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ORIGINAL ARTICLE

Accuracy of non-paralytic anthropometric data for nutritional screening in older patients with stroke and hemiplegia

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BACKGROUND/OBJECTIVES: Although malnutrition commonly affects stroke patients, there are no validated screening tools. We verified the usefulness of non-paralytic anthropometric measurements for the nutritional screening of stroke.
SUBJECTS/METHODS: A cross-sectional study was conducted in consecutive stroke patients with hemiplegia aged ⩾65 years, with Mini Nutritional Assessment Short Form score ⩽11. Diagnostic malnutrition criteria from the European Society for Clinical Nutrition and Metabolism were the reference standards: body mass index (BMI) < 18.5 kg/m^2 or weight loss $>10\%$+BMI < 22 or 20 kg/m^2. Non-paralytic anthropometric measurements (calf circumference (CC), arm circumference (AC), triceps skinfold (TSF) and arm muscle circumference (AMC)) and serum albumin concentration (Alb) at admission were the index tests. Cutoffs were determined by receiver operation curve and Youden index, and accuracy by area under the curve (AUC) and kappa value. Functional independence measures at discharge and discharge destination were collected.
RESULTS: We included 488 patients (224 men and 264 women) with a mean age of 78.8 years and mean BMI of 22.0 and 21.1 kg/m^2, respectively. Eighty-one men and 124 women had malnutrition. The AUC for CC, AC, TSF, AMC and Alb was 0.859, 0.825, 0.764, 0.745 and 0.670 for men, and 0.881, 0.843, 0.796, 0.742 and 0.658 for women, respectively. In both sexes, CC had the highest kappa (0.533, 0.608; both $P < 0.001$) with cutoff values ⩽31 and ⩽30 cm. Patients with lower CC showed significantly worse functional outcomes and lower proportion of return to home ($P < 0.001$).
CONCLUSIONS: Non-paralytic CC indicated malnutrition with sufficient accuracy and good correlation with functional capacity; it may be a useful nutritional screening tool for stroke.

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INTRODUCTION

Stroke has momentous influence on the life and health of humans on a worldwide scale. Stroke is not only the second leading cause of death but also the sixth leading cause of loss of disability-adjusted life years[1] and the first cause of requirement for public long-term care insurance in Japan.[2] Stroke patients often experience malnutrition, which is an independent risk factor for death and functional dependency.[3,4] We previously reported that in Japan 42% of older stroke patients in the convalescent stage experienced malnutrition.[5] Moreover, risk for malnutrition among stroke patients was an independent risk factor for interference with activities of daily living and poor hospital discharge outcome in both the acute and convalescent stages.[5,6] Interestingly, it has been reported that improving nutritional status is correlated with better functional outcome among older stroke patients at the convalescent stage who are malnourished.[7,8] Therefore, early detection of malnutrition is encouraged as part of the medical care of stroke patients.

Nevertheless, a method of nutritional screening for stroke patients has not been established.[9,10] Although validated nutritional screening tools were used in several studies, none of these were validated specifically for stroke patients.[9] In addition, the results of the nutritional screening tools are often biased because patients are often limited by sequelae of stroke. For example, applying the Subjective Global Assessment[11] to patients with aphasia is considerably difficult because of the challenges faced when conducting the interview to determine the usual body weight or habitual food intake. In 2015, the European Society for Clinical Nutrition and Metabolism (ESPEN) published the diagnostic criteria for malnutrition[12] based on body mass index (BMI) and loss of body weight or fat-free mass index. Although these criteria are quite simple and clinically useful, it is often difficult to measure the body weight of patients with paresis or unconsciousness. In fact, 45–66% of stroke patients do not undergo routine assessment of BMI, as revealed by multi-center study results.[13,14] If the simpler validated methods, such as anthropometric measurements, can confirm the diagnosis of malnutrition in patients with paresis, it may be helpful for improving patients' outcomes.

Several studies that investigated the accuracy of anthropometry for malnutrition have been reported.[15,16] To our knowledge, none of these studies focused on stroke patients. Therefore, we conducted a cross-sectional study to evaluate the accuracy of non-paralytic anthropometric measures of older stroke patients with hemiplegia.

