. The number of patients classified as malnourished or at risk of malnutrition according to the MNA-SF and MNA total score was 157 (46.7%), and 168 (50.0%), respectively. Sensitivity and specificity for malnutrition were

100% and 58.9% for MNA-SF, and 96.9% and 54.9% for MNA total score, respectively. In addition, the sensitivity and specificity of the MNA-SF for MNA total score < 24 were 81.0% and 87.5%, respectively, suggesting that both MNA-SF and MNA total scores are useful for the nutritional assessment of patients undergoing CR. Compared to the MNA-SF ≥ 12 group, the MNA-SF < 12 group presented significantly lower BMI and Hb and significantly lower scores on the MNA assessment for protein and water intake and self-assessment of nutritional and health status, which indicated the need for dietary intervention. This is the first report evaluating the usefulness of the MNA total score for Japanese CR patients.

In our study, in patients with a mean age of 70.1 years, the MNA-SF indicated 6.3%, 40.5%, and 53.3% of malnourished, at risk of malnutrition, and normal nutritional status, whereas MNA total score indicated 2.7%, 47.3%, and 50.0%, respec-
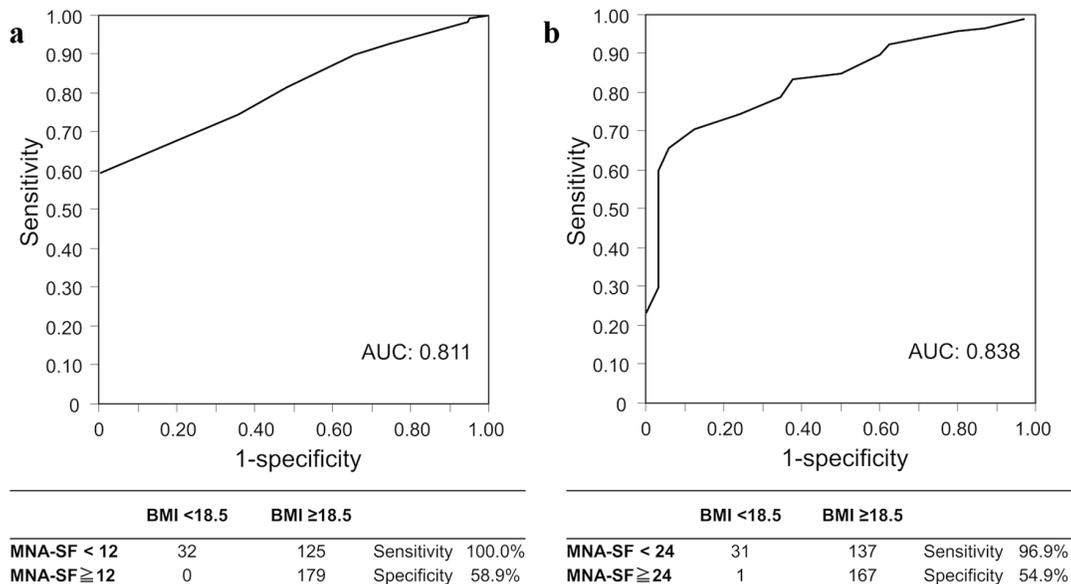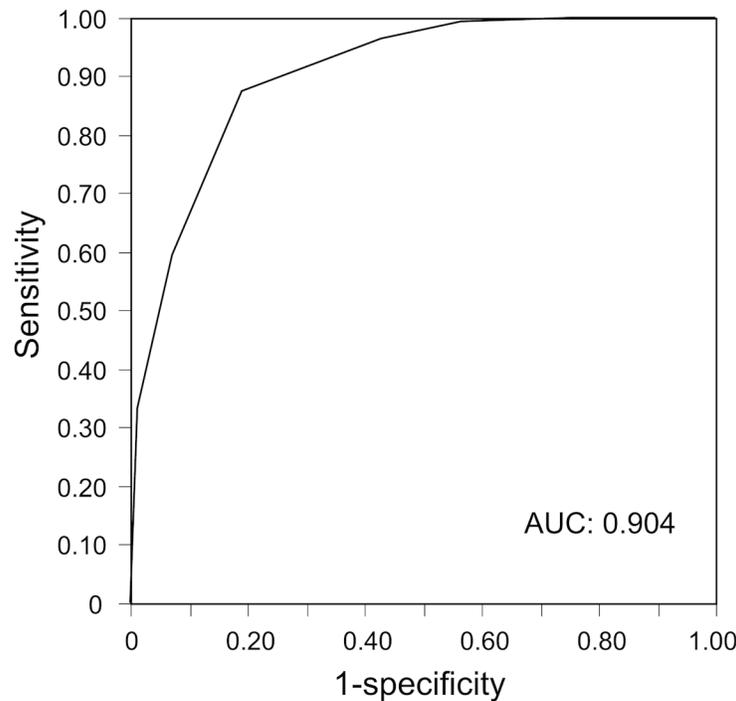

