



Effectiveness of Global Leadership Initiative on Malnutrition and Subjective Global Assessment for diagnosing malnutrition and predicting wound healing in patients with diabetic foot ulcers

Zhimin Yuan^{1†}, Chunjie Jiang^{2†}, Guojuan Lao³, Yan Zhang⁴, Chunying Wang⁴, Yingying Zhu³, Chaogang Chen¹, Jianmin Ran², Chengzhi Wang³ and Ping Zhu^{2*}

¹Department of Clinical Nutrition, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, People's Republic of China

²Department of Endocrinology and Metabolism, Guangzhou Red Cross Hospital, Jinan University, Guangzhou, People's Republic of China

³Department of Endocrinology and Metabolism, Sun Yat-sen Memorial Hospital, Sun Yat-sen University, Guangzhou, People's Republic of China

⁴Department of Endocrinology and Metabolism, Shenshan Medical Center, Memorial Hospital of Sun Yat-sen University, Shanwei, People's Republic of China

(Submitted 15 November 2023 – Final revision received 6 April 2024 – Accepted 11 April 2024 – First published online 18 April 2024)

Abstract

Malnutrition significantly hampers wound healing processes. This study aimed to compare the effectiveness of the Global Leadership Initiative on Malnutrition (GLIM) and Subjective Global Assessment (SGA) in diagnosing malnutrition and predicting wound healing in patients with diabetic foot ulcers (DFU). GLIM criteria were evaluated for sensitivity (sE), specificity (SP), positive predictive value, negative predictive value and kappa (κ) against SGA as the reference. Modified Poisson regression model and the DeLong test investigated the association between malnutrition and non-healing ulcers over 6 months. This retrospective cohort study included 398 patients with DFU, with a mean age of 66.3 ± 11.9 years. According to SGA and GLIM criteria, malnutrition rates were 50.8% and 42.7%, respectively. GLIM criteria showed a sE of 67.3% (95% CI 60.4%, 73.7%) and SP of 82.7% (95% CI 76.6%, 87.7%) in identifying malnutrition, with a positive predictive value of 80.0% and a negative predictive value of 71.1% ($\kappa = 0.50$) compared with SGA. Multivariate analysis demonstrated that malnutrition, as assessed by SGA, was an independent risk factor for non-healing (relative risk (RR) 1.84, 95% CI 1.45, 2.34), whereas GLIM criteria were associated with poorer ulcer healing in patients with estimated glomerular filtration rate ≥ 60 ml/min/1.73m² (RR: 1.46, 95% CI 1.10, 1.94). SGA demonstrated a superior area under the receiver's operating characteristic curve for predicting non-healing compared with GLIM criteria (0.70 (0.65–0.75) *v.* 0.63 (0.58–0.65), $P < 0.01$). These findings suggest that both nutritional assessment tools effectively identify patients with DFU at increased risk, with SGA showing superior performance in predicting non-healing ulcers.

Keywords: Global Leadership Initiative on Malnutrition; Subjective Global Assessment; Nutritional assessment; Diabetes; Wound healing

The prevalence of diabetes has been on the rise in China over the past decades, resulting in an increased prevalence of diabetic foot ulcers (DFU)⁽¹⁾. The lifetime risk of developing a foot ulcer in individuals with diabetes is estimated to be as high as 25%. Globally, a lower limb is lost to diabetes-related complications every 30 s⁽²⁾. Risk factors contributing to foot diseases, such as peripheral neuropathy and vascular disease, are present in over

10% of patients at the time of diabetes diagnosis. Moreover, the first year following a diagnosis of diabetes poses a heightened risk period for foot ulcers and subsequent amputations⁽³⁾. The prolonged non-healing and deterioration of ulcers significantly increase the risk of major amputations and mortality, imposing significant economic burdens on families and society⁽⁴⁾. Among the various factors influencing the prognosis of DFU, malnutrition

Abbreviations: CC, calf circumference; DFU, diabetic foot ulcer; eGFR, estimated glomerular filtration rate; GLIM, Global Leadership Initiative on Malnutrition; ROC, receiver's operating characteristic; RR, relative risk; SE, sensitivity; SGA, Subjective Global Assessment; SP, specificity.

* **Corresponding author:** Ping Zhu, email pingzhu@ext.jnu.edu.cn

† These authors contributed equally to this work.

stands out as a considerable concern, frequently leading to delayed wound healing⁽⁵⁾. Nutritional intervention is vital to DFU treatment, potentially reducing hospital stays, controlling inflammation and enhancing healing outcomes^(6–8). Consequently, early identification and diagnosis of malnutrition are crucial. However, the optimal method for assessing the nutritional status of patients with DFU remains uncertain.

Traditional nutritional assessments frequently rely on indicators such as body weight, BMI and biochemical parameters. A low BMI ($< 18.5 \text{ kg/m}^2$) is a strong predictor of non-healing and mortality in patients with DFU⁽³⁾. Weight loss, particularly involving skeletal muscle reduction, is independently associated with amputations⁽⁹⁾. Decreased serum albumin levels elevate the risk of treatment failure in osteomyelitis⁽¹⁰⁾ and mortality in patients with DFU⁽¹¹⁾. However, relying solely on a single parameter or index may not effectively identify adult malnutrition.

Internationally, multidimensional nutritional assessment tools such as the Subjective Global Assessment (SGA) and the recently introduced Global Leadership Initiative on Malnutrition (GLIM) criteria are commonly utilised to evaluate malnutrition. SGA incorporates eight semi-quantitative indicators, including medical history and physical examination, allowing for a swift and reproducible assessment of nutritional status^(12,13). It is preferred as a nutritional assessment and prognostic tool for inpatients in various fields, such as internal medicine and general surgery⁽¹⁴⁾, and specific clinical contexts, such as renal disease⁽¹⁵⁾, liver transplantation⁽¹⁶⁾, and critical care⁽¹³⁾. While SGA is considered a 'semi-gold standard', only one study has established the association between malnutrition assessed by SGA and short-term non-healing in patients with DFU⁽⁵⁾.

The GLIM consensus was developed to establish standardised diagnostic criteria for adult malnutrition, aiming to facilitate international comparisons of malnutrition prevalence and the effectiveness of nutritional interventions. This diagnostic framework involves two steps: identifying nutritional risk status and conducting a nutritional assessment, followed by severity grading based on phenotype and aetiology indicators. Although applicable across diverse settings and patient groups, further validation through retrospective or prospective studies is necessary to establish its clinical validity⁽¹⁷⁾. Only two small-scale studies have incorporated GLIM into the nutritional assessment of patients with DFU, providing limited predictive value concerning ulcer outcomes^(18,19). There is a lack of data regarding the application of GLIM among Chinese patients with DFU.

Therefore, our study aimed to compare the prevalence of malnutrition in middle-aged and older Chinese patients with DFU using the GLIM criteria and SGA. Furthermore, a modified Poisson regression model was used to investigate the relationship between malnutrition and the non-healing of ulcers over 6 months.

