Tohoku J. Exp. Med., 2024, **262**, 221-228

Appropriate Anthropometric Indices for Geriatric Nutritional Risk Index in Predicting Mortality in Older Japanese Patients: A Comparison of the Lorentz Formula and Body Mass Index

Kou Kitabayashi,[1,2] Suguru Yamamoto[1] and Ichiei Narita[1]

[1]Division of Clinical Nephrology and Rheumatology, Niigata University Graduate School of Medical and Dental Sciences, Niigata, Niigata, Japan
[2]Shinkohkai Murakami Kinen Hospital, Niigata, Niigata, Japan

The Geriatric Nutritional Risk Index (GNRI) is a popular nutritional screening tool. However, the calculation of ideal body weight (IBW) differs among studies. We aimed to compare GNRI calculated using the Lorentz formula (LF) with a body mass index (BMI) and to investigate the cutoffs based on original or quartile criteria for the association with mortality in elderly patients in Japan. This retrospective study enrolled patients aged 65 and older in a long-term care hospital. The GNRI was calculated using two different IBW methods: the LF and a BMI of 22 kg/m^2. We categorized GNRI results based on the original criteria or quartile criteria. Mortality outcomes were analyzed using the GNRI based on IBW (LF or BMI) and its classification (original criteria or quartile) through Cox proportional hazard regression. There were 262 participants, including 160 women, with a median age of 86. There was a notable difference between GNRI-BMI and GNRI-LF. The GNRI-LF original and quartile criteria did not show an association with mortality. A significant association with mortality was found between Q1 and Q4 in the GNRI-BMI quartile criteria (hazard ratio: 2.60; 95% confidence interval: 1.66-4.07, $p < 0.01$), but not the GNRI-BMI original criteria. The GNRI calculated using BMI with quartile criteria proved to be a reliable predictor of mortality for Japanese elderly inpatients. The calculation method of GNRI and the appropriate cutoff point should be considered based on the patient's background.

Keywords: ideal body weight; long-term care; nutritional screening; prognosis; survival
Tohoku J. Exp. Med., 2024 April, **262** (4), 221-228.
doi:10.1620/tjem.2024.J001

Introduction

Older inpatients have a high prevalence of malnutrition (Cereda et al. 2016; Leij-Halfwerk et al. 2019), which is associated with adverse outcomes, such as mortality, longer hospitalizations, frailty, and reduced quality of life (QOL) (Abizanda et al. 2016; Dent et al. 2019; Ligthart-Melis et al. 2020; Tucker et al. 2022). Nutritional status in older patients is often paid attention to malnutrition rather than obesity. Adequate nutritional support can improve the prognosis of these (Gomes et al. 2019); therefore, proper nutritional screening is needed to identify the risk of poor clinical outcomes (Dent et al. 2019).

The Geriatric Nutritional Risk Index (GNRI) is a nutritional screening tool comprised of information regarding serum albumin (Alb), height, and body weight. The GNRI helps assess the nutritional status of patients in acute, subacute, and nursing care settings, who may be affected by various statuses such as aging, dementia, post-stroke disability, malignancy, heart failure, chronic kidney disease, and COVD-19 (Bouillanne et al. 2005; Cereda et al. 2008; Hao et al. 2019; Lv et al. 2019; Dong et al. 2021; Nakagawa et al. 2021; Song et al. 2021). A feature of GNRI is that it uses ideal body weight (IBW) in the calculation formula. IBW is defined as body weight at lowest mortality or morbidity (Sandowski 2000). Initially, the Lorentz formula (LF) was used to calculate IBW for original GNRI measurements (Bouillanne et al. 2005). However, it is unknown whether LF is an appropriate method for IBW in the Asian race. Meanwhile, several

Received November 11, 2023; revised and accepted January 3, 2024; J-STAGE Advance online publication January 12, 2024
Correspondence: Suguru Yamamoto, Division of Clinical Nephrology and Rheumatology, Niigata University Graduate School of Medical and Dental Sciences, 1-757 Asahimachi-dori, Niigata, Niigata 951-8510, Japan.
e-mail: yamamotos@med.niigata-u.ac.jp

studies have used body mass index (BMI) to calculate IBW (Kinugasa et al. 2013; Huang et al. 2016; Maruyama et al. 2018). In Japan, body weight at BMI 22 kg/m^2 is treated as IBW because body weight is associated with the lowest morbidity (Tokunaga et al. 1991). The GNRI calculation with BMI may differ from that using LF in predicting clinical outcomes in older inpatients. Originally, to predict the mortality, GNRI was categorized with the original criteria (< 82, major risk; 82-91, moderate risk; 92-98, low risk; and > 98, no risk); however, the appropriate cutoff point may be considered based on the patient's background.

The present study examined the disparities in GNRI results using an IBW based on BMI and LF methods. Furthermore, we investigated the correlation between mortality and GNRI using BMI or LF, considering original or quartile criteria in elderly Japanese inpatients at a long-term care hospital.

Materials and Methods

Design and participants

This was a retrospective study. Inpatients aged 65 years and older were included in a long-term care (LTC) ward covered by medical or LTC insurance (Iryou-ryouyou byoushou or Kaigo-ryouyou byoushou). Japanese LTC ward covered by medical insurance has a case-mix classification system, a 3 × 3 matrix with three medical levels and three activities of daily living (ADL) levels. For medical levels, Level 3 requires 24-hour monitoring by physicians and nurses, including subacute myelo-optic neuropathy (SMON), total parenteral nutrition, being on a medical ventilator, drainage, tracheotomy care with fever, and oxygen therapy. Level 2 includes multiple sclerosis, neurological disease, Parkinson's disease, spinal injury with paraplegia, emphysema (COPD), cancer requiring pain control, pneumonia, urinary tract infection, wound infection, persistent vomiting, pressure ulcer, delirium, depression, violent behavior, dialysis, tube feeding with fever, aspiration (eight or more times per day), tracheotomy care, blood sugar check (three or more times per day), and foot care. Level 1 includes conditions other than Level 2 and 3. ADL levels are determined by the summation of the ADL scores for ADL activities of bed mobility, transfer, eating, and toileting, each measured on a scale of 0 to 6 (higher scores = more dependent). Level 3 corresponds to scores of 23-24, Level 2 to 11-22, and Level 1 to 0-10 (Igarashi et al. 2018). A patient in an LTC ward covered by LTC insurance has five levels according to the extent of the physical and mental disability. Care-need level 1 is for patients who are less disabled, and care-need level 5 is for patients who are most disabled (Jin et al. 2018).