	BMI <18.5	BMI ≥18.5		
MNA-SF < 12	32	125	Sensitivity	100.0%
MNA-SF ≧ 12	0	179	Specificity	58.9%

	BMI <18.5	BMI ≥18.5		
MNA-SF < 24	31	137	Sensitivity	96.9%
MNA-SF ≧ 24	1	167	Specificity	54.9%

Figure 3. Screening accuracy of (a) MNA-SF and (b) MNA total score for malnutrition. AUC: area under the curve; MNA: mini nutritional assessment; ROC: receiver operator characteristic; SF: short form.

	MNA-total score <24	MNA-total score ≥24		
MNA-SF < 12	136	21	Sensitivity	81.0%
MNA-SF ≧ 12	32	147	Specificity	87.5%

Figure 4. ROC curves of MNA-SF for MNA overall score < 24. AUC: area under the curve; MNA: Mini Nutritional Assessment; ROC: receiver operator characteristic; SF: short form.

tively. Fukui et al reported that an MNA-SF in older adults with aortic stenosis in Japan with a mean age of 83.8 years indicated 11.3% of malnourished, 42.3% of at risk of malnutrition, and 46.4% of normal [18]. Considering the difference in mean age of patients, our results appeared to be similar to those reported by Fukui et al [18]. On the other hand, regarding reports from other countries, in Germany, Kather et al evaluated MNA-SF in older adults undergoing CR with a mean age of 82.3 years, with 4.9% malnourished, 33.6% at risk for malnutrition, and 61.5% normal [14]. In Italy, Tonet et al evaluated MNA-SF in ACS patients with a mean age of 82 years, with 4% malnourished, 40% at risk for malnutrition, and 56% normal [19]. In Italy, Passantino et al evaluated the MNA total score in CR patients with a mean age of 67.1 years, with 1.9% malnourished, 40.1% risk of malnutrition, and 58% normal [20]. Our results on the distribution of nutritional status were comparable to those reported in the Europe.

In this study, BMI < 18.5 was used as an indicator of malnutrition. BMI is not an absolute indicator of malnutrition, but it is one of indicator to assess malnutrition. We compared the accuracy of the MNA-SF and MNA total score for malnutrition under the same conditions, with a cut-off value for BMI assuming malnutrition. We think the issue to be cleared is the accuracy of using BMI to determine malnutrition. In the

Global Leadership Initiative on Malnutrition (GLIM) report of 2019, low BMI was a diagnostic criterium for malnutrition [21-23], and reference values included BMI < 18.5 for Asians of < 70 years and BMI < 20 for those of ≥ 70 years [1]. In addition, Zhang et al reported a meta-analysis of various indicators for determining malnutrition in the older adults [24]. In their report, BMI was a significant determinant for all malnutrition status defined by MNA < 17, Subjective Global Assessment (SGA) of C, Nutrition Risk Screening 2002 ≥ 3, and Geriatric Nutritional Risk Index < 92, with cut-off values (95% CI) of 20.89 (19.81, 21.96), 19.77 (18.11, 231.42) 22.60 (21.23, 23.97) and 20.24 (18.46, 22.03), respectively [24]. Given these results, we believe that the BMI cut-off value we used (< 18.5) was reasonable in assuming malnutrition.

The sensitivity and specificity of MNA-SF with a cut-off value of 12 for malnutrition were 100.0% and 58.9%, whereas those of MNA total score with cut-off value of 24 were 96.9% and 54.9%, respectively. In this study, the sensitivity of both MNA-SF and MNA total score to malnutrition was sufficiently high, and both seemed to be effective for malnutrition screening.

