




Frequency of Sarcopenia, Sarcopenic Obesity, and Changes in Physical Function in Surgical Oncology Patients Referred for Prehabilitation

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Abstract

Purpose: Sarcopenia and suboptimal performance status are associated with postoperative complications and morbidity in cancer patients. Prehabilitation has emerged as an approach to improve fitness and muscle strength in patients preoperatively. We sought to describe the frequency of sarcopenia and sarcopenic obesity (SO) in a cohort of cancer patients referred for prehabilitation and the association between body composition and physical function. **Methods:** In this retrospective review of 99 consecutive cancer patients referred for prehabilitation prior to intended oncologic surgery, prehabilitation included physical medicine and rehabilitation (PM&R) physician evaluation of function and physical therapy for individualized home-based exercise. Sarcopenic A was defined using sex-adjusted norms of skeletal muscle (SKM), measured using the sliceOmatic software (TomoVision, 2012) on computed tomography images at baseline. Sarcopenic B was defined by abnormal SKM and physical function. SO was defined as sarcopenia with BMI \geq 25. Six-minute walk test (6MWT), 5 times sit-to-stand (5 \times STS), and grip strength were obtained at consultation (baseline) and at preoperative follow-up (if available). **Results:** Forty-nine patients (49%) were Sarcopenic A, 28 (28%) SO, and 38 (38%) Sarcopenic B. Age was negatively correlated with SKM ($P = .0436$). There were no significant associations between Sarcopenic A/B or SO with baseline or changes in physical function. Assessed by sex, Sarcopenic A females had low 5 \times STS ($P = .04$) and Sarcopenic B females had low GS ($P = .037$). Sarcopenic B males had low preoperative GS ($P = .026$). 6MWT and grip strength at baseline were lower than age- and sex-related norms (both $P < .001$). Preoperatively, 6MWT distance and 5 \times STS time improved (both $P < .001$). Functional improvement in the sarcopenic and nonsarcopenic patients did not differ according to sex. **Conclusions:** In this cohort of prehabilitation surgical oncology patients, frequencies of sarcopenia and SO were high, and baseline physical function was abnormal but improved significantly regardless of body composition. These findings suggest that patients have considerable prehabilitation needs and are capable of improving with comprehensive care.

Keywords

Sarcopenia, Sarcopenic obesity, Prehabilitation, Cancer rehabilitation, Body composition

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Introduction

Weight loss in patients with cancer is nonspecific, as it can represent starvation, disease progression, cachexia, or sarcopenia. Body-composition changes in the form of either cachexia or sarcopenia are recognized as important prognostic factors in cancer patients, especially in the preoperative period. Improved body composition and physical function are both protective against perioperative complications for cancer patients undergoing surgery.¹

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Sarcopenia is a syndrome that results from age-associated skeletal muscle (SKM) loss and leads to progressive functional impairment.² This syndrome has been associated with disuse, chronic illnesses, change in endocrine function, inflammation, and nutritional deficiencies.² Sarcopenia has been diagnosed based on low muscle mass from imaging including dual energy X-ray absorptiometry, magnetic resonance imaging, or computed tomography and can be further supported with findings of abnormal physical function tests.^{3,4} Whereas cachexia is disease-associated muscle loss, sarcopenia is the degenerative loss of SKM mass, quality, and strength associated with aging.⁵ Additionally, because the incidence of overweight and obese patients is increasing, severely malnourished patients may present with body mass indexes (BMIs) within the normal range, masking a severely sarcopenic body composition.⁶ Sarcopenic obesity (SO), defined as the presence of sarcopenia with a BMI greater than 25 kg/m² as cited by numerous studies in a recent review, has become a concern in managing patients in cancer treatment.⁷ SO has been associated with increased postoperative morbidity and 30-day mortality in patients undergoing surgery for colorectal and pancreatic cancer.^{8,9}

Surgical resection is often a necessary treatment in the cancer continuum of care. Depending on the type of surgery, declines in basic physical function prior to surgical intervention may portend a difficult postoperative period.¹⁰ Also, surgical intervention and the postoperative period are known to be associated with significant declines in physical function, nutrition, and quality of life.¹⁰⁻¹² A recent review reported that some physical performance measures are associated with survival.¹³ However, little is known about the association between physical function and sarcopenia preoperatively. The potential negative impact of sarcopenia may not only be related to the severity of the muscle loss, but also the magnitude of surgery.

The goals of cancer prehabilitation include minimizing declines in physical function before and after surgery. These programs include combinations of exercise, nutrition, and/or psychology interventions. Body composition is an important component of the patient evaluation and may be predictive of prehabilitation potential. Therefore, it is important to describe the body composition and functional status of these patients to highlight the need for early intervention. The purpose of this study was to determine: (1) the frequency of sarcopenia based on traditional quantitative and updated definitions and SO, (2) the association between body composition and response to prehabilitation, (3) the impact of prehabilitation on functional changes in cancer patients prior to surgery.