MATERIALS AND METHODS

Setting and study participants

This study was designed as a cross-sectional, medical chart review. We analyzed a single rehabilitation hospital cohort in Nagasaki, Japan, which had been enrolled for a previous study.[17] The hospital comprises three Kaifukuki (convalescent) rehabilitation wards. The wards are part of a

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unique system in Japan that is approved by the public health-care insurance. These wards aim to improve the recovery from activities of daily living and return to home for patients who experienced certain diseases or injuries, such as stroke, traumatic brain injury and proximal femoral neck fractures, within a 2-month period.[18] Public health-care insurance coverage allows up to 180 min/day during 60–180 days of comprehensive rehabilitation by a multidisciplinary rehabilitation team composed of rehabilitation physicians, nurses, physiotherapists, occupational therapists, speech–language – hearing therapists, registered dietitians, social workers, dental hygienists, care workers, pharmacists and others.

Study participants were admitted to the hospital between April 2011 and February 2015. Consecutive patients with a stroke event and hemiplegia who were aged 65 years or over were potentially eligible for this study. Participants with tetraplegia or paraplegia, those with anthropometric measures available only for the paralytic side, or those with missing values of anthropometric measures or body weight were excluded.

This study was approved by the Ethics Committee of Nagasaki Rehabilitation Hospital in accordance with the principles of the Helsinki Declaration. We supplied information of the study to all patients and explained the opt-out option, which allowed patients to withdraw from the study at any time.

Diagnostic malnutrition criteria as reference standard

The diagnostic malnutrition criteria proposed by ESPEN[12] in March 2015 were used as the reference standards in this study. The criteria were deemed to be clinically reasonable because over 75% of the ESPEN members accepted the criteria.[12] According to these criteria, participants underwent nutritional screening with the Mini Nutritional Assessment Short Form (MNA-SF)[19] by registered dietitians. The participants with 12 or more points on the MNA-SF were defined as 'not malnourished', whereas those with 11 points or less underwent the subsequent assessments. Diagnosis of malnutrition was determined on the basis of two alternatives:[12] (1) participants with body mass index (BMI) <18.5 kg/m^2; (2) participants who experienced body weight loss $>10\%$, with BMI <20 kg/m^2 (aged <70 years) or <22 kg/m^2 ($\geqslant 70$ years). When the usual body weight and the magnitude of weight loss could not be investigated because the participants had cognitive impairment, aphasia or did not measure their weight on a regular basis, the latter method was not used. Height was directly measured by nurses or care workers on admission day. Similarly, body weight was measured by nurses or care workers using a calibrated scale. The BMI was calculated as body weight (kg)/height (m)^2.

Anthropometry as index test

Four anthropometric measurements that are generally used for assessing nutritional status were selected as index tests in this study: arm circumference (AC), triceps skinfold (TSF), arm muscle circumference (AMC) and calf circumference (CC). All anthropometric measurements were investigated by registered dietitians on the non-paralytic side of each patient under the recumbent or seated position depending on the patients' physical function. The AC was measured using the commercially available measure at the center of the upper limb, whereas TSF was determined by the anthropometric calliper at the same site. The CC was measured using a CC-specific measure.[20] After we measured AC and TSF, we estimated AMC by the following formula: AMC (cm) = AC (cm)–(0.314*TSF (mm)).

As all anthropometric data were measured before the ESPEN criteria were published,[12] the investigator who performed the measurements did not know whether any patient was diagnosed with malnutrition in the ESPEN criteria. We also collected serum albumin concentration (Alb) data, which were obtained within 7 days before and 7 days after admission, to compare the capability of malnutrition detection. All data used in this study were collected from electronic medical charts.

Outcome measures

To confirm predictability of the anthropometric measures, we compared functional outcomes and discharge outcomes between groups with higher and lower anthropometric values. The former were expressed by the functional independence measure (FIM) at discharge. The FIM is one of the most popular tools for assessing the activities of daily livings, ranging from 18 to 126 points.[21] Discharge outcome was classified as home and others (long-term care facilities, long-term care hospitals or acute care hospitals).

