



OPEN Geriatric Nutrition Risk Index is closely associated with sarcopenia and quality of life in gastric cancer patients: a cross-sectional study

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Impaired nutritional status is closely related to the development of sarcopenia and poor quality of life (QoL) in cancer patients. This study aimed to investigate the association of Geriatric Nutritional Risk Index (GNRI) with sarcopenia and QoL in patients with gastric cancer (GC). Sarcopenia was diagnosed based on the Asian Working Group for Sarcopenia 2019 criteria. This cross-sectional study included a total of 311 patients with GC. Among them, 57 (18.3%) patients were diagnosed with sarcopenia. GNRI showed significant correlations with sarcopenia-related indicators including skeletal muscle index, handgrip strength, gait speed, and 5-time chair stand time ($p < 0.001$). A significant association was observed between GNRI and sarcopenia [odds ratio (OR) = 0.815, 95% confidence interval (CI): 0.760–0.874, $p < 0.001$] in the multivariate analysis. The optimal cutoff value of GNRI for predicting sarcopenia was 94.98, with a sensitivity of 75.4% and specificity of 73.2%. Patients with low GNRI exhibited significantly lower scores in terms of global health status and most functional scales. Furthermore, the majority of symptoms exhibited greater severity in patients with low GNRI. In conclusion, the present study revealed that GNRI was closely associated with sarcopenia and QoL, and could effectively predict sarcopenia in patients with GC.

Keywords Geriatric nutritional risk index, Sarcopenia, Quality of life, Gastric cancer

Sarcopenia is a clinically significant condition characterized by age-related decline in muscle mass, strength, and function. It is associated with an increased risk of adverse health outcomes including falls, functional decline, frailty, and mortality¹. Given its significant prevalence and unfavorable clinical outcomes among cancer patients, particularly in the elderly population, sarcopenia has gained increasing research interest within the field of oncology².

Gastric cancer (GC) is a highly prevalent malignancy worldwide. On one hand, the incidence of GC progressively increases with advancing age, reaching a median age at diagnosis of 70 years³. On the other hand, patients with GC are more prone to experience reduced food intake, limited physical activity, and systemic inflammatory responses during disease progression⁴. Consequently, GC patients face an elevated risk of developing sarcopenia. According to a recent review, the average prevalence of sarcopenia in GC patients was found to be $19.09 \pm 8.06\%$ ⁴. The presence of sarcopenia has been demonstrated to be associated with an increased risk of postoperative complications and poorer long-term survival in patients with GC^{5,6}. Therefore, timely screening and diagnosis of sarcopenia, followed by proactive intervention measures, are crucial for reducing postoperative complications and enhancing overall prognosis in GC patients.

Recently, SARC-F has been recommended as the primary screening tool for identifying sarcopenia in accordance with international guidelines on sarcopenia, including the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) and the Asian Working Group for Sarcopenia (AWGS) 2019^{7,8}. However, previous meta-analysis studies have indicated that SARC-F exhibits low to moderate sensitivity in identifying sarcopenia, thereby limiting its suitability for sarcopenia screening^{9,10}. Consequently, there is currently a lack of widely accepted, straightforward, and efficient predictive indicators or measurement tools available to facilitate the identification of sarcopenia.

The geriatric nutritional risk index (GNRI), a widely used objective nutritional screening tool, can be easily calculated using serum albumin levels and ideal body weight¹¹. A strong correlation has been observed between

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malnutrition and sarcopenia, indicating the potential diagnostic value of nutritional screening tools in the diagnosis of sarcopenia. Based on this hypothesis, GNRI may serve as a valuable tool for identifying sarcopenia. Previous studies have established a significant association between GNRI and the risk of sarcopenia in patients with diabetes^{12,13}, cirrhosis¹⁴, and maintenance hemodialysis¹⁵. However, further investigation is necessary to determine the predictive value of GNRI for sarcopenia, particularly in cancer patients where research is scarce. Moreover, limited studies have examined the relationship between GNRI and QoL in cancer patients. Therefore, the aim of this study was to investigate the association of GNRI with the risk of sarcopenia and QoL, as well as to evaluate its predictive value for sarcopenia in patients with GC.

Result

Patient characteristics

This study finally included a total of 311 patients diagnosed with GC, as shown in Fig. 1. Among them, 64 (20.6%) exhibited low muscle mass, 49 (15.8%) had low muscle strength, and 208 (66.9%) demonstrated low physical performance. Additionally, 57 (18.3%) patients were diagnosed with sarcopenia based on AWGS 2019 criteria. The demographic and clinical characteristics of the patients were shown in Table 1. There were 221 (71.1%) males and 90 (28.9%) females, with an average age of 66.1 ± 8.9 years and an average BMI of 23.47 ± 3.34 kg/m². Compared to patients with high GNRI (≥ 98), those with low GNRI (< 98) exhibited significantly lower levels of BMI, Albumin, Hemoglobin, PNI, L3-SMI, gait speed, and handgrip strength ($p < 0.05$). Additionally, they demonstrated higher levels of age, CRP, and 5-time chair stand time ($p < 0.05$). Moreover, a higher prevalence of poor ECOG performance status, advanced TNM stage, hypoproteinemia and anemia was observed among