Methods

Study population

A single-centre, retrospective cohort study was conducted at the Endocrinology Department of Sun Yat-sen Memorial Hospital, Sun Yat-sen University, involving patients hospitalised for the

first time with DFU between October 2016 and June 2021. Inclusion criteria comprised a diagnosis of type 2 diabetes and DFU, and age ≥ 18 years. Exclusion criteria included pregnancy or lactation, presence of Charcot's foot without ulcers, acute pancreatitis, severe liver disease, active malignancy, ongoing immunosuppressive therapy, history of radiation therapy at the ulcer site, additional ulcers such as pressure ulcers and non-healing wounds after significant amputation, and those cases with incomplete medical data. The study was approved by the Medical Ethics Committee of Sun Yat-sen Memorial Hospital, Sun Yat-sen University (SYSKY-2023-883-01), which waived the requirement for written consent following the China legislation governing the ethical review of biomedical research involving human subjects. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline (online Supplementary Table 1).

Baseline information collection

A standardised data collection form was employed to gather patient information, including date of birth, sex, smoking status, history of foot ulcers, lower limb amputation, duration of diabetes, associated complications and characteristics of foot lesions. Smoking status was categorised as active or ceased within the preceding month. Samples of wound secretions were obtained during the initial debridement for pathogen culture and drug sensitivity testing. The ulcer's area (cm^2) was calculated as the product of the longest measurement in length and the width perpendicular to it⁽²⁰⁾. Within 24 h of admission, standard procedures were utilised to measure leucocytes count, Hb, albumin, creatinine, TAG, total cholesterol, HDL-cholesterol, LDL-cholesterol, glycated Hb (HbA_{1c}) and urinary protein. Moreover, some patients were evaluated for C-reactive protein and procalcitonin levels. Estimated glomerular filtration rate (eGFR) was calculated using the Cockcroft–Gault formula for women ($\text{eGFR} = \text{body weight} \times 0.85 \times (140 - \text{age})/72 / \text{creatinine}$) and for men ($\text{eGFR} = \text{body weight} \times (140 - \text{age})/72 / \text{creatinine}$)⁽²¹⁾. Lower limb arterial disease encompasses acute or severe limb ischaemia, intermittent claudication, rest pain, or a history of peripheral vascular reconstruction⁽²²⁾. It is characterised by reduced or absent distal arterial pulsations, ankle–brachial index < 0.9 , toe–brachial index < 0.75 , or evidence of lower limb arterial stenosis or occlusion determined through Doppler ultrasound or arteriography. Diabetic neuropathy was defined as two or more abnormalities among the following five tests: abnormal temperature sensation, diminished or absent sensation upon nylon filament testing, abnormal vibration perception, absence of ankle reflex, and slowing nerve conduction in two or more nerves. Diabetic foot infections were evaluated using the classification developed by the Infectious Diseases Society of America⁽²³⁾. Various classification systems have been employed to describe the severity of DFU, such as Wagner's grading and the SINBAD system⁽²⁰⁾. Among these, the SINBAD system is widely regarded as the preferred framework for communication among healthcare professionals, characterising the severity of DFU. In our study, the SINBAD system was utilised to assign a score of 0 or 1 based on ulcer site (S), ischaemia (I), neuropathy (N), bacterial infection (B) and ulcer depth (D), where a total score of SINBAD ≥ 4 indicated severe DFU.



Nutritional evaluation

Within 48 h of admission, a proficient nutritionist conducted routine nutritional assessments. Patient data were gathered concerning dietary intake the week before admission or over an extended period, self-reported weight changes, gastrointestinal symptoms and activity levels. Height, weight, non-dominant calf circumference (CC), triceps skinfold thickness (TSF) and mid-arm circumference (MAC) were measured using established methods^(24,25). For patients unable to stand, knee length was used to estimate height⁽²⁶⁾, while a wheelchair scale measured weight. BMI and mid-upper arm muscle circumference (MAMC) were calculated as follows: BMI (kg/m^2) = weight (kg)/height (m^2) and MAMC (cm) = $\text{MAC (cm)} - \pi \times \text{TSF (cm)}$.

Nutritional Risk Screening-2002 (NRS-2002) scores ≥ 3 indicate nutritional risk presence⁽²⁷⁾. SGA assesses weight fluctuations, dietary intake, functional capacity, gastrointestinal symptoms, metabolic stress, subcutaneous fat loss, muscle wasting, and ankle or sacral oedema. Nutritional status is categorised as A for well-nourished, B for moderately malnourished or C for severely malnourished⁽¹²⁾. In this study, moderate and severe malnutrition were combined and designated as malnutrition.

The GLIM criteria were applied for *post hoc* routine nutritional assessment data analysis. As DFU meets the aetiology criterion for disease/inflammation, C-reactive protein ($> 10 \text{ mg/l}$) or leucocytes ($> 10.0 \times 10^9/\text{l}$)⁽²⁸⁾ were utilised as inflammation-supporting indicators. Malnutrition was diagnosed when patients with NRS-2002 scores ≥ 3 satisfied at least one phenotype criterion: unintentional weight loss of $\geq 5\%$ within the past 6 months or $\geq 10\%$ for > 6 months⁽¹⁷⁾; low BMI: $< 18.5 \text{ kg}/\text{m}^2$ if < 70 years or $< 20 \text{ kg}/\text{m}^2$ if ≥ 70 years⁽¹⁷⁾; and reduced muscle mass: CC serves as a surrogate indicator, with a CC ≤ 30 cm for men and ≤ 29 cm for women⁽²⁹⁾.

Diabetic foot ulcer treatment and outcomes

Following the guidelines established by the International Working Group on the Diabetic Foot, a multidisciplinary team provided personalised care to all patients. Malnourished individuals received systematic dietary advice and, when necessary, oral or intravenous nutritional supplementation. Decisions regarding blood flow reconstruction or major amputation were made based on guidelines and team consensus.

Post-discharge wound care was facilitated through WeChat communication, allowing for sharing media files, such as photos and videos of the DFU, to instruct family members in wound management. Patients attended foot clinics monthly for dressing changes, and those with deteriorating wounds were readmitted for further intervention. A 6-month follow-up ensued after enrolment, with the primary outcome being complete wound healing, defined as complete epithelialisation of the lesion over two consecutive follow-up visits, encompassing the foot and ankle distal recovery to the amputation site. Details regarding major amputations and fatalities were obtained through medical record inquiries or phone communications.

Statistical analysis

MedCalc statistical software was used to determine an appropriate sample size based on a significance level of 0.05 and an allowable error of 0.10 (90% power). This calculation resulted in a minimum expected AUC of 0.70, a null hypothesis value of 0.5 and a ratio of well-nourished to malnourished of 3.237, based on a previous study conducted using the GLIM to determine nutritional status in patients with DFU⁽¹⁸⁾. The minimum sample size required was 119. Anticipating a response rate of 90% would result in a total sample size of 132. With these assumptions, 398 cases had sufficient power to detect the effect size.

Data were analysed using SPSS version 24.0 software. The Kolmogorov–Smirnov normality test was applied to continuous data. Normally distributed data were expressed as means and standard deviations, while non-parametric data were presented as medians and interquartile ranges (IQR). Inter-group comparisons were conducted using non-paired *t* tests or Mann–Whitney *U* tests. Categorical data were presented as frequencies (*n*) and percentages (%), with inter-group comparisons performed using the χ^2 test.

