Background

The term malnutrition refers to any imbalance in nutritional status, which is a set of parameters indicative of health, performance, suitability for and recovery after surgery. Imbalance can lean towards an unhealthy lack (undernutrition) or excess (obesity). Nutrition deficiency states include undernutrition and sarcopenia, the latter being a condition that specifically affects the muscular component of the musculoskeletal system. It is called nutrition-related sarcopenia when opposed to physical inactivity-, age-, or disease-related sarcopenia. The morbid accumulation of body fat leads to obesity, being also defined as excess malnutrition. The codes in the global standard for diagnostic classification of diseases (ICD-11) are 5B54 for undernutrition and 5B81 for obesity, both part of the chapter “05 Nutritional disorders”. Sarcopenia is an entity of the chapter “15 Diseases of the musculoskeletal system or connective tissue” and is coded FB32.Y. It is not uncommon for these conditions to coexist in the same individual especially if old, giving rise to high-risk geriatric conditions. Examples are sarcopenic obesity or sarcopenic undernutrition. Among community-dwelling older adults, sarcopenic obesity seems to affect around 6.28% of people in west China (Yang et al., 2022) and 8.2% in the North of the Netherlands (Wagenaar et al., 2021), with one in five over-50s likely being undernourished, frail, or sarcopenic (Almohaisen et al., 2022). A very low weight patient or those who are obviously overweight are easy to spot by clinicians, but hybrid malnutrition phenotypes are challenging to distinguish without specific evaluation and can be the most complex to manage. A sarcopenic patient presents a reduction in muscle quantity/quality and strength such as to affect physical abilities and functional status, with resistance-based exercise being the primary treatment and increased dietary protein intake being recommended when the aetiology is nutrition-related (Dent et al., 2018). A patient with excess or defective imbalance in nutritional status shows alterations in body composition, unhealthy eating habits, and altered laboratory parameters, such as pre-albumin, haemoglobin, or lymphocyte count. Nutritional care and therapy aim to restore calorie and protein intake based on individual needs and bring body weight to reference ranges.

Recently, the diagnostic criteria for undernutrition were issued by the global leadership initiative on malnutrition (GLIM) (Cederholm et al., 2019), those for sarcopenia by the European working group on sarcopenia in older people (EWGSOP) (Cruz-Jentoft et al., 2019), and those for sarcopenic obesity by the European society for clinical nutrition and metabolism (ESPEN) together with the European association for the study of obesity (EASO) (Donini et al., 2022). Consequences of malnutrition phenotypes encompass metabolic impairments, rising comorbidities, disability, and institutionalization (Batsis & Villareal, 2018). Uncovering these conditions in orthopaedic surgery may be vital to apply the most appropriate diagnostic-therapeutic paths to the right patient at the right time.

This article introduces the clinical frameworks to approach malnutrition in arthroplasty patients using the latest diagnostic criteria in a cohort of older patients awaiting admission for hip replacement. The narrative explores the differences between well-nourished and malnourished patients for what concerned laboratory parameters, diet quality, and patient reported outcome measures in the study cohort.

Methods

This is a cross-sectional descriptive investigation on a subset of data from a prospective observational study approved by the Ethics Committee of San Raffaele Hospital on April 2019 (protocol name: NUTRIANCA; approval code: 39/int/2019). The study was hosted and conducted at our Italian IRCCS Orthopedic Institute Galeazzi and registered on Clinicaltrials.gov (NCT03981354). The NUTRIANCA study was planned to observe the perioperative change in nutritional status indicators and whether they could have a role in determining outcomes after total joint arthroplasty. This preliminary report aims at describing malnutrition prevalence at baseline to characterise different phenotypes.

Participants

The subjects were screened from the population of older patients undergoing hip replacement. We recruited males and females aged between 60 and 85 years with the indication

of primary total hip arthroplasty. Exclusion criteria were ≥ class/stage III heart or kidney failure, active cancer, major neuropsychiatric diseases, and unwillingness to carry out the evaluations. Written informed consent was obtained from the patients enrolled in the study. After recruitment, subjects undergo assessments for what concerned eating behaviours, anthropometry, physical performance, laboratory parameters, and patient reported outcome measures.