The enrollment period was between February 1, 2014, and May 31, 2020; follow-up was performed through May 31, 2021. The study endpoint was death. The following patients were excluded from the present study: those discharged or transferred to other hospitals and those missing serum Alb values or body weight measurements. The protocol for the present study was created by the Helsinki Declaration of 1975, revised in 2013, and approved by the ethics committee of Shinkohkai Murakami Kinen Hospital (No. 2021; approved June 21, 2021). Patients could opt out if they wished not to participate in the present study.

Data collection

Age, sex, height, body weight, biochemical measurements, morbidity, oral function, and survival time were collected from medical records at the starting point. Height was measured using a height gauge or a measuring tape. Serum Alb, blood urea nitrogen, serum creatinine, hemoglobin (Hb), lymphocyte count, and C-reactive protein (CRP) levels were measured in the non-fasting state, and serum Alb levels were measured using the bromocresol green method. Morbidities included stroke, dementia, cancer, diabetes, kidney disease, heart disease, neuromuscular disease, pulmonary disease, liver disease, and pressure ulcers. The Functional Oral Intake Scale (FOIS) assessed oral function. It categorized subjects receiving tube feeds as levels 1-3, those with dysphagia as levels 4-5, and those without dysphagia as levels 6-7 (Crary et al. 2005; Souza et al. 2020). FOIS was assessed by a registered dietitian (K.K.). Cognitive function was assessed by the revised Hasegawa dementia scale (HDS-R). The scale consists of 9 simple questions with a maximum score of 30. If the score is less than 21, a patient has a probability of dementia (Imai and Hasegawa 1994).

Calculation and classification of GNRI

IBW was calculated using LF (IBW-LF) or BMI (IBW-BMI), with height being the actual value utilized. The calculation of IBW-LF is as follows:

For males: height − 100 − [(height − 150) / 4]

For females: height − 100 − [(height − 150) / 2.5] (Bouillanne et al. 2005)

IBW-BMI was calculated as follows:

height (m) × height (m) × 22

GNRI was calculated using the following formula:

1.489 × serum Alb (g/L) + 41.7 × [actual body weight (kg) / IBW (kg)]

The GNRI calculated using IBW-LF was defined as GNRI-LF, and that calculated using IBW-BMI as GNRI-BMI. If actual body weight / IBW exceeded 1, the value was set to 1 (Yamada et al. 2008). GNRI were classified as follows: < 82, major risk; 82-91, moderate risk; 92-98, low risk; and 98, no risk, based on a previous report (Bouillanne et al. 2005). We also used the GNRI quartiles to examine their association with outcomes.

Statistical analysis

The differences between IBW-LF and IBW-BMI, and between GNRI-LF and GNRI-BMI, were analyzed using the Wilcoxon signed-rank test, while the agreement between GNRI-LF and GNRI-BMI was evaluated using Bland-Altman plots. The Kappa (κ) coefficient was used to ana-

Table 1. Participant characteristics.

	All (n = 262)	Male (n = 102)	Female (n = 160)
Age (years)	86 (81-91)	83 (79-88)	88 (83-92)
Height (cm)	150 (143-160)	160 (155-165)	145 (140-150)
Body weight (kg)	42.4 (36.0-46.9)	43.2 (38.8-51.4)	39.7 (34.3-45.0)
BMI (kg/m^2)	18.1 (16.2-20.9)	17.4 (15.5-20.0)	19.0 (16.9-21.8)
Alb (g/dL)	3.3 (3.0-3.6)	3.3 (2.9-3.5)	3.3 (3.0-3.6)
BUN (mg/dL)	19.5 (14.5-27.9)	17.1 (13.3-24.3)	20.9 (15.5-29.5)
Cr (mg/dL)	0.62 (0.45-0.82)	0.68 (0.53-0.84)	0.58 (0.44-0.78)
eGFR (mL/min/1.73m^2)	81 (55-101)	84 (68-110)	75 (52-99)
Hb (g/dL)	11.5 (10.0-12.9)	11.7 (10.1-13.1)	11.3 (10.0-12.7)
Lymphocyte count (/mm^3)	1,329 (999-1,728)	1,294 (975-1,730)	1,349 (1,018-1,728)
CRP (mg/dL)	0.57 (0.11-1.70)	0.87 (0.18-2.41)	0.47 (0.08-1.49)
HDS-R (score)	0 (0-9)	0 (0-8)	0 (0-10)
Less than 21 score (n, %)	242 (92%)	95 (93%)	147 (92%)
Comorbidity (n, %)			
Stroke	116 (44%)	55 (46%)	69 (43%)
Dementia	85 (32%)	27 (26%)	58 (36%)
Diabetes	24 (9%)	11 (11%)	13 (8%)
Cancer	22 (8%)	11 (11%)	7 (11%)
Kidney disease	21 (8%)	9 (9%)	12 (8%)
Heart disease	16 (6%)	3 (3%)	13 (8%)
Neuromuscular disease	11 (4%)	9 (9%)	2 (1%)
Pulmonary disease	13 (5%)	7 (7%)	4 (6%)
Liver disease	4 (2%)	2 (2%)	2 (1%)
Pressure ulcer	4 (2%)	0 (0%)	4 (3%)
Oral function (n, %)			
No dysphagia	50 (19%)	17 (17%)	33 (21%)
Dysphagia	96 (37%)	34 (33%)	62 (39%)
Tube feeds	116 (44%)	51 (50%)	65 (41%)

All values are expressed as the median (interquartile range), or number (%).
Alb, serum albumin; BUN, blood urea nitrogen; BMI, body mass index; Cr, serum creatinine; CRP, C-reactive protein; eGFR, estimated glomerular filtration rate; Hb, hemoglobin; HDS-R, the revised Hasegawa dementia scale.