AUC of ROC curve for malnutrition was slightly higher in MNA total score than MNA-SF (0.837 vs. 0.811). The sensitivity and specificity of the MNA-SF with cut-off value of 12 for the MNA total score < 24 were 81.0%, and 87.5%, re-

Table 3. Background Characteristics of Patients With Discrepancies Between MNA-SF and MNA Total Score

	MNA-SF < 12			MNA-SF ≥ 12		
	MNA-total score < 24	MNA-total score ≥ 24	P	MNA-total score < 24	MNA-total score ≥ 24	P
Number	136	21		32	147	
Age (years), mean ± SD	70.1 ± 11.9	71.5 ± 11.8	0.48	69.3 ± 9.4	70.1 ± 11.4	0.30
Sex (male), n (%)	80 (58.8%)	17 (81.0%)	< 0.05	17 (53.1%)	95 (64.6%)	0.22
CVD at beginning of CR, n (%)						
Open heart surgery	57 (41.9%)	10 (47.6%)	0.36	16 (50.0%)	68 (46.3%)	0.81
Chronic heart failure	59 (43.4%)	6 (28.6%)		10 (31.3%)	44 (29.9%)	
Other	20 (14.7%)	5 (23.8%)		6 (18.8%)	35 (23.8%)	
BMI, mean ± SD	21.4 ± 4.1	22.0 ± 2.2	0.14	24.2 ± 6.0	24.5 ± 3.0	< 0.05
Hemoglobin (g/dL), mean ± SD	12.1 ± 2.0	13.4 ± 1.3	< 0.05	13.0 ± 1.9	13.2 ± 1.7	0.52
Creatinine (mg/dL), mean ± SD	1.45 ± 2.07	1.00 ± 0.66	0.61	1.47 ± 1.93	1.12 ± 1.51	0.36
eGFR (mL/min/1.73 m^2), mean ± SD	57.3 ± 25.8	62.7 ± 16.3	0.35	57.7 ± 26.8	64.4 ± 20.8	0.17
TG (mg/dL), mean ± SD	120.5 ± 60.4	86.4 ± 40.7	0.10	129.3 ± 56.3	112.0 ± 54.6	0.32
LDL-C (mg/dL), mean ± SD	97.5 ± 31.0	100.2 ± 27.5	0.54	95.3 ± 25.4	98.7 ± 27.7	0.77
HDL-C (mg/dL), mean ± SD	49.9 ± 15.0	56.3 ± 16.7	0.14	55.3 ± 18.4	54.0 ± 15.7	0.88
HbA1c (%), mean ± SD	6.1 ± 1.0	5.8 ± 0.5	0.14	6.0 ± 0.7	6.0 ± 0.6	0.86
CRP (mg/dL), mean ± SD	0.72 ± 1.85	0.19 ± 0.32	< 0.05	0.23 ± 0.41	0.59 ± 1.56	0.52
MNA-assessment						
G. Lives independently	0.8 ± 0.4	0.9 ± 0.3	0.46	0.7 ± 0.5	0.9 ± 0.3	< 0.05
H. Takes more than four prescription drugs per day	0.1 ± 0.3	0.3 ± 0.5	0.05	0.1 ± 0.3	0.2 ± 0.4	0.07
I. Pressure sores or skin ulcers	0.6 ± 0.5	0.8 ± 0.4	0.10	0.5 ± 0.5	0.8 ± 0.4	< 0.05
J. How many full meals does the patient eat daily?	2.0 ± 0.2	2.0 ± 0.0	0.42	1.8 ± 0.4	1.9 ± 0.3	0.38
K. Selected consumption markers for protein intake	0.7 ± 0.4	0.9 ± 0.2	< 0.05	0.5 ± 0.4	0.9 ± 0.3	< 0.05
L. Consumes two or more servings of fruit or vegetables	0.8 ± 0.4	1.0 ± 0.0	< 0.05	0.6 ± 0.5	0.9 ± 0.3	< 0.05
M. How much fluid is consumed per day?	0.6 ± 0.3	0.9 ± 0.2	< 0.05	0.6 ± 0.4	0.8 ± 0.3	< 0.05
N. Mode of feeding	1.9 ± 0.4	2.0 ± 0.0	0.32	1.8 ± 0.6	2.0 ± 0.1	< 0.05
O. Self-assessment of nutritional status	1.6 ± 0.6	2.0 ± 0.2	< 0.05	1.4 ± 0.6	1.9 ± 0.3	< 0.05
P. In comparison with other people of the same age, how does the patient consider his/her health status?	1.6 ± 0.6	2.0 ± 0.2	< 0.05	0.4 ± 0.4	1.1 ± 0.7	< 0.05
Q. Mid-arm circumference in cm	0.8 ± 0.4	0.9 ± 0.2	0.06	0.9 ± 0.3	1.0 ± 0.1	0.38
R. Calf circumference in cm	0.7 ± 0.5	0.9 ± 0.4	0.11	0.8 ± 0.4	0.9 ± 0.2	< 0.05