Measures

- As a measure of cumulative morbidity, we calculated the Charlson comorbidity index (CCI) (Charlson et al., 1987) developed to be used in longitudinal studies to pool comorbid conditions, such as congestive heart failure, diabetes, and liver disease, that are known to alter the risk of mortality.
- Eating behaviours were assessed with the Medi-Lite index (Briguglio et al., 2019), which asks patients how many times they daily or weekly consume foods from nine food groups: fruit, vegetables, legumes, cereals, fish, meat, dairy, alcohol, and olive oil.
- Malnutrition screening was done with the mini nutritional assessment-short form (MNA-SF) (Briguglio, Wainwright, & Lombardi, 2023), which encompasses six questions about decrease in food intake (A), recent involuntary weight loss (B), current mobility (C), acute disease/psychological stress (D), neuropsychiatric issues (E), and body mass index (F1).
- Anthropometry was evaluated through weight (W, kg), height (H, m), body mass index (BMI, $kg \cdot m^{-2}$) calculation, and bioimpedance analysis (BIA 101 BIVA® PRO, Akern s.r.l., Pisa, Italy). The quantitative body composition analysis gave phase angle (PhA, degree), total body water (TBW, L), extra cellular water (ECW, L), intra cellular water (ICW, L), fat-free mass (FFM, kg), fat mass (FM, kg), body cell mass (BCM, kg), skeletal muscle mass (SMM, kg), and appendicular skeletal muscle mass (ASMM, kg).
- To quantitatively measure the maximal grip strength we used a hand-held dynamometer on the dominant hand, repeated three times, and averaging the three ratings. Patients were sitting upright in a chair with the elbow positioned at 90° on the armrest to minimize the influence of weight of the segment on the measure.

- To objectively assess walking ability, mobility, and balance we used the timed up and go test (TUG, s) that measures the seconds a patient takes to rise from a chair, walk 3 metres, turn, and walk back to sit on the same chair. The functional mobility was also assessed with the gait speed, measuring the time the subjects took to safely walk a specified distance of ten metres (10MWT, $s \cdot m^{-1}$).
- To support the discriminating phases of malnutrition diagnostic algorithms we retrieved the following blood analytes: red blood cells (RBCs, $10^6 \cdot \mu L^{-1}$), haemoglobin (g/dL), white blood cells (WBCs, $10^3 \cdot \mu L^{-1}$), percentages of WBCs subclasses (%), transthyretin ($mg \cdot dL^{-1}$), albumin ($g \cdot dL^{-1}$), total proteins ($g \cdot dL^{-1}$), and C-reactive protein (CRP, $mg \cdot dL^{-1}$).
- As a measure of outcomes reported by patients, we asked patients to fill the short forms of both hip disability and osteoarthritis outcome score-physical function (HOOS-PS) (Davis et al., 2008) and 12-item health survey from which the physical health composite summary was extracted (SF-12 PCS). In particular, the HOOS-PS is a condition-specific tool that records how well a subject responds to being able to descend stairs, get in/out of bath or shower, sit, run, and twist/pivot on the loaded leg. Pain related to the hip was evaluated with a visual analogue scale (VAS pain).

Diagnostic criteria

In **Table 1** we report the diagnostic schemes used for undernutrition, sarcopenia, and sarcopenic obesity. Undernutrition was diagnosed using GLIM diagnostic scheme (Cederholm et al., 2019), which consists of a diagnostic assessment and severity grading. Diagnosis requires the co-existence of at least one phenotypic criterion (non-volitional weight loss, low BMI, reduced muscle mass) and at least one etiologic criterion (reduced food intake or assimilation, disease burden/inflammatory condition). Severity is determined based on the phenotype.

Sarcopenia was diagnosed using the second algorithm issued from the EWGSOP (Cruz-Jentoft et al., 2019), which encompasses an assessment, confirmation of diagnosis, and severity quantification in practice. The diagnosis is based on the co-occurrence of low muscle strength

and low muscle quantity or quality. Sarcopenia is considered severe in case of concomitant low physical performance.

