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Sarcopenia Evaluation in Multiple Myeloma Patients Before and After Autologous Stem Cell Transplantation: A Prospective Study

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ABSTRACT

Purpose: The aim of this study is to assess the presence of sarcopenia in multiple myeloma (MM) patients both before and after autologous stem cell transplantation (ASCT) and to investigate if ASCT is a causative factor for sarcopenia. This study is the first to examine the impact of ASCT on sarcopenia in individuals with MM via bioelectrical impedance analysis (BIA), computed tomography (CT), and performance tests simultaneously.

Materials and Methods: The prospective study was conducted from January 2022 to April 2023. The median duration of the follow-up period was 12 months. All of the participants were assessed for sarcopenia by BIA, CT, and performance tests at 1 month (±2 weeks) prior to the conditioning regimen and 6 months (±4 weeks) following the transplant. The EWGSOP 2018 guideline was used for sarcopenia diagnosis.

Results: In the study, 102 patients who were ≥ 18 years and diagnosed with MM according to the criteria established by the International Myeloma Working group (IMWG) were enrolled. Pre-ASCT, 47 (46%) patients and post-ASCT, 51 patients (50%) were sarcopenic ($p = 0.12$). Pre-ASCT, a low skeletal muscle index (SMI) was identified in 51% of the patients, and this percentage increased to 56% after ASCT ($p = 0.03$). In multivariate analysis, female sex (odds ratio [OR]: 1.25; 95% CI: 1.12–1.38; and $p = 0.007$), higher Hematopoietic Cell Transplantation-Specific Comorbidity Index (HCT-CI) score (OR: 1.16; 95% CI: 1.04–1.29; and $p = 0.008$), and lower body mass index (BMI) (OR per unit increase: 0.94; 95% CI: 0.88–0.99; and $p = 0.045$) were independently associated with sarcopenia.

Conclusions: Our study revealed a high prevalence of sarcopenia among individuals with MM. We demonstrated that individuals with comorbidities, a low BMI, and female sex have a higher predisposition to sarcopenia. There was no increase in the occurrence of sarcopenia after ASCT; however, SMI decreased.

1 | Introduction

Multiple myeloma (MM), which is characterized by the neoplastic proliferation of clonal plasma cells, ranks as the second most common hematological malignancy [1]. Constitutional symptoms, such as exhaustion, weight loss, and pain, arise due to the effect of differentiated plasma cells and elevated levels of cytokines in the bone marrow. Movement restriction and pathological fractures arise as a result of osteolytic bone lesions.

Sarcopenia is characterized by the European Working Group on Sarcopenia in Older People (EWGSOP) as the presence of both reduced physical performance and/or diminished muscular strength, together with a decrease in muscle mass [2]. Sarcopenia is caused by immobilization and muscle loss, which are predisposed to by advanced age, fatigue and chronic diseases [3]. The relationship between sarcopenia and many solid tumors has been investigated. More attention has been paid to lymphoma and allogeneic transplants in hematological cancers [4]. Contradictory literature exists concerning the incidence and impacts of sarcopenia among patients with MM. Autologous stem cell transplantation (ASCT) is a critical stage in consolidation treatment. However, there is limited research examining the impact of ASCT on muscle mass and strength, as well as the effect of sarcopenia on ASCT outcomes.

The commonly used techniques for determining muscle mass include computed tomography (CT), bioelectrical impedance analysis (BIA), dual x-ray absorptiometry (DXA), and magnetic resonance imaging (MRI) [2, 5]. CT is considered the gold standard imaging method [6]. BIA is the favored approach due to its cost-effectiveness, convenience and ability to be repeated. Tests such as handgrip strength and chair stand are utilized to assess muscular strength, while gait speed and the timed get-up and go test (TUG) etc. are employed to evaluate physical performance [2, 7].

This study aimed to assess the presence of sarcopenia in MM patients both before and after ASCT and to investigate if ASCT is a causative factor for sarcopenia. Furthermore, the objective was to ascertain the impact of sarcopenia on the duration of post-transplant hospitalization and engraftment, as well as identify the risk factors associated with sarcopenia. This study is the first to examine the impact of ASCT on muscle mass, physical performance, and muscular strength in individuals with MM.

2 | Methods

2.1 | Patient Selection

Our study included patients who were 18 years or older and diagnosed with MM according to the criteria established by the International Myeloma Working group (IMWG) [8]. These patients were scheduled to undergo ASCT in our clinic between January 2022 and April 2023. The study included individuals who had a left ventricular ejection fraction $> 40\%$ and did not have any symptomatic cardiac diseases, had a carbon monoxide diffusion capacity $> 50\%$ and did not have any symptomatic pulmonary disease. The individuals were eligible for ASCT.

The study excluded patients diagnosed with amyloidosis, relapsed MM, those who had previously received ASCT or allogeneic stem cell transplantation, individuals unable to undergo strength tests due to physical deformity, patients with hypervolemia caused by renal failure, and those with metal implants in their bodies.

All of the patients included in the study provided their consent to participate according to the regulations of our local ethical committee.