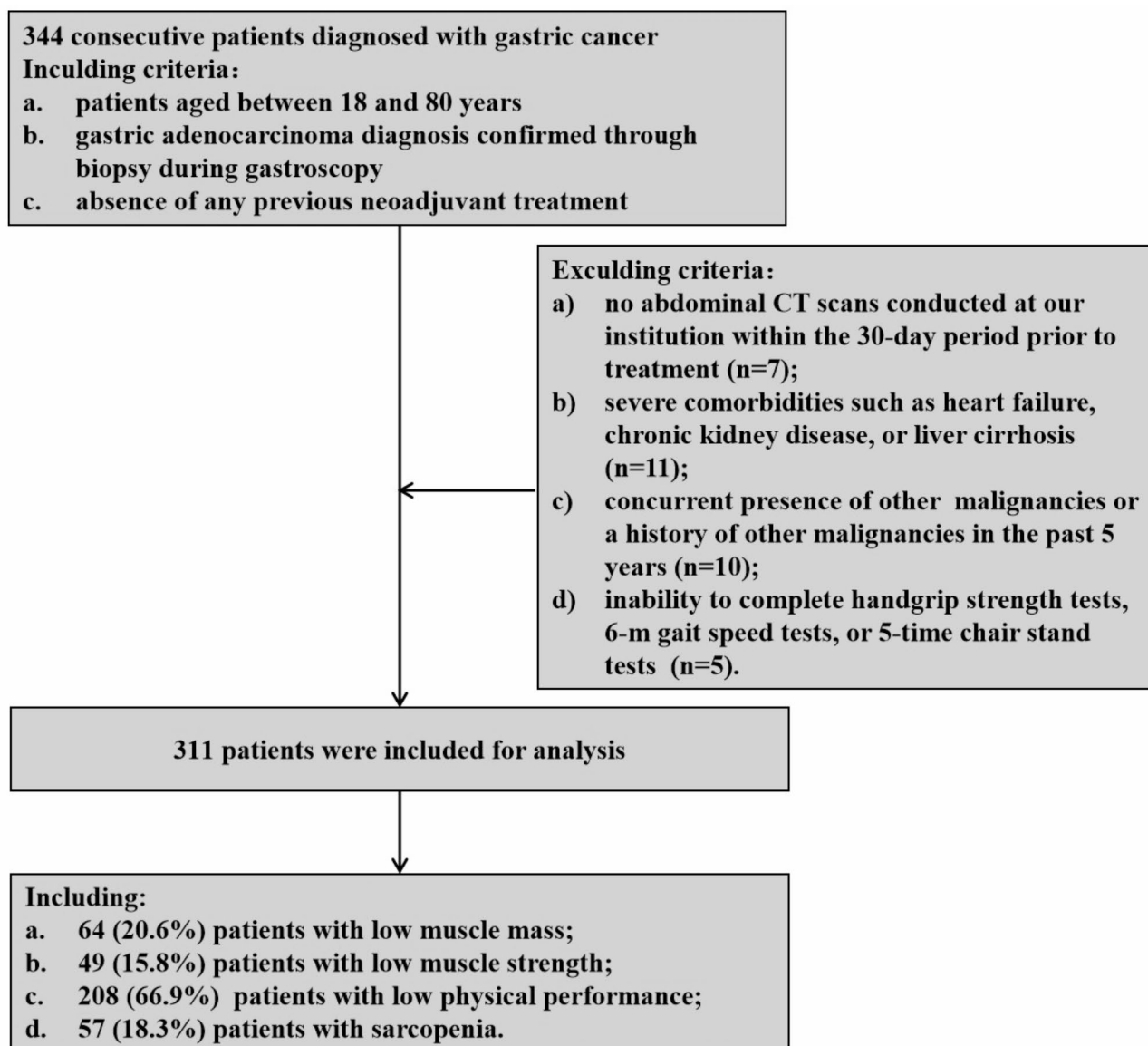


Fig. 1. The flowchart of inclusion and exclusion of patients.

| | Total (n = 311) | Low GNRI (n = 144) | High GNRI (n = 167) | p-value |
|---|--------------------|-----------------------|---------------------|---------|
| Sex, n (%) | | | | 0.155 |
| Male | 221 (71.1) | 108 (75.0) | 113 (67.7) | |
| Female | 90 (28.9) | 36 (25.0) | 54 (32.3) | |
| Age, years | 66.1 ± 8.9 | 66.8 ± 8.5 | 65.5 ± 9.1 | 0.171 |
| BMI, kg/m ² | 23.47 ± 3.34 | 21.47 ± 2.49 | 25.20 ± 3.00 | < 0.001 |
| ECOG performance status, n (%) | | | | < 0.001 |
| 0 | 188 (60.5) | 65 (45.1) | 123 (73.7) | |
| 1 | 81 (26.0) | 45 (31.3) | 36 (21.6) | |
| 2 | 34 (10.9) | 27 (18.8) | 7 (4.2) | |
| 3 | 8 (2.6) | 7 (4.9) | 1 (0.6) | |
| CCI score, n (%) | | | | 0.691 |
| 0 | 240 (77.2) | 114 (79.2) | 126 (75.4) | |
| 1 | 49 (15.8) | 20 (13.9) | 29 (17.4) | |
| 2 | 22 (7.1) | 10 (6.9) | 12 (7.2) | |
| TNM stage, n (%) | | | | < 0.001 |
| I | 75 (24.1) | 16 (11.1) | 59 (35.3) | |
| II | 62 (19.9) | 35 (24.3) | 27 (16.1) | |
| III | 132 (42.4) | 60 (41.7) | 72 (43.1) | |
| IV | 42 (13.5) | 33 (22.9) | 9 (5.4) | |
| CRP, mg/L | 4.57 ± 10.17 | 6.52 ± 13.78 | 2.88 ± 4.84 | 0.050 |
| Albumin, g/L | 37.07 ± 4.35 | 34.05 ± 3.33 | 39.66 ± 3.33 | < 0.001 |
| Hemoglobin, g/L | 115.4 ± 24.9 | 104.3 ± 24.6 | 125.1 ± 20.9 | < 0.001 |
| Neutrophil, 10 ⁹ /L | 3.91 ± 1.86 | 3.92 ± 2.37 | 3.91 ± 1.28 | 0.115 |
| Lymphocyte, 10 ⁹ /L | 1.55 ± 0.57 | 1.48 ± 0.60 | 1.61 ± 0.53 | 0.019 |
| CRP ≥ 5 mg/L, n (%) | 72 (23.2) | 44 (30.6) | 28 (16.8) | 0.004 |
| Hypoproteinemia, n (%) | 95 (30.5) | 79 (54.9) | 16 (9.6) | < 0.001 |
| Anemia, n (%) | 132 (42.4) | 94 (65.3) | 38 (22.8) | < 0.001 |
| NLR | 2.82 ± 1.78 | 3.05 ± 2.32 | 2.63 ± 1.08 | 0.798 |
| PNI | 44.81 ± 5.30 | 41.45 ± 4.41 | 47.70 ± 4.18 | < 0.001 |
| L3-SMI, cm ² /m ² | 44.95 ± 7.59 | 42.63 ± 7.21 | 46.96 ± 7.36 | < 0.001 |
| Gait speed, m/s | 1.09 ± 0.15 | 1.05 ± 0.15 | 1.11 ± 0.15 | 0.001 |
| Handgrip strength, kg | 32.02 ± 8.66 | 29.89 ± 7.89 | 33.86 ± 8.89 | < 0.001 |
| Chair stand test, s | 13.17 ± 2.62 | 13.85 ± 3.04 | 12.58 ± 2.02 | < 0.001 |
| Gait speed < 1 m/s, n (%) | 73 (23.5) | 46 (31.9) | 27 (16.2) | 0.001 |
| Chair stand time ≥ 12 s, n (%) | 201 (64.6) | 106 (73.6) | 95 (56.9) | 0.002 |
| Low muscle mass, n (%) | 64 (20.6) | 47 (32.6) | 17 (10.2) | < 0.001 |
| low muscle strength, n (%) | 49 (15.8) | 38 (26.4) | 11 (6.6) | < 0.001 |
| low physical performance, n (%) | 208 (66.9) | 108 (75.0) | 100 (59.9) | 0.005 |
| Sarcopenia, n (%) | 57 (18.3) | 44 (30.6) | 13 (7.8) | < 0.001 |