Cohen's kappa (κ) coefficient was employed to assess the consistency between SGA and GLIM criteria in diagnosing malnutrition. The κ values were interpreted as follows: 0–0.20 for slight agreement, 0.21–0.40 for fair agreement, 0.41–0.60 for moderate agreement, 0.61–0.80 for substantial agreement and 0.81–1.00 for almost perfect agreement⁽³⁰⁾. The receiver's operating characteristic (ROC) curve analysis was employed to assess the concurrent validity of the GLIM criteria, using SGA as the reference. Sensitivity (SE), specificity (SP), positive predictive value and negative predictive value were calculated, with values $> 80\%$ classified as good, values $< 80\%$ and $> 50\%$ regarded as fair, and values $< 50\%$ considered poor⁽³¹⁾. Modified Poisson regression analysis was conducted to estimate relative risk (RR) and 95% (CI for the association between malnutrition and ulcer healing. Covariates with $P < 0.1$ in univariate analysis were included in the multivariate regression analysis. Given the inclusion of BMI in the GLIM criteria, it was omitted from the multivariate regression analysis for outcome prediction. Subgroup analysis was conducted to detect significant interactions. The DeLong test, performed using MedCalc software, compared the area under the ROC curve to predict non-healing between the two nutritional assessment methods. Statistical significance was set at a two-sided *P*-value of 0.05.

Results

Baseline characteristics

In our study, out of 500 patients admitted to the hospital with DFU, 398 were included in the analysis. Figure 1 illustrates the flow chart of the research and the selection of eligible participants. Baseline characteristics are summarised in Table 1. The mean age was 66.3 ± 11.9 years, with men comprising 64.6% of the sample. The median duration of type 2 diabetes was 10.0 (IQR 5.0, 20.0) years, with 38.9% having concurrent CVD, approximately half of whom



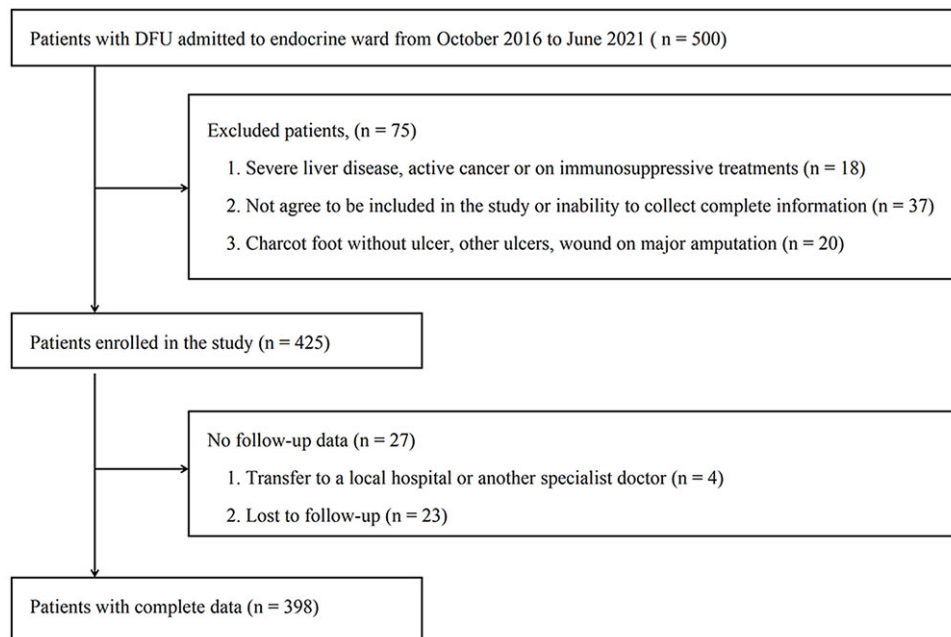


Fig. 1. Flow chart showing the selection of eligible participants with diabetic foot ulcers.

also had diabetic kidney disease. Among them, fifty-one cases (12.8%) had ulcers on both feet, and the analysis focused on the more severe foot condition based on the SINBAD score. The duration of DFU was 2.0 (0.8, 4.0) months, with 268 cases (67.3%) classified as neuro-ischaemic ulcers, sixty-seven (16.8%) as ischaemic ulcers and thirty-nine (9.8%) as neuropathic ulcers. Patients with moderate to severe infections accounted for 333 cases (83.7%) and sixty-seven (16.8%) underwent minor amputations.

A total of 297 patients (74.6%) were identified as having nutritional risk. The patients had a median BMI of 22.9 kg/m², and based on the GLIM criteria, forty-three cases (10.8%) had a low BMI, while eighty-one (20.4%) experienced weight loss of $\geq 5\%$. Compared with well-nourished individuals, patients with malnutrition were older and more likely to have co-morbidities such as stroke. They also exhibited more severe foot lesions and infections, displaying lower BMI, CC, MAMC, albumin, Hb and serum lipid levels (all $P < 0.05$). However, there were no significant differences between the two groups regarding the duration of type 2 diabetes, types of foot ulcers, HbA1c levels and eGFR (all $P > 0.05$).

Diagnosing malnutrition using two assessment tools

With SGA, 191 cases (48.0%) were categorised as moderately malnourished and eleven (2.8%) as severely malnourished, resulting in an overall malnutrition rate of 50.8%. According to the GLIM criteria, the malnutrition rate was 42.7%. The agreement between the two assessment tools for diagnosing malnutrition was moderate ($\kappa = 0.50$, $P = 0.043$). Using SGA as the reference, the GLIM criteria exhibited an area under the ROC curve of 0.75 (95% CI 0.70, 0.79), with a sE of 67.3% (95% CI 60.4%, 73.7%) and SP of 82.7% (95% CI 76.6%, 87.7%). The positive predictive value was 80.0%, and the negative predictive

value was 71.1%. As depicted in Fig. 2, among the 136 patients diagnosed with malnutrition by both assessment tools, thirty-four were not classified as malnourished by SGA and sixty-six were not classified as malnourished by the GLIM criteria.

Malnutrition and adverse outcomes of diabetic foot ulcer

Within 6 months, 205 cases of ulcers did not heal (51.5%), including forty-four that underwent significant amputation and nineteen resulting in death. The non-healing rate of ulcers in patients with malnutrition was significantly higher than in well-nourished patients (SGA: 71.3% *v.* 31.1%; GLIM: 66.5% *v.* 40.4%, both $P < 0.001$). After adjusting for confounding factors such as age, sex, smoker, co-morbidities, SINBAD score, gangrene, BMI, and levels of HbA1c, eGFR, and albumin, modified Poisson regression analysis revealed that malnutrition, as assessed by SGA, was an independent risk factor for non-healing ulcers (RR: 1.84; 95% CI 1.45, 2.34) (Table 2). Similarly, patients identified as malnourished by GLIM had a 1.28 times higher risk of non-healing ulcers than well-nourished individuals (RR: 1.28; 95% CI 1.05, 1.56). Furthermore, the analysis of predictive values for non-healing indicated that SGA exhibited a higher area under the ROC curve compared with the GLIM criteria (0.70 (0.65–0.75) *v.* 0.63 (0.58–0.65), $P < 0.01$) (Fig. 3).