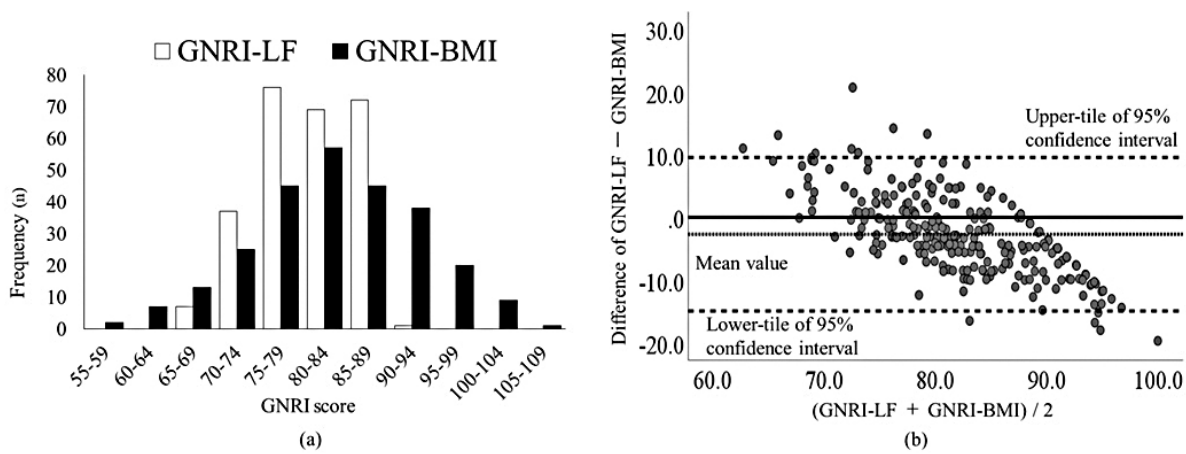

Fig. 1. Prevalence of the geriatric nutritional risk index (GNRI) scores (a), and Bland-Altman plot (b).
GNRI-BMI is distributed normally, as confirmed by the Shapiro-Wilk test ($p = 0.75$), while GNRI-LF is not ($p < 0.01$).
BMI, body mass index; LF, Lorentz formula.

Table 2. Differences and trends in nutritional risk groups for geriatric nutritional risk index (GNRI) original criteria by Lorentz formula (LF) or body mass index (BMI).

	Sex (% female)	Age (years)	BMI (kg/m^2)	Alb (g/dL)	CRP (mg/dL)	Lymphocyte count (mm^3)	Hb (g/dL)
GNRI-LF original criteria							
Major risk (n = 150)	52%	87 (82-91)	16.7 (15.3-17.6)	3.3 (2.9-3.5)	0.59 (0.11-2.20)	1,218 (946-1,576)	11.0 (9.9-12.4)
Moderate risk (n = 112)	73%	85 (80-91)	21.5 (20.1-23.3)	3.4 (3.1-3.8)	0.56 (0.12-1.52)	1,498 (1,057-1,889)	12.2 (10.4-13.0)
p-value of group difference	< 0.01	0.14	0.01	0.01	0.81	< 0.01	< 0.01
GNRI-BMI original criteria							
Major risk (n = 115)	52%	88 (82-91)	16.4 (15.0-17.9)	3.0 (2.7-3.2)	0.75 (0.16-2.58)	1,238 (933-1,566)	10.4 (9.5-12.0)
Moderate risk (n = 93)	63%	85 (79-91)	18.5 (17.3-20.7)	3.4 (3.2-3.6)	0.47 (0.09-1.33)	1,325 (1,012-7,194)	11.6 (10.8-13.0)
Low risk (n = 36)	75%	84 (75-87)	21.9 (20.2-24.1)	3.6 (3.4-3.8)	0.47 (0.68-1.99)	1,417 (1,056-1,776)	12.6 (10.4-13.2)
No risk (n = 18)	78%	88 (78-91)	22.3 (21.2-24.7)	4.0 (3.8-4.1)	0.12 (0.04-1.20)	1,693 (1,234-2,305)	12.4 (10.6-13.9)
p-value of group difference	0.03	0.03	< 0.01	< 0.01	0.02	0.07	< 0.01
p-value of trend	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01

All values are expressed as the median (interquartile range) or number of patients (%).
Alb, serum albumin; CRP, C-reactive protein; Hb, hemoglobin.

Table 3. Differences and trends among nutritional risk groups for geriatric nutritional risk index (GNRI) quartile criteria by Lorentz formula (LF) or body mass index (BMI).

