ORIGINAL RESEARCH

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Immature Granulocyte Percentage in Post-Menopausal Sarcopenic Individuals: A Potential Novel Biomarker?

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Abstract

Objective: Sarcopenia is an age-related muscle disorder marked by loss of muscle mass, strength, and function. Post-menopausal women face an increased risk due to alterations in hormones and metabolism. In addition, systemic inflammation has been proposed as a key contributor in this population. Although standard inflammatory markers, such as interleukin-6 and tumor necrosis factor-α, are not readily available, the percentage of immature granulocytes (IGr%), easily obtained from routine blood tests, may serve as an indicator of inflammation. To investigate the association between IGr% and sarcopenia in post-menopausal women and identify related clinical and laboratory factors.

Materials and Methods: This study was designed as a retrospective observational analysis. The study included post-menopausal women who attended the Geriatrics and General Internal Medicine outpatient clinics between May and August 2024. Assessment of sarcopenia included the strength, assistance with walking, rising from a chair, climbing stairs, and falls questionnaire, handgrip strength, bioelectrical impedance analysis, and a 4-meter gait speed test. Basic activities of daily living (ADL) were measured with the Katz ADL scale, instrumental activities were assessed with the Lawton IADL scale, and nutritional risk was assessed with the nutritional risk screening (NRS-2002). Laboratory parameters included IGr%, C-reactive protein (CRP), albumin, and white blood cell count (WBC).

Results: Among 198 participants (mean age: 59 years), 43.9% had probable or confirmed sarcopenia. Sarcopenic women were older ($p < 0.001$), had lower lumbar bone density ($p = 0.024$), had more comorbidities ($p = 0.001$), and had greater functional dependency ($p = 0.001$). Sarcopenic individuals showed a significantly higher IGr% in univariate analysis ($p = 0.046$), while no significant differences were observed among other inflammatory markers, such as CRP, WBC, neutrophils (NEUTs), lymphocytes (LYMPH), the NEUT-to-LYMPH ratio and the platelet-to-LYMPH ratio (all $p > 0.05$). Multivariate analysis revealed that older age [odds ratio (OR): 1.058, 95% confidence interval (CI): 1.022–1.096; $p = 0.002$] and albumin (OR: 0.891, 95% CI: 0.773–0.981; $p = 0.023$) were independent predictors of sarcopenia.

Conclusion: Although IGr% was higher in sarcopenic individuals in univariate analysis, it did not remain an independent predictor after adjustment. However, as a readily available, cost-effective parameter from the routine complete blood count, IGr% may serve as an early biomarker reflecting low-grade systemic inflammation in sarcopenia, a finding that warrants confirmation in larger, prospective, multicenter studies.

Keywords: Aging, immature granulocyte percentage, postmenopause, sarcopenia

Introduction

Sarcopenia, a common progressive muscle condition, is associated with adverse health outcomes, including falls, bone fractures, disability, and increased mortality. Over the past decades, the concept and diagnostic criteria of sarcopenia have evolved. In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) proposed that the condition be diagnosed on the basis of reduced muscle mass combined with

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either low muscle strength or impaired physical performance (1). Later, the EWGSOP2, introduced by the same group, released revised guidelines that refined the definition and diagnosis of sarcopenia in older adults. The 2019 update marked a major shift by integrating muscle function into the diagnostic algorithm, moving away from earlier approaches that focused primarily on low muscle mass. In this framework, muscle function—particularly reduced muscle strength—is emphasized as the central and initial diagnostic indicator (2). In this algorithm, individuals with low muscle strength are classified as having "probable sarcopenia"; the presence of low muscle mass or impaired muscle quality confirms the diagnosis, and the presence of impaired physical performance categorizes the condition as "severe sarcopenia" (2). The group further advises the use of population-specific reference data for determining diagnostic cut-off values. Consequently, Turkish-specific reference values are defined in the literature (3).

Although sarcopenia is commonly associated with aging, emerging data suggest it may develop earlier than previously thought (4). Low muscle mass, weakness, and poor physical performance, hallmarks of sarcopenia, correlate with higher morbidity and mortality rates in the geriatric population; moreover, sarcopenia is directly linked to quality of life and healthy aging, even in individuals under the age of 65. The sarcopenic phenotype encompasses a multifactorial etiology that extends beyond chronological age (2). Because of hormonal changes, post-menopausal women are especially vulnerable to sarcopenia.