Methods

The University of Texas MD Anderson Cancer Center Institutional Review Board approved this retrospective study

(protocol #PA17-0796) and provided ethical approval of conducting this study. The institutional review board determined that informed consent was not required. The medical records of consecutive patients who received outpatient Physical Medicine and Rehabilitation (PM&R) and physical therapy (PT) consultations for prehabilitation from October 2015 to January 2018 were reviewed primarily for functional outcome measures (Figure 1). Within this cohort, patients who underwent computed tomography (CT) of the abdomen and pelvis (as part of their standard care) within 30 days prior to or 7 days after the consultation date were included in this study. Images from these CT scans were used to determine the software-measured body composition (to diagnose sarcopenia or SO) as described below.

The Prehabilitation Intervention

At this institution, patients referred for comprehensive prehabilitation are evaluated by a PM&R physician for oversight of a home-based exercise program, nutrition assessment, and monitoring of body composition via bioimpedance. Also during the PM&R visit, patients are evaluated and receive treatment of any musculoskeletal or neuromuscular conditions, any pre-existing functional impairments, or a cancer symptom profile that may interfere with their ability to exercise. Figure 2 shows the prehabilitation program referral schema. Patients are also evaluated by a senior PT in the clinic, undergo a series of functional outcome measurements: 6-minute walk test (6MWT), grip strength (GS) via handheld dynamometry, and 5 times sit-to-stand (5×STS). Patients receive an individualized exercise program modeling American College of Sports Medicine and American Cancer Society's exercise recommendations for cancer survivors at that time.¹⁴ Patients are advised to engage in 30 minutes of moderate-intensity exercise 3 to 5 days per week, including 2 sessions of full-body strengthening exercises weekly. Patients receive in-person demonstrations of the exercises by PT which may be individualized, are provided with handouts containing the exercise regimen, exercise precautions and are sent video clips of the strengthening exercises. If patients reported more than 150 minutes of aerobic activity weekly and reported at least 2 strengthening sessions weekly, they were deemed fully adherent; patients who completed some aerobic and some strengthening exercises were recorded as partially adherent, and non-adherent patients reported no exercise at all. Patients were recorded as unknown adherence if could not be reached by telephone or exercise activity reports were omitted on the electronic medical record. Patients are advised to return to the clinic for a preoperative visit where the functional outcome measurements are repeated.

For each patient who presented for prehabilitation in the clinic, body composition was measured using a dual frequency total body bioimpedance scale (TBF-310; Tanita