2.2 | Study Design and Sarcopenia Definition

One month (± 2 weeks) prior to the conditioning regimen and 6 months (± 4 weeks) following the transplant, participants were assessed for sarcopenia. The hematopoietic cell transplantation comorbidity index (HCT-CI) was utilized to assess the risk score and comorbidities of the patients prior to ASCT [9]. Each participant was evaluated twice, once prior to the ASCT and once afterward, using a BIA, muscle strength test, and physical performance test. Contrast-enhanced thoracic-abdominal CT and/or PET-CT were used.

The EWGSOP2 guideline defines sarcopenia as the presence of both low muscular strength and/or low physical performance, together with reduced muscle mass [2]. Although EWGSOP2 proposes a staged classification (probable, confirmed, and severe sarcopenia), in our study, individuals with decreased muscle mass (identified by BIA and CT) who had low muscular strength and/or physical performance were classified as sarcopenic (Figure 1). This approach was chosen due to the limited sample size, as further subdivision into three categories would have resulted in small subgroup numbers, potentially reducing statistical power and increasing the risk of Type II error.

2.3 | Body Composition Assessment by BIA

The BIA method was employed to ascertain the body compartments using the Body Composition TANITA-SC-240 MA device (Tanita Corp., Tokyo, Japan). The Tanita device is equipped with 8 electrodes and operates using a constant current of 50 kHz. It evaluates the fat rate, muscle mass and fat-free mass values for five specific parts of the body (right and left arm, right and left leg, and trunk). This is done using 5 separate current waves. This gadget allows for the measurement of 20 parameters, such as participants' body weight, body muscle mass and percentage, body fat mass and percentage, total body water, bone mass, and body mass index (BMI), in a time frame of 30–60 s. Patients refrained from intensive physical activity throughout the 24-h period before to analysis. They consumed their final meal a minimum of 2.5 h prior, voided their bladder prior to the examination, and removed all metallic items. The equation used to determine skeletal muscle mass (SMM) was derived using the data obtained from the BIA device.

The formula to calculate SMM (kg) is as follows: $\text{SMM (kg)} = (0.401 \times [\text{height}^2/\text{resistance}] + [3.825 \times \text{gender}] - [0.071 \times \text{age}] + 5.102)$. In this formula, height is provided in centimeters, resistance is measured in ohms, gender is represented by 1 for males and 0 for women, and age is supplied in years.

The skeletal muscle mass index (SMI) may be calculated by dividing the SMM by the square of the height (h) in square meters (m^2).

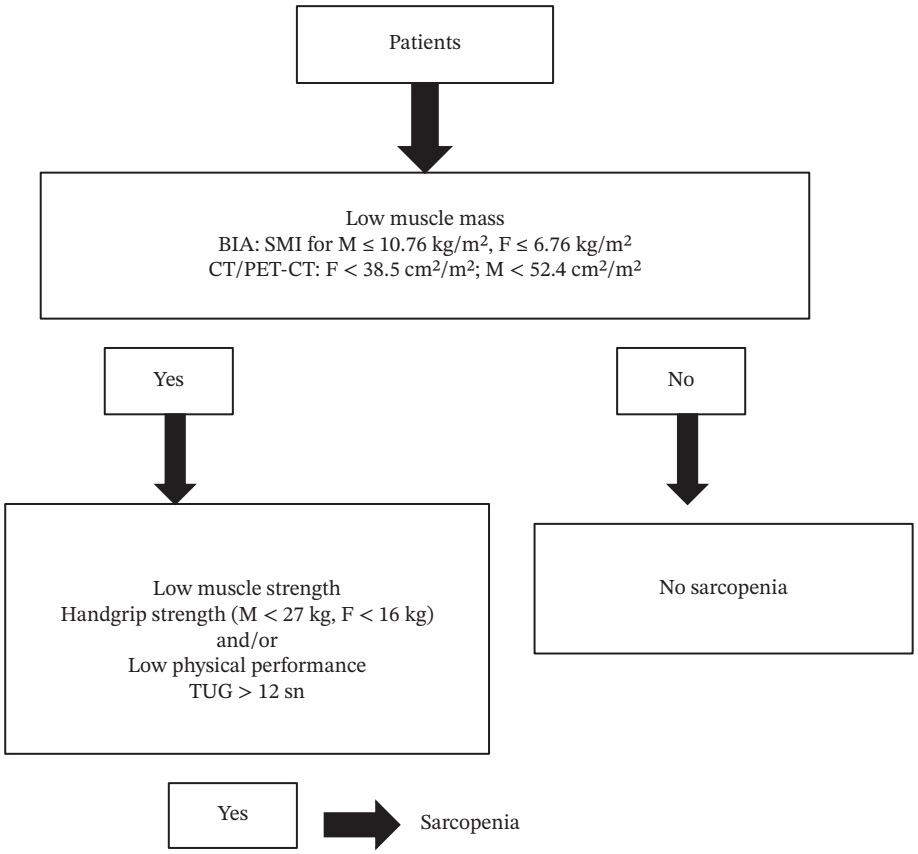


FIGURE 1 | Diagnostic algorithm for sarcopenia. Patients with low muscle mass (assessed by BIA and CT/PET-CT) were further evaluated for muscle strength and physical performance. Sarcopenia was defined as low muscle mass with low muscle strength and/or low physical performance.