	Sex (% female)	Age (years)	BMI (kg/m^2)	Alb (g/dL)	CRP (mg/dL)	Lymphocyte count (mm^3)	Hb (g/dL)
GNRI-LF quartile criteria							
Q1 (GNRI: < 76.9; n = 65)	48%	85 (81-90)	15.1 (14.0–15.6)	3.1 (2.9–3.4)	0.77 (0.13–2.56)	1,232 (1,010–1,633)	11.0 (9.7–12.2)
Q2 (GNRI: 76.9-80.0; n = 65)	55%	88 (83-91)	17.3 (16.9–17.7)	3.2 (3.0–3.4)	0.42 (0.08–1.62)	1,231 (854–1,583)	10.6 (9.9–12.4)
Q3 (GNRI: 80.1-85.8; n = 66)	67%	85 (80-91)	19.6 (18.7–20.2)	3.4 (2.9–3.6)	0.50 (0.13–1.32)	1,367 (1,015–1,743)	12.1 (10.8–12.9)
Q4 (GNRI: > 85.8; n = 65)	75%	85 (81-91)	22.7 (21.8–24.3)	3.4 (3.2–3.8)	0.56 (0.12–1.68)	1,513 (1,092–1,907)	12.2 (10.2–13.0)
p-value of group difference	< 0.01	0.25	< 0.01	< 0.01	0.45	0.051	< 0.01
p-value of trend	< 0.01	0.65	< 0.01	< 0.01	0.46	0.030	< 0.01
GNRI-BMI quartile criteria							
Q1 (GNRI: < 77.2; n = 65)	49%	87 (83-91)	15.4 (14.1-17.4)	2.8 (2.5-3.1)	0.99 (0.20-2.87)	1,290 (1,026-1,578)	10.3 (9.5–12.1)
Q2 (GNRI: 77.2-83.3; n = 63)	54%	88 (82-91)	17.2 (16.0-18.4)	3.2 (3.0-3.3)	0.62 (0.14-2.12)	1,161 (838-1,565)	11.1 (10.0–12.1)
Q3 (GNRI: 83.4-90.3; n = 69)	65%	84 (79-89)	18.5 (17.3-20.1)	3.4 (3.2-3.7)	0.39 (0.09-1.10)	1,266 (1,012-1,758)	12.0 (10.6–13.1)
Q4 (GNRI: > 90.3; n = 65)	75%	85 (78-91)	22.1 (20.5-24.0)	3.7 (3.4-3.9)	0.29 (0.07-1.46)	1,528 (1,147-1,897)	12.4 (10.8–13.2)
p-value of group difference	0.01	0.02	< 0.01	< 0.01	< 0.01	0.03	< 0.01
p-value of trend	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01

All values are expressed as the median (interquartile range) or number of patients (%).
Alb, serum albumin; CRP, C-reactive protein; Hb, hemoglobin.

lyze the understanding of nutritional risk between the GNRI-LF and GNRI-BMI original criteria. Based on the nutritional risk for each criterion, background data, including sex, age, BMI, Alb, CRP, lymphocyte count, and Hb, were analyzed using the chi-square test or the Kruskal-Wallis test. Additionally, the Mantel-Haenszel and Jonckheere-Terpstra tests were utilized to study trends. Based on nutritional risk in each group, the survival curve was drawn using the Kaplan-Meier method, and the log-rank test was conducted to analyze survival time. Cox proportional hazard regression was used to calculate the hazard risk-adjusted sex, age, each comorbidity (as a single index), and oral function. We selected candidate model covariates based on expected clinical relevance and known associations suggested by prior research studies. Model results were estimated using three progressive sets of potential confounders: Model 1: crude; Model 2: model 1 + sex and age; Model 3: model 2 + comorbidity; and Model 4: model 3 + oral function. Since oral function can affect the nutritional status in this population, we selected it as a confounding factor. Statistical significance was set at $p < 0.05$, and all statistical analyses were performed using SPSS version 26 for Windows (IBM Corp., Armonk, NY, USA).