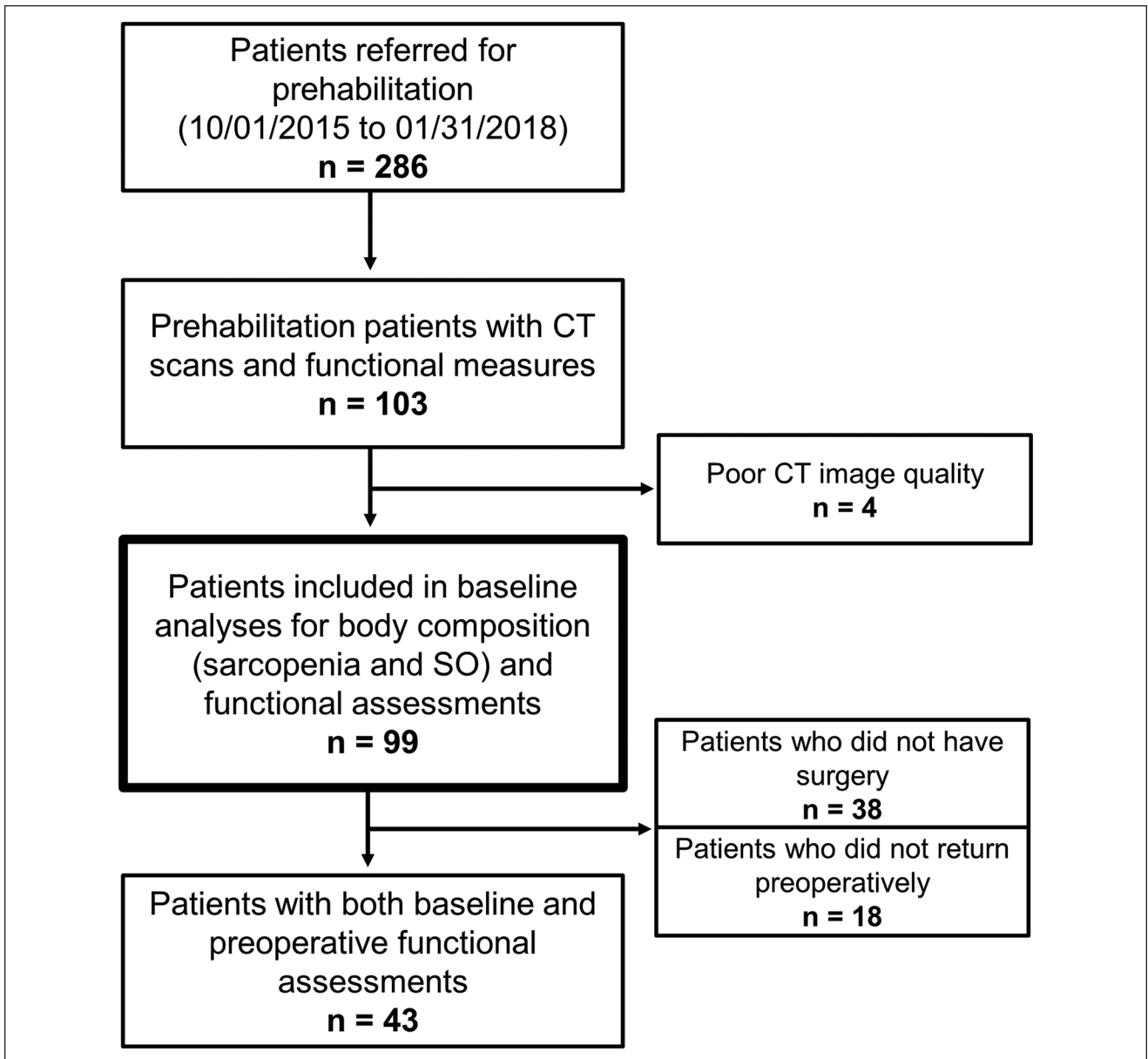


Figure 1. Patient flow diagram outlining which prehabilitation patients were evaluated in this study. Abbreviations: CT, computed tomography; SO, sarcopenic obesity.

Corporation of America, Arlington Heights, IL). Factors such as timing of measures (time of day), hydration status, fasting versus fed state, or recent exercise were not recorded. These measures included weight, body mass index, body fat weight, body fat percentage, and fat-free mass. This information was not used for the diagnosis of sarcopenia due to lack of normative data.

Body Composition Analysis

To determine the status of sarcopenia based on traditional quantitative values (Sarcopenic A) and updated definitions (Sarcopenic B), and SO in this cohort of patients, CT images

of the abdomen and pelvis obtained for routine clinical care were reviewed for anthropometric analyses. Using the sliceOmatic software program (version 5.0; TomoVision, Magog, Quebec, Canada), cross-sectional areas of SKM and visceral, subcutaneous, and intramuscular fat were assessed at the L3 vertebral body midpoint on serial CT images (Figure 3). Cross-sectional areas were standardized to the square of the patient's height in meters. Per well-referenced standards, sarcopenia was defined as SKM index of less than or equal to $38.9 \text{ cm}^2/\text{m}^2$ for women and less than or equal to $55.4 \text{ cm}^2/\text{m}^2$ for men,⁴ denoted as Sarcopenic A in this study. There have been variable definitions of SO—some, such as the World Health Organization (WHO) have