Table 1. Demographic and clinical characteristics of study patients stratified by GNRI. BMI, Body Mass Index; CCI, Charlson Comorbidity Index; CRP, C-reactive protein; ECOG, Eastern cooperative oncology group; GNRI, geriatric nutritional risk index; L3, the third lumbar vertebra; NLR, neutrophil-to-lymphocyte ratio; PNI, Prognostic Nutritional Index. SMI, Skeletal Muscle Index. TNM, tumor–node–metastasis.

patients with low GNRI ($p < 0.05$). Furthermore, the prevalence of low muscle mass, low muscle strength, low physical performance, and sarcopenia in patients with low GNRI were significantly higher than those with high GNRI ($p < 0.05$).

Correlations between GNRI and clinical parameters

As shown in Fig. 2, we conducted a Pearson correlation analysis between GNRI and various clinically relevant parameters in patients with GC. The GNRI values showed positive associations with hemoglobin and PNI, while exhibiting negative associations with Age, NLR, and CRP ($p < 0.05$). Furthermore, the GNRI values showed significant correlations with sarcopenia-related indicators including L3-SMI ($r = 0.41$, $p < 0.001$), handgrip strength ($r = 0.28$, $p < 0.001$), gait speed ($r = 0.30$, $p < 0.001$), and 5-time chair stand time ($r = -0.31$, $p < 0.001$). Additionally, in the multivariate linear regression analysis adjusted for age, sex, CCI score, ECOG performance