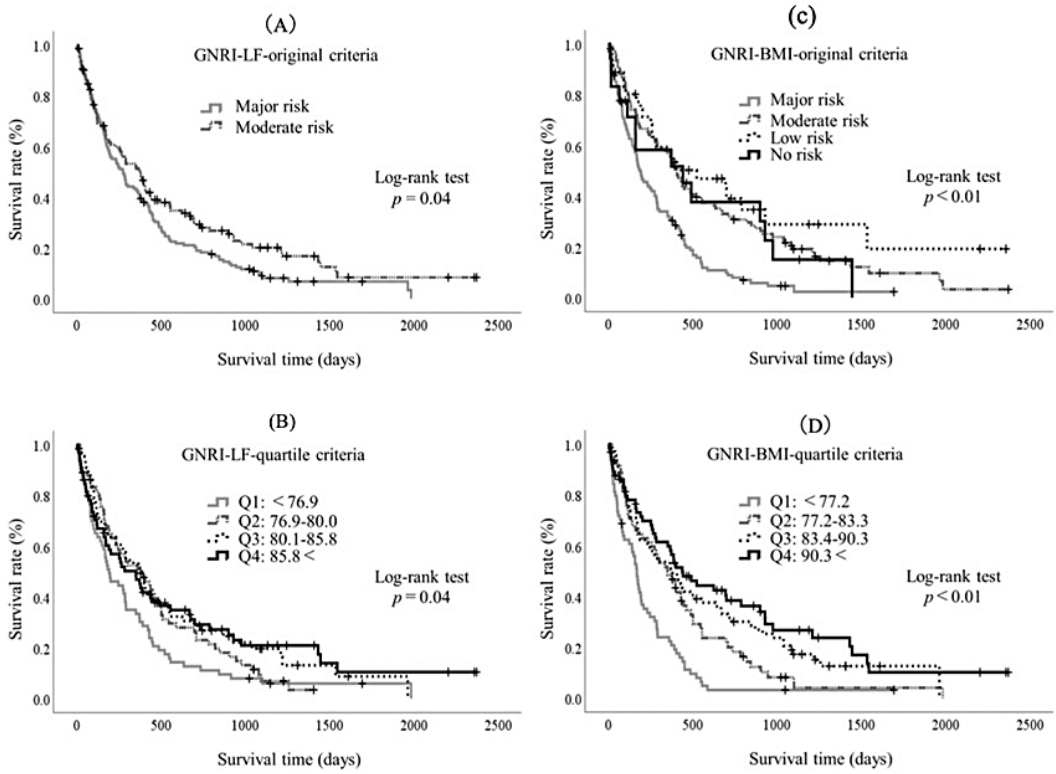

Fig. 2. Kapan-Meier survival curve of each geriatric nutritional risk index (GNRI) criteria.
(A) GNRI-LF original criteria. The median survival times were 274 days (95% CI: 208-340 days) for major risk, and 373 days (95% CI: 266-480 days) for moderate risk. (B) GNRI-LF quartile criteria. The median survival times were 192 days (95% CI: 106-278 days) for Q1, 365 days (95% CI: 204-526 days) for Q2, 374 days (271-478 days) for Q3, and 351 days (95% CI: 217-485 days) for Q4. (C) GNRI-BMI original criteria. The median survival times were 192 days (95% CI: 141-232 days) for major risk, 407 days (95% CI: 344-470 days) for moderate risk, 524 days (95% CI: 109-939 days) for low risk, and 442 days (95% CI: 48-436 days) for no risk. (D) GNRI-BMI quartile criteria. The median survival times were 169 days (95% CI: 140-198 days) for Q1, 351 days (95% CI: 242-460 days) for Q2, 378 days (95% CI: 216-540 days) for Q3, and 438 days (95%CI: 282-594 days) for Q4. BMI, body mass index; CI, confidence interval; LF, Lorentz formula.

Results

Participant's characteristics

There were 262 participants in the present study, including 160 females, with a median age of 86 [interquartile range (IQR): 81-91 years]. A subject in the LTC ward covered by medical insurance was 65 patients with medical level 3, 25%; level 2, 65%; level 1, 11%; and ADL level 3, 46%; level 2, 40%; and level 1, 14%. The other 197 subjects were in the LTC ward covered by LTC insurance, and the care-need level was level 1, 1%; level 2, 1%; level 3, 12%; level 4, 21%; and level 5, 66%. The median value of HDS-R was 0 (IQR: 0-9), and the prevalence of a score less than 21 was 92%. The median value and IQR for BMI, Alb, lymphocyte count, and CRP were as follows: 18.1 kg/m^2 (IQR: 16.2-20.9 kg/m^2); 3.3 g/dL (IQR: 3.0-3.6 g/dL); 1,329/mm^3 (IQR: 999-1,728/mm^3); and 0.57 mg/dL (IQR: 0.11-1.70 mg/dL), respectively. Comorbidities included stroke (44%), dementia (32%), diabetes (9%), cancer (8%), kidney disease (8%), heart disease (6%), pulmonary disease (5%), neuromuscular disease (4%), liver disease (2%), and pressure ulcers (2%). The oral function was as follows: no dysphagia, 19%; dysphagia, 37%; and tube feeds, 44%. The route of tube feeding was nose: 64% and gastrostomy: 36%. The cause of tube feeds was stroke, 64%; dementia, 18%; dysphagia, 3%; and others, 14% (Table 1).

The distribution of GNRI by FOIS level is as follows: Median GNRI was No dysphagia: 83.5 (78.4-87.7); Dysphagia: 79.5 (76.3-83.9); and Tube feeding in the GNRI-LF: 80.1 (76.7-85.3), p-value = 0.04. On the other hand, the median GNRI of GNRI-BMI was No dysphagia 86.2 (80.7-94.8), Dysphagia: 80.7 (75.1-88.0), and Tube feeding: 83.7 (78.1-90.5), p-value = 0.02.

Comparison between GNRI-LF and GNRI-BMI

The median values for IBW-LF and IBW-BMI were 50.0 kg (IQR: 45.8-56.2 kg) and 49.5 kg (IQR: 45.0-56.3 kg), respectively, and showed a significant difference in the median value of 0.80 kg (estimated 95% confidence interval, CI: 0.75-0.80 kg; $p < 0.01$). The distributions for the GNRI-LF and GNRI-BMI groups are shown in Fig. 1. The median values for GNRI-LF and GNRI-BMI were 80.2

Table 4. Results of Cox hazard analysis for four geriatric nutritional risk index (GNRI) criteria.

	Model 1	Model 2	Model 3	Model 4
	Hazard ratio (95% confidence interval)			
GNRI-LF original criteria				
Moderate risk (82-91)	Ref			
Major risk (< 82)	1.32 (1.01-1.73)[a]	1.11 (0.84-1.47)	1.13 (0.84-1.52)	1.13 (0.83-1.52)
GNRI-LF quartile criteria				
Q4 (> 85.8)	Ref			
Q3 (80.1-85.8)	1.03 (0.70-1.52)	1.03 (0.70-1.52)	1.00 (0.67-1.51)	0.99 (0.66-1.50)
Q2 (76.9-80.0)	1.18 (0.81-1.73)	1.03 (0.70-1.51)	0.99 (0.66-1.49)	0.98 (0.65-1.49)
Q1 (< 76.9)	1.61 (1.11-2.35)[a]	1.41 (0.96-2.06)	1.42 (0.94-2.15)	1.41 (0.92-2.14)
GNRI-BMI original criteria				
No risk (> 98)	Ref			
Low risk (92-98)	0.67 (0.35-1.31)	0.88 (0.45-1.72)	0.89 (0.44-1.81)	0.89 (0.44-1.80)
Moderate risk (82-91)	0.88 (0.50-1.56)	0.91 (0.52-1.61)	0.87 (0.48-1.59)	0.87 (0.48-1.59)
Major risk (< 82)	1.70 (0.97-2.99)	1.52 (0.86-2.68)	1.62 (0.89-2.98)	1.67 (0.90-3.08)
GNRI-BMI quartile criteria				
Q4 (> 90.3)	Ref			
Q3 (83.4-90.3)	1.22 (0.83-1.80)	1.20 (0.81-1.76)	1.16 (0.78-1.72)	1.18 (0.79-1.75)
Q2 (77.2–83.3)	1.60 (1.08-2.36)[a]	1.23 (0.82-1.83)	1.34 (0.88-2.03)	1.38 (0.90-2.10)
Q1 (< 77.2)	2.81 (1.90-4.16)[b]	2.24 (1.51-3.33)[b]	2.47 (1.61-3.79)[b]	2.60 (1.66-4.07)[b]

[a]$p < 0.05$; [b]$p < 0.01$.
BMI, body mass index; LF, Lorentz formula.
Model 1: crude; Model 2: model 1 + sex and age; Model 3: model 2 + comorbidity; Model 4: model 3 + oral function.

