ORIGINAL ARTICLE

The accuracy of the Geriatric Nutritional Risk Index in detecting frailty and sarcopenia in hospitalized older adults

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Abstract

Background Malnutrition, sarcopenia, and frailty are prevalent conditions amongst hospitalized elderly. They are associated with numerous adverse health outcomes. The co-existence of these problems is common, with malnutrition playing a major role in the pathogenesis of the other two. Whether nutritional screening tools are useful for frailty and sarcopenia screening needs further evaluation.

Aim To evaluate the accuracy of the Geriatric Nutritional Risk Index (GNRI) in identifying frailty and sarcopenia in hospitalized older adults.

Methods One hundred and fifty hospitalized patients (≥ 60 years) were recruited. Skeletal Muscle Index was obtained using bioelectrical impedance analysis. Muscle strength and physical performance were measured by handgrip strength and timed up and go test, respectively. GNRI and the Mini Nutritional Assessment (MNA) tool were used for nutritional assessment.

Results GNRI had lower sensitivity but higher specificity compared to MNA in predicting frailty and dynapenia. GNRI discriminated the presence of sarcopenia but not pre-sarcopenia (AUC = 0.683, $p = 0.02$, and AUC = 0.586, $p = 0.12$), while MNA did not discriminate the presence of pre-sarcopenia nor sarcopenia in the studied sample (AUC = 0.56, $p = 0.25$ and AUC = 0.6, $p = 0.09$).

Conclusions Sarcopenia, frailty, and malnutrition coexisted in 26% of our sample. GNRI Score at ≤ 86.73 was 71.9% sensitive and 65.6% specific for detecting frailty and its score at ≤ 89.04 was 64.42% sensitive and 63.53% specific for detecting sarcopenia. GNRI is a simple method, which could be used for sarcopenia, and frailty screening in all elders attending primary care settings where other tools for assessing muscle mass are unavailable.

Keywords GNRI and MNA · GNRI in frailty and sarcopenia · Sarcopenia and frailty

Introduction

Sarcopenia, frailty, and malnutrition are interrelated health problems that present with phenotypically overlapping features and share similar etiological factors, i.e., decreased food intake, inflammation, hormonal changes, physical inactivity, and altered metabolism [1]. Altered body composition is one of the major shared features of these conditions; both sarcopenia and frailty are characterized by the loss of fat-free mass, mainly skeletal muscle mass, while, malnutrition is characterized by decreased fat and fat-free masses [2]. The affection of muscle strength and function are common features of sarcopenia and frailty, but not malnutrition [3, 4].

Malnutrition is a common, yet under-recognized comorbidity in hospitalized older adults with a prevalence rate ranging between 30 and 55%, depending on the studied population and the used assessment tools [5]. It plays a major role in the pathogenesis of both frailty [6] and sarcopenia [7, 8]. Whether the nutritional assessment tools could predict frailty and sarcopenia needs further evaluation.

There are numerous tools available for nutritional assessment in the elderly. They include Mini Nutritional Assessment (MNA) tool [9] and Geriatric Nutritional Risk Index (GNRI) [10]; both are accepted for diagnosing malnutrition in older patients in the hospital setting.

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GNRI was found to be a reliable predictor of muscle function. A strong correlation between the GNRI, handgrip strength (HGS), and arm muscle area (AMA) was reported. However, this correlation disappeared when female participants were analyzed separately [11]. Data regarding the relationship between GNRI and muscle mass using Bioelectrical Impedance Analysis (BIA) is still lacking. Similarly, studies to examine the accuracy of GNRI in detecting frailty and sarcopenia as possible consequences of malnutrition are needed. Our objective was to evaluate the ability of GNRI to identify frailty and sarcopenia in hospitalized older adults.

Methods

Study design and population

A cross-sectional study was conducted involving 150 older adults admitted to the geriatric department of a teaching hospital (Ain Shams University Hospital, Egypt) between October 2016 and March 2018. The inclusion criterion was age > 60 years. Exclusion criteria were sepsis, hemodynamic instability, terminal illness, malignancy, those receiving nutritional support (such as patients on Ryle's tube feeding or parenteral nutrition), presence of end-organ failure (liver, renal, respiratory, or heart failure) or neurological, severe musculoskeletal diseases that can impair HGS, and timed up and go (TUG). We excluded cachexia by excluding those with malignancy, end-organ failure, and those with CRP ≥ 3 mg/dL.