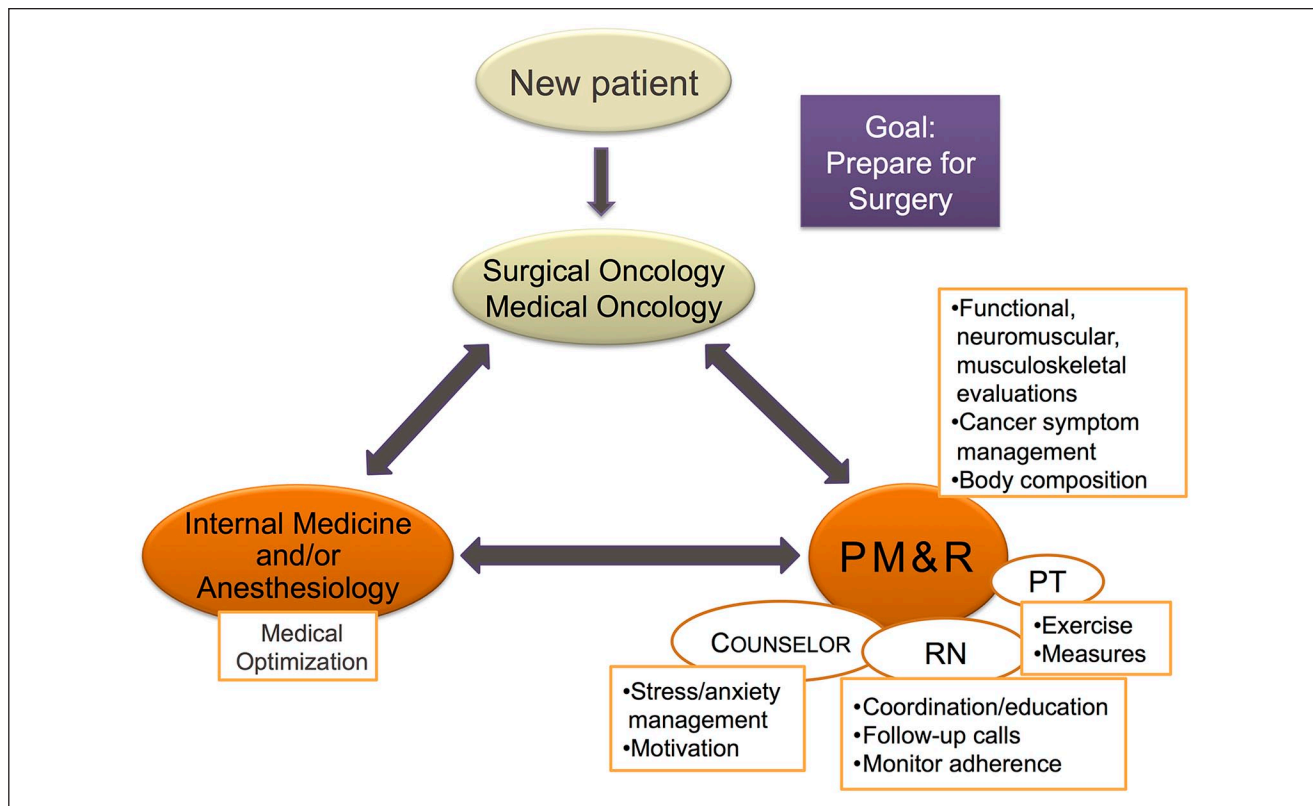


Figure 2. This is the referral pathway for prehabilitation for patients at this comprehensive cancer center. Patients may be referred directly by the surgical oncology, medical oncology teams, internal medicine perioperative clinic, or anesthesiology preoperative assessment clinic with the primary goal of preparing patients for surgery.

Abbreviations: PM&R, physical medicine and rehabilitation; RN, registered nurse; PT, physical therapist.

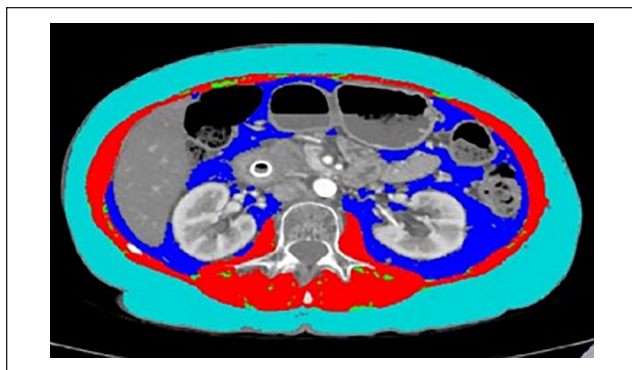


Figure 3. A sample processed CT image of a study patient obtained using the sliceOmatic software program that includes cross-sectional areas of SKM (red), visceral fat (blue), subcutaneous fat (teal), and intramuscular fat (green).

used the cut-off of BMI of at least 30 kg/m^2 for obesity; a majority of studies on the other hand, have used a cut off BMI of at least 25 kg/m^2 and for that reason, this study follows the more common definition.⁷ Thus, SO was defined as sarcopenia and a BMI of at least 25 kg/m^2 (overweight or

obese) as per referenced studies.^{7,15} Furthermore, the diagnosis of Sarcopenic B included patients who were below the SKM index cut-off values from CT images⁴ and had abnormal GS (score less than 59.5 pounds for males or less than 35.3 pounds for females) or 5×STS (score greater than 15 seconds).^{3,16}

Statistical Analysis

Data were summarized using descriptive statistics, including means with standard deviations, medians with interquartile ranges (IQRs) for continuous variables, and frequencies and proportions for categorical variables. Descriptive statistics were used to summarize the patient characteristics, frequency of sarcopenia and SO, physical function outcome measures, and bioimpedance-measured body composition. Scores of physical function measures that were not completed by patients (including because they were unable to) were omitted. Chi-square and Wilcoxon rank sum tests were applied to evaluate the association of categorical and continuous variables, respectively. Thus, the associations between the presence of or absence of sarcopenia and SO with age and the physical function measures were

determined by the Chi-square test. The Wilcoxon rank sum tests were applied to determine the correlation between SKM and change in the physical function scores. Changes in physical function measures from the baseline time point to the preoperative follow-up time point were evaluated using the Wilcoxon signed rank test. Change in function was subjected to intention-to-treat analysis. Therefore, patients who were not adherent or had unknown adherence to their exercise programs were analyzed as with the patients who were fully or partially adherent to them. Pearson correlation statistics were reported along with 95% confidence intervals to evaluate the relationship between 2 continuous variables. The Wilcoxon signed rank test was also applied to comparison of patients' baseline physical function measurements with age- and sex-related norm values.¹⁷⁻²¹ All tests were two-sided, and *P* values less than .05 were considered significant. All analyses were performed using SPSS software (version 24; IBM, Armonk, NY).