During menopause, defined as the permanent cessation of menstruation for at least 12 consecutive months due to ovarian failure or surgical removal of the ovaries (e.g., bilateral oophorectomy) (5), estrogen levels decline sharply. This estrogen deficiency, in combination with age-related decreases in bone mineral density (BMD) and muscle mass, as well as increased inflammation and adiposity, significantly contributes to the development and progression of sarcopenia in this group (6). Although the World Health Organization states that menopause occurs between 45 and 55 years (7), the average age at menopause in Türkiye is reported to be 47 years (8,9). This suggests that Turkish women may enter the period of increased vulnerability to sarcopenia relatively early, underscoring the importance of early preventive strategies in this population.

The mechanisms underlying sarcopenia remain under investigation, but core elements appear to be oxidative stress, neuromuscular dysfunction, endocrine disorders, malnutrition, physical inactivity, and, prominently, inflammation (10). The literature indicates that the inflammatory response is associated with loss of muscle mass and impaired physical function; accordingly, inflammatory biomarkers have been proposed as valuable tools for understanding the diagnosis, prognosis, and pathogenesis of sarcopenia (11). However, the routine clinical availability of specific cytokines, such as interleukin (IL)-6, IL-1, and tumor necrosis factor (TNF)-α, is limited due to cost-effectiveness issues. Therefore, the percentage of immature granulocytes (IGr%), readily available from a complete blood count (CBC), has become a valuable indicator of systemic inflammation (12).

In the bone marrow, IGr% identifies early myeloid precursor cells, including promyelocytes, myelocytes, and metamyelocytes. Typically, these cells are not found in the peripheral blood; however, inflammation, infection, or bone marrow stimulation can cause them to appear in the bloodstream (13). Findings suggest that IGr% levels could serve as a valuable biomarker for both inflammatory and infectious conditions (14). Moreover, elevated IGr% levels are associated with various non-infectious conditions, including diabetic kidney disease, myocardial infarction, stroke, rheumatic disorders, and metastatic cancer (15-18).

Given the revised EWGSOP2 definition of sarcopenia, investigating the relationship between sarcopenia and IGr% in post-menopausal women is particularly important. This study aimed to evaluate sarcopenia status, analyze routine CBC parameters, examine the association between IGr% and sarcopenia, and identify clinical and laboratory factors associated with post-menopausal sarcopenia. We hypothesized that higher IGr% levels would be associated with sarcopenia, reflecting subclinical systemic inflammation in this population.

Materials and Methods

This study was a retrospective observational analysis. Post-menopausal women attending the Geriatrics and General Internal Medicine outpatient clinics between May and August 2024 provided the data. The study received ethical approval from Marmara University's Local Ethics Committee (decision number: 09.2025-25-0174, date: 21.03.2025).

Patients whose last menstrual period had occurred less than one year earlier, and those with a cardiac pacemaker or limb prostheses, which preclude measurement by bioelectrical impedance analysis (BIA), were excluded from the study. In addition, participants with active infection and C-reactive protein (CRP) levels above 10 mg/L, those receiving active antibiotic or steroid therapy, and those with a diagnosis of malignancy were also excluded. A CRP cut-off of <10 mg/L was applied to exclude participants with active infection or systemic inflammation, minimizing potential confounding effects on the assessment of sarcopenia-related parameters.

Patient data, including sociodemographics, comorbidities, medical and medication histories, and laboratory results, were collected during routine outpatient visits. Menopausal history, including age at menopause and type of onset (physiological or

surgical), was also recorded. Measurements of calf, waist, and hip circumferences were also recorded.

Strength, assistance with walking, rising from a chair, climbing stairs, and falls is an easy-to-use, self-report screening tool for sarcopenia that assesses five key functional components. Each question is scored on a 0–2 point scale, depending on how difficult the question is for the respondent. In total, 10 points were recorded as the maximum score and 0 points as the minimum. Scores of 4 or higher indicate that individuals are at risk of sarcopenia (19). Muscle strength assessment involved measuring handgrip strength using a hand-held dynamometer (Jamar®). Participants, seated with their dominant elbow flexed at 90°, were asked to squeeze the device with maximal effort. The highest result from the three test runs informed the analysis. The procedure was repeated three times, and the best measurement was noted. Values below 22 kilograms (kg) were considered low and indicative of probable sarcopenia (3).

Muscle mass was estimated using BIA, a non-invasive technique that measures the resistance of body tissues to a weak electrical current. The Tanita BC-532 device was employed in this analysis. Using BIA, fat-free mass was calculated and then multiplied by 0.566 to determine skeletal muscle mass (SMM) (20).