CR: cardiac rehabilitation; CVD: cardiovascular disease; eGFR: estimated glomerular filtration rate; MNA: Mini Nutritional Assessment; SF: short form; BMI: body mass index; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglyceride; CRP: C-reactive protein; HbA1c: hemoglobin A1c; SD: standard deviation.

spectively. The cut-off value of MNA-SF for the MNA total score < 24 in the ROC analysis according to the actual data of this study was 12, which is consistent with the commonly used cut-off value of MNA-SF. These results suggest that the current cut-off value of MNA-SF is also reasonable for CR patients in Japan.

On the other hand, the 81.0% of sensitivity of MNA-SF to MNA total score < 24 indicates that 19% of patients with MNA total score < 24 will be missed by MNA-SF. The MNA-SF < 12 group included 12.5% of patients with MNA total score ≥ 24, and the MNA-SF ≥ 12 group included 20.1% of patients with MNA total score < 24. These results indicate that there was some discrepancy between MNA-SF and MNA total score. For MNA-SF < 12 patients, MNA total score will be evaluated in clinical practice, thus cases with MNA-SF ≥ 12 and MNA total score < 24 were clinically problematic. In patients with MNA-SF ≥ 12, those with an MNA total score < 24 presented a significantly lower BMI compared to those with MNA total score ≥ 24. Therefore, to reduce the risk of missing out on malnutrition, evaluation of MNA total score should be considered in cases with low BMI even with MNA-SF ≥ 12. The BMI cut-off value corresponding to MNA total score < 24 was calculated as 21.1 (AUC: 0.717) in the ROC analysis (data not shown). Therefore, even if MNA-SF ≥ 12, the MNA total score should be evaluated for cases with BMI ≤ 22.

In our study, the MNA-SF < 12 group showed significantly lower protein and water intake than the MNA-SF ≥ 12 group. Amino acid intake can enhance the effects of exercise in older women with sarcopenia [3]. Moreover, amino acid intake in older adults with frailty or pre-frailty can improve the lower limb muscle strength and physical function [25]. Therefore, it is important to evaluate the nutritional status and nutritional guidance including detail intake to improve physical function and quality of life.

The present study had several limitations. This was a single-center study; therefore, the results might contain selection bias. For instance, 92.0% of patients could walk freely outside, 97.3% had no mental problems, and 96.7% could eat on their own (data not shown). The study included only patients who had stable cardiac function and had participated CR. In this study, BMI < 18.5 was used as a malnutrition indicator. BMI can be affected by cognitive function, heart failure status, fluid retention and dietary intake. In addition, this study did not assess malnutrition by GLIM or SGA. Time from hospitalization or surgery to initiation of CR was not considered. The MNA sensitivity to malnutrition might vary if other indicators are used. Therefore, the results of this study should be interpreted with these considerations in mind.

Conclusions

MNA-SF and MNA total score are useful for evaluating the nutritional status of patients undergoing CR, and the current cut-off values for MNA-SF and MNA total score are appropriate for patients undergoing CR. Approximately half of phase II CR patients might be malnourished or at risk of malnutrition, which suggests the need for nutritional intervention including nutritional guidance.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Informed Consent

Informed consent was obtained.

Author Contributions

YN has designed and performed the study. YN, MN-Y, KS and TM have drafted and edited the manuscript. MD, YS, JN, MK, KF, HK, JX, AA, and MT have assisted data collection. YN supervised the writing of this manuscript.

Data Availability

The authors declare that data supporting the findings of this study are available within the article.

Abbreviations

AUC: area under the curve; BMI: body mass index; CR: cardiac rehabilitation; CRP: C-reactive protein; CVD: cardiovascular disease; GLIM: Global Leadership Initiative on Malnutrition; Hb: hemoglobin; MNA: Mini Nutritional Assessment; MNA-SF: Mini Nutritional Assessment-short form; ROC: receiver operating characteristic

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