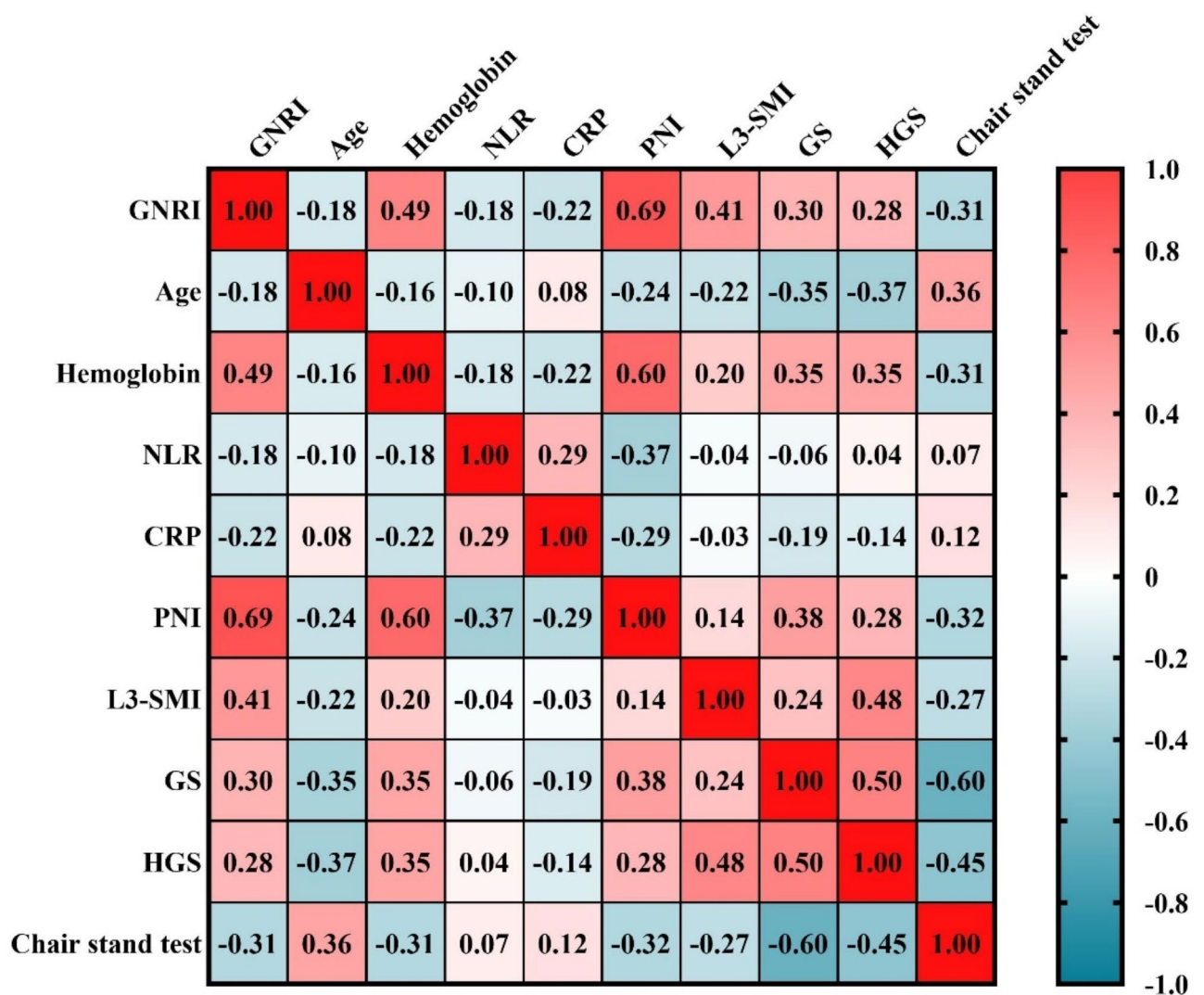


Fig. 2. The Person analysis of GNRI and clinically relevant parameters. CRP, C-reactive protein; GNRI, Geriatric Nutritional Risk Index; GS, gait speed; HGS, handgrip strength; L3, the third lumbar vertebra; NLR, neutrophil-to-lymphocyte ratio; PNI, Prognostic Nutritional Index. SMI, Skeletal Muscle Index.

status, TNM stage, hypoproteinemia and anemia, significant associations were also found between GNRI and sarcopenia-related indicators, except for gait speed (Table 2).

Association of GNRI with sarcopenia and its components

GNRI values were significantly lower in patients with low muscle mass, low muscle strength, low physical performance, and sarcopenia compared to those without ($p < 0.001$, Fig. 3). A significant association was observed between an increase of one-unit in GNRI and the presence of low muscle mass (OR = 0.849, 95% CI: 0.800–0.901, $p < 0.001$), low muscle strength (OR = 0.929, 95% CI: 0.877–0.985, $p = 0.014$), low physical performance (OR = 0.959, 95% CI: 0.921–0.997, $p = 0.035$), and sarcopenia (OR = 0.815, 95% CI: 0.760–0.874, $p < 0.001$) after adjusting for age, sex, CCI score, ECOG performance status, TNM stage, hypoproteinemia and anemia (Table 3). Additionally, low GNRI (< 98) was also found to be significantly associated with the presence of low muscle mass (OR = 4.846, 95% CI: 2.230–10.531, $p < 0.001$), low muscle strength (OR = 2.486, 95% CI: 1.001–6.179, $p = 0.050$), and sarcopenia (OR = 5.599, 95% CI: 2.411–13.001, $p < 0.001$), except for low physical performance (OR = 1.476, 95% CI: 0.746–2.918, $p = 0.263$) in the multivariate logistic regression analysis (Table 3).

GNRI for detecting sarcopenia

The ROC curves were conducted to evaluate the diagnostic accuracy of GNRI, PNI, and Albumin in identifying sarcopenia. As shown in Fig. 4, the area under the curve (AUC) of GNRI (AUC = 0.782, 95% CI: 0.720–0.844, $P < 0.001$) for sarcopenia was larger than that of PNI (AUC = 0.653, 95% CI: 0.579–0.726, $P < 0.001$) and Albumin (AUC = 0.619, 95% CI: 0.541–0.696, $P = 0.005$). The GNRI exhibited the highest specificity, accuracy,

| | Model | Coefficient B (95% CI) | p-value | Standardized β | Adjusted R^2 |
|---|-----------------------|---------------------------|---------|----------------------|----------------|
| L3-SMI, cm ² /m ² | Crude | 0.323 (0.242 to 0.405) | < 0.001 | 0.406 | 0.162 |
| | Adjusted ^a | 0.438 (0.349 to 0.528) | < 0.001 | 0.550 | 0.435 |
| Gait speed, m/s | Crude | 0.620 (0.451 to 0.789) | < 0.001 | 0.295 | 0.084 |
| | Adjusted ^a | 0.002 (-0.0002 to 0.004) | 0.083 | 0.114 | 0.266 |
| Handgrip strength, kg | Crude | 0.256 (0.158 to 0.353) | < 0.001 | 0.282 | 0.076 |
| | Adjusted ^a | 0.202 (0.118 to 0.285) | < 0.001 | 0.222 | 0.624 |
| Chair stand test, s | Crude | -0.087 (-0.079 to -0.009) | < 0.001 | -0.328 | 0.105 |
| | Adjusted ^a | -0.044 (-0.079 to -0.009) | 0.015 | -0.165 | 0.217 |

Table 2. Crude and adjusted linear regression analysis of GNRI (independent variable) and sarcopenia-related indicators (dependent variable). a Model adjusted for age, sex, CCI, ECOG performance status, TNM stage, hypoproteinemia and anemia. CCI, Charlson Comorbidity Index; ECOG, Eastern cooperative oncology group; GNRI, geriatric nutritional risk index; L3, the third lumbar vertebra; SMI, skeletal muscle index. TNM, tumor–node–metastasis.