Subgroup analysis further revealed an interaction between malnutrition, as assessed by SGA, and albumin levels on non-healing outcomes ($P = 0.034$) (Table 3). In the subgroup with albumin levels ≥ 30 g/l (190 cases), the non-healing rate was higher in patients with malnutrition compared with those well-nourished (67.8% *v.* 22.1%, $P < 0.001$). After adjusting for potential confounders, malnutrition significantly increased the risk of non-healing (RR: 2.67; 95% CI 1.80, 3.97, $P < 0.001$). In the subgroup with albumin levels < 30 g/l (208 cases), this association remained significant after adjusting for multiple

Table 1. Baseline characteristics of patients with DFU by nutritional status

Variables	Total (n 398)		GLIM criteria				P	SGA				P
	n	%	Well-nourished (n 228)		Malnutrition (n 170)			Well-nourished (n 196)		Malnutrition (n 202)		
Age (years)												
Mean	66.3		64.0		69.4		< 0.001	65.1		67.5		0.051
SD	11.9		12.4		10.5			12.5		11.2		
Men	257	64.6	153	67.1	104	61.2	0.221	136	69.4	121	59.9	0.048
Smoking	106	26.6	60	26.3	46	27.1	0.868	55	28.1	51	25.2	0.526
Duration of DM (years)												
Median	10.0		10.0		10.0		0.922	10.0		10.0		0.607
25–75th quartiles	5.0, 20.0		5.3, 18.8		5.0, 20.0			5.0, 20.0		5.8, 19.3		
DPN	307	77.1	180	78.9	127	74.7	0.319	155	79.1	152	75.2	0.363
PAD	335	84.2	186	81.6	149	87.6	0.101	161	82.1	174	86.1	0.275
IHD	102	25.6	53	23.2	49	28.8	0.207	40	20.4	62	30.7	0.019
Stroke	78	19.6	32	14.0	46	27.1	0.001	28	14.3	50	24.8	0.009
DKD	198	49.7	118	51.8	80	47.1	0.354	100	51.0	98	48.5	0.617
Duration of DFU (months)												
Median	2.0		1.0		2.0		0.004	1.0		2.0		0.053
25–75th quartiles	0.8, 4.0		0.7, 4.0		1.0, 4.3			0.7, 3.4		1.0, 4.0		
SINBAD sore												
Median	4		4		5		0.007	4		5		< 0.001
25–75th quartiles	4, 5		4, 5		4, 5			3, 5		4, 5		
Moderate to severe infected	333	83.7	182	79.8	151	88.8	0.016	147	75.0	186	92.1	< 0.001
MDR	89	22.4	38	16.7	51	30.0	0.002	36	18.4	53	26.2	0.060
Gangrene	163	41.0	73	32.0	90	52.9	< 0.001	59	30.1	104	51.5	< 0.001
BMI (kg/m ²)												
Median	22.9		24.2		21.2		< 0.001	23.9		21.8		< 0.001
25–75th quartiles	20.9, 25.6		22.5, 27.0		19.0, 22.9			22.1, 26.7		19.8, 24.2		
	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
CC (cm)	31.4	4.1	33.7	3.1	28.3	3.1	< 0.001	33.0	3.4	29.9	4.1	< 0.001
MAMC (cm)	23.4	2.5	24.2	2.4	22.3	2.3	< 0.001	24.2	2.2	22.6	2.5	< 0.001
Albumin (g/l)	29.2	6.3	30.1	6.4	28.1	6.0	0.002	31.9	5.8	26.6	5.7	< 0.001
Hb (g/l)	106.4	21.9	109.5	21.1	102.2	22.5	0.001	114.0	20.2	99.0	21.2	< 0.001
TAG (mmol/l)												
Median	1.2		1.2		1.1		0.006	1.2		1.1		0.032
25–75th quartiles	0.9, 1.6		0.9, 1.7		0.8, 1.4			0.9, 1.7		0.8, 1.5		
TC (mmol/l)	3.8	1.3	3.9	1.3	3.8	1.3	0.491	4.1	1.3	3.6	1.3	0.001
HDL-cholesterol (mmol/l)	0.9	0.3	0.9	0.3	0.9	0.2	0.873	0.9	0.2	0.8	0.3	0.008
LDL-cholesterol (mmol/l)	2.4	0.9	2.4	0.9	2.4	0.9	0.535	2.6	0.9	2.3	0.9	0.001
Leucocytes ($\times 10^9/l$)												
Median	10.0		9.8		10.6		0.071	8.96		11.48		< 0.001
25–75th quartiles	7.5, 13.5		7.3, 12.9		8.0, 14.5			7.2, 12.2		8.2, 15.3		
HbA1c > 8.0 %												
n	221		124		91		0.865	105		110		0.860
%	54.4		54.4		53.5			53.6		54.5		
eGFR (ml/min/1.73m ²)	73.5	32.4	71.3	31.2	75.2	33.5	0.425	73.3	29.2	72.7	34.5	0.747

DPN, diabetic peripheral neuropathy; PAD, peripheral arterial disease; IHD, ischaemic heart disease; DKD, diabetic kidney disease; DFU, diabetic foot ulcers; SINBAD, site, ischaemia, neuropathy, bacterial infection, area and depth; MDR, multidrug-resistant; CC, calf circumference; MAMC, mid-upper arm muscle circumference; TC, total cholesterol; eGFR, estimated glomerular filtration rate.

Values are presented as mean \pm SD or the median (25–75th quartiles).

Boldface type indicates $P < 0.05$.

variables (RR: 1.32; 95% CI 1.02, 1.72, $P = 0.036$). This observation suggests a substantial correlation between malnutrition and adverse outcomes regardless of albumin levels.

Furthermore, an interaction was observed between malnutrition identified by the GLIM criteria and the eGFR regarding non-healing outcomes ($P = 0.046$) (Table 3). Among patients with eGFR ≥ 60 ml/min/1.73m² (260 cases), those with malnutrition exhibited a significantly higher non-healing rate compared with individuals who were well-nourished (67.0% *v.* 33.1%, $P < 0.001$). The modified Poisson regression analysis revealed that malnutrition increased the risk of non-healing (RR: 1.46; 95% CI 1.10, 1.94, $P = 0.009$). However, among patients

with eGFR < 60 ml/min/1.73m² (138 cases), the association between malnutrition and healing was not substantial (RR: 1.13; 95% CI 0.86, 1.48, $P = 0.376$).