Sample size calculation

As this study was conducted using a database that was collected for our previous study,[17] we included a given number of participants. Therefore, we calculated the required sample size post-hoc using the following equation:

$$\text{Samplesize(N)} = 4Z_\alpha^2 P(1-P)/W^2$$

Z_α = standard normal deviate;
P = expected sensitivity of calf circumference;
W = width of confidence interval.

According to previous reports,[15,16] we expected that CC would have highest accuracy among each anthropometric measurement, and the expected sensitivity of CC for detecting malnutrition was 0.75.[16] If the s.d. from normal was 1.96 (with a 95% confidence level), the width of the confidence interval being ± 0.06, the required sample size of subjects with malnutrition was 204. On the basis of our previous report,[5] the incidence of malnutrition in stroke patients in the convalescent stage was approximately 42%. Therefore, a sample of 476 participants was required in this study.

Statistical analysis

Statistical analysis was conducted using the IBM Statistical Package for the Social Sciences, version 21 (IBM Corporation; Armonk, NY, USA). Parametric data were expressed as mean (s.d.), whereas nonparametric data were reported using the median and interquartile range. After stratification of participants by sex, demographic data were compared between the malnutrition and non-malnutrition groups using an unpaired *t*-test, chi-squared test and Mann–Whitney's *U*-test. Significance was established when the *P*-value was <0.05.

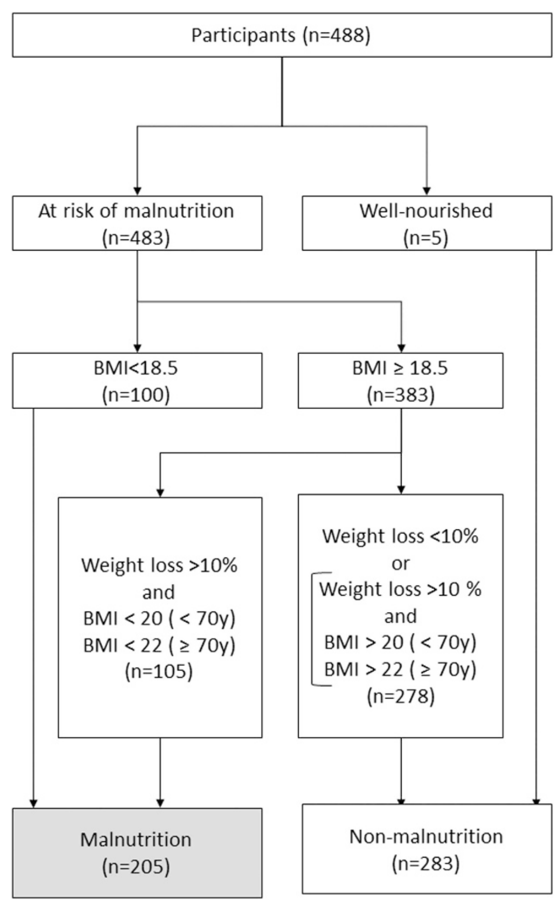

Figure 1. The diagnostic process for malnutrition of 488 patients with stroke and hemiplegia based on the ESPEN diagnostic criteria for malnutrition.

Table 1. Characteristics of the 488 older adult participants with hemiplegia due to stroke admitted to rehabilitation hospital

