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Original article

Evaluation of the efficacy of six nutritional screening tools to predict malnutrition in the elderly

Kalliopi-Anna Poulia [a,b], Mary Yannakoulia [c], Dimitra Karageorgou [c], Maria Gamaletsou [d], Demosthenes B. Panagiotakos [c], Nikolaos V. Sipsas [d], Antonis Zampelas [b,*]

[a] Department of Nutrition, Laikon General Hospital, Athens, Greece
[b] Unit of Human Nutrition, Department of Food Science and Technology, Agricultural University of Athens, Greece
[c] Department of Nutrition and Dietetics, Harokopio University, Athens, Greece
[d] Pathophysiology Department, Laikon General Hospital and Medical School, National and Kapodistrian University of Athens, Greece

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SUMMARY

Background & aims: Malnutrition in the elderly is a multifactorial problem, more prevalent in hospitals and care homes. The absence of a gold standard in evaluating nutritional risk led us to evaluate the efficacy of six nutritional screening tools used in the elderly.
Methods: Two hundred forty eight elderly patients (129 men, 119 female women, aged 75.2 ± 8.5 years) were examined. Nutritional screening was performed on admission using the following tools: Nutritional Risk Index (NRI), Geriatric Nutritional Risk Index (GNRI), Subjective Global Assessment (SGA), Mini Nutritional Assessment – Screening Form (MNA-SF), Malnutrition Universal Screening Tool (MUST) and Nutritional Risk Screening 2002 (NRS 2002). A combined index for malnutrition was also calculated.
Results: Nutritional risk and/or malnutrition varied greatly, ranging from 47.2 to 97.6%, depending on the nutritional screening tool used. MUST was the most valid screening tool (validity coefficient = 0.766, CI 95%: 0.690–0.841), while SGA was in better agreement with the combined index ($\kappa = 0.707$, $p = 0.000$). NRS 2002 although was the highest in sensitivity (99.4%), it was the lowest in specificity (6.1%) and positive predictive value (68.2%).
Conclusions: MUST seem to be the most valid in the evaluation of the risk for malnutrition in the elderly upon admission to the hospital. NRS 2002 was found to overestimate nutritional risk in the elderly.

1. Introduction

Poor nutritional status in the elderly predisposes for adverse functional and clinical outcomes.[1] Malnutrition, in specific, is associated with increased morbidity and mortality, prolonged hospital stay, increased morbidity and mortality and subsequent increase in the cost of health care.[2–4] It is more prevalent in settings where disease and disabilities are common, i.e. in hospitals and care homes, ranging from 37 to 82% and 19–65%, respectively.[5,6]

Malnutrition in the elderly is a multifactorial health problem consisting of physiological, social and economic parameters, often referred as the "nine d's", namely poor dentition, dysgeusia, dysphagia, diarrhea, depression, disease, dementia, dysfunction and drugs.[4] The variety of reasons that can trigger the development of malnutrition in the elderly has led scientists to develop methods for the early recognition of the problem and, thus, the development of a variety of nutritional screening tools. Some are based on biochemical and clinical indexes [i.e. the Nutritional Risk Index (NRI) and the Geriatric Nutritional Risk Index (GNRI)[7]], others on anthropometry, mobility, cognitive state and self perception of health and nutrition [i.e. the Mini Nutritional Assessment (MNA)[8] and it's shorter version, the Mini Nutritional Assessment Screening Form (MNA-SF)[9] as well as the Malnutrition Universal Screening Tool (MUST)[10]], while others are combining data from medical history, clinical and subjective evaluation of the patient [such as the Subjective Global Assessment (SGA)[11] and the Nutritional Risk Screening 2002 (NRS 2002)[12,13]].

Abbreviations: NRI, Nutritional Risk Index; GNRI, Geriatric Nutritional Risk Index; SGA, Subjective Global Assessment; MNA-SF, Mini Nutritional Assessment – Screening Form; MUST, Malnutrition Universal Screening Tool; NRS 2002, Nutritional Risk Screening 2002; VCs, Validity Coefficients; ECOG, Eastern Cooperative Oncology Group; ECOG Performance status, Performance status; BMI, Body Mass Index.

* Corresponding author. Iera Odos 75, Athens 11855, Greece. Tel.: +30 2105294701; fax: +30 2105294945.
E-mail address: azampelas@aua.gr (A. Zampelas).

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Having in mind the vast variety of the available instruments to estimate nutritional risk and to perform nutritional screening, in the present study we attempted to evaluate the efficacy of the main nutritional screening tools developed or used for elderly people on admission to the hospital.

2. Materials and methods

2.1. Subjects

Two hundred forty eight patients (129 men, 119 women) were consecutively enrolled in the study. All patients were over the age of 60 (mean age 75.2 ± 8.5 years). They were emergently admitted to the Clinic of Pathologic Physiology of Laikon General Hospital of Athens from January until September 2009 and the necessary data were collected during a prospective study for the risk factors of nosocomial infections. Participants were informed about the aim of the study and written consent was given by either the patients or their relatives. The study protocol was approved by the Medical Research Ethics Committee of the Laikon General Hospital.

2.2. Anthropometric measurements

Anthropometric measurements were performed with the subjects wearing light clothing, without shoes. Body weight and height were measured by the same researcher, at the time of recruitment, i.e. on admission, and just before discharge, using a scale and a wall-mounted stadiometer to the nearest 0.5 kg and 0.5 cm, respectively. If anthropometric measurements were not feasible (e.g. in the case of a patient unable to stand or unconscious), recalled height and weight were used instead (if reliable and realistic), provided from the patient or the patient's relatives. Body Mass Index (BMI) was computed as weight (in kilograms) divided by height (in meters squared). Percentage of unintentional weight loss over the last 6 months was calculated following patient' s reports.