According to the BIA, a skeletal muscle mass index (SMI) of $\leq 10.76\ kg/m^2$ in males and $\leq 6.76\ kg/m^2$ in women is classified as a low muscle mass index [2].

2.4 | Muscle Strength Assessment

A handgrip dynamometer (TAKEI 5401 Hand Dynamometer, 100 kg) was utilized to determine low muscle strength. The volunteers exerted maximum force on the instrument using their dominant hand, squeezing, and releasing it three times at intervals of 2 minutes. The average of three measurements was determined as muscular strength. Male patients were classified as having poor muscle strength if it was < 27 kg while female patients were classified as having low muscle strength if it was < 16 kg [2].

2.5 | Evaluating Physical Performance

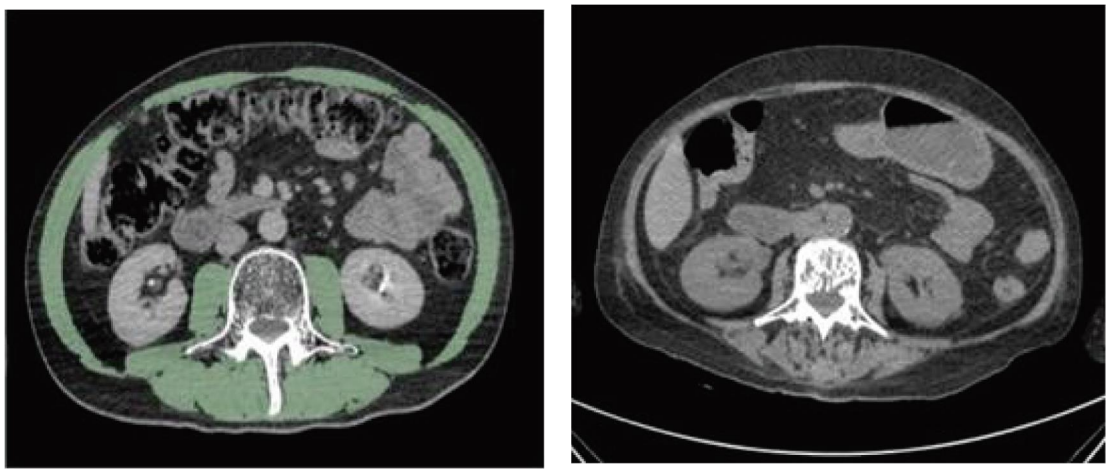
Physical performance tests allow for the assessment of not only just muscular function, but also the peripheral and central neurological systems, including balance [10]. The TUG was employed for this aim. The volunteers were positioned in a standard seat. The individuals were instructed to rise from their seats, go a distance of 10 feet, pivot, and then return to a seated position on the chair. If the total duration exceeded or was ≥ 12 s, it was classified as low physical performance [10].

2.6 | Analyzing CT Images

As the present study was designed prospectively, follow-up imaging was systematically scheduled and performed at 6 months after transplantation for all included patients. For PET/CT examinations, only the CT component was used for skeletal muscle analysis, independent of contrast administration. Axial section images acquired from a PET/CT device (Siemens Biograph Horizon) and 2-mm section thickness images obtained from two different multi-slice computed tomography (MSCT) devices (Toshiba Aquilion PRIME and Philips Ingenuity CT) were utilized to generate measurements with 3D-Slicer (Version 5.6.1) software. The potential effect of contrast media was neglected, as it was considered unlikely to significantly influence the differentiation between muscle and adipose tissue. The psoas, paraspinal muscles (erector spinae and quadratus lumborum), and abdominal muscles (transverses abdominis, external and internal oblique muscles, and rectus abdominis) were distinguished from surrounding tissues and marked at the level of the third lumbar vertebra (L3) using Hounsfield units (HUs) ranging from -29 to $+150$. To ensure accurate measurements, muscle contours were manually edited, and the area of muscle contained within the section was measured (cm^2) (Figure 2).

SMI was determined by dividing the muscle area at the L3 level (measured in cm^2) by the square of the individual's height in meters (measured in m^2). A SMI of less than $38.5\ cm^2/m^2$ is considered indicative of low muscle mass in women, whereas in males, values below $52.4\ cm^2/m^2$ are acknowledged as indicative of low muscle mass [11].

At different intervals, two radiologists with more than 10 years of experience in the musculoskeletal system analyzed CT images while remaining unaware of the patients' clinical histories. Two



(a) (b)

FIGURE 2 | Example of muscle area evaluated on CT in non-sarcopenic MM patient (a) and sarcopenic MM patient (b). The green lined area contained psous, paraspinal muscles and abdominal wall muscles at the level of third lumber vertabra.

observers conducted measurements across different cases. Interobserver agreement was not evaluated as part of this study.

2.7 | Mobilization of Stem Cells and Conditioning Regimen for Transplantation

Subcutaneous granulocyte colony-stimulating factor (GCSF) (10 μg/kg/day) was provided for mobilization, either alone or in combination with cyclophosphamide. The goal was to mobilize 3×10^6 CD34+ cells/kg and this goal was successfully reached in 95.2% of the patients.

Sixty nine patients were mobilized with GCSF alone, while 33 patients were mobilized with a combination of GCSF and cyclophosphamide (1.5 g/m^2 for two consecutive days). Twelve patients unable to collect cells using these methods were effectively mobilized with plerixafor.