Discussion

To the best of our knowledge, this study makes the first attempt to assess the efficacy of the GLIM criteria and SGA in identifying malnutrition among patients with DFU. Our findings revealed a malnutrition prevalence of approximately 51% according to SGA and about 43% according to the GLIM criteria, with a

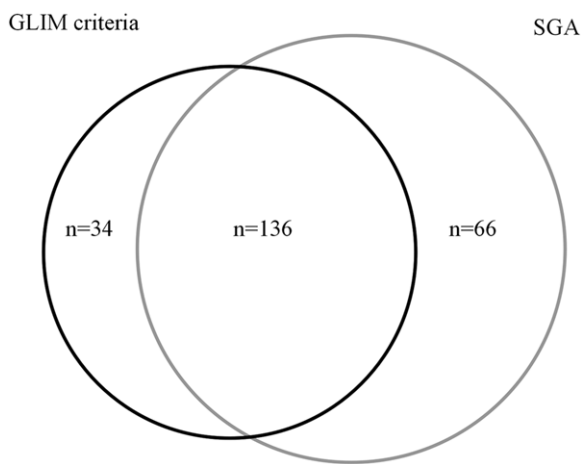


Fig. 2. Overlap of patients with malnutrition between the GLIM criteria and SGA for 398 hospitalised patients with diabetic foot ulcers included in a *post hoc* analysis on the validity of the GLIM criteria compared with SGA. GLIM, Global Leadership Initiative on Malnutrition; SGA, Subjective Global Assessment.

moderate level of agreement between the tools. SGA exhibited superior predictive ability for the non-healing outcomes of DFU compared with the GLIM criteria. Furthermore, our modified Poisson regression analysis indicated that malnutrition assessed by SGA independently increased the risk of non-healing. However, GLIM criteria were associated with poorer ulcer healing, specifically in patients with $eGFR \geq 60$ ml/min/1.73m².

SGA is a widely utilised multidimensional nutritional assessment tool in clinical settings, offering a rapid means of determining nutritional status with SE, reliability and predictive potential for various disease outcomes^(13–16). It further demonstrates substantial agreement with other assessment methods⁽³²⁾. According to SGA, over half of patients with DFU experience malnutrition, likely due to reduced nutrient intake, elevated energy and protein requirements, heightened losses, and inflammation, all of which render patients with DFU susceptible to malnutrition⁽⁵⁾. As anticipated, we found that malnutrition, as determined by SGA, increased the risk of non-healing ulcers, aligning with the findings of Zhang SS *et al.*, who reported that 69% of patients with malnutrition failed to achieve healing within 6 months⁽⁵⁾.

The GLIM consensus introduces a novel approach to diagnosing adult malnutrition, endorsing validation using ‘semi-gold standard’ methods such as SGA⁽¹⁷⁾. Brito JE *et al.*⁽³³⁾ reported that the GLIM criteria effectively identified malnutrition in hospitalised patients. Moreover, the GLIM criteria have demonstrated applicability for nutritional assessment in acute and critically ill patients^(34–36). However, a retrospective study indicated good SP (> 80%) and reduced sE (< 80%) for the GLIM criteria when omitting ‘low muscle mass’ as a phenotype criterion for malnutrition diagnosis⁽³⁷⁾. Furthermore, the accuracy of GLIM diagnosis varies depending on the screening methods used. In a large-scale prospective study involving patients with cancer undergoing major abdominal surgery, GLIM diagnosis utilising the Mini Nutritional Assessment Short-Form (MNA-SF) screening demonstrated the highest consistency with SGA ($\kappa = 0.56$) compared with NRS-2002, with good SP (83%),

fair sE (72%) and a negative predictive value of 82%⁽³⁸⁾. A recent meta-analysis of subgroup data from seven eligible studies involving 2137 hospitalised patients revealed the superior diagnostic value of GLIM criteria over SGA (sE 81%, SP 80% and area under the ROC curve 0.87)⁽³⁹⁾.

Only two small-sample studies have employed the GLIM criteria to evaluate the nutritional status of patients with DFU. In a prospective study involving seventy-seven patients with ischaemic foot ulcers, muscle mass was assessed using arm circumference, revealing a malnutrition prevalence of 71.4% (the nutritional screening method was unreported)⁽¹⁹⁾. Another study with 110 individuals with DFU employed bioelectrical impedance analysis to assess diminished muscle mass, identifying a malnutrition rate of 23.6% (screened using NRS-2002)⁽¹⁸⁾. However, neither study observed a correlation between malnutrition and outcomes (such as non-healing ulcers or death), nor did they validate diagnostic accuracy. In our research, malnutrition was diagnosed in 42.7% of patients, consistent with findings from a meta-analysis (44.2%)⁽³⁹⁾. Discrepancies in malnutrition rates can be attributed to variations in patient characteristics, different criteria for assessing ‘low muscle mass’, the potential impact of oedema on measurement of fat-free mass and CC obtained through bioelectrical impedance analysis, or diverse nutritional screening methods^(40,41).

Moreover, GLIM criteria exhibited good SP and fair sE in identifying malnutrition in patients with DFU compared with SGA. Based on expert consensus, the GLIM criteria aim to establish a diagnostic framework for protein-energy malnutrition. They share core assessment indicators with SGA (such as reduced food intake, gastrointestinal symptoms, weight and body composition changes, and stress). This similarity explains the moderate agreement between the two tools ($\kappa = 0.50$). Our study findings indicate that the GLIM criteria demonstrate reasonable SP (82.7%) but lower SE (67.3%) in assessing malnutrition among patients with DFU. This observation suggests that while the GLIM criteria may effectively identify a more significant number of well-nourished patients with DFU, they may still overlook some cases of malnutrition. Several potential reasons account for this discrepancy. One reason is the limited accuracy of BMI in distinguishing body composition and malnutrition according to GLIM guidelines⁽¹⁷⁾. For instance, oedema could overestimate BMI, although SGA might still categorise these patients as malnourished. Ascites or oedema in patients with liver cirrhosis could impede agreement between GLIM and SGA⁽⁴²⁾. In addition, the methods used by the two tools to measure muscle mass are different. GLIM recommends sophisticated techniques such as using dual-energy X-ray absorptiometry, bioelectrical impedance analysis, computed tomography, or MRI for assessing muscle mass, or cost-effective and accessible physical examinations or body measurements such as CC, especially considering Asian standards⁽¹⁷⁾. Given the likelihood of low CC in patients with DFU and its superior predictability of functional and frailty indicators over MAC⁽⁴³⁾, CC was chosen to gauge muscle mass. However, the presence of oedema and severe obesity could impact its effectiveness. SGA assesses muscle mass loss across various muscle groups

Table 2. Modified Poisson regression analyses of risk factors for a 6-month wound unhealing among patients with DFU