2.3. Biochemical analyses and clinical examination

Blood samples to determine albumin were drawn from all patients on admission and before discharge and were analyzed in the core lab of Laikon General Hospital for serum albumin, using colorimetry. Normal range for albumin was set at 3.5–5.5 g/dl.

The Eastern Cooperative Oncology Group (ECOG) Performance status (ECOG Performance status) was also reported. ECOG performance status includes scales and criteria set by doctors and researchers to assess how patient's disease is progressing and how the disease state affects patient's daily living abilities. ECOG performance status ranges from 0 to 5, with 0 given to fully active patients, being able to carry on all pre-disease performance without restriction, 1 to restricted in physically active but ambulatory patients, being able to carry out work of light or sedentary nature, 2 to ambulatory and capable of self-care patients but unable to carry out any work activities, 3 to patients capable of only limited self-care, confined to bed or chair, 4 to completely disabled patients and 5 to dead patients.[14]

2.4. Assessment of the nutritional risk

The nutritional status of the study participants was evaluated on the first 48 h following admission using a variety of tools, namely NRI, GNRI, SGA, MNA-SF, MUST and NRS 2002, as presented in Table 1. From the above mentioned questionnaires SGA, MUST and NRS 2002 were translated by 2 independent bilingual translators. Another English expert who did not have knowledge of the original tools then back translated the Greek version. The backward translation was sent to a group of English experts for comments and then the final version of the translated questionnaires were applied.

2.4.1. NRI and GNRI

NRI has been used as an index of malnutrition, combining albumin with a second nutrition indicator, i.e. recent weight loss, which is frequently used for grading the level of malnutrition. NRI is calculated as follows: NRI = (1.519 × serum albumin concentrations, g/L) + 41.7 (present weight/usual weight).[15] Patients are categorized according to their NRI score as "well nourished, "mildly malnourished" "moderately malnourished", for, and or "severely malnourished", according to the rating in Tables 2 and 3.

GNRI is an adaptation of NRI for older patients and it is calculated by the equation: GNRI = (1.489 × serum albumin, g/L) + 41.7 (present body weight/Ideal Body Weight),[7] where ideal weight is calculated by Lorentz Equations.[16] The need for the development of GNRI was emerged due to the difficulty of identifying usual body weight in geriatric patients, a value that was replaced by ideal body weight as calculated by Lorentz equations,[17] Patients are categorized as "well nourished" or, moderate or severe

Table 1
Presentation of the indexes used as nutritional screening tools for the evaluation of malnutrition.

Screening tool	Year of validation	Application and setting	Measurements and data	Initial purpose
MNA-SF	2001	Validated in all settings	6 parts, evaluating swallowing ability anthropometric data, physical and cognitive condition and mobility	To detect malnutrition in the elderly
MUST	2003	All community and hospital settings	Combines weight status, weight loss history, nutritional intake and the effect of acute disease	To detect malnutrition in adult populations
SGA	1987	Hospital, all clinical settings	Physical signs of malnutrition, functional capacity, gastrointestinal disturbances	To detect overt malnutrition
NRS 2002	2002	Acute hospital	Weight status, weight loss history, nutritional intake, severety of disease	To detect malnutrition and identify patients who need closer monitoring
NRI	1980	Hospital	Serum albumin, weight alterations	To detect malnutrition and its associations to postoperative complications
GNRI	2005	Acute hospital, rehabilitation care, long term care	As in NRI	As in NRI, especially designed for the elderly

MNA-SF: Mini Nutritional Assessment Screening Form, MUST: Malnutrition Universal, Screening Tool, NRS 2002: Nutritional Risk Screening 2002, NRI: Nutritional Risk Index, GNRI: Geriatric Nutritional Risk Index. All data are presented as (Mean ± SD or relative frequencies).

Table 2
Characteristics of the patients.

Characteristics	$n = 248$
Sex	
Male	129 (52%)
Female	119 (48%)
Body weight (kg)	68.2 ± 13.5
Height (cm)	164 ± 8.1
Age (years)	75.2 ± 8.5
BMI (kg/m^2)	25.1 ± 4.5
Ethnicity	
Caucasian/Greek	248
Length of stay in hospital (days)	10.3 ± 12.0
ECOG status (N) (%)	
Fully active	84 (33.9%)
Restricted	85 (34.3%)
Ambulatory	20 (8.1%)
Limited self-care	21 (8.5%)
Completely disabled	38 (15.3%)
Cause of admission (*n*) (%)	
Neurological syndrome	27 (10.9%)
Fever	39 (15.7%)
Blood disease	62 (25.0%)
Rheumatological disease	25 (10.1%)
Malignancy	32 (12.9%)
Hemorrhage	26 (10.5%)
Liver/pancreatic/gallbladder disease	17 (6.8%)
Electrolyte imbalance/kidney disease	12 (4.8%)
Pulmonary disease	6 (2.4%)
Diabetes mellitus	2 (0.8%)

risk of nutrition related complications, according to the rating in Table 3.[7] It should be stressed that NRI and GNRI are indexes of risk for development of nutrition related problems and not nutritional screening tools. However, they are strongly correlated with other variables of nutritional status, so they can be used as tools for malnutrition grading.[18]