Melphalan was administered as a conditioning regimen at two different doses: a low dosage of 140 mg/m^2 and a standard dose of 200 mg/m^2. Melphalan was administered at either a low or standard dose based on the patients' performance status, comorbidities, and renal function.

2.8 | Assessment of Neutrophil and Platelet Engraftment Days

Neutrophil engraftment was accepted as the first day on which the neutrophil count target of 0.5×10^9/L was reached for three consecutive days; platelet engraftment was accepted as the day when the target of 20×10^9/L was achieved without replacement.

2.9 | Statistical Analysis

Categorical variables were represented by the number (n) and percentage (%), whereas numerical variables were represented by the mean and standard deviation if the requirements for parametric tests were satisfied. If not, the median (minimum–maximum) was used. To assess whether the variables followed a normal distribution, the Kolmogorov–Smirnov test was applied. Cross-tables are used to compare prevalence of sarcopenia according to different age, BMI, ISS, and HCT-CI categories. For independent categorical comparisons, Pearson's chi-square test was applied when $\geq 80\%$ of expected cell counts were ≥ 5; otherwise, Fisher's exact test was used.

For continuous variables, pre- and post-ASCT comparisons were performed using paired statistical tests, with the paired Student's t-test applied to normally distributed variables and the Wilcoxon signed-rank test used for non-normally distributed variables. Changes in muscle mass, muscle strength, and functional test categories before and 6 months after ASCT were evaluated using paired categorical analyses. Accordingly, the McNemar test was applied for dichotomous variables, while the McNemar–Bowker test was used for variables with more than two categories, as appropriate.

Univariate and multivariate regression analyses were used to investigate the associations between potential variables and sarcopenia in patients before ASCT. Factors showing univariate association with the outcome at issue ($p < 0.2$) were extracted as candidate variables to be used in the multivariate analysis. The data analysis was performed using the Statistical Package for the Social Science (SPSS Inc, Chicago, Illinois, USA) Version 24.0, and a p value of < 0.05 was considered significant.

2.10 | Ethical Considerations

This study received approval from the institutional ethical review board (2021/14–25) and was performed in adherence to the principles outlined in the Declaration of Helsinki. No artificial intelligence tools were used for study design, data analysis, or interpretation.

3 | Results

3.1 | Patient and Disease Characteristics

In the study, 102 patients who matched the inclusion criteria were enrolled. The average duration of the follow-up period was 12 months. The median interval between the pre-ASCT sarcopenia assessment and ASCT was 14 days (range: 1–23 days). Post-ASCT sarcopenia assessments were performed at a median of

6.1 months following transplantation (range: 5.2–7.3 months). The patients' median age was 57 years (min 34–max 75). Out of the total number of patients, 80% were younger than 65 years old and 91% of them had an HCT-CI score ranging from 0 to 2 (Table 1).

Melphalan at a dose of 200 mg/m^2 was administered as a conditioning regimen to 68.7% of the patients ($n = 70$), while 31.3% ($n = 32$) were administered a reduced dose of 140 mg/m^2 (Table 1). Neutrophil engraftment was successfully accomplished in all patients within an average of 10 ± 2 days, whereas platelet engraftment was completed within 11 ± 3 days. The mean duration of hospitalization was 23 ± 3 days. There was no significant difference observed in platelet/neutrophil engraftment days and duration of hospitalization between patients with sarcopenia and those without sarcopenia (Table 1).

A total of 64 out of 102 patients (62%) received lenalidomide/bortezomib as part of their maintenance treatment. The 1-year nonrelapse mortality rate was 2.9% ($n = 3$), with one patient being sarcopenic and two patients not being sarcopenic.

Pre-ASCT, 47 (46%) patients were sarcopenic, and post-ASCT, 51 patients (50%) were sarcopenic (Table 2). Although there was an increase in the prevalence of sarcopenia after ASCT, this increase was not statistically significant ($p = 0.12$).

The incidence of sarcopenia in pre- and post-ASCT female patients was higher compared with male patients, and this difference was statistically significant ($p = 0.001$ and $p = 0.008$ respectively) (Table 2). In multivariate analysis, female sex (odds ratio [OR]: 1.25; 95% confidence interval [CI]: 1.12–1.38; and $p = 0.007$) and a higher HCT-CI (OR: 1.16; 95% CI: 1.04–1.29; and $p = 0.008$) were independently associated with an increased risk of sarcopenia, whereas higher BMI was independently associated with a reduced risk (OR per unit increase in BMI: 0.94; 95% CI: 0.88–0.99; and $p = 0.045$). No significant association was observed between sarcopenia and age or ISS stage.

The mean BMI in patients without sarcopenia was 26.4 ± 4.5, while it was 24.5 ± 5.1 in those with sarcopenia (Table 3). It was shown that higher BMI had a protective effect against sarcopenia (OR: 0.94; 95% Cl: 0.88–0.99; and $p = 0.045$) (Table 2).

3.2 | Change of Muscle Mass Index

The mean values of pre-ASCT and post-ASCT BIA, CT, and SMI for the patients are presented in Table 3.