All participants were subjected to a comprehensive geriatric assessment including detailed socio-demographic data, medical history, and physical examination. Nutritional assessment was done using MNA [9] and GNRI [10]. Physical performance measures included TUG and HGS.

Nutritional assessment

Mini Nutritional Assessment (MNA)

MNA evaluates 18 items including anthropometric, general state, dietary parameters and self-perception regarding health and nutrition with a maximal score of 30 points. The MNA was developed to evaluate older adults in hospitals, nursing homes or community. Patients are considered malnourished if MNA < 17, at risk of malnutrition if MNA between17 and 23.5, and well-nourished if MNA ≥ 24 [9, 12].

Geriatric Nutritional Risk Index (NRI): [10]

GNRI is a modified Nutritional Risk Index (NRI) adjusted for elderly patients. It is calculated using the following equation: $GNRI = [1.489 \times albumin\ (g/L)] + [41.7 \times (weight/WLo)]$.

WLo is the ideal weight calculated from the Lorentz formula, when the "weight/WLo" is equal to or greater than 1, the ratio is set to 1. Patients are stratified into four categories according to GNRI cut-off values: GNRI < 82: major risk of nutrition-related complications, GNRI 82 to 92 = moderate risk of nutrition-related complications, GNRI 92 to ≤ 98 = low risk, while GNRI > 98 = no risk of nutritional-related complications. To compare GNRI with MNA, we adopted the three categories modification of GNRI cut-off values proposed by Cereda et al. where the two groups of major and moderate risk were combined into a single category [13].

Assessment of physical performance

Handgrip strength (HGS)

It was measured by a hand-held dynamometer (Jamar Hydraulic Hand Dynamometer). The patients were in the seated position. They were instructed to squeeze the handle as hard as possible for 3–5 s with the dominant hand. The measurement was repeated two times after a recovery period of 30 s. The mean of the three trials was calculated. HGS reflects the early changes in muscle function and correlates well with nutritional status [14, 15].

Timed up and go test (TUG)

The TUG test was performed using an ordinary armchair and stopwatch. Subjects were seated with their back against the chair. They were instructed to stand up, walk for 3 m (to a mark on the floor), turn around, walk back to the chair, and sit down. The task was done at the ordinary walking speed wearing the usual footwear. Time calculation in seconds started on the word "go" and stopped as the subject sat down. One untimed trial was allowed before testing. The test was conducted three times and a mean value was calculated for the study [16].

Muscle mass measurement

Muscle mass was measured using direct segmental multi-frequency Bioelectrical Impedance Analysis the In-Body (570) body composition analyzer (Biospace, Inc., Cerritos, CA, USA). BIA is a non-invasive, rapid, and reproducible tool that is widely used to assess basal metabolic rate, fat mass, lean mass, and total body water [17]. Patients wore regular indoor clothing and stood barefooted in upright position with their feet on the feet electrodes and their arms abducted with hands holding on to the hand electrodes. Of the total sample, only 119 participants performed muscle

mass measurements. Skeletal muscle mass (SMM) was automatically assessed through the manufacturer software, then Skeletal Muscle index (SMI) was calculated by adjusting skeletal muscle mass for height squared (SMI = SMM/ht2).

Frailty status

Frailty was defined according to the criteria proposed by Fried et al [4]. We adopted the modifications made by Avila-Funes et al. to diagnose frailty [18]: by the presence of three or more of shrinking, exhaustion, low physical activity, slow gait speed, and weak grip strength. The pre-frail stage was diagnosed when one or two criteria were present.

[1] Shrinking was defined as an unintentional recent weight loss of ≥ 3 kg in the prior year or having a body mass index < 21 kg/m^2.

[2] Exhaustion was determined by two self- reported questions from the Center for Epidemiological Studies-Depression scale (CES-D) ''I felt that everything I did was an effort'' and ''I could not get going.'' The frequencies of these feelings in the prior week were graded as follows: 0 = rarely or none of the time; 1 = some or a little of the time; 2 = a moderate amount of the time; or 3 = most of the time. A score of ''2'' or ''3'' to either of these questions was considered as frail for exhaustion.