Sarcopenic obesity was diagnosed using the indications of the ESPEN and EASO (Donini et al., 2022). The diagnostic procedure requires a screening for high BMI or waist circumference, subsequent two-step diagnosis investigating altered skeletal muscle function parameters (handgrip strength or chair stand test) and altered body composition (increased fat mass and reduced muscle mass), and a final two-step staging considering the presence of complications attributable to sarcopenic obesity (e.g., metabolic diseases, functional disabilities, cardiovascular and respiratory diseases).

[Table 1]

Data analysis

Given the descriptive nature of this report, we primarily planned to inform about the naturally occurring prevalence of malnutrition phenotypes in our study group with no inferential statistics to demonstrate directions of associations. Descriptors were reported in the text as means ± standard deviation. To uncover sexual differences in the descriptors, we used the rank-based nonparametric Mann–Whitney U test. One-way analysis of covariance (ANCOVA) was run to determine whether clinical descriptors differed based on malnutrition categorisation amongst the study groups whilst controlling for sex, years of age, BMI, CCI, and chronic medications (Bonferroni 95% confidence intervals). Results are reported as adjusted group means ± standard error, with ANCOVA outputs holding a statistical significance if $p < 0.05$. These descriptive analyses were performed with the software IBM SPSS Statistics (version 22.0, Chicago, IL, USA). Raw data used in this report are shared, after deidentification, immediately and indefinitely as **Supplementary 1** to the article.

Results

The characteristics of the cohort are reported in **Table 2**. We found sexual differences in handgrip ($p < 0.001$), PhA ($p = 0.007$), FFM ($p < 0.001$), ASMMI ($p < 0.001$), SMM/W ($p < 0.001$), and RBCs ($p = 0.016$). Three patients dropped for surgery deferral and were excluded from the cohort analysis. The diagnostic assessment of undernutrition could be applied to forty-eight patients, sarcopenia to forty-five, and sarcopenic obesity to forty-seven. Nine subjects (18.75%) were found to be undernourished, of which eight a moderate and one with severe undernutrition. Six (13.34%) were sarcopenic and two of these had severe sarcopenia. Two (4.26%) had sarcopenic obesity, of which one patient had complicated class II sarcopenic obesity and another had class II sarcopenic obesity with no related complications. Overall, four out of forty-five patients (8.88%) suffered from both undernutrition and sarcopenia.

Screening malnutrition

The MNA-SF scores from 0 to 14 (0–7 = malnourished, 8–11 = at risk, 12–14 = no risk). The MNA-SF was similar between well-nourished and malnourished (12.89 ± 0.29 vs. 12.68 ± 0.52, $p = 0.739$), with no differences in the responses about food intake, weight loss, mobility, acute disease, neuropsychiatric issues, and body mass index.

[Table 2]

Diet

The Medi-Lite index gives from 0 to 18 points, with higher values being representative of greater adherence to the Mediterranean dietary pattern. Solely for meat and dairy products, the lower the consumption the higher the attributed score whereas for alcohol the highest rated answer is a moderate daily consumption of 1-2 units. The Medi-Lite index was similar between the malnutrition group (10.28 ± 0.71) compared to the well-nourished group (9.98 ± 0.39) and no statistically significant difference was found ($p = 0.725$). Malnourished patients consumed less cereals than well-nourished (0.85 ± 0.17 vs. 1.44 ± 0.9, $p = 0.006$) as well as less meat (1.89 ±

0.27 vs. 1.07 ± 0.15, $p = 0.015$). No inter-group differences were found for what concerned fruit, vegetables, legumes, fish, dairy, alcohol, and olive oil.

Anthropometry

Analysis on bioimpedance output showed no differences between malnourished and well-nourished in the adjusted means of PhA (5.35° ± 0.20 vs. 5.37° kg ± 0.11), FFM (53.52 kg ± 1.81 vs. 54.96 kg ± 0.98), FM (23.51 kg ± 1.47 vs. 22.76 kg ± 0.80), ASMMI (6.91 $kg \cdot m^{-2}$ ± 0.17 vs. 7.11 $kg \cdot m^{-2}$ ± 0.9), and SMM/W (30.92% ± 1.30 vs. 31.75% ± 0.70).