	Men				*Women*			
	Overall	*Non-malnutrition*	*Malnutrition*	*P-value*	*Overall*	*Non-malnutrition*	*Malnutrition*	*P-value*
Number of participants	224	143	81		264	140	124	
Age, years								
Mean (s.d.)	77.2 (7.5)	76.0 (7.5)	79.0 (7.3)	0.004[a]	80.2 (7.2)	78.3 (7.3)	82.4 (6.5)	< 0.001[a]
Days from stroke onset to admission								
Median (25–75 percentile)	23 (17–33)	21 (17–32)	26 (17–38)	0.169[b]	21 (16.3–29)	20 (16–27.8)	23 (18–30)	0.027[b]
Stroke subtype, n (%)				0.586[c]				0.011[c]
Cerebral infarction	177 (79.0)	116 (81.1)	61 (75.3)		192 (72.7)	112 (80.0)[d]	80 (64.5)[d]	
Intracerebral hemorrhage	42 (18.8)	24 (16.8)	18 (22.2)		63 (23.9)	23 (16.4)[d]	40 (32.3)[d]	
Subarachnoid hemorrhage	5 (2.2)	3 (2.1)	2 (2.5)		9 (3.4)	5 (3.6)	6 (3.2)	
Hemiplegic side, n *(%)*				0.894[c]				0.392[c]
Right	123 (54.9)	79 (55.2)	44 (54.3)		131 (49.6)	74 (52.9)	59 (47.6)	
Left	101 (45.1)	64 (44.8)	37 (45.7)		133 (50.4)	66 (47.1)	65 (52.4)	
FIM on admission, points								
Total FIM, median (25–75 percentile)	60 (33–84)	64 (41–89)	49 (26.5–73)	0.001[b]	51.5 (26–76)	61.5 (35–84)	39.5 (22–64)	< 0.001[b]
Initial nutritional screening, n *(%)*[e]				< 0.001[c]				< 0.001[c]
Malnourished	140 (62.5)	70 (49.0)[d]	70 (86.4)[d]		186 (70.5)	74 (52.9)[d]	112 (90.3)[d]	
At risk of malnutrition	79 (35.3)	68 (47.6)[d]	11 (13.6)[d]		78 (29.5)	66 (47.1)[d]	12 (9.7)[d]	
Normal nutritional status	5 (2.2)	5 (3.5)	0		0	0	0	

Abbreviation: FIM, functional independence measure. [a]Paired *t*-test. [b]Mann–Whitney's *U*-test. [c]Chi-square test. [d]Significantly different according to residual test. [e]Assessed by Mini Nutritional Assessment Short Form as follows; 0–7 points, malnourished; 8–11 points, at risk of malnutrition; 12–14 points, normal nutritional status.

Table 2. Anthropometric data and serum albumin of 488 older adult patients with hemiplegia due to stroke admitted to our rehabilitation hospital

	Men				*Women*			
	Overall	*Non-malnutrition*	*Malnutrition*	*P-value*	*Overall*	*Non-malnutrition*	*Malnutrition*	*P-value*
Number of participants	224	143	81		264	140	124	
Height, cm				0.597[a]				0.071[a]
Mean (s.d.)	161.3 (6.1)	161.4 (6.1)	161.0 (6.1)		149.0 (5.9)	149.6 (6.4)	148.3 (5.2)	
Weight, kg				< 0.001[a]				< 0.001[a]
Mean (s.d.)	57.4 (9.4)	61.7 (8.0)	49.8 (6.2)		47.1 (9.4)	53.1 (7.8)	40.3 (5.8)	
BMI, kg/m²				< 0.001[a]				< 0.001[a]
Mean (s.d.)	22.0 (3.2)	23.7 (2.6)	19.2 (1.9)		21.1 (3.7)	23.7 (2.9)	18.3 (2.1)	
AC, cm				< 0.001[a]				< 0.001[a]
Mean (s.d.)	26.3 (2.7)	27.3 (2.4)	24.3 (2.2)		24.8 (3.2)	26.5 (2.5)	22.8 (2.8)	
TSF, mm				< 0.001[b]				< 0.001[b]
Median (25–75 percentile)	8 (6–11)	10 (8–12)	6 (5–8)		12 (8–16)	14 (11–20)	9 (6–12)	
AMC, cm				< 0.001[a]				< 0.001[a]
Mean (s.d.)	23.5 (2.3)	24.2 (2.1)	22.2 (2.1)		21.0 (2.4)	21.9 (2.1)	19.9 (2.2)	
CC, cm				< 0.001[a]				< 0.001[a]
Mean (s.d.)	31.5 (3.2)	32.4 (2.8)	28.0 (2.7)		29.7 (3.5)	31.8 (2.8)	27.4 (2.6)	
Serum albumin, g/dl[c]				< 0.001[a]				< 0.001[a]
Mean (s.d.)	3.6 (0.4)	3.7[d] (0.3)	3.5[e] (0.4)		3.6 (0.4)	3.7[d] (0.4)	3.4[f] (0.3)	