[3] Slowness was diagnosed if the time to walk 6 m was ≥ 8 s for height ≤ 173 cm or > 7 s for height > 173 cm in males, and ≥ 8 s for height ≤ 159 cm or > 7 s for height > 159 cm in females, or time to complete TUG test ≥ 19 s.

[4] Weakness was diagnosed using the cut-off points for HGS proposed by Fried's criteria:

- For women: BMI ≤ 23 with HGS ≤ 17, BMI 23.1–26 with HGS ≤ 17.3, BMI 26.1–29 with HGS ≤ 18, and BMI > 29 with HGS ≤ 21.
- For men: BMI ≤ 24 with HGS ≤ 29, BMI 24.1–26 with HGS ≤ 30, BMI 26.1–28 with HGS ≤ 30, and BMI > 28 with HGS ≤ 32.

[5] Low physical activity was diagnosed in individuals who had no daily leisure activities such as walking or gardening and/or deny doing some sport activity per week.

Sarcopenia status

Sarcopenia was defined according to the European Working Group on Sarcopenia in Older Persons (EWGSOP) using an algorithm of gait speed, HGS and SMI [3]. However, participants were reclassified according to the recent update of the EWGSOP2 which updated the operational definition of sarcopenia using low muscle strength as the primary parameter of sarcopenia [19].

Participants were classified based on this recent definition as follows:

1. Probable sarcopenia if low muscle strength was detected.
2. Confirmed sarcopenia diagnosis by additional documentation of low muscle quantity/quality.
3. Severe sarcopenia if low muscle strength, low muscle quantity/quality, and low physical performance were all documented.

Pre-sarcopenia was defined as low SMI only.

We used the following EWGSOP2 cut-off points to define sarcopenia:

- HGS < 27 kg for men and < 16 kg for women
- SMI < 7.0 kg/m2 for men and < 5.5 kg/m^2 for women.
- TUG test ≥ 20 s

Ethical consideration

The study was performed in adherence to the principles established by the Declaration of Helsinki and the study methodology was reviewed and approved by the Research Review Board of the Geriatrics and Gerontology Department, Faculty of Medicine, Ain Shams University. Informed verbal consent was obtained from all the participants because some of the participants were illiterate and could not provide signed consent. The verbal consent was documented in the presence of a next of kin and a nurse. The ethics committee approved using of verbal consent. All patients diagnosed as being malnourished or at risk of malnutrition were subjected to a multidisciplinary nutritional care plan including health education, dietary modifications, enteral nutrition, and parenteral nutrition as needed.

Statistical analyses

The collected data were coded, tabulated, revised, and analyzed using SPSS package 22. For the ROC curves, we used MedCalc Statistical Software version 18.9.1 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2018).

Quantitative variables were presented in the form of means and standard deviation. Qualitative variables were presented in the form of frequency tables (number and percent). A comparison between quantitative variables was carried out using ANOVA or Student t test. A comparison between qualitative variables was carried out using Pearson's χ^2 test. Correlation between two quantitative variables was carried out using Spearman's correlation

coefficient. Statistical difference was accepted when $p < 0.05$. Receiver operating characteristic (ROC) curves were constructed. The area under each ROC curve was calculated to assess the ability of the assessed score to predict recorded outcomes.

Results

The clinical characteristics of the participants by gender are shown in Table 1. There was no significant difference between both genders regarding age, BMI, TUG, albumin, SMI, MNA, and GNRI. Diabetes mellitus (DM), hypertension (HTN) were more prevalent among women, while pulmonary conditions were more prevalent in men.

Men had higher HGS ($p = 0.000$). Although, not reaching statistical significance women were more frail compared to men. (46.5% vs. 29.1%, $p = 0.07$).

Patients were categorized into four groups according to GNRI score. Those with major malnutrition-related risk had significantly lower BMI, HGS, and MNA score. They had prolonged TUG. 65.9% of those with major nutritional-related risk were frail compared to 5% in those with no risk ($p = 0.000$). Dynapenia but not decreased muscle mass was significantly more prevalent in the group with major nutritional risk.