Results

There were 286 potential surgical candidates referred to the PM&R prehabilitation clinic during the study period. Of these patients, 103 had both CT scans of the abdomen and pelvis and baseline functional outcome measurements from their PT consultations. Four patients were excluded because the quality of their CT images was too poor for assessment (Figure 1). Table 1 summarizes the characteristics and body composition profiles of the remaining 99 patients included in the study. Their mean age was 72 years (standard deviation, 10 years), and 58 (59%) of the patients were female. The most common primary cancer diagnoses were gastrointestinal (59%), genitourinary (15%), and gynecologic (7%) cancers and sarcoma (7%) as patients with these cancers had CT scans of the abdomen as part of their routine care. Thirty-two (32%), 25 (25%), 17 (17%), and 25 (25%) of the patients had full, partial, no, and unknown adherence to their exercise programs, respectively. Sixty-one (62%) patients ended up having surgery. Reasons patients did not have surgery included progressive disease (19%), poor performance status (8%), poorly controlled medical comorbidities (3%), stable disease (3%), and other factors (5%). The median BMI was 26.6 kg/m² (IQR, 22.6-31.5 kg/m²). Nine (9%), 29 (29%), 34 (34%), and 27 (27%) patients were underweight, had a normal weight, were overweight, and were obese, respectively, based on BMI.

The primary objective was to describe the frequency of sarcopenia and SO in this cohort of patients undergoing prehabilitation. As outlined in Table 2, 49 (49%) patients were sarcopenic based on CT scan body compositions measures of low SKM (Sarcopenic A), 28 (28%) of whom fulfilled the criteria for SO. With the additional criteria of abnormal 5×STS or GS for patients with low SKM, 38 (39%) fulfilled the criteria of Sarcopenic B. The second objective was

Table 1. Patient Characteristics. Clinical and Demographic Data and Body Composition Measures for the Study Patients at Baseline. (N=99).

| Characteristic | N (%) |
|------------------------------------------------------------------------------|-------------------|
| Mean age, years (SD) | 72 (10) |
| Female sex | 58 (59) |
| Race/ethnicity | |
| White | 71 (72) |
| Asian | 11 (11) |
| Black | 9 (9) |
| Other | 8 (8) |
| Cancer diagnosis | |
| Gastrointestinal | 58 (59) |
| Genitourinary | 15 (15) |
| Gynecologic | 7 (7) |
| Sarcoma | 7 (7) |
| Breast | 5 (5) |
| Lung | 1 (1) |
| Other | 6 (6) |
| Median prehabilitation duration, days (IQR) | 54 (30-90) |
| Underwent surgery | 61 (62) |
| Median BMI, kg/m ² (IQR) | 26.6 (22.6-31.5) |
| Median SKM index, cm ² /m ² (IQR) ^a | 45.0 (40.0-53.2) |
| Median intramuscular fat, cm ² /m ² (IQR) ^a | 6.3 (3.9-9.2) |
| Median visceral fat, cm ² /m ² (IQR) ^a | 49.3 (20.0-78.9) |
| Median subcutaneous fat, cm ² /m ² (IQR) ^a | 72.9 (48.2-100.4) |
| Median fat mass, pounds (IQR) ^b | 52.0 (34.0-73.0) |
| Median fat mass, % (IQR) ^b | 32.3 (21.7-38.9) |

Abbreviations: SD, standard deviation; IQR, interquartile range; BMI, body mass index; SKM, skeletal muscle.

^aBody composition as measured using CT images.

^bBody composition as measured using the bioimpedance scale.

Table 2. Sarcopenic A Diagnosis Based on Normative Cut-Off Values from CT Scan Measures.⁴ Sarcopenic Obesity (n=28) was Defined as Sarcopenic A and Body Mass Index ≥25 kg/m².^{7,15} Sarcopenic B Diagnosis was Based on CT Scan Measures and Abnormal Physical Function.^{3,4}

| Sarcopenic A | Sarcopenic B | | Total |
|--------------|--------------|----|-------|
| | Yes | No | |
| Yes | 38 | 11 | 49 |
| No | 0 | 50 | 50 |
| Total | 38 | 61 | |

to determine the association between body composition and baseline physical function and response to prehabilitation. There were no significant associations between the classification of Sarcopenia A or Sarcopenia B with age, baseline functional measures, or changes in functional measures. With sex-specific analyses, both Sarcopenic A and Sarcopenic B females had worse baseline median 5×STS scores (17.5 seconds [11.18-20.6] and 18.85 seconds [16.06-21.59]) than non-sarcopenic females (11.64 seconds [10.03-14.6] and 11.5 [10.09-14.48]), (*P*=.04, *P*=.011, respectively). (Fourteen of the 18 females had abnormal

Table 3. Baseline Functional Measures. Comparison of Baseline Functional Test Results with Normative Data Based on Age and Sex¹⁶⁻²⁰ for: (a) The Entire Cohort (N=99) and (b) The Patients Who had Both Baseline and Preoperative Functional Test Results Recorded (N=43).