(IQR: 77.0-85.8) and 83.4 (IQR: 77.2-90.3), respectively, which indicated a significant difference in the median value of −2.9 (95% CI: −2.2 to −3.7; $p < 0.01$). When the GNRI-LF was calculated using the original criteria, the major- and moderate-risk populations were 57% and 43%, respectively, and no patients were categorized in the low- or no-risk groups. For the GNRI-BMI, the population was distributed as follows: Major risk, 44%; Moderate risk, 36%; Low risk, 14%; and No risk, 7%.

Association of nutritional risks with GNRI-LF and GNIR-BMI

Sex, BMI, Alb, CRP, lymphocyte count, and Hb of GNRI original criteria by LF and BMI were shown in Table 2. BMI, Alb lymphocyte count, and Hb were significant differences in GNRI-LF original criteria. GNRI-BMI original criteria showed a significant difference and trend in age, BMI, Alb, CRP, and Hb.

The quartiles for GNRI-LF were defined as follows: Q1, < 76.9; Q2, 76.9-80.0; Q3, 80.1-85.8; and Q4, > 85.8, and significant differences and trends were found for sex, BMI, Alb, and Hb among the groups. Sex, age, BMI, Alb, CRP, and Hb showed significant differences and trends among the GNRI-BMI original criteria. The quartiles for GNRI-BMI were categorized as follows: Q1 (< 77.2), Q2 (77.2-83.3), Q3 (83.4-90.3), and Q4 (> 90.3). The differences and trends in these nutritional and inflammatory markers were much clearer than those observed in the GNRI-LF quartile criteria (Table 3). The medical level, ADL level, care-need level, cognitive function, comorbidity, and oral function according to each criterion were shown in Supplementary Tables S1 and S2.

Survival analysis for GNRI-LF and GNRI-BMI

During the median follow-up period of 290 days (95% CI: 168-456 days), 223 patients died, and 39 were censored. One year mortality of the participants was 55%. Survival curves of each criterion were drawn in Fig. 2. The median survival times for the GNRI-LF original criteria were 274 days (95% CI: 208-340 days) for major risk and 373 days (95% CI: 266-480 days) for moderate risk, and there was a difference between the two groups ($p = 0.04$) (Fig. 2A). For the GNRI-LF quartile criteria, the median survival times were as follows: Q1, 192 days (95% CI: 106-278 days); Q2, 365 days (95% CI: 204-526 days); Q3, 374 days (95% CI: 271-478 days); and Q4, 351 days (95% CI: 217-485 days). A significant difference was found among the quartile criteria ($p = 0.04$) (Fig. 2B). The median survival times for the GNRI-BMI original criteria were as follows: Major risk, 192 days (95% CI: 141-243 days); Moderate risk, 407 days (95% CI: 344-470 days); Low risk, 524 days (95% CI: 109-939 days); and No risk, 442 days (95% CI: 48-836 days). There was a significant difference among the nutritional risk groups ($p < 0.01$) (Fig. 2C). For the GNRI-BMI quartile criteria, the median survival times were as follows: Q1, 169 days (95% CI: 140-198 days); Q2, 351 days (95% CI: 242-460 days); Q3: 378 days (95% CI: 216-540 days); and Q4, 438 days (95% CI: 282-594 days). The

survival time varied significantly among the quartiles ($p < 0.01$) (Fig. 2D).

Cox hazard analysis revealed a significantly higher hazard rate (HR) in the Q4 of the GNRI-BMI criteria compared to the Q1 across all models, as outlined below: Model 1 (HR: 2.81; 95% CI: 1.90-4.61; P < 0.01); Model 2 (HR: 2.24; 95% CI: 1.51-3.33; $p < 0.01$); Model 3 (HR: 2.47; 95% CI: 1.61-3.79; $p < 0.01$); and Model 4 (HR: 2.60; 95% CI:1.66-4.07; $p < 0.01$). There was no significant difference in Model 4 when considering other criteria (Table 4).

Discussion

In this study, we conducted a comparison between GNRI calculated using BMI and LF and also investigated the cutoffs based on original or quartile criteria for the association with mortality in elderly patients admitted to long-term care hospitals in Japan. Our findings indicate that the GNRI-BMI quartile criteria demonstrated the most potent predictive power for mortality in this population.

The patients were assessed with moderate and major risks, but none with low or no risk when the GNRI was calculated using the LF with the original criteria (Fig. 1), as indicated by a previous report (Araki et al. 2022). LF is known to overestimate IBW when height is < 150 cm (Bouillanne et al. 2005), which comprises 57% of the population in the present study. Lower BMI (Nakajima et al. 2009) and GNRI (Cereda et al. 2015) are associated with inflammatory markers in the older population. The present study showed a clear association between CRP and GNRI-BMI, although not GNRI-LF (Table 2). Therefore, utilizing BMI to calculate GNRI may be more accurate than LF for evaluating nutritional status in the older Japanese population.