A low SMI was identified in 51% of the patients before ASCT, and this percentage increased to 56% after transplantation. A reduction in mean SMI values was seen in both males and females during post-transplant assessments ($p = 0.03$) (Table 3). There was no significant correlation seen between SMI and ISS stage.

3.3 | Evaluation of Muscle Strength and Physical Performance

Out of the 47 patients who identified as pre-ASCT sarcopenia, we observed that 12 patients had just low muscular strength, 26 patients had only low physical performance, and 9 patients had low scores in both evaluations. There was no statistically significant difference in muscular strength and physical performance after ASCT when compared with the data before to the ASCT ($p = 0.95$).

TABLE 1 | Patient's characteristics.

Characteristics of the patients	Value ($N = 102$)
Age (years), median (min–max)	57 (34–75)
Gender *n* (%)	
Men	46 (45.1%)
Women	56 (54.9%)
Age status *n* (%)	
< 65 years	82 (80.4%)
≥ 65 years	20 (19.6%)
HCT-CI score *n* (%)	
0–2	93 (91.2%)
≥ 3	9 (8.8%)
ISS, *n* (%)	
Stage 1	35 (34.3%)
Stage 2	26 (25.5%)
Stage 3	41 (40.2%)
Melphalan dose *n* (%)	
140 mg/m^2	32 (31.3%)
200 mg/m^2	70 (68.7%)
Time of engraftment (days) (mean ± Sd)	
Platelet ≥ 20×10^3/uL	11 ± 3
Neutrophil ≥ 0.5×10^3/uL	10 ± 2
Length of hospitalization (days) (mean ± Sd)	23 ± 3

Abbreviations: HCT-CI, Hematopoietic Cell Transplantation-Comorbidity Index; ISS, International Scoring System; SD, standard deviation.

According to the EWGSOP2-based classification, 34 patients (33%) were identified as having probable sarcopenia, 12 patients (12%) as confirmed sarcopenia, and 9 patients (9%) as severe sarcopenia.

4 | Discussion

Patients with MM exhibited a significant reduction in SMI following ASCT, according to this study. Nevertheless, there was an increase in sarcopenia, but this rise did not reach statistical significance. Sarcopenia was shown to be associated with female gender and low BMI, which were recognized as independent risk factors. There was no significant difference observed in the duration of hospitalization, as well as the time it took for neutrophil and platelet engraftment, between patients with sarcopenia and those without sarcopenia.

Several studies in the literature have examined the correlation between solid malignancies, administered chemotherapies, and sarcopenia [12]. There is a scarcity of studies undertaken on MM patients, and the existing ones have conflicting outcomes [13, 14]. Our study is the first prospective study examining the impact of ASCT on muscle mass, physical performance, and muscular strength in patients with MM.

Sarcopenia is a multifactorial disorder caused by complex pathophysiological mechanisms. Sarcopenia is predisposed to be caused by a decrease in exercise, insufficient intake of nutrients,

TABLE 2 | Association of sarcopenia with patient characteristics.

Variable *n* (%)	Before the onset of ASCT sarcopenia status			Sixth month after the onset of ASCT sarcopenia status		
	Yes	No	*p* value	Yes	No	*p* value
Gender						
Male	12 (26.1%)	34 (73.9%)	0.001*	14 (30.4%)	32 (69.6%)	0.008*
Female	35 (62.5%)	21 (37.5%)		37 (66%)	19 (34%)	
Age						
< 65 years	36 (43.9%)	46 (56.1%)	0.37	39 (47.5%)	43 (52.5%)	0.26
≥ 65 years	11 (55%)	9 (45%)		12 (60%)	8 (40%)	
HCT-CI score						
0–2	40 (43%)	53 (57%)	0.046*	44 (47.3%)	49 (52.7%)	0.133*
≥ 3	7 (77.8%)	2 (22.2%)		7 (77.8%)	2 (22.2%)	
ISS stage						
ISS-1	14 (40%)	21 (60%)	0.62	18 (51.4%)	17 (49.6%)	0.61
ISS-2	12 (46.2%)	14 (53.8%)		11 (44%)	15 (56%)	
ISS-3	21 (51.2%)	20 (48.8%)		22 (55%)	18 (45%)	
BMI status						
Obese	5 (33.3%)	10 (66.7%)	0.045*	3 (50%)	3 (50%)	0.045*
Overweight	10 (34.5%)	19 (65.5%)		4 (25%)	12 (75%)	
Normal	18 (41.9%)	25 (58.1%)		30 (46.8%)	34 (53.2%)	
Under weight	14 (93.3%)	1 (6.7%)		14 (93.3%)	1 (6.7%)	

Note: ISS: The International Staging System.
Abbreviations: ASCT, Autologous Stem Cell Transplantation; BMI: Body Mass Index; HCT-CI, Hematopoietic Cell Transplantation-Comorbidity Index; SD, standard deviation.
*p value < 0.05.

TABLE 3 | Patients' characteristics pre and post transplantation by gender.