| Variable | Median score (IQR) | | P value |
|--------------------------------------------|---------------------|---------------------|---------|
| | Baseline | Normative | |
| a. Entire cohort | N=99 | | |
| 6MWT, meters (N=98) | 366.0 (230.0-450.0) | 499.0 (471.0-538.0) | <.001 |
| Right GS, pounds (N=98) | 41.7 (35.0-58.3) | 54.9 (48.2-84.2) | <.001 |
| Left GS, pounds (N=98) | 41.7 (31.7-52.6) | 51.5 (43.6-81.4) | <.001 |
| 5×STS time, seconds (N=86) | 11.8 (9.9-17.5) | 12.6 (11.4-12.6) | .005 |
| b. Patients who had preoperative follow-up | N=43 | | |
| 6MWT, meters (N=42) | 366.0 (210.0-420.0) | 499.0 (471.0-538.0) | <.001 |
| Right GS, pounds (N=43) | 41.7 (35.0-55.0) | 54.9 (52.5-81.9) | <.001 |
| Left GS, pounds (N=43) | 41.7 (28.3-50.0) | 51.5 (48.3-77.3) | <.001 |
| 5×STS time, seconds (N=35) | 11.2 (9.5-13.9) | 12.6 (11.4-12.6) | .86 |

Bold P values indicate statistical significance.

The Wilcoxon signed rank test was applied here.

Abbreviations: IQR, interquartile range; 6MWT, six-minute walk test; GS, grip strength; 5×STS, five times sit-to-stand.

5×STS that was used to assign them to the Sarcopenic B diagnosis.) Sarcopenic B females also had worse preoperative right GS (26.67 pounds [23.33-31.67]) than non-sarcopenic B females (43.3 pounds [35-50]), ($P=.037$). Sarcopenic B versus non-sarcopenic B males had lower baseline right GS scores (53.33 pounds [38.33-61.66] versus 70 pounds [61.67-80], $P=.003$) and left GS scores (45 pounds [40-51.67] versus 66.67 [65-75], $P=.0002$), and worse preoperative left GS (49.17 pounds [45.83-51.67]) than non-sarcopenic males B (69.84 pounds [60-76.84]), ($P=.026$). (Eighteen of 20 males had abnormal GS which was used to assign them the Sarcopenic B diagnosis). There were no statistically significant associations between the classification of female and male Sarcopenic A and Sarcopenic B with age (only trend for), 6MWT at baseline, physical function changes (including improvement versus decline in the functional tests), or inability to perform the tests. Furthermore, we observed no significant associations of SO with age, baseline functional measures, or changes in functional measures except for a significant association between SO and right GS (median, 45.3 [IQR, 40.0-68.3]; $P=.022$). In addition, we found a significant negative correlation between age and SKM index ($r=-0.20$, $P=.0436$). We found no associations among visceral fat or subcutaneous fat, with age. We also observed no significant correlations between SKM index and changes in physical function measures. Furthermore, sarcopenia was not associated with having surgery. The frequency of surgery was not significantly different between patients who were sarcopenic (32 [65%]) and those who were not (29 [58%]; $P=.537$).

We compared patients' body compositions measured using a bioimpedance scale (baseline values included in Table 1) with those measured using CT images. We observed

a significant association between fat-free mass measured using the bioimpedance scale and SKM index measured using CT images ($r=0.607$, $P<.0001$). We also saw significant correlations of body fat percentage measured using the bioimpedance scale with intramuscular, visceral, and subcutaneous fat values measured using CT ($r=0.405$, $P=0.0001$; $r=0.379$, $P=.0003$; and $r=0.733$, $P<.0001$, respectively).

The third objective of this study was to determine the impact of prehabilitation on functional changes in cancer patients prior to surgery. Table 3 shows comparisons of the baseline functional test results with age- and sex-matched norms for community-dwelling adults.¹⁷⁻²⁰ In the entire cohort, 6MWT, GS and 5×STS results at baseline were lower than age- and sex-related norms ($P<.001$, $P<.001$, and $P=.005$, respectively). In the 43 patients who returned to the clinic for follow-up visits and completed their preoperative functional measurements, 6MWT and GS test results at baseline were lower than age- and sex-related norms ($P<.001$, $P<.001$, respectively).

In addition, we found significant improvement in the 6MWT and 5×STS test results during the preoperative period ($P<.001$ for both) in these patients (Table 4). The prehabilitation time duration and 6MWT distance were not significantly correlated ($r=0.22$, $P=.23$).

Discussion

We sought to determine the baseline body composition on patients referred to PM&R clinic for prehabilitation prior to oncology surgery, whether body composition is associated with physical function, and whether prehabilitation impacts physical function preoperatively. In this study, 49 (49%)

Table 4. Functional Measures Preoperatively. Changes in Physical Functional Measures from Baseline to Preoperative Follow-Up (N=43). In the 6MWT and GS Measures, Higher Values Denote Better Function; Whereas in the 5×STS Test, Lower Value Denotes Better Function.

| Variable | Median score (IQR) | | | P value |
|----------------------------|---------------------|------------------------|---------------------|-----------------|
| | Baseline | Preoperative follow-up | Change | |
| 6MWT, meters (N=42) | 366.0 (210.0-420.0) | 388.0 (282.0-450.0) | 29.0 (-6.0 to 60.0) | <.001 |
| Right GS, pounds (N=43) | 41.7 (35.0-55.0) | 43.3 (31.7-55) | 1.7 (-3.3 to 3.3) | .578 |
| Left GS, pounds (N=43) | 41.7 (28.3-50.0) | 43.3 (30.0-51.7) | 0 (-5.0 to 4.2) | .630 |
| 5×STS time, seconds (N=35) | 11.2 (9.5-13.9) | 10.3 (8.7-11.6) | -1.7 (-3.1 to -0.2) | <.001 |

Bold P values indicate statistical significance.