There was no statistically significant difference between the different groups according to GNRI regarding the prevalence of sarcopenia ($p = 0.06$) (Table 2).

According to MNA score, participants were classified into three groups. Those with malnutrition had a higher prevalence of frailty, dynapenia, and sarcopenia (Table 3). There was a moderate correlation between GNRI scores and MNA scores ($r = 0.518$, $p < 0.001$). Tables 2 and 3 showed that GNRI and MNA scores positively correlated with BMI, HGS, and SMI, and negatively correlated with age and TUG (Tables 2 and 3).

Table 4 and Fig. 1 show the AUC, sensitivity, specificity, positive predictive value, and negative predictive value of GNRI score, albumin, BMI, and MNA score for prediction of frailty, sarcopenia, dynapenia, and decreased muscle mass.

GNRI score had lower sensitivity but higher specificity compared to MNA for the prediction of frailty and dynapenia. The BMI was the only statistically significant tool for detecting decreased muscle mass (AUC = 0.97, $p = 0.001$). GNRI could predict the presence of sarcopenia but not pre-sarcopenia (AUC = 0.683, $p = 0.02$, and AUC = 0.586, $p = 0.12$), while MNA did not predict the presence of pre-sarcopenia nor sarcopenia in the studied sample (AUC = 0.56, $p = 0.25$, and AUC = 0.6, $p = 0.09$), respectively.

Table 1 Clinical characteristics of both genders

	Female 71 (47.33%)	Male 79 (52.67%)	*p* values
Age (years) (mean ± SD)	70.05 ± 7.78	68.67 ± 7.76	0.30
Weight (Kg) (mean ± SD)	75.67 ± 22.72	76.69 ± 19.24	0.76
Physical activity level			
Light	36 (50.7%)	22 (27.8%)	0.004
Moderate	35 (49.3%)	57 (72.2%)	
Intense	0	0	
BMI (kg/m^2) (mean ± SD)	30.00 ± 8.62	29.00 ± 6.61	0.20
Waist hip ratio (mean ± SD)	1.00 ± 0.11	1.00 ± 0.08	0.95
MNA (mean ± SD)	18.58 ± 4.80	19.82 ± 4.62	0.18
GNRI (mean ± SD)	87.29 ± 9.34	87.44 ± 9.44	0.92
Albumin g/L (mean ± SD)	31.00 ± 6.21	31.10 ± 6.24	0.92
Performing BIA *n* (%)			
Unable to perform BIA	19 (26.8%)	12 (15.2%)	0.08
Performed BIA	52 (73.2%)	67 (84.8%)	
SMI (ASM/height^2)¶	8.51 ± 4.97	8.87 ± 4.53	0.68
HGS (kg) (mean ± SD)	16.90 ± 6.73	23.76 ± 9.86	0.000
TUG			
Unable to perform	21 (29.6%)	13 (16.5%)	0.55
Performed TUG	50 (70.4%)	66 (83.5%)	
TUG (s) (mean ± SD)	24.39 ± 12.88	19.42 ± 15.19	0.06
Fraity *n* (%)			
Robust	26 (36.6%)	41 (51.9%)	0.079
Prefrail	12 (16.9%)	15 (19.0%)	
Frail	33 (46.5%)	23 (29.1%)	
Dynapenia: decreased HGS *n* (%)	34 (47.9%)	35 (44.3%)	0.39
Sarcopenia *n* (%)¶			
No	24 (46.2%)	27 (40.3%)	0.26
Probable	3 (5.8%)	8 (11.9%)	
Confirmed	12 (23.1%)	13 (19.4%)	
Severe	5 (9.6%)	2 (3.0%)	
Presarcopenia: (Low muscle quantity without sarcopenia) *n* (%)	8 (15.4%)	17 (25.4%)	
Comorbidities *n* (%)			
DM	39 (54.9%)	28 (35.4%)	0.017
HTN	49 (69%)	37 (46.8%)	0.006
IHD	26 (36.6%)	26 (32.9%)	0.63
CKD	19 (26.8%)	18 (22.8%)	0.53
CLD	9 (12.7%)	13 (16.5%)	0.51
Pulmonary disorders	11 (15.5%)	23 (29.1%)	0.001
Anemia	20 (28.2%)	19 (24.1%)	0.56