Characteristics	GLIM criteria*			SGA†		
	RR	95 % CI	P	RR	95 % CI	P
Malnutrition‡	1.28	1.05, 1.56	0.016	NA		NA
Malnutrition§	NA		NA	1.84	1.45, 2.34	< 0.001
Age	1.00	0.99, 1.01	0.671	1.00	0.99, 1.01	0.626
Men	1.00	0.82, 1.22	0.998	1.05	0.86, 1.28	0.666
Current smoker	1.21	0.99, 1.48	0.062	1.21	0.99, 1.48	0.063
Previous DFU	1.08	0.91, 1.29	0.375	1.10	0.93, 1.31	0.264
Hypertension	0.85	0.70, 1.04	0.118	0.90	0.74, 1.10	0.313
IHD	1.10	0.92, 1.31	0.303	1.09	0.92, 1.30	0.332
Stroke	1.08	0.88, 1.32	0.487	1.07	0.87, 1.30	0.530
Lung disease	1.18	0.99, 1.42	0.070	1.16	0.97, 1.38	0.115
Duration of DFU ≥ 2 months	1.30	1.06, 1.60	0.013	1.32	1.08, 1.62	0.006
SINBAD score ≥ 4	0.87	0.66, 1.14	0.309	0.84	0.65, 1.09	0.186
MDR	1.17	0.96, 1.41	0.115	1.19	0.99, 1.42	0.058
Gangrene	1.55	1.26, 1.91	< 0.001	1.55	1.27, 1.90	< 0.001
BMI < 18.5 kg/m ²	NA		NA	0.97	0.77, 1.23	0.812
Albumin < 30 g/l	1.45	1.15, 1.84	0.002	1.26	1.00, 1.58	0.047
Hb < 100 g/l	1.06	0.86, 1.31	0.599	0.99	0.80, 1.22	0.933
HDL-cholesterol < 1.03 mmol/l	1.01	0.80, 1.29	0.918	1.03	0.82, 1.28	0.826
HbA1c ≥ 8.0 %	0.91	0.75, 1.10	0.325	0.93	0.77, 1.12	0.396
eGFR < 60 ml/min/1.73m ²	1.03	0.86, 1.25	0.723	1.06	0.89, 1.27	0.513
Albuminuria	1.05	0.84, 1.32	0.670	1.01	0.81, 1.25	0.951

DFU, diabetic foot ulcers; GLIM, Global Leadership Initiative on Malnutrition; SGA, Subjective Global Assessment; RR, relative risk; IHD, ischaemic heart disease; SINBAD, site, ischaemia, neuropathy, bacterial infection, area and depth; MDR, multidrug-resistant; NA, not available; eGFR, estimated glomerular filtration rate.

Boldface type indicates *P* < 0.05.

* Adjusted by age, sex, smoker, IHD, stroke, lung disease, ulcers duration, gangrene, SINBAD score, Hb, HDL-cholesterol, albumin, HbA1c, eGFR, albuminuria and MDR.

† Adjusted by age, sex, smoker, IHD, stroke, lung disease, ulcers duration, gangrene, SINBAD score, Hb, HDL-cholesterol, albumin, HbA1c, eGFR, albuminuria, MDR and BMI.

‡ Moderate to severe malnutrition defined by GLIM criteria.

§ Moderate to severe malnutrition defined by SGA.

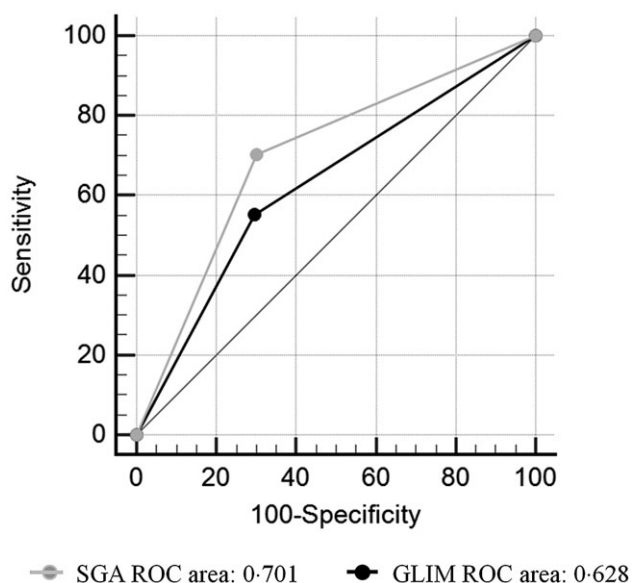


Fig. 3. Sensitivity and specificity by ROC curve for the predictive value of clinical outcomes based on malnutrition obtained by the GLIM criteria and SGA among patients with diabetic foot ulcers. ROC, receiver's operating characteristic; GLIM, Global Leadership Initiative on Malnutrition; SGA, Subjective Global Assessment.

(temporal, clavicular, shoulder, scapular, interosseous muscles, knees, quadriceps and gastrocnemius), possibly offering a more suitable approach for well-trained healthcare professionals. Furthermore, SGA's focus on recent weight

fluctuations enhances its ability to identify early-stage malnutrition compared with the GLIM criteria.

In our analysis of the clinical effectiveness of nutritional assessment tools, SGA and GLIM criteria for diagnosing malnutrition were independently associated with short-term non-healing of DFU. We further demonstrated that SGA exhibited superior predictive capability for non-healing compared with the GLIM criteria. SGA effectively predicted prognosis across all patients with DFU, while the GLIM criteria showed limited performance in predicting ulcer healing among those with impaired kidney function (eGFR < 60 ml/min/1.73m²). It is worth noting that subgroup analysis with relatively wide CI hinted at a trend of heightened non-healing associated with malnutrition. Moreover, patients with impaired kidney function frequently experience microvascular damage, an increased risk of neuropathy and compromised vascular function, all of which were correlated with suboptimal wound healing and survival rates⁽¹¹⁾.

Notable strengths of our study include the pioneering evaluation of the performance of the GLIM criteria in patients with DFU and its comparison with the semi-gold standard SGA, a widely accepted nutritional assessment method. Moreover, data collection and nutritional assessment were executed by well-trained, dedicated nutritionists. However, several limitations warrant comment. First, the study's single-centre and retrospective design may limit generalisability, although comprehensive data on GLIM criteria and confounding factors, such as co-morbidities and biochemical markers, were obtained. Second, the primary muscle mass assessment methods recommended by the GLIM consensus were not feasible; however, obtaining dual-energy X-ray absorptiometry,

Table 3. Relative risk (95 % CI) for a 6-month wound unhealing according to nutritional status stratified by potential risk factors among patients with DFU