Abbreviations: AC, arm circumference; AMC, arm muscle circumference; BMI, body mass index; CC, calf circumference; TSF, triceps skinfold. [a]Unpaired *t*-test. [b]Mann–Whitney's *U*-test. [c]Twenty patients were missing. [d]Seven patients were missing. [e]One patient was missing. [f]Five patients were missing.

To estimate the accuracy of malnutrition screening by anthropometric measurements, receiver operation characteristics curve and area under the curve (AUC) of each anthropometric measurement and Alb were assessed according to the ESPEN malnutrition criteria. To define the optimal cutoffs for each anthropometric measurement, the Youden index[22] was calculated using the following formula: sensitivity + specificity − 1. Anthropometric measurements with maximum Youden index values were set as cutoffs. After assessing the possibility of malnutrition with the cutoff, sensitivity, specificity, positive predictive value and negative predictive value were computed to determine the accuracy of malnutrition screening. In addition, the kappa value was calculated to determine the concordance between the reference indices and each anthropometric measurement.

RESULTS

Seven hundred fifty-eight subjects were eligible for this study. Of them, 175 subjects were excluded owing to paraplegia or

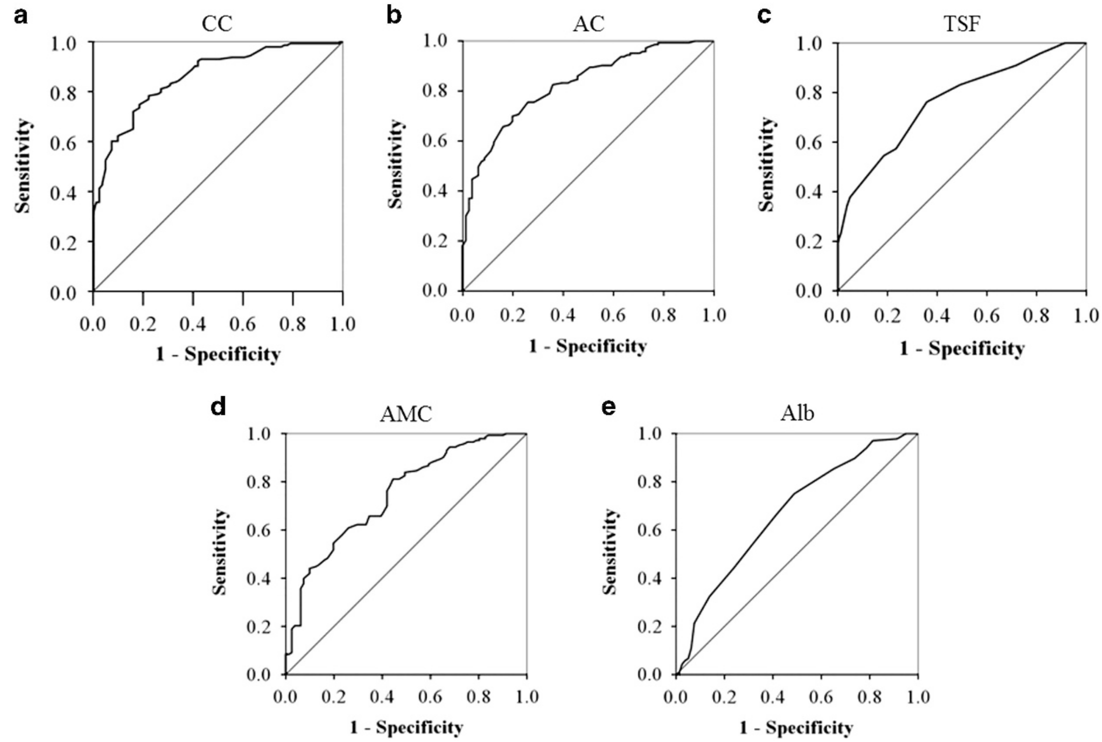

Figure 2. The receiver operation characteristics curve of non-paralytic anthropometric data and serum albumin (Alb) for male participants. (**a**) CC: cutoff < 31.1 cm, AUC 0.859. (**b**) AC: cutoff < 26.2 cm, AUC 0.825. (**c**) TSF: cutoff < 8 mm, AUC 0.764. (**d**) AMC: cutoff < 22.7 cm, AUC 0.745. (**e**) Alb: cutoff < 3.5 g/dl, AUC 0.670.