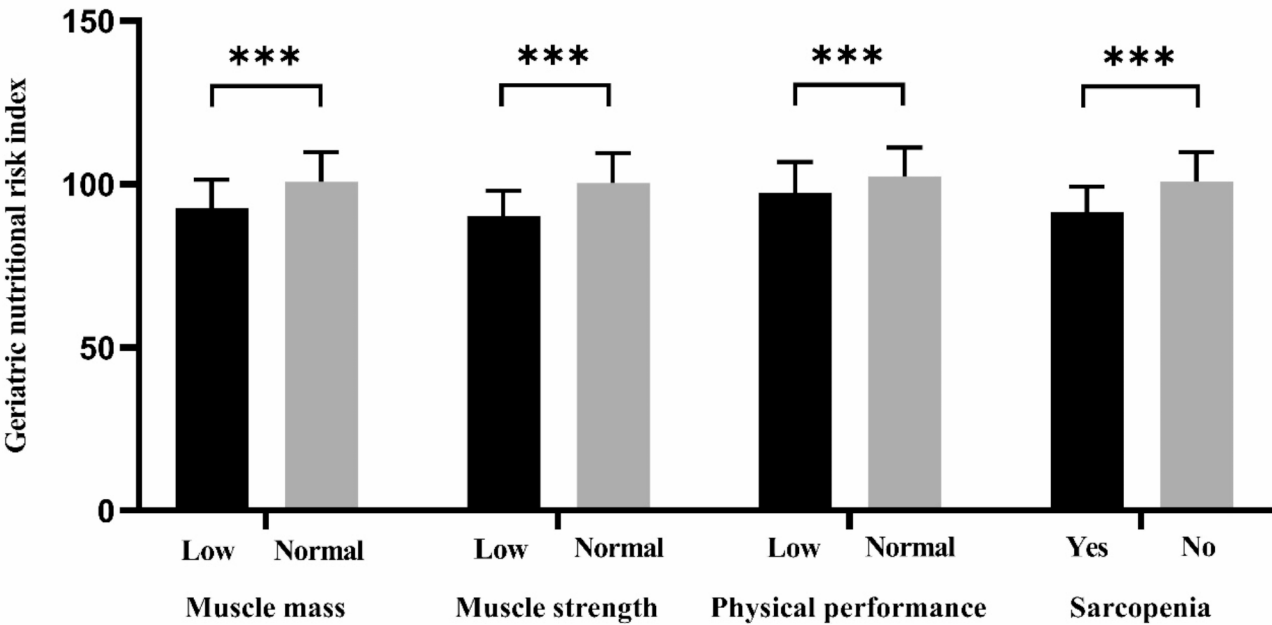


Fig. 3. Bar plot comparing GNRI between patients with sarcopenia and without sarcopenia and in different muscle mass, muscle strength, and physical performance groups. GNRI, Geriatric Nutritional Risk Index.

positive likelihood ratio (LR+), and the lowest negative likelihood ratio (LR-) when compared to PNI and Albumin (Supplementary Table S1). The optimal cutoff value of GNRI for predicting sarcopenia was 94.98, with a sensitivity of 75.4% and specificity of 73.2%.

Association between GNRI and QoL

According to the QoL assessed by the EORTC QLQ-C30, patients with low GNRI exhibited significantly lower scores in terms of global health status, physical functioning, role functioning, emotional functioning, and social functioning compared to those with high GNRI ($p < 0.05$, Table 4). Moreover, patients with low GNRI demonstrated higher scores in terms of fatigue, nausea and vomiting, pain, dyspnea, insomnia, appetite loss, and constipation ($p < 0.05$). Additionally, as shown in supplementary Table S2, GNRI showed significant positive associations with the scores of global health status and most functional scales excluding cognitive function ($p < 0.05$). Conversely, it displayed negative correlations with the scores of major symptom scales and single items except for diarrhea and financial difficulties ($p < 0.05$).

Discussion

The present study was one of the few that investigate the association between GNRI and the risk of sarcopenia and QoL in cancer patients. Our findings demonstrated significant correlations between GNRI and sarcopenia-related indicators, including L3-SMI, handgrip strength, gait speed, and 5-time chair stand time. Moreover, we observed a significant association between GNRI and the presence of low muscle mass, low muscle strength,

| Variable | Crude OR (95% CI) | p-value | Adjusted OR (95% CI) ^a | p-value |
|----------------------------------|----------------------|---------|-----------------------------------|---------|
| GNRI (continuous variable) | | | | |
| Low muscle mass | 0.903 (0.871–0.935) | < 0.001 | 0.849 (0.800–0.901) | < 0.001 |
| Low muscle strength | 0.901 (0.867–0.937) | < 0.001 | 0.929 (0.877–0.985) | 0.014 |
| Low physical performance | 0.942 (0.916–0.968) | < 0.001 | 0.959 (0.921–0.997) | 0.035 |
| Sarcopenia | 0.883 (0.848–0.919) | < 0.001 | 0.815 (0.760–0.874) | < 0.001 |
| GNRI < 98 (categorical variable) | | | | |
| Low muscle mass | 4.275 (2.321–7.874) | < 0.001 | 4.846 (2.230–10.531) | < 0.001 |
| Low muscle strength | 5.084 (2.487–10.392) | < 0.001 | 2.486 (1.001–6.179) | 0.050 |
| Low physical performance | 2.010 (1.234–3.274) | 0.005 | 1.476 (0.746–2.918) | 0.263 |
| Sarcopenia | 5.212 (2.673–10.165) | < 0.001 | 5.599 (2.411–13.001) | 0.001 |

Table 3. Crude and adjusted logistic regression analysis of GNRI (independent variable) and sarcopenia and its components (dependent variable). ^aModel adjusted for age, sex, CCI, ECOG performance status, TNM stage, hypoproteinemia and anemia. CCI, Charlson Comorbidity Index; ECOG, Eastern cooperative oncology group; GNRI, Geriatric Nutritional Risk Index; TNM, tumor–node–metastasis.