Subgroup	n	GLIM criteria				SGA			
		RR	95 % CI	P	P interaction	RR	95 % CI	P	P interaction
Age (years)					0.572				0.157
< 65	169	1.47	1.05, 2.06	0.026		1.57	1.12, 2.20	0.009	
≥ 65	229	1.19	0.93, 1.53	0.165		2.04	1.46, 2.86	< 0.001	
Sex					0.127				0.372
Men	257	1.08	0.84, 1.38	0.555		1.69	1.30, 2.19	< 0.001	
Women	141	1.73	1.20, 2.49	0.004		2.27	1.39, 3.73	0.001	
Current smoking					0.820				0.694
Yes	106	1.15	0.78, 1.71	0.483		1.62	1.10, 2.40	0.015	
No	292	1.33	1.05, 1.68	0.017		1.94	1.43, 2.63	< 0.001	
BMI (kg/m ²)					NA				0.988
< 22.89 (median)	196	NA		NA		1.83	1.26, 2.66	0.002	
≥ 22.89	202	NA		NA		1.86	1.32, 2.62	< 0.001	
HbA1c (%)					0.592				0.749
< 8.0	182	1.16	0.89, 1.51	0.275		1.46	1.05, 2.02	0.023	
≥ 8.0	216	1.32	0.99, 1.77	0.058		2.15	1.52, 3.04	< 0.001	
eGFR (ml/min/1.73m ²)					0.046				0.575
< 60	138	1.13	0.86, 1.48	0.376		1.58	1.12, 2.22	0.009	
≥ 60	260	1.46	1.10, 1.94	0.009		2.01	1.45, 2.80	< 0.001	
Albumin (g/l)					0.356				0.034
< 30	208	1.10	0.88, 1.36	0.415		1.32	1.02, 1.72	0.036	
≥ 30	190	1.55	1.06, 2.28	0.025		2.67	1.80, 3.97	< 0.001	
Gangrene					0.897				0.746
Yes	163	1.16	0.93, 1.45	0.200		1.57	1.19, 2.07	0.001	
No	235	1.37	0.95, 1.96	0.088		2.19	1.46, 3.27	< 0.001	
Duration of DM (years)					0.063				0.178
< 10	144	0.86	0.60, 1.25	0.430		1.55	1.03, 2.34	0.036	
≥ 10	254	1.56	1.22, 2.01	0.001		2.12	1.55, 2.89	< 0.001	

DFU, diabetic foot ulcers; GLIM, Global Leadership Initiative on Malnutrition; SGA, Subjective Global Assessment; RR, relative risk; NA, not available; eGFR, estimated glomerular filtration rate.

Adjusted by age, sex, smoker, IHD, stroke, lung disease, ulcers duration, gangrene, SINBAD score, Hb, HDL-cholesterol, albumin, HbA1c, eGFR, albuminuria, MDR and BMI except for the corresponding subgroup variables.

Boldface type indicates $P < 0.05$.

bioelectrical impedance analysis, computed tomography or MRI is frequently challenging. Further research could explore combining CC with other indicators, such as MAMC and muscle functions⁽⁴⁴⁾. Third, reliance on self-reported data for food intake and weight changes may introduce bias. Fourth, focusing on baseline nutritional status without tracking dynamic indicators and the relatively brief follow-up duration may not accurately capture long-term effects. Fifth, including cases with bilateral and multiple ulcers contributes to heterogeneity and reflects genuine characteristics of the DFU population. Finally, the lack of information regarding oedema and obesity in the population may lead to an under-estimation of malnutrition due to their impact on body measurements such as CC and MAC.

Conclusions

Malnutrition is prevalent among hospitalised patients with DFU. While both nutritional assessment tools could identify patients with DFU at risk, SGA demonstrated superior capability in predicting non-healing ulcers. The GLIM criteria could be a better independent prognostic indicator for patients with $eGFR \geq 60$ ml/min/1.73m². These findings emphasise the significance of employing appropriate assessment tools for malnutrition detection, facilitating timely nutritional intervention and optimising clinical outcomes.

Acknowledgements

The authors would like to express their gratitude to the participants for their contribution to the research.

This work was supported by the Guangdong Basic and Applied Basic Research Foundation (2020A15110963), the Guangdong Clinical Research Center for Metabolic Diseases (2020B1111170009), the Guangzhou Key Laboratory for Metabolic Diseases (202102100004), and the Guangzhou Municipal Science and Technology Project (2023A03J0985).

Z. M. Y., C. J. J. and P. Z. conceived and designed the study; Z. M. Y., G. J. L. and C. Z. W. wrote and revised the manuscript; Y. Z. and C. Y. W. performed the collection of data; Z. M. Y. and Y. Y. Z. carried out the statistical analysis and interpretation of data; C. Z. W., C. G. C., P. Z. and J. M. R. supervised the data analysis and interpretation; C. Z. W. and P. Z. were responsibility for the integrity and accuracy of the data. All authors critically reviewed and approved the final manuscript.

The authors declare no conflict of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit <https://doi.org/10.1017/S0007114524000874>