2.4.2. SGA questionnaire

SGA grade of malnutrition is determined using data collected about weight loss, changes in dietary intake, symptoms from the gastrointestinal tract (i.e. diarrhea, nausea, anorexia), physical function and parameters of physical examination, i.e. loss of subcutaneous fat, loss of muscular mass, presence of ascites, edema and dehydration. Normally nourished patients are classified as "grade A", patients with moderate malnutrition as "grade B" and the severely malnourished as "grade C"(Table 3).[19] To avoid potential observer bias, SGA was performed by the same medical doctor. SGA has been tested and validated in different clinical settings and, due to the inclusion of data from clinical examination as well as from medical history and anthropometry, it is considered a rather accurate, relatively easy to perform and a quick tool for estimating nutritional risk.[2,20–27] Among the disadvantages of SGA, subjectivity and the need of a medical doctor to perform the clinical examination are often included.[24,27–29]

2.4.3. MUST

MUST is a screening tool developed for all adult patients across all health care settings.[30] It has been validated for the screening of patients with malnutrition and in clinical setting it has been proven to have high internal validity and reproducibility.[31,32] It uses current BMI, unintentional weight loss and the presence of any acute disease effect that could compromise nutritional intake for >5 days.[32] It includes three parameters rating them as 0, 1 or 2 as follows: BMI > 20 kg/m^2 = 0; 18.5–20.0 kg/m^2 = 1; <18.5 kg/m^2 = 2; weight loss <5% = 0; 5–10% = 1; >10% = 2; acute disease: absent = 0; if present = 2. Overall risk of malnutrition is established as presented in Table 3.

2.4.4. NRS 2002

NRS 2002, the nutritional screening tool proposed by the ESPEN guidelines for the nutritional screening of patients,[13] combines two scores, the "nutritional score" of 0–3 and the "severity of disease score" of 0–3 plus 1 point if the patient is above 70 years of age. Nutritional risk is established according to the rating in Table 3. It is considered an easy to perform and quick screening tool, which does not require additional calculations (e.g. BMI). However, the fact that is requires a subjective evaluation of the severity of disease could alter the final result of the screening. It should also be stressed though that NRS 2002 has been validated for its accuracy to detect patients likely to be benefited from any means of nutritional support and not as a screening tool for malnutrition per se.[13]

2.4.5. MNA-SF

MNA-SF, the shorter form of MNA, is a nutritional screening tool especially designed for the elderly.[9] It consists of six questions, scored from zero to two or three. These questions address present weight loss, appetite, mobility, psychological stress, neuropsychological problems and BMI. Patients are categorized as with "normal nutritional status", at "nutritional risk" and "malnourished", as presented in Table 3.[9] Compared to MNA, MNA-SF is considered a more convenient screening tool, as it is quicker and easier to be completed, requiring less than 5 min. It has been validated as a nutritional screening tool and it can be used for an initial screening and then combined with MNA, in cases of patients requiring a more detailed nutritional assessment.[9] MNA and MNA-SF are considered to be the most appropriate tools for elderly patients. [12,13] A disadvantage of MNA and MNA-SF is that are not appropriate for patients who cannot provide reliable information about themselves (i.e. patients with Alzheimer's disease, dementia, stroke, etc) and for patients receiving nutritional support through nasogastric tubel feeding.[22]

Table 3
Ratings of malnutrition according to the screening tools.

Screening tool	Nutritional Status/risk
Nutritional Risk Index (NRI)	
>100	Well nourished
97.5 < NRI < 100	Mildly malnourished
83.5 ≤ NRI ≤ 97.5	Moderately malnourished
<83.5	Severely malnourished
Geriatric Nutritional Risk Index	
>98	Well nourished – at no risk of nutrition related complications
92 ≤ GNRI ≤ 98	At low risk of nutrition related complications
82 ≤ GNRI < 92	At moderate risk of nutrition related complications
>82	At severe risk of nutrition related complications
Subjective Global Assessment (SGA)	
Grade A	Normally nourished
Grade B	Moderate malnourished
Grade C	Severely malnourished
Malnutrition Universal Screening Tool (MUST)	
0	Low risk of malnutrition
1	Medium risk malnutrition
2	High risk of malnutrition
Nutritional Risk Screening 2002 (NRS 2002)	
0	No risk
1–2	Low risk
3–4	Medium risk
≥5	High risk
Mini Nutritional Assessment – Screening Form (MNA – SF)	
12–14	Normal nutritional status
8–11	At nutritional risk
0–7	Malnourished

2.4.6. Combined index

Since there is no gold standard in estimating nutritional status on admission to the hospital for elderly patients we decided to calculate a combined index as a reference tool, using the methodology previously suggested by Pablo et al.[33] It derives from a merge of the results of the nutritional indexes measured: in specific, if the patient is evaluated as malnourished to any degree or at risk of malnutrition according to at least four out of six pre-mentioned tools, he/she was categorized as malnourished in the combined index classification.

2.5. Statistical analysis

Continuous variables were expressed as mean values ± standard deviation (Mean ± SD), while categorical variables as absolute and relative frequencies. The Shapiro–Wilk test was applied to evaluate normality of the distributions. All reported *P*-values are based on two-sided tests and compared to a significance level of 5%. Cohen's kappa (κ) statistic was calculated to determine diagnostic concordance between the assessment tools (i.e. MNA-SF, MUST, SGA, GNRI, NRI, and NRS 2002). κ is a statistical measure of inter–annotator agreement for qualitative variables. In case of complete agreement between the variables, then $\kappa = 1$. If there is no agreement among the variables measured (other than what would be expected by chance) then $\kappa \leq 0$.