Physical tests

The adjusted maximal grip strength was higher in well-nourished compared to malnourished patients (25.29 kg ± 1.10 vs. 22.16 kg ± 1.99), but no statistically significant difference was found ($p = 0.187$). No between-group difference was found for the TUG or gait speed.

Blood analytes

Malnourished patients compared to well-nourished had significantly higher WBCs (8.41 $10^3 \cdot \mu L^{-1}$ ± 0.61 vs. 6.55 $10^3 \cdot \mu L^{-1}$ ± 0.33, $p = 0.013$), neutrophils (67.05% ± 2.50 vs. 58.91% ± 1.36, $p = 0.008$), and NLR (3.39 ± 0.20 vs. 2.16 ± 0.27, $p = 0.012$), but they exhibited lesser values of lymphocytes (23.35% ± 2.04 vs. 28.62% ± 1.11, $p = 0.033$). No inter-group differences were found for what concerned other laboratory parameters.

Patient reported outcome measures

The 5-item HOOS-PS spans from 0 to 100, with the lowest score indicating absence of impairment. Conversely, higher scores of the SF-12 PCS indicate better physical functioning from the patient's perspective. The HOOS-PS was similar between malnourished and well-nourished (43.63 ± 7.69 vs. 46.33 ± 4.27) as well as the SF-12 PCS (40.63 ± 2.91 vs. 34.44 ± 1.62). The pain VAS level reported for the hip was significantly lower in malnourished compared to well-nourished (4.20 ± 0.74 vs. 6.75 ± 0.42, $p = 0.008$).

Discussion

We describe the baseline characteristics of 57 older patients undergoing total hip arthroplasty, focusing on the diagnostic schemes for malnutrition subtypes. Approximately 37% of cohort subjects met the criteria for undernutrition, sarcopenia, sarcopenic obesity, or had concurrent undernutrition and sarcopenia. This prevalence is in line with literature showing that half of older patients undergoing major orthopaedic surgery are at risk of malnutrition or malnourished upon admission or will be after surgery (Briguglio, Wainwright, Southern, et al., 2023). However, given that the diagnostic algorithms have been issued recently, it is plausible to think that the definition of malnourished patients reported in the not-so-recent literature does not reproduce the schemes used in this article. The risk screening, malnutrition diagnosis, and the study of altered parameters closely related to the patient's nutritional status are, in fact, three different approaches (Briguglio, Wainwright, & Lombardi, 2023).

To investigate the prediction potential some descriptors of nutritional interest on postoperative outcomes, the MNA-SF (Denny et al., 2020), BMI (Jensen et al., 2021), albumin (Khoshbin et al., 2021), lymphocytes (Marín et al., 2002), and PhA (Lim & Lim, 2020) are often used. Although they might be good indicators of the health status, they are not suitable to exclusively classify a specific phenotype, make a diagnosis, or inform on the underlying aetiology. The associations between a single parameter and any malnutrition phenotype can only reasonably indicate that the patient may suffer from increased risk (Norman et al., 2023). We found no differences in most of the descriptors, comprising the MNA-SF or PhA. However, it should be noted that we based the statistics of this article on inter-group analysis of covariance (well-nourished vs. malnourished). Since it is known that undernutrition, sarcopenia, and obesity display different signs, grouping patients with different diagnosis may have reduced the trueness of our observations. Though, it could not have been done otherwise since it is not feasible to run statistics between small groups.

It was interesting to observe lower levels of hip pain reported by malnourished patients. This may be ascribed to the greater body weight of well-nourished patients (78.64 kg) compared to

malnourished (74.07 kg) given that hip pain is known to generally increase with increased BMI (Andersen et al., 2003). A reduced consumption of meat, although in line with the Mediterranean dietary model, could limit intake of high biological value proteins and contribute to protein-energy malnutrition onset especially when concomitant intake of cereals and derivatives, which represent an important daily energy source, is insufficient (Dwyer et al., 2020). From this perspective, our observation on the inter-group differences in meat and cereal consumption is in line with literature.