Variable	Pre- ASCT mean ± Sd	Post- ASCT mean ± Sd	*p* value
BMI			0.76
For men	25.2 ± 3.6	24.1 ± 3.1	
For women	25.8 ± 5.7	24.3 ± 4.2	
SMI by BIA (kg/m^2)			0.03*
For men	14.1 ± 3.20	13.8 ± 3.22	
For women	6.5 ± 1.70	6.82 ± 2.4	
SMI by CT (cm^2/m^2)			0.01*
For men	54.1 ± 7.27	51.5 ± 8.55	
For women	38.2 ± 5.71	34.7 ± 6.51	

Abbreviations: ASCT, autologous stem cell transplantation; BIA, bioelectrical impedance analysis; BMI, body mass index; CT, computed tomography; HCT-CI, Hematopoietic Cell Transplantation-Comorbidity Index; SD, standard deviation; SMI, skeletal muscle index.
*p value < 0.05.

weakened neuromuscular functions, apoptosis in muscle cells, and hormonal changes associated with aging [2].

In healthy individuals, during bone remodeling, receptor activator of nuclear factor kappa-B ligand (RANKL) activates osteoclasts, whereas osteoprotegerin functions as a decoy receptor for RANKL and attenuates RANKL-mediated bone resorption. When myeloma cells infiltrate the bone marrow, osteoprotegerin production by stromal cells is reduced, and the enhanced activity of RANKL leads to uncontrolled bone resorption [15]. As a result, in patients with MM, a decrease in the secretion of osteoprotegerin and RANKL, an increased release of cytokines such as IL3, IL-6, and CCL3, binding stromal derived factor 1 alpha to CXCR4, enhance osteoclastic activity and bone resorption [15]. Changes in bone structure lead a decrease in mobility and muscle breakdown [15]. Ren et al. did study on rats and found that the expression of the sclerosteosis (SOST) gene increased in myoblasts in MM, leading to sarcopenia [16].

Thus, we believe that patients with MM are prone to sarcopenia, depending on the disease pathogenesis and complications. In line with our prediction, the prevalence of sarcopenia before ASCT was determined to be 46% among MM patients in this study. Similarly, Williams et al. discovered the presence of pre-ASCT

sarcopenia in 51% of 142 MM patients [14]. In a separate study carried out in Germany, sarcopenia was reported in 112 (86%) out of 129 MM patients who received ASCT [13]. We believe that we found the frequency of sarcopenia to be lower, both because our methods of measuring muscle mass are different and because we also included muscle strength and physical performance criteria in our study.

There was no significant correlation seen between the incidence of sarcopenia and the ISS stage and age. We believe that we did not detect a significant link with age since the patients undergoing ASCT generally were well-performing and middle-aged.

The study identified that being female is a risk factor for sarcopenia both before and after transplantation (Table 3). Umit et al. conducted a study where they analyzed PET/CT scans of 105 MM patients at the L3 vertebra level [17]. They observed a reduction in metabolic volume in women and an increase in men after transplantation. Jabbour et al. further investigated individuals with lymphoma [18]. They demonstrated that the skeletal muscle area in males was higher than females and decreased after transplantation.

This study utilized both CT imaging to measure the muscular area of the L3 vertebra and BIA technique to calculate the SMI in order to assess muscle mass. Statistically, it was established that there was a reduction in SMI after transplanting using both procedures. According to the literature, it has also been reported that BIA and CT are correlated with SMI results in colorectal cancer patients [19]. Hence, we believe that both methods can be employed in patients with MM, contingent upon the ability of the physician.

This study found no statistically significant change in post-ASCT muscle strength and physical activity. Kramer et al. demonstrated a 6% reduction in muscle strength 1 month after allogeneic transplantation as compared with pretransplantation levels [20]. According to another study, there was an average reduction of 5 kg in muscle strength after transplantation until the patient was discharged [21]. Nevertheless, in both studies, the assessment of muscular strength was conducted in the early period after allogeneic transplantation. We believe that we did not detect any difference in muscle strength since the conditioning regimens in ASCT were lighter, fewer complications occurred, and we evaluated at the 6th month.

Schulz et al. observed a reduction in grip strength during the 2-month period after allogeneic transplantation in 26 patients. However, they did not find any changes in physical performance. In their study, it was shown that patients with sarcopenia had extended durations of hospitalization and worse rates of survival in comparison to individuals without sarcopenia [21]. In our study, the average duration of hospitalization was greater in patients with sarcopenia; however, the difference did not reach statistical significance.

In this study, a significant association between sarcopenia and engraftment time or length of hospital stay was not observed. However, our analysis demonstrated that female sex, a higher HCT-CI score, and lower BMI were significantly associated with an increased risk of sarcopenia. We believe that this risk stratification approach may contribute to improved supportive care strategies in patients undergoing ASCT. Our aim is to raise awareness among clinicians that patients with these characteristics may benefit from closer monitoring and early supportive interventions, including nutritional support, early physiotherapy or rehabilitation programs, vitamin and mineral supplementation, and cautious use of corticosteroids when feasible.

Multiple studies have demonstrated the detrimental impact of sarcopenia on both quality of life and survival. Lin et al. reported that pre- and post-ASCT sarcopenia was associated with a rise in NRM among patients with lymphoma [22]. The HOVON-123 research involved screening 220 elderly individuals with MM. It was shown that having a low SMI and reduced muscular strength were linked to the premature discontinuation of treatment and a decrease in overall survival [23]. Hence, we believe that the identification of sarcopenia is crucial for guiding treatment decisions and enhancing the results of treatment, as well as enhancing the overall quality of life for the patient.