BMI body mass index, *MMSE* Mini mental state Examination, *GDS* Geriatric depression scale, *MNA* mini nutritional assessment, *GNRI* Geriatric Nutrition Risk Index, *BIA* bioelectrical impedance analysis, *ASM/height2* height adjusted appendicular skeletal muscle, *SMI* skeletal muscle mass index, *HGS* Hand grip strength, *TUG* timed up and Go test, *DM* diabetes mellitus, *HTN* hypertension, *IHD* Ischemic heart disease, *CKD* chronic kidney disease, *CLD* Chronic liver disease

¶Analysis was performed for the participants performed BIA ($n = 119$)

Discussion

Although nutrition is an important determinant of health in the elderly, it is difficult to obtain a reliable nutritional history from many older patients or their caregivers during hospital admission. Therefore, GNRI is considered a perfect tool for predicting malnutrition-related complications in this age group. It is an objective tool including measured albumin, knee height, and actual body weight. It does not require much effort of the elderly to participate in the assessment procedures and it eliminates the bias in MNA caused by caregivers' reporting [10, 20, 21].

In this study, the prevalence of malnutrition based on MNA scores was 39.3% ($n = 59$), and the prevalence of major and moderate risk of nutrition-related complications was 64.4% ($n = 97$) based on GNRI scores. However, there is no reliable data on the prevalence of malnutrition among hospitalized geriatric patients in Egypt. The prevalence of malnutrition in hospitalized elderly patients differs significantly between studies due to the lack of standardized assessment tools and variability in cut-off for anthropometric measures [22].

Several studies have reported the association between GNRI and malnutrition-related morbidities (pressure sores, infection) and mortality [10, 13, 21, 23]; however, this is the first study to assess the accuracy of GNRI in identifying frailty and sarcopenia as possible complications of malnutrition. The correlation between GNRI score and muscle dysfunction (as measured by HGS) was reported in two studies [11, 24]. The decreased HGS was considered as a poor adaptation to malnutrition in elderly population leading to exaggerated age related imbalance of skeletal muscle protein turnover [24].

In this study, HGS, BMI, and SMI correlated with GNRI and MNA scores. Previous reports suggested that HGS can identify malnutrition in hospitalized Chinese elderly and it correlated well with Subjective Global Assessment (SGA) and Nutrition Risk Screening (NRS 2002) scores. The optimal HGS cut-off for detecting malnutrition were 24.9 kg and 15.2 kg for men and women (age 65–74 years) using SGA. They were 27.5 kg for men and 17.0 kg for women using NRS 2002 [25].

In this study, we assessed the usefulness of GNRI as a nutritional screening tool for detecting frailty and sarcopenia.

Table 2 Differences in clinical variables among GNRI categories and related correlations

	Nutrition related risk according to GNRI				p values	GNRI score	
	Severe GRI < 82	Moderate 82 ≤ GNRI < 92	Low 92 < GNRI ≤ 98	No risk GNRI > 98		r	p values
n	41	56	33	20			
Age	70.83 ± 6.91	70.14 ± 8.38	67.06 ± 7.77	68.05 ± 6.72	0.135	−0.165	0.04
BMI	27.20 ± 6.00	28.30 ± 6.82	31.17 ± 8.54	33.20 ± 9.51	0.009	0.245	0.003
MNA	20.08 ± 4.35	20.46 ± 4.07	21.65 ± 3.82	24.07 ± 3.24	0.002	0.518	0.000
HGS	16.93 ± 9.18	20.29 ± 9.39	23.03 ± 8.51	24.35 ± 7.01	0.006	0.294	0.000
TUG	35.59 ± 20.72	17.98 ± 7.95	16.17 ± 6.11	15.75 ± 6.49	0.000	−0.289	0.002
SMI: ASM/height2¶	7.38 ± 3.27	8.41 ± 4.88	9.83 ± 5.18	10.11 ± 5.34	0.11	0.221	0.016
Fried criteria							
Robust	9 (22.0%)	25 (44.6%)	21 (63.6%)	12 (60.0%)	0.000		
Prefrail	5 (12.2%)	11 (19.6%)	3 (9.1%)	7 (35.0%)			
Frail	27 (65.9%)	20 (35.7%)	9 (27.3%)	1 (5.0%)			
Dynapenia	28 (67.3%)	25 (44.6%)	12 (36.4%)	4 (20.0%)	0.002		
Decreased muscle mass¶	10 (55.6%)	19 (70.4%)	31 (73.8%)	20 (62.5%)	0.49		
EWGSOP2 definition of sarcopenia¶							
No	12 (37.5%)	30 (71.4%)	20 (74.1%)	14 (77.8%)	0.06		
Probable	7 (21.9%)	3 (7.1%)	1 (3.7%)	1 (5.6%)			
Confirmed	9 (28.1%)	7 (16.7%)	3 (11.1%)	2 (11.1%)			
Severe	4 (12.5%)	2 (4.8%)	3 (11.1%)	1 (5.6%)			