Sensitivity, specificity and predictive values for each nutrition screening tool were calculated by the use of the combined index, which was considered the criterion of true malnutrition of any degree, as follows: Sensitivity = A/A + B; Specificity = D/C + D; Positive predictive value = A/A + C; Negative predictive value = D/B + D, where A = malnourished patients by both the nutritional tool and the combined index, B = malnourished by the combined index but not from the nutritional tool, C = malnourished by the nutritional tool but not by the combined index, and D = not malnourished either by the nutritional screening tool or by the combined index.

We also applied an extended "method of triads" to our six variables in order to assess validity and reproducibility of the screening tools. It was assumed that all the estimations of the nutritional status were linearly related to the True nutritional status or the patients (T), according to the methodology of the "method of triads".[34,35] Pair-wise correlations between nutritional screening tools were computed and Validity Coefficients (VCs) between the estimation of the nutritional status by the nutritional screening tools and the True but latent nutritional status of the patients were estimated, as presented in Figs. 1 and 2. 95% Confidence Intervals were also computed for each VC. Statistical analysis was performed using SPSS for Windows, version 13.0 (SPSS Inc., Chicago, IL).

3. Results

Mean hospital stay was 10.3 ± 12.0 days, ranging from 1 to 102 days (Table 2). Based on the ECOG Performance status assessment, the majority of the patients on admission were either fully active [n = 84, (33.9%)] or restricted [n = 85, (34.3%)], while only 20 patients (8.1%) were ambulatory, 21 (8.5%) were of limited self care and 38 (15.3%) completely disabled. Twelve patients (4.8%) were unable to stand even when supported and their anthropometric measurements were obtained by recalls either by the patients or by their closest relatives. The frequency of any degree of malnutrition or risk of developing malnutrition on admission to the hospital varied greatly, depending on the nutritional screening tool used. According to the combined index, 66.9% of the patients were at risk of malnutrition of any degree, while this percentage varied from 47.2% (GNRI) to 97.6% (NRS 2002). The percentage of patients with normal nutritional status varied accordingly, from 2.4% (NRS 2002) to 52.8% (GNRI), while 33.1% of the patients were found not at risk of malnutrition according to the combined index (Fig. 1).

Agreement between our method of assessing the risk of malnutrition, i.e. the results according to the combined index was also in great variation. In descending order, the highest agreement with the combined index was found in SGA [86.3% (214/248) of the cases ($\kappa = 0.707$, $p = 0.000$)], followed by MUST [83.9% (208/248) of the patients ($\kappa = 0.638$, $p = 0.000$)], MNA-SF [81.5% (202/248) of the patients ($\kappa = 0.545$, $p = 0.000$)], NRI [80.2% (186/232) of the patients ($\kappa = 0.550$, $p = 0.000$)], GNRI [73.1% (171/235) of the cases ($\kappa = 0.465$, $p = 0.000$)], while NRS 2002 had the lowest agreement with the combined index [68.5% (170/248) of the patients ($\kappa = 0.088$, $p = 0.000$)].

The validity of the tools examined as estimated by the extended method of triads revealed that MUST had the best correlation with the True nutritional status of the patients [$VC_{MUST\text{-}T} = 0.766$ (95% CI: 0.690–0.841)], followed by MNA-SF [$VC_{MNA\text{-}T} = 0.633$ (95% CI: 0.572–0.694)], GNRI [$VC_{GNRI\text{-}T} = 0.465$ (95% CI: 0.383–0.547)], NRI [$VC_{NRI\text{-}T} = 0.437$ (95% CI: 0.360–0.514)] and SGA [$VC_{SGA\text{-}T} = 0.427$ (95% CI: 0.349–0.505)]. NRS 2002 had the lowest correlation with the true nutritional status with a $VC_{NRS\ 2002\text{-}T}$ equal to 0.060 (95% CI: 0.029–0.091).

Statistical evaluation of the efficacy of nutritional screening tools to predict malnutrition is presented in Table 4. The highest sensitivity was found in descending order in NRS 2002 (99.4%), MNA-SF (98.1%), MUST (87.3%), SGA (84.3%), NRI (71.7%) and GNRI (66.0%). On the other hand NRS 2002 was found to have the lowest specificity among the screening tools (6.1%), followed by NRI (48.8%), MNA-SF (50%), MUST (76.8%), SGA (91.4%) and GNRI, which was found to be the highest in specificity (92.1%). NRS 2002 had also the lowest positive predictive value (68.2%), while the highest was the one of SGA (95.2%). MNA-SF was found to have the best negative predictive value (93.2%), while NRI had the lowest (29.3%).