4.1 | Study Limitations

We acknowledge that our study has certain limitations. First, clinically relevant ASCT outcomes such as severe infections, treatment-related toxicities, ICU transfer, mucositis severity, rehospitalizations, treatment modifications, quality of life, functional recovery, and survival endpoints (PFS/OS) were not systematically assessed. In addition, the relatively short median follow-up period limits survival analyses. We did not segregate sarcopenic obese individuals into distinct groups. We did not categorize R-ISS according to patients' cytogenetics. Several potential confounding factors that may influence muscle mass and function during the first 6 months following ASCT were not systematically adjusted for in the present study. These include infectious complications, physiotherapy or rehabilitation interventions, nutritional support, disease relapse, or progression. The scope of our investigation is limited to a single center. Accordingly, the present findings mainly describe the prevalence and early risk profile of sarcopenia, and larger studies with longer follow-up and comprehensive clinical endpoints are required to determine its prognostic and therapeutic relevance.

5 | Conclusions

Our study revealed a high prevalence of sarcopenia among individuals diagnosed with MM. We demonstrated that individuals with comorbidities, a low BMI, and female patients have a higher predisposition to sarcopenia. There is no increase in the occurrence of sarcopenia after ASCT; however, there is a reduction in SMI. Consequently, individuals with MM should undergo assessment for sarcopenia during the whole process of diagnosis and treatment. Adequate dietary and exercise assistance should be given, especially after ASCT.

Author Contributions

Elcin Erdogan Yucel: conceptualization, data curation, and writing the original draft. Guner Hayri Ozsan: conceptualization and methodology. Caner Ozturk: data curation and methodology. Alper Togay: methodology and formal analysis. Merve Kakcı: data curation and formal analysis. Omer Seker: data curation and writing. Canan Altay: data curation and methodology. Lalit Batra: supervision and language editing. Inci Alacacioglu: conceptualization, supervision, and writing–review and editing.

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Disclosure

All authors have approved the final manuscript.

Ethics Statement

This study received approval from the Dokuz Eylul University Ethical Review Board (2021/14–25), which was carried out in adherence to the principles outlined in the Declaration of Helsinki.

Consent

Patients were not involved in the design, conduct, or reporting or dissemination plans of this research. Refer to the Methods section for further details.

Informed written consent was obtained from all patients prior to the study in accordance with the Declaration of Helsinki.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The dataset should be provided in case of need after obtaining the permission of all authors. The data are not publicly available because of privacy and ethical restrictions.

References

1. N. Howlader, A. M. Noone, M. Krapcho, et al., *SEER Cancer Statistics Review, 1975–2018* (SEER), https://seer.cancer.gov/csr/1975_2018/.

2. A. J. Cruz-Jentoft, G. Bahat, J. Bauer, et al., "Sarcopenia: Revised European Consensus on Definition and Diagnosis," *Age and Ageing* 48, no. 1 (2019): 16–31, https://doi.org/10.1093/ageing/afy169.

3. C. L. Sun, L. Francisco, T. Kawashima, et al., "Prevalence and Predictors of Chronic Health Conditions After Hematopoietic Cell Transplantation: A Report From the Bone Marrow Transplant Survivor Study," *Blood* 116, no. 17 (2010): 3129–3139, https://doi.org/10.1182/blood-2009-06-229369.

4. A. Surov and A. Wienke, "Sarcopenia Predicts Overall Survival in Patients With Malignant Hematological Diseases: A Meta-Analysis," *Clinical Nutrition* 40, no. 3 (2021): 1155–1160, https://doi.org/10.1016/j.clnu.2020.07.023.

5. T. Cederholm, R. Barazzoni, P. Austin, et al., "ESPEN Guidelines on Definitions and Terminology of Clinical Nutrition," *Clinical Nutrition* 36, no. 1 (2017): 49–64, https://doi.org/10.1016/j.clnu.2016.09.004.

6. D. Albano, C. Messina, J. Vitale, and L. M. Sconfienza, "Imaging of Sarcopenia: Old Evidence and New Insights," *European Radiology* 30, no. 4 (2019): 2199–2208, https://doi.org/10.1007/s00330-019-06573-2.

7. R. A. Fielding, B. Vellas, W. J. Evans, et al., "Sarcopenia: An Undiagnosed Condition in Older Adults. Current Consensus Definition: Prevalence, Etiology, and Consequences. International Working Group on Sarcopenia," *Journal of the American Medical Directors Association* 12, no. 4 (2011): 249–256, https://doi.org/10.1016/j.jamda.2011.01.003.

8. S. V. Rajkumar, M. A. Dimopoulos, A. Palumbo, et al., "International Myeloma Working Group Updated Criteria for the Diagnosis of Multiple Myeloma," *The Lancet Oncology* 15, no. 12 (2014): e538–e548, https://doi.org/10.1016/s1470-2045(14)70442-5.

9. M. L. Sorror, M. B. Maris, R. Storb, et al., "Hematopoietic Cell Transplantation (HCT)-Specific Comorbidity Index: A New Tool for Risk Assessment Before Allogeneic HCT," *Blood* 106, no. 8 (2005): 2912–2919, https://doi.org/10.1182/blood-2005-05-2004.