BMI Body mass index, *MNA* mini nutritional assessment, *GNRI* Geriatric nutrition risk index, *HGS* Hand grip strength, *TUG* timed up and Go test, *ASM/height2* height adjusted appendicular skeletal muscle, *SMI* skeletal muscle mass index, *EWGSOP2* Updated European Working Group on Sarcopenia in Older Persons

¶Analysis was performed for the participants performed BIA ($n = 119$)

Table 3 Differences in clinical variables among MNA categories and related correlations

n	Nutritional status according to MNA			p values	MNA score	
	Malnourished	At risk	No risk		r	p values
	59	47	44			
Age	69.95 ± 7.79	70.09 ± 8.34	67.84 ± 6.87	0.29	− 0.118	0.151
BMI	28.17 ± 6.72	27.49 ± 7.13	32.69 ± 8.38	0.002	0.219	0.007
GNRI	82.96 ± 8.11	85.487 ± 8.70	95.29 ± 6.26	0.000	0.518	0.000
HGS	17.92 ± 8.94	19.91 ± 9.287	24.64 ± 7.90	0.001	0.248	0.000
TUG	26.95 ± 18.28	21.55 ± 13.39	15.84 ± 6.69	0.003	− 0.280	0.002
ASM/height2¶	8.14 ± 4.75	7.39 ± 3.71	10.60 ± 5.08	0.007	0.265	0.000
Fried criteria						
Robust	15 (25.4%)	21 (44.7%)	31 (70.5%)	0.000		
Prefrail	11 (18.6%)	10 (21.3%)	5 (11.4%)			
Frail	33 (55.9%)	16 (34.0%)	8 (18.2%)			
Dynapenia	37 (62.7%)	22 (46.8%)	10 (22.7%)	0.000		
Decreased muscle mass¶	29 (64.4%)	25 (69.4%)	26 (68.4%)	0.87		
EWGSOP2 definition of sarcopenia¶						
No	20 (44.4%)	25 (69.4%)	31 (81.6%)	0.002		
Probable	9 (20.0%)	1 (2.8%)	2 (5.3%))			
Confirmed	11 (24.4%)	9 (25.0%)	1 (2.6%)			
Severe	5 (11.1%)	1 (2.8%)	4 (10.5%)			

BMI Body mass index, *MNA* mini nutritional assessment, *GNRI* Geriatric nutrition risk index, *HGS* Hand grip strength, *TUG* timed up and Go test, *ASM/height2* height adjusted appendicular skeletal muscle, *SMI* skeletal muscle mass index, *EWGSOP2* Updated European Working Group on sarcopenia in older persons

¶Analysis was performed for the participants performed BIA (*n* = 119)

Table 4 Sensitivity, specificity, area under the curve (AUC), positive predictive value (PPV) and negative predictive value (NPV) of GNRI, MNA, albumin, and body mass index