4. Discussion

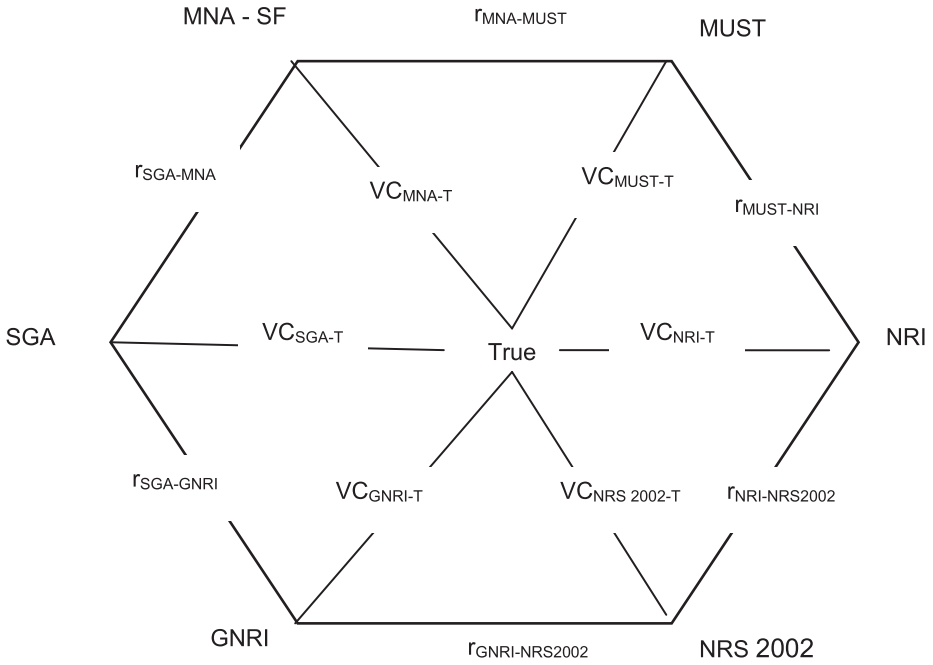
The present study is the first evaluation of six nutritional screening tools focused on the nutritional status of the elderly. Studies that have been conducted in the past on this topic used either lower number of nutritional tools or they refer to a more general population, i.e. adults of any age.[22,26] Moreover, it is the first time that the extended methods of triads is applied for the evaluation of nutritional screening tools, a statistical method for the assessment of validity and reproducibility, even when the true value is latent. In our case, where nutritional status and nutritional risk can only be estimated and not accurately measured, given the limited available time in clinical setting, this statistical method of the evaluation of existing and used it practice nutritional screening tools can be proven of great value and importance.

According to our study, the risk of malnutrition of any stage according to the combined index was found to be present at the 66.9% of the patients on admission. Our results are in agreement with other studies, where the risk of malnutrition in elderly patients entering a secondary health institute ranges from 37 to 82%.[5,6,36] Variations among studies on the malnutrition rates can be attributed to the nutritional screening tools used and/or to the population under investigation.

MUST according to VCs was found to have the greater validity among the screening tools measured; it also had the second higher value of agreement with the combined index. MUST was especially developed for nutritional screening and it combines the basic characteristics needed for a nutritional screening tool, i.e. it is straightforward, quick and easy to use.[30,32] Moreover it as it

includes objective and subjective information to limit bias by the personnel performing the screening and to include the impact of the examiner's experience, which can be proven valuable. Its high level of validity and the agreement with the combined index could lead us to the conclusion that MUST, as the easiest to apply among the tools used, is an extremely useful screening instrument in settings where time and personnel resources are limited.

On the other hand, SGA, a nutritional tool that includes information on weight loss, change in dietary intake, symptoms from the gastrointestinal tract and subjective assessment of physical parameters, was found to have the greatest agreement with the combined index, having at the same time high values of sensitivity, specificity, positive and negative predictive values and satisfactory validity as estimated by VC. SGA has been tested and evaluated in



$$VC_{MUST-T} = \sqrt{r_{MUST-MNA} * r_{MUST-SGA} * r_{MUST-NRI} * r_{MUST-GNRI} * r_{MUST-NRS2002} / r_{MNA-SGA} * r_{SGA-GNRI} * r_{GNRI-NRS2002} * r_{NRS2002-NRI}}$$

$$VC_{NRS2002-T} = \sqrt{r_{NRS2002-NRI} * r_{NRS2002-SGA} * r_{NRS2002-MUST} * r_{NRS2002-GNRI} * r_{NRS2002-MNA} / r_{NRI-MUST} * r_{SGA-GNRI} * r_{GNRI-MNA} * r_{MUST-MNA}}$$

$$VC_{NRI-T} = \sqrt{r_{NRI-NRS2002} * r_{NRI-SGA} * r_{NRI-MUST} * r_{NRI-GNRI} * r_{NRI-MNA} / r_{NRS2002-GNRI} * r_{SGA-GNRI} * r_{SGA-MNA} * r_{MUST-MNA}}$$

$$VC_{MNA-T} = \sqrt{r_{MNA-MUST} * r_{MNA-SGA} * r_{MNA-NRI} * r_{MNA-GNRI} * r_{MNA-NRS2002} / r_{NRS2002-GNRI} * r_{SGA-GNRI} * r_{NRI-NRS2002} * r_{MUST-NRI}}$$

$$VC_{SGA-T} = \sqrt{r_{SGA-MUST} * r_{SGA-MNA} * r_{SGA-NRI} * r_{SGA-GNRI} * r_{SGA-NRS2002} / r_{NRS2002-GNRI} * r_{MUST-MNA} * r_{NRI-NRS2002} * r_{MUST-NRI}}$$