10. M. Cesari, S. B. Kritchevsky, A. B. Newman, et al., "Added Value of Physical Performance Measures in Predicting Adverse Health-Related Events: Results From the Health, Aging and Body Composition Study," *Journal of the American Geriatrics Society* 57, no. 2 (2009): 251–259, https://doi.org/10.1111/j.1532-5415.2008.02126.x.

11. C. M. Prado, J. R. Lieffers, L. J. McCargar, et al., "Prevalence and Clinical Implications of Sarcopenic Obesity in Patients With Solid Tumours of the Respiratory and Gastrointestinal Tracts: A Population-Based Study," *The Lancet Oncology* 9, no. 7 (2008): 629–635, https://doi.org/10.1016/s1470-2045(08)70153-0.

12. U. Oflazoglu, S. Caglar, H. E. Yılmaz, et al., "The Relationship Between Sarcopenia Detected in Newly Diagnosed Colorectal Cancer Patients and FGF21, Irisin and CRP Levels," *European Geriatric Medicine* 13, no. 4 (2022): 795–803, https://doi.org/10.1007/s41999-022-00635-3.

13. F. B. Ordonez, D. Wolleschak, Y. Zeller, et al., "Parameters of Body Composition do Not Predict Survival in Patients with Multiple Myeloma Undergoing Autologous Stem Cell Transplantation," *Leukemia and Lymphoma/Leukemia and Lymphoma* 65 (2024): 825–832, https://doi.org/10.1080/10428194.2024.2319226.

14. A. Williams, D. Baruah, J. Patel, et al., "Prevalence and Significance of Sarcopenia in Multiple Myeloma Patients Undergoing Autologous Hematopoietic Cell Transplantation," *Bone Marrow Transplantation* 56, no. 1 (2020): 225–231, https://doi.org/10.1038/s41409-020-01008-9.

15. E. Terpos, D. Christoulas, and M. Gavriatopoulou, "Biology and Treatment of Myeloma Related Bone Disease," *Metabolism* 80 (2018): 80–90, https://doi.org/10.1016/j.metabol.2017.11.012.

16. J. Ren, J. Wang, X. Yao, et al., "Investigation of the Underlying Mechanism of Sclerosteosis Expression in Muscle Tissue in Multiple Myeloma With Sarcopenia," *Journal of Inflammation Research* 16 (2023): 563–578, https://doi.org/10.2147/jir.s391465.

17. E. G. Umit, U. Korkmaz, M. Baysal, et al., "Evaluation of Sarcopenia With F-18 FDG PET/CT and Relation With Disease Outcomes in Patients With Multiple Myeloma," *European Journal of Cancer Care* 29, no. 6 (2020): https://doi.org/10.1111/ecc.13318.

18. J. Jabbour, B. Manana, A. Zahreddine, et al., "Sarcopenic Obesity Derived From PET/CT Predicts Mortality in Lymphoma Patients Undergoing Hematopoietic Stem Cell Transplantation," *Current Research in Translational Medicine* 67, no. 3 (2019): 93–99, https://doi.org/10.1016/j.retram.2018.12.001.

19. N. C. Souza, M. C. Gonzalez, R. B. Martucci, et al., "Comparative Analysis Between Computed Tomography and Surrogate Methods to Detect Low Muscle Mass Among Colorectal Cancer Patients," *Journal of Parenteral and Enteral Nutrition* 44, no. 7 (2019): 1328–1337, https://doi.org/10.1002/jpen.1741.

20. M. Kramer, P. Heussner, P. Y. Herzberg, et al., "Validation of the Grip Test and Human Activity Profile for Evaluation of Physical Performance During the Intermediate Phase After Allogeneic Hematopoietic Stem Cell Transplantation," *Supportive Care in Cancer* 21, no. 4 (2012): 1121–1129, https://doi.org/10.1007/s00520-012-1634-1.

21. S. V. W. Schulz, D. A. Bizjak, E. Moebes, et al., "Monitoring of Strength, Inflammation and Muscle Function in Allogenic Stem-Cell Transplantation Patients—A Pilot Study for Novel Biomarker and Risk Stratification Determination," *Frontiers in Immunology* 14 (2023): 1129687, https://doi.org/10.3389/fimmu.2023.1129687.

22. R. J. Lin, L. Michaud, S. M. Lobaugh, et al., "The Geriatric Syndrome of Sarcopenia Impacts Allogeneic Hematopoietic Cell Transplantation Outcomes in Older Lymphoma Patients," *Leukemia and Lymphoma/Leukemia and Lymphoma* 61, no. 8 (2020): 1833–1841, https://doi.org/10.1080/10428194.2020.1742909.

23. C. A. M. Stege, K. Nasserinejad, M. D. Levin, et al., "Geriatric Impairments and Low Muscle Mass are Associated With Treatment Discontinuation and Overall Survival in Newly Diagnosed Non-Transplant Eligible Multiple Myeloma Patients (nte-NDMM) Treated With Dose-Adjusted Melphalan-Prednisone-Bortezomib (MPV)—Results of the Dutch HOVON 123 Study," *Blood* 132, no. Supplement 1 (2018): 1889, https://doi.org/10.1182/blood-2018-99-1169.