Limitations

The main limitation of this investigation is that patients with neurological or psychiatric disorders, which are among the aspects mostly influencing functional independence, eating behaviour, and chronic disease management, were excluded from the recruitment. This may have underestimated the malnutrition prevalence.

Conclusion

We provided an up-to-date understanding for diagnosing malnutrition in hip arthroplasty care. We found that the prevalence of malnutrition phenotypes was high in our cohort undergoing elective hip replacement. A summary slide of the study is reported in **Figure 1**. Undernutrition, sarcopenia, and sarcopenic obesity are generally acknowledged to negatively affect outcomes after surgery but evidence in orthopaedics is poor given that diagnostic criteria have not been issued until recently. In orthopaedic practice, there is the need to integrate the screening and diagnosis of malnutrition on pre-operative risk assessment and decision making. This is important to uncover the weight of these conditions on recovery after surgery. Understanding the effects of these conditions long overlooked could yield discoveries that reshape the concept of patient vulnerability and the role of nurses and dietitians in compensating for gaps during the entire perioperative care trajectory.

[Figure 1]

Future directions

If it were to be discovered that a patient with a diagnosis of malnutrition before total joint arthroplasty is more at risk of complications and slow recovery than a well-nourished patient, prehabilitation could help optimise the nutritional status and mitigate the risk. Experimental studies are needed to find the most appropriate pre- and post-operative intervention for each malnutrition phenotype. Close supervised initiatives may be preferred for some older patients to enhance adherence and motivation (Halsen et al., 2023). Holistic patient care ought to continue after discharge to help individuals to cope with the vulnerable conditions that made them sick in the first place (Briguglio, Cordani, et al., 2023).

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Tables

Table 1 Diagnostic algorithm parameters used in our cohort to diagnose malnourished patients.

Malnutrition phenotype	Phases	
Undernutrition	1. Assessment	• Unintentional weight loss: MNA-SF question B = 0 or low BMI: < 20 $kg \cdot m^{-2}$ if < 70 y or < 22 $kg \cdot m^{-2}$ if ≥ 70 y or low MM: ASMM/H ($kg \cdot m^{-2}$) < 7 in M and < 6 in F • Assimilation: severe gastro-intestinal condition or disease burden: Charlson comorbidity index ≥ 5 or inflammation: CRP ≥ 1 $mg \cdot dL^{-1}$ and NLR ≥ 4
	2. Severity	• Phenotype: PhA < 4°
Sarcopenia	1. Assessment	• Strength: HGS < 16 kg in F and < 27 kg in M
	2. Confirmation	• Quantity: ASMM (kg) < 20 kg in M and < 15 kg in F or ASMI < 7 $kg \cdot m^{-2}$ in M and < 5.5 $kg \cdot m^{-2}$ in F
	3. Severity	• Performance: TUG ≥ 20 s or 10MWT ≤ 0.8 $m \cdot s^{-1}$
Sarcopenic obesity	1. Screening	• BMI ≥ 25 $kg \cdot m^{-2}$
	2. Two-step diagnosis	• Function: HGS < 16 kg in F and < 27 kg in M • Composition: FM% > 40.7% in F and > 27.3% in M • Class I sarcopenia: SMM/W 35.6-32.2% in F and 42.9-38.2% in M or class II sarcopenia: SMM/W < 32.2% in F and < 38.2% in M
	3. Two-step staging	• Staging I: no complications or staging II if at least one related complication

Acronyms MNA-SF = mini nutritional assessment-short form; BMI = body mass index; ASMMI = appendicular skeletal muscle mass index; CRP = C-reactive protein; NLR = neutrophil-lymphocyte ration; PhA = phase angle; HGS = handgrip strength; TUG = timed up and go; 10MWT = ten metre walk test; FM = fat mass; SMM/W = skeletal muscle mass divided by weight.

Table 2 Characteristics of the study cohort.