	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	p values
Frailty						
GNRI score at ≤ 86.73	0.741	71.9	65.6	56.2	79.2	< 0.001
Albumin ≤ 30 g/L	0.720	69.64	67.02	55.7	78.7	< 0.001
BMI ≤ 25 kg/m²	0.607	42.11	73.12	49.0	67.3	0.02
MNA ≤ 20	0.690	80.36	52.13	50.0	81.7	< 0.001
Sarcopenia¶						
GNRI score at ≤ 89.04	0.683	64.42	63.53	63.0	64.4	0.02
Albumin ≤ 31 g/L	0.607	53.3	69.6	63.2	60.4	0.07
BMI < 28.65 kg/m²	0.869	82.2	84.7	84.1	83.0	0.0001
MNA ≤ 23	0.600	71.1	45.7	56.1	61.8	0.09
Dynapenia						
GNRI score at ≤ 89.04	0.687	71.9	60.49	60.5	71.00	< 0.001
Albumin ≤ 31 g/L	0.687	68.12	62.96	61.0	69.9	< 0.001
BMI ≤ 25.07 kg/m²	0.591	44.9	74.1	59.6	61.2	0.04
MNA ≤ 21.5	0.667	81.16	53.09	59.6	76.8	0.002
Pre-sarcopenia: decreased muscle mass¶						
GNRI score at ≤ 87.15	0.586	60.00	58.23	42.10	74.20	0.12
Albumin ≤ 28 g/L	0.548	40.00	72.15	42.10	70.4	0.39
BMI ≤ 26.04 kg/m²	0.970	92.5	91.14	96.0	84.1	0.001
MNA ≤ 23	0.561	77.50	36.71	38.3	76.3	0.25

GNRI Geriatric Nutrition Risk Index, *MNA* mini nutritional assessment, *BMI* body mass index

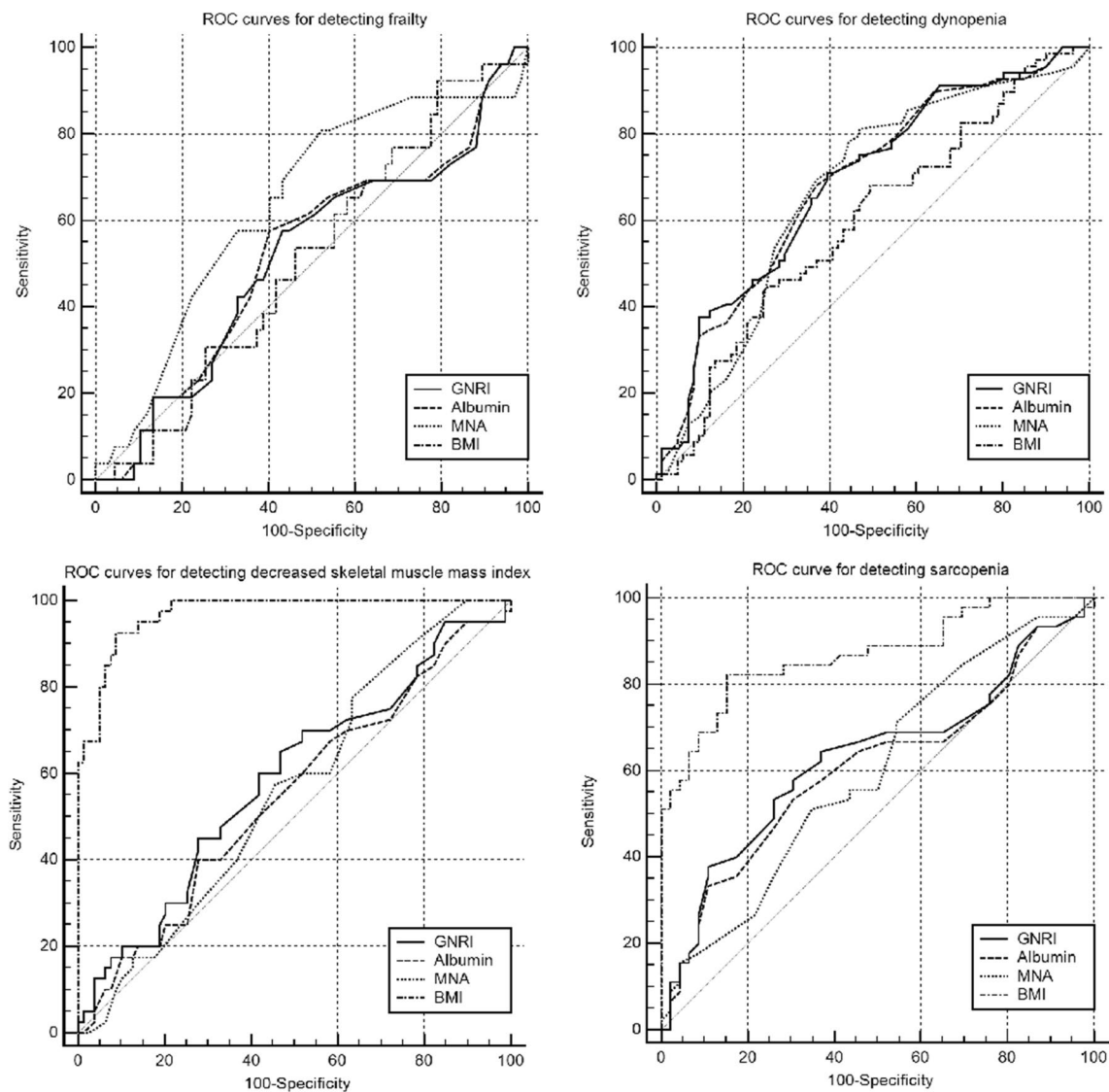¶Analysis was performed for the participants performed BIA (*n* = 119)