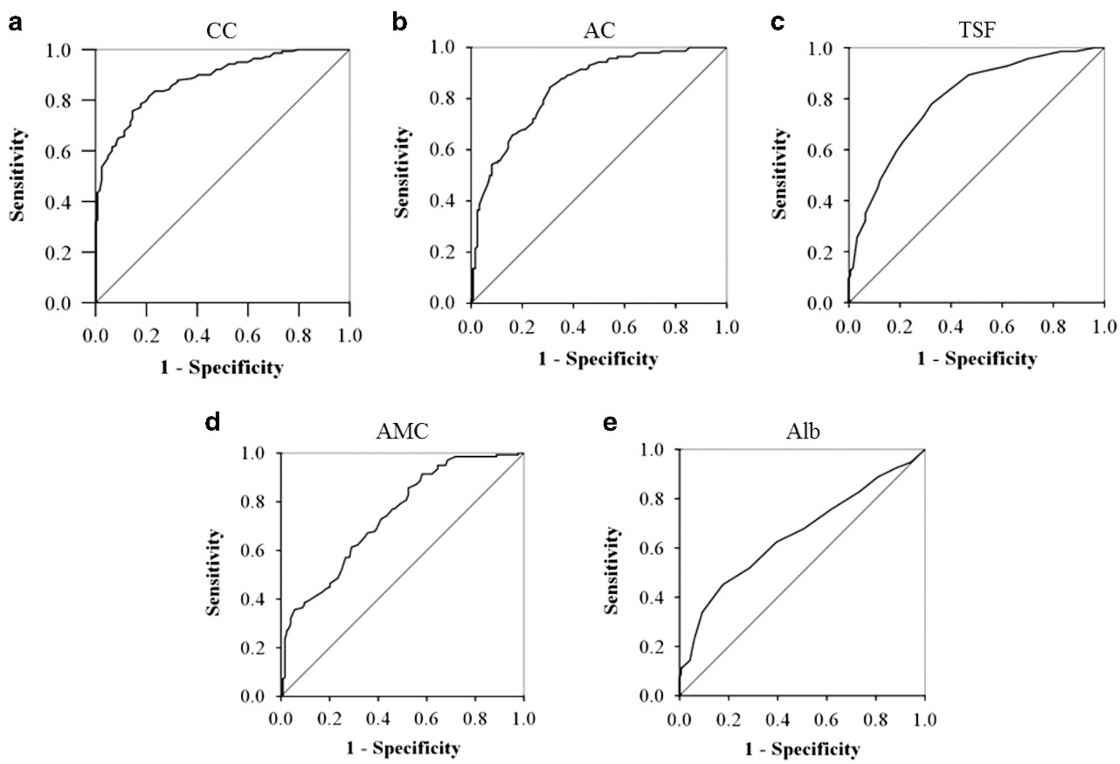

Figure 3. The receiver operation characteristics curve of non-paralytic anthropometric data and serum albumin (Alb) for female participants. (**a**) CC: cutoff < 30.1 cm, AUC 0.881. (**b**) AC: cutoff < 24.1 cm, AUC 0.843. (**c**) TSF: cutoff < 11 mm, AUC 0.796. (**d**) AMC: cutoff < 19.8 cm, AUC 0.742. (**e**) Alb: cutoff < 3.8 g/dl, AUC 0.658.

tetraplegia, 91 underwent anthropometric assessment of the paralytic side and 4 were missing anthropometric data or body weight data. Finally, a total of 488 participants, that is 224 men and 264 women with stroke and hemiplegia, with a mean age of 77.2 and 80.2 years, respectively, were analyzed in this study. Most of the participants experienced cerebral infarction (79.0% for men and 72.7% for women) followed by intracerebral hemorrhage (18.8% for men and 23.9% for women), and others presented subarachnoid hemorrhage (2.2% for men and 3.4% for women). There were no missing data except for Alb (20 patients with missing data) and FIM at discharge (88 patients with missing data).