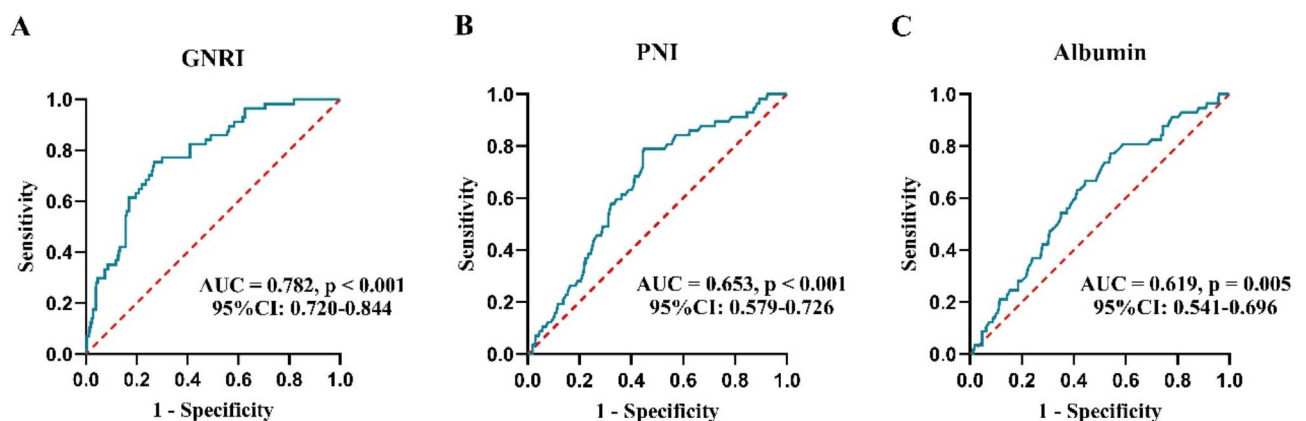


Fig. 4. Receiver operating characteristic (ROC) curve of GNRI (A), PNI (B), and Albumin (C) in identifying sarcopenia. GNRI, Geriatric Nutritional Risk Index; PNI, Prognostic Nutritional Index.

| | Low GNRI (n = 144) | High GNRI (n = 167) | p-value |
|------------------------|--------------------|---------------------|---------|
| Global health status | 60.07 ± 26.33 | 74.22 ± 26.09 | < 0.001 |
| Physical functioning | 85.89 ± 16.49 | 90.88 ± 13.56 | 0.002 |
| Role functioning | 84.90 ± 21.32 | 92.42 ± 15.60 | < 0.001 |
| Emotional functioning | 84.32 ± 14.77 | 87.97 ± 15.30 | 0.006 |
| Cognitive functioning | 86.44 ± 16.61 | 89.67 ± 13.01 | 0.163 |
| Social functioning | 82.18 ± 22.70 | 87.53 ± 21.55 | 0.038 |
| Fatigue | 24.51 ± 21.26 | 14.04 ± 17.77 | < 0.001 |
| Nausea and vomiting | 14.35 ± 20.26 | 8.38 ± 16.55 | 0.003 |
| Pain | 19.21 ± 21.26 | 14.07 ± 18.11 | 0.029 |
| Dyspnea | 16.90 ± 22.30 | 12.37 ± 20.53 | 0.046 |
| Insomnia | 23.63 ± 30.99 | 14.57 ± 22.72 | 0.012 |
| Appetite loss | 23.61 ± 29.99 | 11.58 ± 21.00 | < 0.001 |
| Constipation | 14.81 ± 22.91 | 10.18 ± 20.60 | 0.029 |
| Diarrhea | 9.03 ± 19.80 | 7.98 ± 16.45 | 0.999 |
| Financial difficulties | 28.70 ± 31.44 | 23.55 ± 28.65 | 0.154 |

Table 4. Comparison of quality of life between patients with low GNRI and high GNRI. GNRI, Geriatric Nutritional Risk Index.

poor physical performance, and sarcopenia in the multivariate analysis. Additionally, GNRI exhibited superior diagnostic accuracy for detecting sarcopenia based on the latest AWGS consensus compared to other nutritional indicators such as PNI and Albumin levels. We also assessed the impact of GNRI on QoL in GC patients, and found that GNRI was associated with major aspects of QoL in this study. Therefore, based on the findings of our study, GNRI can be considered as an effective tool for the assessment of sarcopenia and QoL in patients with GC.

The prevalence of sarcopenia based on AWGS2019 criteria in our study was found to be 18.3%, which is consistent with the findings of a recent systematic review that reported an average prevalence of 19.09% as previously mentioned⁴. Wu et al. reported that the prevalence of sarcopenia in patients with GC was 11.3% and 20.5%, based on the criteria provided by EWGSOP2 and AWGS2019, respectively¹⁶. However, Tegels et al. reported that the prevalence of sarcopenia was found to be as high as 57.7% in patients undergoing gastric cancer surgery¹⁷. The prevalence of sarcopenia exhibits significant variation due to the absence of a universally acknowledged and standardized definition. According to the latest criteria from EWGSOP2 and AWGS2019, significant discrepancies exist; for instance, in EWGSOP2, muscle strength serves as a prerequisite for diagnosing sarcopenia, whereas both muscle strength and physical performance hold equal importance in AWGS2019^{7,8}. In order to address this issue, the Global Leadership Initiative in Sarcopenia (GLIS) steering committee was established with the objective of convening leading researchers in sarcopenia research to develop a single definition of sarcopenia that can be utilized worldwide¹. The ongoing endeavor towards establishing an operational definition of sarcopenia for clinical and research settings is currently underway.