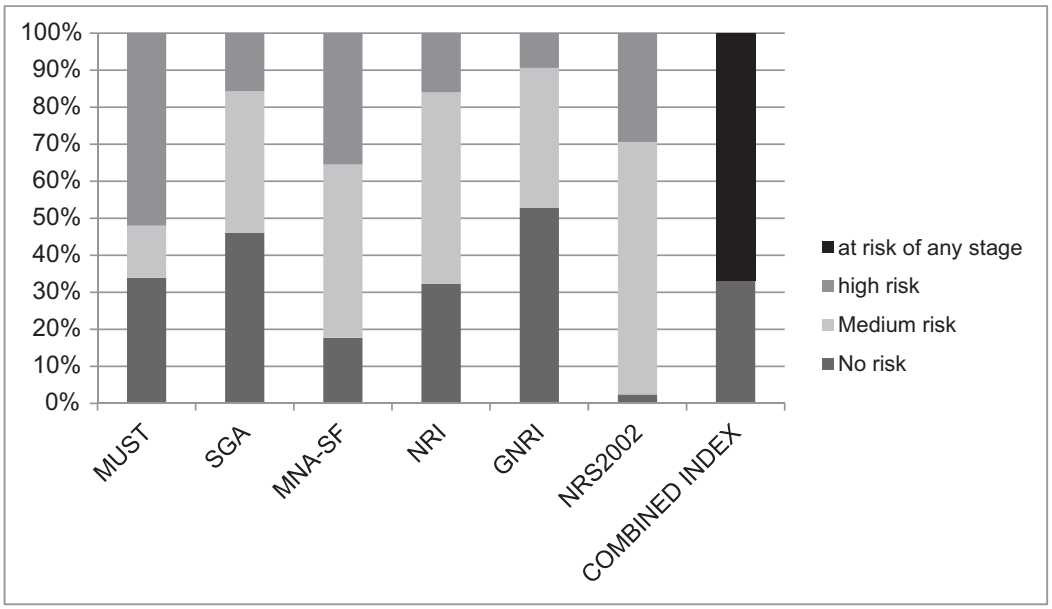
$$VC_{GNRI-T} = \sqrt{r_{GNRI-MUST} * r_{GNRI-MNA} * r_{GNRI-NRI} * r_{GNRI-SGA} * r_{GNRI-NRS2002} / r_{MNA-SGA} * r_{MUST-MNA} * r_{NRI-NRS2002} * r_{MUST-NRI}}$$

where VC_{MUST-T} = validity coefficient for MUST, $VC_{NRS2002-T}$ = validity coefficient for NRS2002, VC_{NRI-T}= validity coefficient for NRI, VC_{MNA-T} = validity coefficient for MNA, VC_{SGA-T} = validity coefficient for SGA, VC_{GNRI-T} = validity coefficient for GNRI, and r = the correlations between the nutritional screening tools.

Fig. 1. The diagrammatic representation of the extended method of triads to estimate Validity Coefficients between the nutrition screening tools. In Fig. 1 the hexagon with all screening tools is presented, along with linear correlations between them and the validity coefficients with the True nutritional status. Validity Coefficients were calculated according to the extended method of triads by the equations included in the figure.

different settings [i.e. on admission to the hospital, in Intensive Care Units (ICU) etc.] and it includes information from clinical examination and medical history, and, therefore, it may provide a more accurate estimation, although subjective, of the nutritional risk of the patient. SGA has been previously compared to other nutritional indexes and tools and it has been proven a reliable way of estimating nutritional risk.[20–22]

The frequency of any degree of malnutrition or risk of developing malnutrition on admission to the hospital varied greatly between the six nutritional tools we examined, and ranged from 47.2% (GNRI) to 90.3% (NRS 2002). The high prevalence of the risk of malnutrition of any stage as measured by NRS 2002 is in agreement with its high sensitivity. High sensitivity of a nutritional screening tool, although desirable, can give false positives, with more patients categorized at risk of malnutrition than it is actually the case.[33] NRS 2002 was also found to have the lowest positive predictive value among the screening tools measured, a finding indicating that patients could have been falsely classified as malnourished or in



	MUST N=248	SGA N=248	MNA-SF N=248	NRI N=232	GNRI N=235	NRS2002 N=248	COMBINED INDEX
No risk, % (n)	33.9 (84/248)	40.7 (126/248)	17.7 (44/248)	32.3 (75/232)	52.8 (124/235)	2.4 (6/248)	33.1 (82/248)
Low or/and Medium risk, % (n)	14.1 (35/248)	41.9 (104/248)	46.8 (116/248)	51.7 (120/232)	37.8 (89/235)	68.2 (169/248)	
High Risk, % (n)	52.0 (129/248)	17.3 (43/248)	35.5 (88/248)	15.9 (37/232)	9.4 (22/235)	29.4 (73/248)	
At risk of any stage, % (n)	66.1 (164/248)	59.2 (147/248)	82.3 (204/248)	67.6 (157/232)	47.2 (111/235)	97.6 (169/248)	66.9 (166/248)

MNA-SF: Mini Nutritional Assessment Screening Form, MUST: Malnutrition Universal Screening Tool, NRS 2002:Nutritional Risk Screening 2002, NRI: Nutritional Risk Index, GNRI: Geriatric Nutritional Risk Index

Fig. 2. Prevalence of malnutrition or risk of malnutrition according to the screening tools used. The figure also includes the precise percentages of patients regarding their nutritional status.

Table 4
Statistical evaluation of the nutritional screening tools, compared to the combined index.

Nutritional Screening tool	NRI	GNRI	NRS 2002	MUST	MNA-SF	SGA
Sensitivity (%)	71.7	66.0	99.4	87.3	98.1	84.3
Specificity (%)	48.8	92.1	6.1	76.8	50.0	91.4
Positive predictive value (%)	85.4	94.6	68.2	88.4	79.9	95.2
Negative predictive value (%)	29.3	56.45	83.3	75.0	93.2	74.3
κ value (p)	0.550 (0.000)	0.465 (0.000)	0.088 (0.000)	0.638 (0.000)	0.545 (0.000)	0.707 (0.000)
VC (95% CI)	0.437 (0.360–0.514)	0.465 (0.383–0.547)	0.060 (0.029–0.091)	0.766 (0.690–0.841)	0.633 (0.572–0.694)	0.427 (0.349–0.505)

κ value derived from Cohen kappa statistics. VCs derived from the extended method of triads. MNA-SF: Mini Nutritional Assessment Screening Form, MUST: Malnutrition Universal Screening Tool, NRS 2002: Nutritional Risk Screening 2002, NRI: Nutritional Risk Index, GNRI: Geriatric Nutritional Risk Index, VC = Validity Coefficient, CI = Confidence Interval.

danger of becoming malnourished. At the same time, NRS 2002 was found to have the lowest agreement with the combined index and the lowest VC, showing low validity and reproducibility to the population examined. This finding is in disagreement with ESPEN nutritional screening guidelines,[12] a result that could be attributed to the fact that our sample includes only elderly patients which may require screening with population specific tools.