The process for the diagnosis of malnutrition followed in this study is shown in Figure 1. According to the MNA-SF, 483 participants (99.0%) were suspected to be malnourished or at risk of malnutrition. Of them, 100 participants (20.5%) were diagnosed as having malnutrition based on a BMI below 18.5 kg/m^2. Conversely, 105 (21.5%) participants out of the remaining 383 participants were diagnosed with malnutrition based on the magnitude of body weight loss and BMI. Usual body weight could not be collected in 90 participants (18.4%). Overall, 205 participants (42.0%) were diagnosed with malnutrition and 283 (58.0%) were not malnourished.

Table 1 indicates the characteristics of study participants. Patients in the malnutrition group were significantly older ($P=0.004$ for men; $P<0.001$ for women) and had lower Total FIM ($P=0.001$ for men; $P<0.001$ for women) than the non-malnutrition group in both sexes. All anthropometric measurements and Alb were significantly lower in the malnutrition group than in the non-malnutrition group for both sexes (Table 2).

The receiver operation characteristics curve indicated that CC had the highest AUC (0.859 for men and 0.881 for women), followed by AC, TSF and AMC (Figures 2 and 3). Inversely, Alb had the lowest AUC for both men and women. After calculating the Youden index, we set the cutoffs of each measurement based on the maximum Youden index. The optimal cutoffs for detecting malnutrition for men and women, respectively, were as follows: CC <31.1 and <30.1 cm; AC <26.2 and <24.1 cm; TSF <8 mm and <11 mm; AMC <22.7 and <19.8 cm; and Alb: <3.5 g/dl and <3.8 g/dl.

Table 3 shows the accuracy of each measurement in men and women. The highest sensitivity was that for CC (81.5% for men and 85.5% for women), whereas the lowest was Alb for men (51.3%) and AMC for women (47.6%). The AMC had the highest specificity for both sexes (81.1% for men and 85.7% for women), whereas the lowest was AC for men (69.9%) and Alb for women (45.1%). Regarding the overall accuracy based on the kappa value, CC showed moderate to substantial agreement according to kappa[23] (0.533 for men, 0.608 for women, both $P<0.001$) in both sexes followed by AC, TSF, AMC and Alb.

Compared with the lower CC groups (⩽31 for men and ⩽30 cm for women), the median FIM at discharge was higher in the higher CC groups for both sexes (114.5 vs 99.5 for men, 104 vs 70 for women; both $P<0.001$). In addition, the lower CC group had a significantly lower proportion of home discharge than the higher CC group (52.0% vs 78.7% for men, 40.0% vs 63.7% for women; both $P<0.001$).

DISCUSSION

This cross-sectional study arrived at two clinical observations. First, CC had moderate to substantial accuracy for the malnutrition screening in older patients with stroke and hemiplegia as defined by ESPEN diagnostic malnutrition criteria. Second, stroke patients with lower CC showed significantly lower functional and poor discharge outcomes than those with higher CC.

In this study, CC in men and women was indicated to have AUC of 0.851 and 0.881 and kappa value of 0.533 and 0.608, respectively. These results provide evidence that non-paralytic CC can adequately screen malnutrition with a cutoff value of ⩽31 for men and ⩽30 cm for women. Leandro-Merhi[15] reported that CC <31 cm and AC <10 percentile had a sensitivity of 41.4% and 28.3%, respectively, in older surgery patients. In addition, Bonnefoy demonstrated that CC <30.5 cm had a sensitivity of 73.2% and specificity of 72.8% in the geriatric unit.[16] The reason for the higher accuracy obtained in this study is partially explained by the good correlation between CC and BMI or age, which is used in the ESPEN criteria.[12,24] As CC can be simply and noninvasively measured, even if it is difficult to measure the patient's body weight, routine CC measurements may be useful for nutrition screening.