Fig. 1 The roc curves of different nutritional assessment parameter in diagnosing frailty, sarcopenia, dynapenia, and decreased muscle mass

Previous attempts to validate nutritional screening tools for frailty and sarcopenia detection were performed. Soysal et al. reported that MNA had an AUC of 0.903 and 0.834 for predicting frailty and prefrailty, respectively [26]. In elderly patients with COPD, the area under curves were 0.875, 0.871, 0.727, and 0.735 for MNA, Mini nutritional assessment- short form, Malnutrition Universal Screening Tool and GNRI for detecting sarcopenia, respectively [27].

In the present study, GNRI score showed good ability to identify hospitalized patients who are frail, sarcopenic, and dynapenic. It failed to predict decreased skeletal muscle mass (pre-sarcopenia). Although, GNRI had lower sensitivity compared to MNA when predicting frailty and weak handgrip, it was more specific. Furthermore, only GNRI and BMI were significant predictors for sarcopenia ($p = 0.02, < 0.0001$, respectively).

BMI was the only significant predictor of pre-sarcopenia (low Skeletal Muscle Mass index). According to Nasimi et al., low BMI and serum albumin level were associated with a higher risk of low SMI [28].

Both MNA < 20, GNRI < 86.73 could predict frailty, (AUC = 0.690, 0.741, respectively). GNRI but not MNA could predict sarcopenia. Moreover, GNRI remains more simple and reliable when assessing elderly patients [20, 21]. It is important to find simple tools to screen for frailty and sarcopenia. The lack of BIA and DXA in the primary care settings may delay detection of these common conditions in older adults, while early implementation of nutritional interventions may reverse them by improving muscle metabolism. The GNRI is a simple method that can be useful in screening for frailty and sarcopenia as consequences of

malnutrition in every older patient attending primary care settings.

Conclusion

In older hospitalized patients, major risk of malnutrition (based on GNRI score) was significantly associated with lower muscle strength, frailty, and sarcopenia. Malnutrition, sarcopenia, and frailty are interrelated conditions that coexisted in 26% of our studied population; therefore, patients at higher risk of malnutrition should be properly assessed for both frailty and sarcopenia.

Compliance with ethical standards

Conflict of interest No potential conflicts of interest were disclosed.

Ethical approval The study was performed in adherence to the principles established by the Declaration of Helsinki and the study methodology was reviewed and approved by the Research Review Board of the Geriatrics and Gerontology Department, Faculty of Medicine, Ain Shams University.

Human and animal rights statement The present study were carried out with full respect to human rights.

Informed consent Informed verbal consent was obtained from all the participants because some of the participants were illiterate and could not provide signed consent. The verbal consent was documented in the presence of a next of kin and a nurse. The ethics committee approved using of verbal consent.

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