According to our analysis, a nutritional screening tool especially designed for the elderly, the MNA-SF, was found to have high sensitivity (98.1%), high negative predictive value (93.2%) and a better agreement with the combined index ($k = 0.545$, $p = 0.000$). Moreover MNA-SF was found to be relatively valid according to VC. This finding is reasonable and expected as MNA-SF is especially designed for elderly.[8,9,37] GNRI, an adaptation of NRI for geriatric patients[7] was also found to have higher specificity and negative predictive value than NRI (92.1% vs 48.8%, 94.6% vs 85.4%, and 56.45 vs 29.9% respectively) and relatively similar validity according to their VCs. Even though GNRI was in lower agreement with the combined index, it seems that it satisfies it's name, being a more specific index for older people. Their similar validity and reproducibility is expected, given that they are both calculated by the use of similar variables, i.e. albumin blood concentrations and weight changes.[7,15].

One limitation of our study is that the nutritional screening tools included in our study has not been validated in Greek population in the past. These questionnaires, though, have been validated and performed in various population groups, including patients from the Mediterranean countries, who have comparable characteristics with the Greek patients. Moreover, the scope of our study was to evaluate the predictive value of different nutrition screening tools detect malnutrition in the sample of elderly patients, and not just to evaluate nutritional risk of the elderly. Therefore the lack of validation in a Greek population is not considered a major limitation affect in the validity of our results. Another limitation of our study is that in a small subsample (12 patients, 4.8% of the sample) anthropometric measurements were not feasible due to physical limitations. Recalled weight was used instead due to the lack of bed-scales in our institution and recalled height instead of alternative measurements, a fact that did not significantly alter the results, when we performed the analysis excluding these patients. As nutritional screening has been recognized as the first step in the treatment of malnutrition,[38] the importance of including a reliable and easy to use tool on patients' screening on admission is great. Having in mind that there is no gold standard, estimating the risk of malnutrition with population specific nutritional screening tools could be rather useful. Moreover, nutritional indexes, due to their objectivity could also be rather helpful in estimating malnutrition risk on admission to the hospital.[15] According to our results, MNA-SF and MUST seem to have better validity, while SGA and MUST are proven to be in better agreement with our standard of malnutrition risk, i.e. combined index. Nonetheless, the geriatric specific index i.e. GNRI, has emerged as an important malnutrition screening instrument.

These results stress out the importance of combining objective and subjective information on estimating nutritional status, in an easy and quick way to perform, in order to facilitate it's completion by the medical staff. Moreover we should always bear in mind that estimation of nutritional risk is indicative of the danger of malnutrition, but only close monitoring of the patients' needs and disease state during hospitalization can reassure its early detection and successful treatment.

Conflict of interest

None of the authors have any financial or personal relationship with other people or organizations that could bias their work.

Statement of authorship

KAP carried out the study, data analysis and interpretation and drafted the manuscript. MY conceived the study and drafted the manuscript. DK carried out the data collection. MG also carried out data collection. DBP participated in the design of the study, performed the statistical analysis and drafted the paper. NS participated in the study design and coordination and drafted the manuscript. AZ supervised the study, participated in its design and drafted the manuscript. All authors have read and approved the final article.

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References

1. Amarantos E, Martinez A, Dwyer J. Nutrition and quality of life in older adults. *J Gerontol A Biol Sci Med Sci* 2001;**56**:54–64.
2. Waitzberg DL, Caiaffa WT, Correia MI. Hospital malnutrition: the Brazilian national survey (IBRANUTRI): a study of 4000 patients. *Nutrition* 2001;**17**:573–80.
3. Correia MI, Campos AC. Prevalence of hospital malnutrition in Latin America: the multicenter ELAN study. *Nutrition* 2003;**19**:823–5.
4. Edington J, Boorman J, Durrant ER, et al. Prevalence of malnutrition on admission to four hospitals in England. The Malnutrition Prevalence Group. *Clin Nutr* 2000;**19**:191–5.
5. Christensson L, Unosson M, Ek AC. Evaluation of nutritional assessment techniques in elderly people newly admitted to municipal care. *Eur J Clin Nutr* 2002;**56**:810–8.
6. Omran ML, Morley JE. Assessment of protein energy malnutrition in older persons, part I: history, examination, body composition, and screening tools. *Nutrition* 2000;**16**:50–63.
7. Cereda E, Pedrolli C. The Geriatric Nutritional Risk Index. *Curr Opin Clin Nutr Metab Care* 2009;**12**:1–7.
8. Vellas B, Guigoz Y, Garry PJ, et al. The Mini Nutritional Assessment (MNA) and its use in grading the nutritional state of elderly patients. *Nutrition* 1999;**15**:116–22.
9. Rubenstein LZ, Harker JO, Salva A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the short-form mini-nutritional assessment (MNA-SF). *J Gerontol A Biol Sci Med Sci* 2001;**56**:M366–72.
10. Russell CA, Elia M. Malnutrition in the UK: where does it begin? *Proc Nutr Soc* 2010;**69**:465–9.