For the GNRI-BMI quartile criteria, the HR for mortality in Q1 was significantly higher than in Q4 (Table 4). However, there was no significant difference between the GNRI-BMI original and the GNRI-LF original/quartile criteria (Table 4). GNRI-BMI, but not GNRI-LF, was normally distributed (Fig. 1). The classification based on GNRI-BMI quartile criteria revealed more distinct differences in nutritional and inflammatory indicators, such as serum Alb and CRP levels, than GNRI-BMI original criteria and GNRI-LF original/quartile (Tables 2 and 3). An association between serum CRP and GNRI calculated using BMI was found in an older patient population in Germany, as demonstrated by a cross-sectional study (Gärtner et al. 2017). Therefore, it was suggested that GNRI-BMI exhibited a stronger association with survival than GNRI-LF (Fig. 2). Careful consideration should be given to the calculation method of GNRI and the appropriate cutoff points, taking into account the patients' backgrounds.

A systematic review reported that enteral nutrition did not improve albumin levels or BMI in elderly individuals (Lan et al. 2017). It also found that enteral nutrition did not significantly affect nutrient intakes, such as protein and lipids, compared to oral intake (Lan et al. 2017). Improper enteral nutrition may worsen the nutritional status of elderly individuals and lead to unfavorable prognostic outcomes. On the other hand, our study showed that the association between GNRI and mortality remained unchanged when data were adjusted for oral function. The results suggest that even in patients with tube feeding, implementing appropriate nutritional management and inflammation treatment can improve survival rates in older patients living in long-term care hospitals.

The present study had several limitations. First, it was a retrospective study conducted at a single hospital with a small sample size. Our subjects may not represent the general older population residing in Japan's long-term care hospitals. Second, although previous studies excluded some comorbidities (Bouillanne et al. 2005; Cereda et al. 2008), we did not exclude any particular diseases in the present study, as Japanese long-term care hospitals are responsible for caring for older people with various illnesses. Finally, we used two methods to measure the height of patients, but it should be standardized by either method. Despite these limitations, the results of the present study are valuable for understanding the role of the GNRI in predicting mortality in Japanese patients living in long-term care hospitals.

In conclusion, the results of the present study indicated a difference in the distribution of GNRI-LF and GNRI-BMI in older Japanese patients living in long-term care hospitals. The GNRI-BMI quartile criteria were better able to predict mortality in the study population than the GNRI-BMI original criteria and GNRI-LF original/quartile criteria. The calculation method of GNRI and the appropriate cutoff point should be considered based on the patient's background.

Author Contributions

Research conception, design, experiments, and data analysis: K.K. and S.Y. Interpretation of data and manuscript writing: K.K., S.Y., and I.N.

Conflict of Interest

The authors declare no conflict of interest.

References

Abizanda, P., Sinclair, A., Barcons, N., Lizan, L. & Rodriguez-Manas, L. (2016) Costs of malnutrition in institutionalized and community-dwelling older adults: a systematic review. *J. Am. Med. Dir. Assoc.*, **17**, 17-23.

Araki, T., Yamazaki, Y., Goto, N., Takahashi, Y., Ikuyama, Y. & Kosaka, M. (2022) Prognostic value of geriatric nutritional risk index for aspiration pneumonia: a retrospective observational cohort study. *Aging Clin. Exp. Res.*, **34**, 563-571.

Bouillanne, O., Morineau, G., Dupont, C., Coulombel, I., Vincent, J.P., Nicolis, I., Benazeth, S., Cynober, L. & Aussel, C. (2005) Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. *Am. J. Clin. Nutr.*, **82**, 777-783.

Cereda, E., Klersy, C., Pedrolli, C., Cameletti, B., Bonardi, C., Quarleri, L., Cappello, S., Bonoldi, A., Bonadeo, E. & Caccialanza, R. (2015) The Geriatric Nutritional Risk Index predicts hospital length of stay and in-hospital weight loss in