Descriptors	Cohort	Females	Males
Subjects (n°)	57	27	30
Age (years)	71.49 ± 6.52	71.47 ± 6.45	71.50 ± 6.70
BMI ($kg \cdot m^{-2}$)	27.00 ± 4.72	25.97 ± 4.56	27.92 ± 4.75
CCI	3.44 ± 1.20	3.19 ± 0.96	3.67 ± 1.35
Medications (n°)	2.74 ± 1.88	2.40 ± 1.70	3.04 ± 2.01
Screening malnutrition			
MNA-SF	12.91 ± 1.40	12.68 ± 1.38	13.11 ± 1.42
Diet			
Medi-Lite index	10.37 ± 2.03	10.54 ± 1.98	10.22 ± 2.10
Anthropometry			
PhA (°)	5.36 ± 0.73	5.03 ± 0.62	5.64 ± 0.71
FFM (kg)	54.26 ± 10.76	44.80 ± 4.03	62.25 ± 7.66
FM (kg)	22.50 ± 9.35	22.20 ± 9.12	22.77 ± 9.71
ASMMI ($kg \cdot m^{-2}$)	7.02 ± 1.16	6.13 ± 0.66	7.77 ± 0.95
SMM/W (%)	31.70 ± 6.02	27.63 ± 4.84	35.14 ± 4.66
Physical tests			
Grip strength (kg)	24.76 ± 9.73	16.76 ± 4.08	31.22 ± 7.99
TUG (s)	12.45 ± 3.78	13.02 ± 4.02	11.96 ± 3.57
10MWT ($s \cdot m^{-1}$)	0.83 ± 0.22	0.80 ± 0.20	0.86 ± 0.24
Blood analytes			
RBCs ($10^6 \cdot \mu L^{-1}$)	4.72 ± 0.48	4.59 ± 0.46	4.84 ± 0.47
Haemoglobin ($g \cdot dL^{-1}$)	14.30 ± 1.24	13.94 ± 1.12	14.62 ± 1.27
WBCs ($10^3 \cdot \mu L^{-1}$)	7.21 ± 1.99	7.33 ± 2.07	7.09 ± 1.93
Neutrophils (%)	61.51 ± 8.24	62.03 ± 9.02	61.03 ± 7.59
Lymphocytes (%)	26.86 ± 7.20	27.64 ± 8.00	26.16 ± 1.42
NLR	2.75 ± 2.25	2.88 ± 2.93	2.64 ± 1.42
Transthyretin ($mg \cdot dL^{-1}$)	25.35 ± 4.59	24.28 ± 3.85	26.19 ± 5.01
Albumin ($g \cdot dL^{-1}$)	4.42 ± 0.35	4.43 ± 0.34	4.41 ± 0.37
Total proteins ($g \cdot dL^{-1}$)	6.86 ± 0.48	6.75 ± 0.47	6.96 ± 0.48
CRP ($mg \cdot dL^{-1}$)	0.37 ± 0.51	0.35 ± 0.48	0.39 ± 0.55
Patient reported measures			
HOOS-PS	47.36 ± 19.43	50.22 ± 15.22	44.16 ± 22.75
SF-12 PCS	34.96 ± 7.58	34.95 ± 7.37	34.97 ± 8.07
VAS pain	6.46 ± 2.13	6.63 ± 2.34	6.25 ± 1.91

Notes Values are mean ± SD. **Acronyms** BMI = body mass index; CCI = Charlson comorbidity index; MNA-SF = mini nutritional assessment-short form; PhA = phase angle; FFM = fat-free mass; FM = fat mass; ASMMI = appendicular skeletal muscle mass index; SMM/W = skeletal muscle mass divided by weight: TUG = timed up and go test; 10MWT = ten metre walk test; RBCs = red blood cells; WBCs = white blood cells: NLR = neutrophil-lymphocyte ration; CRP = C-reactive protein; HOOS-PS = hip disability and osteoarthritis outcome score-physical function; SF-12 PCS = physical health composite summary of the 12-item health survey. VAS = visual analogue scale.

Figure

Figure 1 Summary slide of the descriptive study investigating the prevalence of malnutrition phenotypes in a cohort of older patients with end-stage osteoarthritis awaiting admission for hip replacement.