11. Detsky AS, McLaughlin JR, Baker JP, et al. What is subjective global assessment of nutritional status? *JPEN J Parenter Enteral Nutr* 1987;**11**:8–13.
12. Kondrup J, Rasmussen HH, Hamberg O, Stanga Z. Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. *Clin Nutr* 2003;**22**:321–36.
13. Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. *Clin Nutr* 2003;**22**:415–21.
14. Oken MM, Tormey DC, Davis TE, et al. Toxicity And Response Criteria Of The Eastern Cooperative Oncology Group. *Am J Clin Oncol* 1982;**5**:649–55.
15. Schneider S, Hebuterne X. Use of nutritional scores to predict clinical outcomes in chronic diseases. *Nutrition Reviews* 2000;**58**:31–8.
16. Bouillanne O, Morineau G, Dupont C, et al. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. *Am J Clin Nutr* 2005;**82**:777–83.
17. Robbins LJ. Evaluation of weight loss in the elderly. *Geriatrics* 1989;**44**:31–4.
18. Cereda E, Limonta D, Pusani C, Vanotti A. Assessing elderly at risk of malnutrition: the new Geriatric Nutritional Risk Index versus Nutritional Risk Index. *Nutrition* 2006;**22**:680–2.
19. Baker JP, Detsky AS, Wesson DE, et al. Nutritional assessment: a comparison of clinical judgement and objective measurements. *N Engl J Med* 1982;**306**:969–72.
20. Persson MD, Brismar KE, Katzarski KS, Nordenstrom J, Cederholm TE. Nutritional status using Mini Nutritional Assessment and Subjective Global Assessment predict mortality in geriatric patients. *J Am Geriatr Soc* 2002;**50**:1996–2002.
21. Wakahara T, Shiraki M, Murase K, et al. Nutritional screening with Subjective Global Assessment predicts hospital stay in patients with digestive diseases. *Nutrition* 2007;**23**:634–9.
22. Bauer JM, Vogl T, Wicklein S, Trogner J, Muhlberg W, Sieber CC. Comparison of the Mini Nutritional Assessment, Subjective Global Assessment, and Nutritional Risk Screening (NRS 2002) for nutritional screening and assessment in geriatric hospital patients. *Z Gerontol Geriatr* 2005;**38**:322–7.
23. Planas M, Audivert S, Perez-Portabella C, et al. Nutritional status among adult patients admitted to an university-affiliated hospital in Spain at the time of genoma. *Clin Nutr* 2004;**23**:1016–24.
24. Ockenga J, Freudenreich M, Zakonsky R, Norman K, Pirlich M, Lochs H. Nutritional assessment and management in hospitalised patients: implication for DRG-based reimbursement and health care quality. *Clin Nutr* 2005;**24**:913–9.
25. Kawaguchi Y, Sugino N, Arai J, et al. Nutritional assessment of patients on continuous ambulatory peritoneal dialysis. *Nippon Jinzo Gakkai Shi* 1993;**35**:843–51.
26. Kyle UG, Kossovsky MP, Karsegard VL, Pichard C. Comparison of tools for nutritional assessment and screening at hospital admission: a population study. *Clin Nutr* 2006;**25**:409–17.
27. Plauth M, Cabre E, Riggio O, et al. ESPEN Guidelines on Enteral Nutrition: liver disease. *Clin Nutr* 2006;**25**:285–94.
28. Pirlich M, Schutz T, Norman K, et al. The German hospital malnutrition study. *Clin Nutr* 2006;**25**:563–72.
29. Meier R, Ockenga J, Pertkiewicz M, et al. ESPEN guidelines on enteral nutrition: pancreas. *Clin Nutr* 2006;**25**:275–84.
30. Elia M. *Screening for malnutrition: a multidisciplinary responsibility. Development and use of the 'Malnutrition Universal Screening Tool' ('MUST') for adults*. Malnutrition Advisory Group (MAG), a Standing Committee of BAPEN. Redditch, Worcs: BAPEN; 2003.
31. Elia M. *The MUST report: nutritional screening for adults: a multidisciplinary responsibility*. Maidenhead, Berks, UK: BAPEN (MAG); 2003.
32. Stratton RJ, Hackston A, Longmore D, et al. Malnutrition in hospital outpatients and inpatients: prevalence, concurrent validity and ease of use of the "Malnutrition Universal Screening Tool" (MUST) for adults. *Br J Nutr* 2004;**92**:799–808.
33. Pablo AR, Izaga MA, Alda LA. Assessment of nutritional status on hospital admission: nutritional scores. *Eur J Clin Nutr* 2003;**57**:824–31.
34. Kabagambe EK, Baylin A, Allan DA, Siles X, Spiegelman D, Campos Hannia. Application of the method of triads to evaluate the performance of food frequency questionnaires and biomarkers as indicators of long-term dietary intake. *Am J Epidemiol* 2001;**154**:1126–35.
35. Ocke M, Kaaks R. Biochemical markers as additional measurements in dietary validity studies: application of the method of triads with examples from the European prospective investigation into cancer and nutrition. *Am J Clin Nutr* 1997;**65**:1240S–5S.
36. Guigoz Y, Lauque S, Vellas BJ. Identifying the elderly at risk for malnutrition. The Mini Nutritional Assessment. *Clin Geriatr Med* 2002;**18**:737–57.
37. Ranhoff A, Gjøen A, Mowé M. Screening for malnutrition in elderly acute medical patients: the usefulness of MNA-SF. *J Nutr Health Aging* 2005;**9**:221–5.
38. Blackburn G, Thornton P. Nutritional assessment of the hospitalized patient. *Med. Clin. North Am* 1979;**63**:1103–15.