The skeletal muscle mass index (SMMI) was calculated as SSM divided by body mass index. Participants with an SMMI value below 0.823 kg/(kg/m²)—the established cut-off for Turkish women—were classified as having low muscle mass (3). The 4-meter gait speed test measured physical performance. (21). A gait speed of <0.8 m/s was used to indicate diminished muscle function (21). Patients who met the criteria for sarcopenia and also demonstrated low physical performance were categorized as having severe sarcopenia. In this study, individuals classified as having probable, confirmed, or severe sarcopenia were grouped under the umbrella term "sarcopenia" for analytical purposes.

The functional status of the participants was evaluated using standardized assessment tools. Basic activities of daily living (ADL) were measured using the Katz ADL scale (22), while instrumental activities were assessed using the Lawton IADL scale (23). Participants were grouped as independent, partially dependent, or dependent based on these assessments. Nutritional status was determined with the Nutritional Risk Screening tool (NRS-2002). An NRS-2002 total score of 3 or higher signifies that the individual is either at risk for malnutrition or already malnourished, indicating the need for nutritional support (24). Additionally, participants were asked about any falls they had experienced within the previous year and their fear of falling.

Laboratory parameters included white blood cell count (WBC), IGr%, CRP, and serum albumin level.

Hematological Analysis: CBC analyses were performed on the Mindray BC-6800 Plus (Mindray Bio-Medical Electronics Co., Shenzhen, China), a fully automated hematology analyzer. This device uses SF-Cube fluorescent flow cytometry for cellular analysis (25). Measurements are based on three primary signals: side fluorescence light, abnormal lymphocyte (LYMPH) scatter, and side scatter light. These signals are used to assess structural characteristics, such as cell volume, nucleic acid content, and granularity (26).

The device automatically calculates IGr% parameters: IGr% and IGr% count (absolute number of IGr%s). Reference ranges for IGr%s were defined according to Sysmex technical reports and reference interval studies conducted in healthy donors (e.g., n ≈ 156). When Sysmex XE/XN series automated hematology analyzers were used, the reported upper limits were approximately 0.5% for IG% and 0.03 × 10^9/L for IG count (27). Therefore, these values were adopted as the upper reference limits in the present study. The measurement is performed by identifying specific cell populations using the device's algorithms, which can distinguish early-stage neutrophils (NEUTs), such as myelocytes, metamyelocytes, and promyelocytes (28). SF-Cube technology enables the reliable classification of these cells based on their three-dimensional morphological characteristics (29).

SF-Cube technology integrates three distinct signals generated when cells are exposed to laser light. This technology simultaneously analyzes parameters such as nuclear density, granule content, and cell volume, generating a multidimensional profile of each cell (30). As a result, the detection of rare cell populations, such as IGr%s, becomes both more specific and more sensitive (31).

Statistics

Normality of the variables was evaluated through graphical inspection methods (probability plots and histograms) and the Kolmogorov-Smirnov test. Categorical data were summarized using counts and proportions (n, %). Group comparisons for categorical outcomes were carried out using the chi-square test or Fisher's exact test when appropriate. Continuous variables following a normal distribution were reported as mean ± standard deviation (SD), and differences between groups were examined using the independent-samples t-test. When continuous variables were not normally distributed, medians (with minimum and maximum values) were used, and comparisons were performed using the Mann-Whitney U test. Binary logistic regression was used to investigate associations between variables.

Variables that were significant in univariate analyses were entered into the regression models. Potential multicollinearity among predictors was evaluated using Pearson correlation coefficients, with values exceeding 0.8 considered suggestive

of multicollinearity. The relationship between sarcopenia and potential predictors was examined using multivariable logistic regression analysis. Based on clinical relevance and prior literature, age, serum albumin level, and osteoporosis status were included as independent variables. The ENTER method was used to simultaneously enter all variables into the model. In the regression models, the effect of each independent variable was expressed by the unstandardized regression coefficient (B). The coefficient (B) in the logistic regression model represents the change in the log-odds of the outcome associated with a one-unit increase in the predictor. The exponential coefficient, Exp(B), was presented as the odds ratio (OR). Statistical significance was defined as $p < 0.05$, and 95% confidence intervals (CIs) were calculated. All analyses were performed using IBM SPSS Statistics version 26.0 (Armonk, NY, USA).