The Wilcoxon signed rank test was applied here.

Abbreviations: 6MWT, six-minute walk test; GS, grip strength; 5×STS, five times sit-to-stand.

patients referred for prehabilitation had sarcopenia based on CT scan measured SKM (Sarcopenic A), 28 (28%) had SO, and 38 (38%) were further classified as Sarcopenic B with low SKM and the addition of physical function abnormalities. We conducted sex-specific analyses of Sarcopenic A and Sarcopenic B versus nonsarcopenic patients and found an association between females with Sarcopenic A having low baseline 5×STS scores, females with Sarcopenic B had low baseline GS and males with Sarcopenic B had low preoperative GS. We also found associations between female Sarcopenic B with low baseline 5×STS and male Sarcopenic B with low baseline GS; however these abnormal measures were used to classify patients as Sarcopenic B. There were no specific associations with the 6MWT nor with functional changes during the preoperative period. From baseline to preoperative follow-up visits, we observed significant improvements in functional measures, including 6MWT and 5×STS test results, in both sarcopenic and nonsarcopenic patients. Sarcopenia was not associated with the level of functional improvement.

Prehabilitation for sarcopenia might be more necessary in some cancer patient populations than in others since there is a much higher frequency of sarcopenia or cachexia in certain cancers, such as gastrointestinal and thoracic cancers in comparison to breast cancer. The frequencies of sarcopenia and SO were high in this older patient population with mostly gastrointestinal cancer diagnoses. Sarcopenia and SO are independent predictors of morbidity in patients with pancreatic cancer, diffuse large B-cell lymphoma, lung cancer, or gastrointestinal cancer.^{6,15,22} Sarcopenia also has been associated with mortality in patients with bladder cancer undergoing cystectomy²³ and is an independent predictor of mortality in patients with pancreatic cancer.²⁴⁻²⁶ Because of the perioperative risks associated with sarcopenia, optimizing patient function, nutrition, and body composition preoperatively is important. More than 60% of the patients in our cohort underwent surgery; thus, these patients were deemed ready for surgery. Nineteen (19%) of

the patients had disease progression and were no longer surgical candidates. Thus, in this cohort, the reasons for not having surgery were not based on body composition. More research is needed to determine how, if appropriate, the nonsurgical patients our cohort may be further optimized for treatment.

In general, risk factors for sarcopenia include age, sex, and level of physical activity.²⁷ The patients in our study were older, were mostly female, and had low baseline function and thus were at high risk for sarcopenia. Sarcopenia has been associated with decreased physical function,²⁷ and development of sarcopenia at an older age is associated with a faster decline in strength.²⁸ In this study cohort, although the SKM was negatively-associated with age, the classification of sarcopenia itself was not associated with age, likely due to the high frequency of sarcopenia in this cohort of generally older patients undergoing surgery. When incorporating both physical function measures and low SKM to diagnose sarcopenia, there was a high frequency of Sarcopenic B patients in this study. This demonstrates the prevalence of weakness at baseline in this patient population. It was reassuring that having the diagnosis of Sarcopenic B did not affect the change in physical function in these patients. In developing exercise programs for these patients, the focus should be on strengthening the lower limbs (including the knee extensors and hip extensors) and also, grip strength, as weak grip strength may affect activities of daily living. More research on how classification using Sarcopenic B in surgical oncology patients could impact other cancer outcomes such as survival would be important. Furthermore, sarcopenia and SO were not associated with changes in physical function preoperatively; but we saw improvement the group as a whole. Thus, sarcopenia did not limit the potential for these patients to improve functionally with a prehabilitation physical activity program.

Along with impaired body composition, the patients in this study presented to the PM&R clinic with low physical

function at baseline. Where they were in their treatment trajectories (recently diagnosed versus receiving treatment for recurrence), was variable. Also, the surgical oncology teams may have selected impaired patients to refer to our clinical program. Physical function outcome measures were used to monitor the functional progress of patients undergoing prehabilitation. For example, the 6MWT is a validated test of submaximal exercise capacity. Preoperative 6MWT distance has been associated with intraoperative and postoperative outcomes in cancer patients.²⁹⁻³¹ Improvement in the 6MWT has been associated with decreased incidence of postoperative pulmonary complications and decreased length of hospital stays in patients with lung cancer.³² There was a statistically significant improvement in the 6MWT preoperatively in this study cohort. The median improvement was 29 m, which may seem low; however, studies on colorectal cancer patients show the minimally clinically important difference in the 6MWT may be as low as 19 m.^{33,34} The 5×STS test measures lower limb strength and as such, is a predictor of falls and disability in activities of daily living.^{19,35} In a prospective prehabilitation exercise trial in pancreatic cancer patients conducted by members of our team, physical activity was associated with improved physical function (6MWT and 5×STS) and health-related quality of life.³⁶ Furthermore, esophageal cancer patients with low preoperative GS had higher rates of complications and mortality than ones with strong GS.³⁷ Hand GS in the present study improved during the preoperative period, but not significantly, likely due to a lack of exercises directed at maintaining or improving hand GS. We found a significant association between SO and right GS; this is of limited clinical value however, and may be attributed to multiple statistical comparisons.