Stroke patients with lower CC (⩽31 for men and ⩽30 cm for women) showed a lower FIM at discharge and lower proportion of home discharge. These results are in line with those of previous articles that reported that CC was a better predictor for long-term mortality[25] or functional status in

Table 3. Sensitivity, specificity, PPV, NPV and kappa value of the non-paralytic anthropometric data and serum albumin for detecting malnutrition in 488 older adult participants with stroke and hemiplegia

	CC	*AC*	*TSF*	*AMC*	*Alb*
Men					
Sensitivity, %	81.5	80.2	64.2	55.6	51.3
Specificity, %	74.8	69.9	76.2	81.1	75.0
PPV, %	64.7	60.2	60.5	62.5	54.7
NPV, %	87.7	86.2	79.0	76.3	72.3
Kappa value (*P*-value)	0.533 (< 0.001)	0.468 (< 0.001)	0.399 (< 0.001)	0.376 (< 0.001)	0.266 (< 0.001)
Women					
Sensitivity, %	85.5	69.4	67.7	47.6	82.4
Specificity, %	75.7	84.3	77.9	85.7	45.1
PPV, %	75.7	79.6	73.0	74.7	57.3
NPV, %	84.1	75.6	73.2	64.9	74.1
Kappa value (*P*-value)	0.608 (< 0.001)	0.540 (< 0.001)	0.458 (< 0.001)	0.340 (< 0.001)	0.268 (< 0.001)

Abbreviations: AC, arm circumference; Alb, serum albumin concentration; AMC, arm muscle circumference; CC, calf circumference; NPV, negative predictive value; PPV, positive predictive value; TSF, triceps skinfold.

community-dwelling adults.[26] Decreased CC may denote reduction of skeletal muscle mass due to undernutrition or sarcopenia.[27,28] Therefore, the functional predictability of CC may be partially explained by the loss of skeletal muscle mass or body cell mass. Our findings indicate that decreased muscle mass in stroke patients with disability could lead to poor functional recovery, resulting in a reduced possibility of return to home.

This study had several limitations. First, the reference tests did not completely apply to all participants because we used the same database that was used for previously published articles. Although this study used MNA-SF scores and usual body weight was collected and registered by dietitians at admission, the usual body weight of some patients could not be investigated owing to aphasia, cognitive impairment or failure to contact their relatives. Moreover, we did not use one of the criteria as 'body weight loss $>5\%$ in the past 3 months'[12] because many stroke patients had difficulty remembering previously measured weight values. Therefore, we cannot deny that the prevalence of malnutrition may be underestimated in this cohort. Second, this study included only Japanese participants. Previous French and Brazilian studies used CC cutoffs that were similar to those found in our study.[15,16] However, it is unclear whether the results of our study can also apply to patients of other ethnicities. Third, this study potentially excluded stroke patients who did not need rehabilitation, and those with para/tetraplegia. Therefore, our findings may not be applicable to all stroke patients. Finally, the ESPEN diagnostic criteria for malnutrition have not been validated for stroke patients. Some studies are investigating the prevalence of malnutrition based on the ESPEN criteria.[29,30] However, their validity has yet to be established in stroke patients as is the case with any other nutritional screening tools.[9]

In conclusion, this study indicated that non-paralytic anthropometric measurements, particularly CC $\leqslant 31$ for men and $\leqslant 30$ cm for women, are useful for malnutrition screening in the older patients with stroke and hemiplegia. In addition, stroke patients with lower CC showed significantly worse functional and discharge outcomes than did those with higher CC. We believe that our findings may be applicable for older patients with stroke who require rehabilitation. Further studies are needed to confirm which nutritional screening method has the highest validity for nutritional screening in stroke patients in rehabilitation settings.

CONFLICT OF INTEREST

HW received reimbursement for travel expenses from Nestlé Health Sciences outside the submitted work. SN and TY declare no conflict of interest.

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