Results

One hundred ninety-eight post-menopausal women participated in the study. The mean participant age was 59.4 ± 10.0 years; 33.8% were older than 65 years. Menopause occurred at a mean age of 46.5 ± 5.2 years, with 84.8% of participants experiencing physiological menopause. Hypertension (53.5%), osteoporosis (28.3%), and diabetes mellitus (26.3%) were the most frequent comorbidities. Among the patients, 33% reported a fear of falling, while 25% had a history of falls. ADL independence was reported by 92% of participants in the functional assessment; IADL independence was reported by 78% of participants. Of the participants, 87 (43.9%) showed sarcopenia (Table 1).

As Table 2 shows, post-menopausal women with sarcopenia were significantly older (mean ages, 56.5 vs. 63.1 years; $p < 0.001$), had a higher number of chronic diseases, and used a greater number of medications ($p = 0.001$). Osteoporosis and hypertension were also more common among these individuals ($p = 0.028$ and $p = 0.016$, respectively). In addition, these individuals showed significantly lower femoral neck T-scores [-1.10 (-3.40–1.20) vs -1.50 (-3.40–1.20); $p = 0.042$) and L1–L4 BMD scores (1.054 (0.603–1.522) vs 0.990 (0.668–1.457); $p = 0.024$], along with increased dependence in ADL, both basic and instrumental ($p = 0.001$ and $p < 0.001$, respectively). Sarcopenic individuals also showed a higher IGr% ($p = 0.046$); no significant differences were observed for other inflammatory markers, including CRP, WBC, NEUT, LYMPHs, NEUT-to-LYMPH ratio (NLR), and platelet-to-LYMPH ratio (PLR) (all $p > 0.05$).

Multivariate analysis revealed that older age (OR: 1.058, 95% CI: 1.022–1.096; $p = 0.002$) and albumin (OR: 0.891; 95% CI: 0.773–0.981; $p = 0.023$) were independent predictors of sarcopenia. Increasing age was a significant predictor of sarcopenia, with approximately a 6% increase in risk per year. Sarcopenia showed no significant association with IGr% or osteoporosis in multivariate logistic regression analysis (OR: 6.429; 95% CI: 0.651–63.536; $p = 0.111$ and OR: 1.715; 95% CI: 0.906–3.532; $p = 0.094$) (Table 3).

Table 1. Demographic characteristics of participants (n = 198).

	Total n = 198, n (%)		**Total n = 198, n (%)**
Age*	**59.4 ± 10.0**	**BMI (kg/m²)**	**29.6 ± 5.9**
Age group <65 Years ≥65 Years	 131 (66.2%) 67 (33.8%)	Sarcopenia classification [based on SMMI (kg/kg/m²)] No sarcopenia Sarcopenia • Probable sarcopenia • Sarcopenia • Severe sarcopenia	 111 (56.1%) 87 (43.9%) • 79 (39.9%) • 7 (3.5%) • 1 (0.5%)
Number of chronic diseases*	2 (1–6)	Age at menopause*	46.5 ± 5.2
Number of medications*	3 (1–11)	Type of menopause Physiological Surgical	 168 (84.8%) 30 (15.2%)
Hypertension	106 (53.5%)	Hormone usage Never used Currently using Discontinued	 181 (91.4%) 9 (4.5 5) 8 (4.1%)
Diabetes mellitus	52 (26.3%)	L1-L4 BMD*	1.028 (0.603–1.522)
Osteoporosis	56 (28.3%)	Albumin (g/dL)*	43 (28–49)
Osteoporosis treatment	23 (11.6%)	C-reactive protein, mg/L*	2.8 (0.11–9.9)
Fear of falling	71 (35.9%)	Hemoglobin(×10³/µL)*	13.1 ± 1.2
History of falls	53 (26.8%)	Platelet (×10³/µL)*	252.5 (37.9–554)
History of fractures	42 (21.2%)	Leucocyte (×10³/µL)*	6.7 (3.4–14.0)

Table 1. Continued

	Total n = 198, n (%)		Total n = 198, n (%)
Age*	**59.4 ± 10.0**	**BMI (kg/m²)**	**29.6 ± 5.9**
Functionality–IADL Dependent Partially-dependent Independent	 18 (9.1%) 25 (12.6%) 155 (78.3%)	Neutrophil (×10³/μL)*	3.8 (1.0–10.9)
Functionality–ADL Dependent Partially-dependent Independent	 2 (1.0%) 13 (6.6%) 183 (92.4%)	Lymphocyte (×10³/μL)**	2.2 (0.4–5.8)
Polypharmacy	40 (20.2%)	Immature granulocyte%	0.10 (0.0–1.50)
NRS-2002 score Risk of malnutrition Normal	 175 (88.4%) 23 (11.6%)	Immature granulocyte (×10³/μL)*	0.01 (0.0–0.14)
Slow gait speed (<0.8 m/s)	19 (9.6%)	Immature granulocyte neutrophil ratio	0.003 (0.0–0.04)
Presence of sarcopenia risk (according to SARC-F score)	37 (18.7%)		
Right-hand grip strength-according to Turkish standards (<22 kg)	87 (43.9%)		
SMMI [kg/(kg/m²)]*	0.816 ± 0.140		