elderly patients. *Clin. Nutr.*, **34**, 74-78.
Cereda, E., Pedrolli, C., Klersy, C., Bonardi, C., Quarleri, L., Cappello, S., Turri, A., Rondanelli, M. & Caccialanza, R. (2016) Nutritional status in older persons according to healthcare setting: a systematic review and meta-analysis of prevalence data using MNA®. *Clin. Nutr.*, **35**, 1282-1290.
Cereda, E., Zagami, A., Vanotti, A., Piffer, S. & Pedrolli, C. (2008) Geriatric Nutritional Risk Index and overall-cause mortality prediction in institutionalised elderly: a 3-year survival analysis. *Clin. Nutr.*, **27**, 717-723.
Crary, M.A., Mann, G.D. & Groher, M.E. (2005) Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. *Arch. Phys. Med. Rehabil.*, **86**, 1516-1520.
Dent, E., Hoogendijk, E.O., Visvanathan, R. & Wright, O.R.L. (2019) Malnutrition screening and assessment in hospitalised older people: a review. *J. Nutr. Health Aging*, **23**, 431-441.
Dong, C.H., Chen, S.Y., Zeng, H.L., Yang, B. & Pan, J. (2021) Geriatric nutritional risk index predicts all-cause mortality in patients with heart failure: a systematic review and meta-analysis. *Clinics* (*Sao Paulo*), **76**, e2258.
Gärtner, S., Kraft, M., Kruger, J., Vogt, L.J., Fiene, M., Mayerle, J., Aghdassi, A.A., Steveling, A., Volzke, H., Baumeister, S.E., Lerch, M.M. & Simon, P. (2017) Geriatric nutritional risk index correlates with length of hospital stay and inflammatory markers in older inpatients. *Clin. Nutr.*, **36**, 1048-1053.
Gomes, F., Baumgartner, A., Bounoure, L., Bally, M., Deutz, N.E., Greenwald, J.L., Stanga, Z., Mueller, B. & Schuetz, P. (2019) Association of nutritional support with clinical outcomes among medical inpatients who are malnourished or at nutritional risk: an updated systematic review and meta-analysis. *JAMA Netw. Open*, **2**, e1915138.
Hao, X., Li, D. & Zhang, N. (2019) Geriatric Nutritional Risk Index as a predictor for mortality: a meta-analysis of observational studies. *Nutr. Res.*, **71**, 8-20.
Huang, B.T., Peng, Y., Liu, W., Zhang, C., Chai, H., Huang, F.Y., Zuo, Z.L., Liao, Y.B., Xia, T.L. & Chen, M. (2016) Nutritional state predicts all-cause death independent of comorbidities in geriatric patients with coronary artery disease. *J. Nutr. Health Aging*, **20**, 199-204.
Igarashi, A., Yamamoto-Mitani, N., Morita, K., Matsui, H., Lai, C.K.Y. & Yasunaga, H. (2018) Classification of long-term care wards and their functional characteristics: analysis of national hospital data in Japan. *BMC Health Serv. Res.*, **18**, 655.
Imai, Y. & Hasegawa, K. (1994) The Revised Hasegawa's Dementia Scale (HDS-R)-evaluation of its usefulness as a screening test for dementia. *J. Hong Kong Coll. Psychiatr.*, **4**, 20-24.
Jin, X., Tamiya, N., Jeon, B., Kawamura, A., Takahashi, H. & Noguchi, H. (2018) Resident and facility characteristics associated with care-need level deterioration in long-term care welfare facilities in Japan. *Geriatr. Gerontol. Int.*, **18**, 758-766.
Kinugasa, Y., Kato, M., Sugihara, S., Hirai, M., Yamada, K., Yanagihara, K. & Yamamoto, K. (2013) Geriatric nutritional risk index predicts functional dependency and mortality in patients with heart failure with preserved ejection fraction. *Circ. J.*, **77**, 705-711.
Lan, S.H., Lu, L.C., Yen, Y.Y., Hsieh, Y.P., Chen, J.C., Wu, W.J., Lan, S.J. & Lin, L.Y. (2017) Tube feeding among elder in long-term care facilities: a systematic review and meta-analysis. *J. Nutr. Health Aging*, **21**, 31-37.
Leij-Halfwerk, S., Verwijs, M.H., van Houdt, S., Borkent, J.W., Guaitoli, P.R., Pelgrim, T., Heymans, M.W., Power, L., Visser, M., Corish, C.A. & de van der Schueren, M.A.E.; MaNuEL Consortium (2019) Prevalence of protein-energy malnutrition risk in European older adults in community, residential and hospital settings, according to 22 malnutrition screening tools validated for use in adults >/=65 years: a systematic review and meta-analysis. *Maturitas*, **126**, 80-89.
Ligthart-Melis, G.C., Luiking, Y.C., Kakourou, A., Cederholm, T., Maier, A.B. & de van der Schueren, M.A.E. (2020) Frailty, sarcopenia, and malnutrition frequently (co-)occur in hospitalized older adults: a systematic review and meta-analysis. *J. Am. Med. Dir. Assoc.*, **21**, 1216-1228.
Lv, G.Y., An, L. & Sun, D.W. (2019) Geriatric nutritional risk index predicts adverse outcomes in human malignancy: a meta-analysis. *Dis. Markers*, **2019**, 4796598.
Maruyama, K., Nakagawa, N., Koyama, S., Maruyama, J.I. & Hasebe, N. (2018) Malnutrition increases the incidence of death, cardiovascular events, and infections in patients with stroke after rehabilitation. *J. Stroke Cerebrovasc. Dis.*, **27**, 716-723.
Nakagawa, N., Maruyama, K. & Hasebe, N. (2021) Utility of geriatric nutritional risk index in patients with chronic kidney disease: a mini-review. *Nutrients*, **13**, 3688.
Nakajima, K., Yamaoka, H., Morita, K., Ebata, M., Eguchi, S., Muneyuki, T. & Munakata, H. (2009) Elderly people with low body weight may have subtle low-grade inflammation. *Obesity* (*Silver Spring*), **17**, 803-808.
Sandowski, S.A. (2000) What is the ideal body weight? *Fam. Pract.*, **17**, 348-351.
Song, F., Ma, H., Wang, S., Qin, T., Xu, Q., Yuan, H., Li, F., Wang, Z., Liao, Y., Tan, X., Song, X., Zhang, Q. & Huang, D. (2021) Nutritional screening based on objective indices at admission predicts in-hospital mortality in patients with COVID-19. *Nutr. J.*, **20**, 46.
Souza, J.T., Ribeiro, P.W., de Paiva, S.A.R., Tanni, S.E., Minicucci, M.F., Zornoff, L.A.M., Polegato, B.F., Bazan, S.G.Z., Modolo, G.P., Bazan, R. & Azevedo, P.S. (2020) Dysphagia and tube feeding after stroke are associated with poorer functional and mortality outcomes. *Clin. Nutr.*, **39**, 2786-2792.
Tokunaga, K., Matsuzawa, Y., Kotani, K., Keno, Y., Kobatake, T., Fujioka, S. & Tarui, S. (1991) Ideal body weight estimated from the body mass index with the lowest morbidity. *Int. J. Obes.*, **15**, 1-5.
Tucker, E., Luscombe-Marsh, N., Ambrosi, C. & Lushington, K. (2022) Nutritional status and quality-of-life of older adults in aged care: a systematic review and meta-analysis. *Exp. Gerontol.*, **162**, 111764.
Yamada, K., Furuya, R., Takita, T., Maruyama, Y., Yamaguchi, Y., Ohkawa, S. & Kumagai, H. (2008) Simplified nutritional screening tools for patients on maintenance hemodialysis. *Am. J. Clin. Nutr.*, **87**, 106-113.

Supplementary Files

Please find supplementary file(s);
https://doi.org/10.1620/tjem.2024.J001