References

- Xu Z & Ran X (2016) Diabetic foot care in China: challenges and strategy. *Lancet Diabetes Endocrinol* **4**, 297–298.
- Singh N, Armstrong DG & Lipsky BA (2005) Preventing foot ulcers in patients with diabetes. *JAMA* **293**, 217–228.
- Gazzaruso C, Gallotti P, Pujia A, *et al.* (2021) Predictors of healing, ulcer recurrence and persistence, amputation and mortality in type 2 diabetic patients with diabetic foot: a 10-year retrospective cohort study. *Endocrine* **71**, 59–68.
- Armstrong DG, Boulton AJM & Bus SA (2017) Diabetic foot ulcers and their recurrence. *N Engl J Med* **376**, 2367–2375.
- Zhang SS, Tang ZY, Fang P, *et al.* (2013) Nutritional status deteriorates as the severity of diabetic foot ulcers increases and independently associates with prognosis. *Exp Ther Med* **5**, 215–222.
- Basiri R, Spicer MT, Levenson CW, *et al.* (2020) Nutritional supplementation concurrent with nutrition education accelerates the wound healing process in patients with diabetic foot ulcers. *Biomedicine* **8**, 263.
- Armstrong DG, Hanft JR, Driver VR, *et al.* (2014) Effect of oral nutritional supplementation on wound healing in diabetic foot ulcers: a prospective randomized controlled trial. *Diabetic Med: J Br Diabetic Assoc* **31**, 1069–1077.
- Basiri R, Spicer M, Levenson C, *et al.* (2022) Improving dietary intake of essential nutrients can ameliorate inflammation in patients with diabetic foot ulcers. *Nutrients* **14**, 2393.
- Cheng Q, Hu J, Yang P, *et al.* (2017) Sarcopenia is independently associated with diabetic foot disease. *Sci Rep* **7**, 8372.
- Barshes NR, Mindru C, Ashong C, *et al.* (2016) Treatment failure and leg amputation among patients with foot osteomyelitis. *Int J Lower Extremity Wounds* **15**, 303–312.
- Jeyaraman K, Berhane T, Hamilton M, *et al.* (2019) Mortality in patients with diabetic foot ulcer: a retrospective study of 513 cases from a single Centre in the Northern Territory of Australia. *BMC Endocr Disord* **19**, 1.
- Detsky AS, McLaughlin JR, Baker JP, *et al.* (1987) What is subjective global assessment of nutritional status? *JPEN J Parenter Enter Nutr* **11**, 8–13.
- Sheean PM, Peterson SJ, Gurka DP, *et al.* (2010) Nutrition assessment: the reproducibility of subjective global assessment in patients requiring mechanical ventilation. *Eur J Clin Nutr* **64**, 1358–1364.
- Allard JP, Keller H, Jeejeebhoy KN, *et al.* (2016) Malnutrition at hospital admission-contributors and effect on length of stay: a prospective cohort study from the Canadian Malnutrition Task Force. *JPEN J Parenter Enter Nutr* **40**, 487–497.
- Campbell KL, Ash S, Bauer JD, *et al.* (2007) Evaluation of nutrition assessment tools compared with body cell mass for the assessment of malnutrition in chronic kidney disease. *J Ren Nutr: Offic J Council Renal Nutr Natl Kidney Found* **17**, 189–195.
- Ribeiro HS, Maurício SF, Antônio da Silva T, *et al.* (2018) Combined nutritional assessment methods to predict clinical outcomes in patients on the waiting list for liver transplantation. *Nutrition (Burbank, Los Angeles County, Calif)* **47**, 21–26.
- Cederholm T, Jensen GL, Correia M, *et al.* (2019) GLIM criteria for the diagnosis of malnutrition - a consensus report from the global clinical nutrition community. *J Cachexia Sarcopenia Muscle* **10**, 207–217.
- Lauwers P, Hendriks JMH, Van Bouwel S, *et al.* (2021) Malnutrition according to the 2018 GLIM criteria is highly prevalent in people with a diabetic foot ulcer but does not affect outcome. *Clin Nutr ESPEN* **43**, 335–341.
- López-Valverde ME, Aragón-Sánchez J & Viquez-Molina G (2023) Handgrip strength but not malnutrition according to global leadership initiative on malnutrition criteria is a risk factor for mortality in hospitalized patients with ischemic diabetic foot ulcers. *Adv Wound Care* **12**, 127–134.
- Ince P, Abbas ZG, Lutale JK, *et al.* (2008) Use of the SINBAD classification system and score in comparing outcome of foot ulcer management on three continents. *Diabetes Care* **31**, 964–967.
- Cockcroft DW & Gault MH (1976) Prediction of creatinine clearance from serum creatinine. *Nephron* **16**, 31–41.
- Poredos P, Stanek A, Catalano M, *et al.* (2024) Ankle-Brachial Index: diagnostic tool of peripheral arterial disease and predictor of cardiovascular risk-an update of current knowledge. *Angiology* 33197241226512. (Epublication ahead of print version 04 January 2024).
- Lipsky BA, Berendt AR, Cornia PB, *et al.* (2013) 2012 infectious diseases society of America clinical practice guideline for the diagnosis and treatment of diabetic foot infections. *J Am Podiatric Med Assoc* **103**, 2–7.
- Lohman TG (1981) Skinfolts and body density and their relation to body fatness: a review. *Hum Biol* **53**, 181–225.
- Lohman TG, Roche AF & Martorell R (1998) Anthropometric Standardization Reference Manual, Abridged ed. Champaign, IL: Human Kinetics Books.
- Cheng HS, See LC & Shieh YH (2001) Estimating stature from knee height for adults in Taiwan. *Chang Gung Med J* **24**, 547–556.
- Kondrup J, Allison SP, Elia M, *et al.* (2003) ESPEN guidelines for nutrition screening 2002. *Clin Nutr (Edinburgh, Scotland)* **22**, 415–421.
- Yin L, Lin X, Li N, *et al.* (2021) Evaluation of the global leadership initiative on malnutrition criteria using different muscle mass indices for diagnosing malnutrition and predicting survival in lung cancer patients. *JPEN J Parenter Enter Nutr* **45**, 607–617.
- Maeda K, Koga T, Nasu T, *et al.* (2017) Predictive accuracy of calf circumference measurements to detect decreased skeletal muscle mass and European society for clinical nutrition and metabolism-defined malnutrition in hospitalized older patients. *Ann Nutr Metab* **71**, 10–15.
- Keller H, de van der Schueren MAE, Jensen GL, *et al.* (2020) Global Leadership Initiative on Malnutrition (GLIM): guidance on validation of the operational criteria for the diagnosis of protein-energy malnutrition in adults. *JPEN J Parenter Enter Nutr* **44**, 992–1003.
- Power L, Mullally D, Gibney ER, *et al.* (2018) A review of the validity of malnutrition screening tools used in older adults in community and healthcare settings – a MaNuEL study. *Clin Nutr ESPEN* **24**, 1–13.
- Oliveira G, Tapia MJ, Ocón J, *et al.* (2013) The subjective global assessment predicts in-hospital mortality better than other nutrition-related risk indexes in noncritically ill inpatients who receive total parenteral nutrition in Spain (prospective multicenter study). *J Acad Nutr Diet* **113**, 1209–1218.
- Brito JE, Burgel CF, Lima J, *et al.* (2021) GLIM criteria for malnutrition diagnosis of hospitalized patients presents satisfactory criterion validity: a prospective cohort study. *Clin Nutr* **40**, 4366–4372.
- Theilla M, Rattanachaiwong S, Kagan I, *et al.* (2021) Validation of GLIM malnutrition criteria for diagnosis of malnutrition in ICU patients: an observational study. *Clin Nutr* **40**, 3578–3584.
- Shahbazi S, Hajimohammadebrahim-Ketabforoush M, Vahdat Shariatpanahi M, *et al.* (2021) The validity of the global leadership initiative on malnutrition criteria for diagnosing malnutrition in critically ill patients with COVID-19: a prospective cohort study. *Clin Nutr ESPEN* **43**, 377–382.
- Mitani A, Iwai T, Shichinohe T, *et al.* (2021) The combined usage of the global leadership initiative on malnutrition criteria and controlling nutrition status score in acute care hospitals. *Ann Nutr Metab* **77**, 178–184.



37. Allard JP, Keller H, Gramlich L, *et al.* (2020) GLIM criteria has fair sensitivity and specificity for diagnosing malnutrition when using SGA as comparator. *Clin Nutr* **39**, 2771–2777.
38. Tan S, Wang J, Zhou F, *et al.* (2022) Validation of GLIM malnutrition criteria in cancer patients undergoing major abdominal surgery: a large-scale prospective study. *Clin Nutr* **41**, 599–609.
39. Huo Z, Chong F, Yin L, *et al.* (2022) Accuracy of the GLIM criteria for diagnosing malnutrition: a systematic review and meta-analysis. *Clin Nutr* **41**, 1208–1217.
40. Zhang K-P, Tang M, Fu Z-M, *et al.* (2021) Global leadership initiative on malnutrition criteria as a nutrition assessment tool for patients with cancer. *Nutrition* **91–92**, 111379.
41. KaluŃniak-Szymanowska A, Krzysińska-Siemaszko R, Wieczorowska-Tobis K, *et al.* (2022) Optimal assessment of nutritional status in older subjects with the chronic obstructive pulmonary disease—a comparison of three screening tools used in the GLIM Diagnostic Algorithm. *Int J Environ Res Public Health* **19**, 1025.
42. Santos BC, Fonseca ALF, Ferreira LG, *et al.* (2022) Different combinations of the GLIM criteria for patients awaiting a liver transplant: poor performance for malnutrition diagnosis but a potentially useful prognostic tool. *Clin Nutr* **41**, 97–104.
43. Landi F, Onder G, Russo A, *et al.* (2014) Calf circumference, frailty and physical performance among older adults living in the community. *Clin Nutr* **33**, 539–544.
44. Barazzoni R, Jensen GL, Correia MITD, *et al.* (2022) Guidance for assessment of the muscle mass phenotypic criterion for the Global Leadership Initiative on Malnutrition (GLIM) diagnosis of malnutrition. *Clin Nutr* **41**, 1425–1433.