Our findings showed that abnormalities in body composition are very common in patients with cancer diagnoses referred for prehabilitation. Our results are reassuring in that sarcopenic and nonsarcopenic patients demonstrate similar levels of functional improvement as well as eligibility for surgery. These findings suggest that sarcopenic patients should be referred for prehabilitation exercise interventions and can be expected to have responses similar to those in nonsarcopenic patients. Body composition analyses and consideration of pharmacologic and nonpharmacologic management of sarcopenia may be important contributors prehabilitation in further optimizing patient body composition and further improving function. More research is necessary to determine the role of those interventions in reducing the level of sarcopenia in these patients.

Our findings regarding a strong association between bioimpedance analysis and CT-derived measures of body composition may be helpful for clinical teams that do not have access to CT-derived data, such as those treating primary cancers that do not routinely require CT scans of the abdomen or pelvis and those in small hospitals or developing

countries that may not have access to body-composition software. Furthermore, bioimpedance analysis can be completed in seconds, even in patients who may have functional limitations, while measurement of objective function may take many minutes and requires well-trained personnel to perform these measures reliably. Thus, bioimpedance evaluation may be a valuable alternative to measuring body composition on CT-imaging or obtaining functional measures such as grip strength or walk tests, which may be time-consuming and require more trained personnel. Of note, bioimpedance measures may have more variability and may be influenced by factors such as hydration status, fasting versus fed state, or recent exercise. Although our results regarding the role of bioimpedance are encouraging, more research is necessary before it can be recommended as a routine procedure. Also, more research is necessary to better determine the relationship between CT scans and simpler body composition measurement techniques such as bioimpedance technology.

Limitations

This was a retrospective study conducted with patients seen in a clinical setting, and the intervention was based on clinical presentation and medical needs. Patients in this study were referred by their surgical oncologists due to perceived functional impairment or poor body composition. It is possible that the severity of these changes is less among the general surgical oncology population, but more research is necessary. Another limitation is patients were seen by PTs for a home-based exercise program and some were referred for outpatient or home health rehabilitation if indicated; and thus, there were no objective recordings of physical activity in this clinical intervention. It is reassuring that measures of physical function did improve and therefore, further improvement is expected, if there were objective measures of adherence in the future. Moreover, we did not review the patient's nutritional statuses or weight loss histories, as they were not readily available in the clinical records. This would be important in future efforts as nutrition optimization has been associated with improvement in functional scores in general rehabilitation patients³⁸ and in prehabilitation research involving patients with colorectal cancer.¹² There are multiple ways to define sarcopenia^{4,16,39} but for the purposes of this study and previous studies conducted at our cancer center, sarcopenia was defined by CT scan measures of body composition. We attempted to incorporate the functional tests in the diagnosis of sarcopenia in a second study cohort (Sarcopenic B) as recommended in the Society of Sarcopenia, Cachexia, and Wasting Disorders 2019 consensus statement.⁷ More research needs to be conducted so we have a much more empirically-based definition of sarcopenia rather than a consensus definition. An evidence-based definition would be helpful going into the future.

Furthermore, we used CT scans obtained as part of standard clinical care. Because we included patients with a variety of cancer diagnoses, the timing of subsequent CT scans was variable. Thus, we were unable to follow up on changes in body composition measured using CT images. In future studies, monitoring of body composition changes during treatment using both modalities (CT scans and bioimpedance) would be helpful in detecting changes in sarcopenia or SO status. Also, in order to evaluate the reliability of bioimpedance-measured body composition, studies involving larger patient populations are important. Lastly, there have been excellent efforts to determine the association between body composition and more traditional oncology parameters such as survival.^{7,26,40} Our findings suggest that more research is justified to better characterize ways to practically monitor body composition and physical function so it may be implemented in the regular practice of cancer medicine.

Conclusions

Our preliminary findings suggest cancer patients referred by surgical oncologists to PM&R for prehabilitation have a high frequency of abnormal body composition and abnormal physical function; however, functional improvement is observed in these patients. Thus, the diagnosis of sarcopenia or muscle wasting should not preclude the decision to pursue cancer treatment and the addition of prehabilitation would be helpful to improve physical function. Determining the optimal protocol for monitoring body composition and physical function is important in the care for oncology patients. In addition, conducting body composition analyses and studies of exercise, pharmacologic, and nutrition interventions are important to reduce the frequency and severity of sarcopenia.

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Authors' Note

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