The development and progression of cancer induce a systemic inflammatory state within the patient's body. The activation of inflammatory cytokines has been shown to stimulate muscle wasting by promoting protein breakdown and inhibiting muscle synthesis¹⁸. The presence of cancer can exacerbate many of the factors that contribute to sarcopenia, including anorexia, physical inactivity, and a systemic inflammatory state². Elevated levels of various serum inflammatory cytokines, such as interleukin-6 (IL-6), tumor necrosis factor- α (TNF- α), and CRP, have been observed in patients with sarcopenia¹⁹. The GNRI, which is composed of serum albumin and body weight, has been reported to be associated with systemic inflammation^{20,21}. Consistent with previous findings²⁰, the present study also revealed a negative correlation between GNRI and CRP levels. In addition, cancer patients, particularly those with gastrointestinal malignancies, are more prone to experiencing malnutrition, a condition that has been demonstrated to be associated with the development of sarcopenia. As an indicator of nutritional status, GNRI has been shown as a significant prognostic factor for clinical outcomes in patients with cancer²². Therefore, the association between the GNRI and sarcopenia can be attributed to the presence of systemic inflammation and malnutrition in cancer patients.

Several studies have demonstrated the effectiveness of nutritional screening tools in identifying sarcopenia. Zhang et al. revealed that Mini Nutritional Assessment Short Form (MNA-SF) score exhibited superior efficacy in identifying sarcopenia compared to Nutritional Risk Screening 2002 (NRS2002) score among the elderly population in China²³. Chen et al. conducted a comparative analysis of three nutritional screening tools, including GNRI, Malnutrition Inflammation Score (MIS), and Creatinine Index, to predict sarcopenia in patients with maintenance hemodialysis. The results showed that GNRI demonstrated superior predictability for sarcopenia compared to MIS and Creatinine index¹⁵. Additionally, Shiroma et al. found that GNRI had better diagnostic efficacy for sarcopenia than albumin and controlling nutritional status (CONUT) in patients with type 2 diabetes mellitus (T2DM)²⁴. Consistent with previous studies, our findings also demonstrated that GNRI exhibited superior diagnostic accuracy in detecting sarcopenia compared to PNI and Albumin levels. It is worth noting that nutrition screening tools such as the NRS-2002 score, MNA-SF, and MIS are time-consuming, complex to perform, and prone to bias due to their reliance on subjective evaluation. Our previous studies also revealed that phase angle (PhA) derived from bioelectrical impedance analysis (BIA) exhibited significant associations with sarcopenia and demonstrated fair to good diagnostic accuracy in identifying sarcopenia²⁵. However, it is important to note that the estimation of PhA requires specialized BIA instruments such as InBody S10, which may limit its applicability in medical institutions lacking access to these devices. However, GNRI can be easily implemented in the clinical setting, utilizing laboratory examinations and anthropometric measurements. Consequently, the GNRI can be regarded as a valuable and convenient tool for assessing sarcopenia in cancer patients.

Multiple studies consistently demonstrate a positive correlation between the GNRI and SMI, which serves as a crucial diagnostic indicator for sarcopenia^{12–14,26}. However, it is worth noting that these studies relied on BIA to estimate muscle mass, whereas CT is widely recognized as the gold standard method. Several studies have presented conflicting findings when comparing BIA and CT methods for evaluating muscle mass in disease states^{27–29}. In our previous study, we observed a tendency of BIA method to potentially overestimate skeletal muscle mass in GC patients compared to CT, resulting in a potential underestimation of low muscle mass prevalence³⁰. Therefore, muscle mass was estimated using the gold standard CT approach, making the findings more reliable in the present study.

In this study, we used both the 6-m gait speed test and the 5-time chair stand test to evaluate physical performance. The results revealed that a significant proportion of patients (up to 66.9%) with GC exhibited low physical performance. This can be attributed to the higher prevalence of elderly patients (with an average age of 66.1 ± 8.9 years) and a greater proportion of advanced GC cases (55.9% classified as stages III and IV) in this study. Moreover, consistent with previous research findings³¹, the present study also revealed a significantly higher proportion of patients (64.6%) classified as having low physical performance based on the chair-stand test compared to those diagnosed using the gait speed test (23.5%, $p < 0.001$). Therefore, to clarify the superiority in evaluating performance between the 6-meter walk test and the 5-times chair stand test, further longitudinal studies on the main clinical outcomes will be conducted in our future research.

The present study possessed several notable strengths, including the use of more robust assessments of muscle mass through the CT method and the adoption of the latest AWGS criteria for defining sarcopenia.

However, certain limitations were also acknowledged in this study. Firstly, the cross-sectional design of this study precludes the establishment of causal relationships. Further prospective trials are essential to investigate the potential benefits of increasing GNRI levels in the prevention of sarcopenia among cancer patients. Secondly, as this was a single-center study, the sample size was relatively small and the study population may not be representative of the broader GC population. Lastly, we did not assess dietary intake and total caloric intake in this study, which could potentially serve as confounding factors when evaluating sarcopenia using GNRI.

In conclusion, the present findings demonstrate that GNRI is closely associated with sarcopenia and QoL in patients with GC. Furthermore, GNRI proves to be a valuable predictor for identifying sarcopenia in GC patients. Additionally, GNRI can be easily obtained through laboratory tests and anthropometric measurements in the clinical settings. Therefore, GNRI serves as a straightforward and effective tool for assessing sarcopenia and QoL in cancer patients. However, further validation of our results necessitates multi-centered studies with larger sample sizes and more representative populations.

Methods

Patients

This cross-sectional study included consecutive patients diagnosed with GC at our institution from October 2021 to March 2023. The inclusion criteria were as follows: (1) patients aged between 18 and 80 years; (2) gastric adenocarcinoma diagnosis confirmed through biopsy during gastroscopy; and (3) absence of any previous neoadjuvant treatment. Exclusion criteria included: (1) no abdominal CT scans conducted at our institution within the 30-day period prior to treatment; (2) severe comorbidities such as heart failure, chronic kidney disease, or liver cirrhosis; (3) concurrent presence of other malignancies or a history of other malignancies in the past 5 years; (4) inability to complete handgrip strength (HGS) tests, 6-m gait speed (GS) tests, or 5-time chair stand tests due to physical impairment or a history of total knee or hip replacement. The participants in this study provided informed consent and agreed to the collection and analysis of their data. The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of The Affiliated People's Hospital of Jiangsu University (No. K-20240093-Y).

Data collection

We collected data on the following aspects: (1) Demographic and clinical characteristics, including sex, age, body mass index (BMI) calculated as height divided by weight squared, Eastern Cooperative Oncology Group (ECOG) performance status, comorbidity assessed using the Charlson Comorbidity Index (CCI), and tumor-node-metastasis (TNM) stage based on the eighth edition of the American Joint Committee on Cancer (AJCC); (2) Blood routine and biochemical tests within 48 h after admission: C-reactive protein (CRP), hemoglobin level (anemia defined as < 120 g/L for males and < 110 g/L for females), serum albumin level (hypoproteinemia defined as < 35 g/L), neutrophil and lymphocyte counts along with their ratio known as neutrophil/lymphocyte ratio (NLR); (3) GNRI: calculated as $1.489 \times \text{albumin (g/L)} + 41.7 \times (\text{weight/ideal weight})^{11}$. The ideal weight was determined using the formula: for males: $0.75 \times \text{height (cm)} - 62.5$; and for female: $0.60 \times \text{height (cm)} - 40^{11}$. The patients were stratified into two groups based on a GNRI cut-off of 98, which is a widely accepted diagnostic threshold for identifying undernutrition¹¹. Prognostic nutritional index (PNI): calculated as serum albumin level (g/L) + $5 \times \text{total lymphocyte count (10}^5/\mu\text{L)}$ score³².

Diagnosis of sarcopenia

In accordance with the consensus of the Asian Working Group for Sarcopenia (AWGS) 2109, sarcopenia was diagnosed based on the presence of both low muscle mass and either low muscle strength or low physical performance⁷. The measurement of muscle mass at the third lumbar vertebra (L3) was conducted using Slice-O-Matic software V 5.0 (Tomovision, Magog, QC, Canada) based on CT images, as described in our previous study³⁰. The skeletal muscle cross-sectional areas (cm^2) of L3 were normalized for the square of height (m^2), resulting in the calculation of skeletal muscle index ($\text{L3-SMI, cm}^2/\text{m}^2$). The criteria for low muscle mass were defined as $\text{L3 SMI} \leq 40.8 \text{ cm}^2/\text{m}^2$ for men and $\leq 34.9 \text{ cm}^2/\text{m}^2$ for women³³. The assessment of muscle strength involved using a hand dynamometer (EH101; Camry, Guangdong Province, China) to measure handgrip strength. The criterion for low muscle strength was defined as handgrip strength < 28.0 kg for men and < 18.0 kg for women⁷. The physical performance was evaluated through 6-m gait speed tests and 5-time chair stand tests. The criterion for low physical performance was defined as 6-m gait speed < 1.0 m/s or 5-time chair stand time ≥ 12 s⁷.

Quality of life assessment

The quality of life assessment was conducted using the European Organization for Research and Treatment of Cancer (EORTC) Core Quality of Life Questionnaire (QLQ-C30), which consists of 30 items divided into five functional scales (physical functioning, role functioning, emotional functioning, cognitive functioning, and social functioning), three symptom scales (fatigue, nausea/vomiting, pain), six single items (dyspnea, insomnia, appetite loss, constipation, diarrhea, and financial difficulties), as well as the global health status scale³⁴. Higher scores in global health status and functioning scales indicate a better quality of life, while higher scores in symptom scales and single items suggest more severe symptoms.

Statistical analysis

The average prevalence of sarcopenia in GC patients was reported to be $19.09 \pm 8.06\%$ ⁴. We assumed that the prevalence of sarcopenia at our center was 20%. The sample size was determined using receiver operating characteristic (ROC) analysis to evaluate the diagnostic accuracy of GNRI in identifying sarcopenia, aiming for

an AUC of 0.75 with a confidence interval width of 0.15. By setting the type I error at 0.05, a total sample size of 310 was calculated using PASS version 15.0.5 (Power Analysis and Sample Size, NCSS, USA).

Continuous variables were expressed as mean with standard deviation (SD), while categorical variables are reported as numbers with percentage (%). The comparison of data between patients with and without sarcopenia was conducted using the independent t-test for continuous variables following a normal distribution, the Mann-Whitney U-test for continuous variables with a non-normal distribution, and the Chi-squared test for categorical variables. The correlation between GNRI and clinically relevant parameters was assessed using Pearson correlation analysis. Subsequently, Linear regression analyses were performed to examine the association between GNRI (independent variable) and sarcopenia-related indicators, including L3-SMI, HGS, GS, and 5-time chair stand time (dependent variables). Furthermore, Logistic regression analyses were conducted to assess the association of GNRI with sarcopenia and its components (low muscle mass, low muscle strength, and low physical performance) in the crude or adjusted models, respectively. Due to BMI being a component of GNRI, it was excluded from the multivariate model. The adjusted model included age, sex, CCI score, ECOG performance status, TNM stage, hypoproteinemia and anemia. The ROC curve analysis was performed to assess the diagnostic accuracy of GNRI, PNI, and Albumin in identifying sarcopenia. The optimal cut-off value was determined using the maximal Youden's index, which is calculated by the formula: sensitivity + specificity – 1. The statistical analyses were conducted using SPSS version 25.0 (IBM Corp, Armonk, NY, USA). Statistical significance was defined as a two-sided $p < 0.05$.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

X.Z. and J.Z. designed the study. J.Z., Z.H., Y.G., X.D. and X.W. collected the data. J.Z., X.D. and X.W. analyzed and interpreted the data. J.Z. and Z.H. wrote the manuscript. X.Z. revised and edited the manuscript. All authors reviewed the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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