*Values are expressed as mean ± standard deviation and median (minimum-maximum).
BMI: Body mass index, SMMI: Skeletal muscle mass index, BMD: Bone mineral density, ADL: Activity of daily living, IADL: Instrumental activity of daily living, NRS-2002: Nutritional risk screening-2002, SARC-F: Strength, assistance with walking, rise from a chair, climb stairs, and falls.

Table 2. Characteristics of participants based on sarcopenia.

	No sarcopenia (%), (n = 111)	Sarcopenia (%), (n = 87)	p-value
Age*	**56.5 ± 8.1**	**63.1 ± 10.9**	**<0.001**
Age group <65 years ≥65 years	 86 (77.5%) 25 (22.5%)	 45 (51.7) 42 (48.3)	**<0.001**
Number of chronic diseases*	2 (0–6)	3 (0–6)	**0.001**
Hypertension	51 (45.9%)	55 (63.2%)	**0.016**
Osteoporosis	24 (21.6%)	32 (36.8%)	**0.028**
History of falls	24 (21.6%)	29 (33.3%)	0.092
History of fractures	21 (18.9%)	21 (24.1%)	0.474
Osteoporosis treatment	12 (10.8%)	11 (12.6%)	0.860
Number of medications*	2 (0–11)	3 (0–11)	**0.024**
Age at menopause*	46.1 ± 5.2	46.9 ± 5.3	0.336
Type of menopause Physiological Surgical	 94 (84.7%) 17 (15.3%)	 74 (85.1%) 13 (14.9%)	0.942
Hormone usage Never used Currently using Discontinued	 103 (92.8%) 6 (5.4%) 2 (1.8%)	 78 (89.7%) 3 (3.4%) 6 (6.9%)	0.179
BMI (kg/m²)	30.4 ± 6.1	30.0 ± 5.8	0.916
Femoral neck T-score*	-1.10 (-3.40–1.20)	-1.50 (-3.40–1.20)	**0.042**
L1-L4 BMD*	1.054 (0.603–1.522)	0.990 (0.668–1.457)	**0.024**
Albumin (g/dL)*	43 (36–48)	42 (28–49)	**0.001**
Leucocyte (×10³/μL)*	6.4 (3.4–12.5)	6.7 (3.7–14.0)	0.814

Table 2. Continued

	No Sarcopenia (%), (n = 111)	Sarcopenia (%), (n = 87)	p-value
Age*	**56.5 ± 8.1**	**63.1 ± 10.9**	**<0.001**
Neutrophil (×10³/µL)*	3.6 (1.7–8.8)	4.0 (1.0–10.9)	0.628
Lymphocyte (×10³/µL)**	2.3 (1.1–4.1)	2.2 (0.8–5.8)	0.106
Hemoglobin (×10³/µL)*	13.0 ± 0.9	12.6 ± 1.2	**0.024**
Platelet (×10³/µL)*	241 (37.9–505)	254 (42–507)	0.883
Immatur granulocyte (×10³/µL)*	0.01 (0.0–0.07)	0.01 (0.0–0.14)	0.106
Immature granulocyte,%	0.1 (0.0–0.7)	0.1 (0.0–1.5)	0.046
Immature granulocyte neutrophil ratio	0.003 (0.0–0.04)	0.003 (0.0–0.02)	0.226
C-reactive protein, mg/L*	2.9 (0.3–9.5)	2.2 (0.11–9.9)	0.437
Functionality – ADL Dependent Partially-dependent Independent	 0 (0.0%) 2 (1.8%) 109 (98.2%)	 2 (1.0%) 11 (6.6%) 74 (92.4%)	**0.001**
Functionality – IADL Dependent Partiallyd-dependent Independent	 3 (2.7%) 9 (8.1%) 99 (89.2%)	 15 (17.2%) 16 (18.4%) 56 (64.4%)	**<0.001**
NRS-2002 score Risk of malnutrition Normal	 12 (10.8%) 99 (89.2%)	 11 (12.6%) 76 (87.4%)	0.690

*Values are expressed as mean±standard deviation and median (minimum-maximum).
BMI: Body mass index, BMD: Bone mineral density, ADL: Activity of daily living, IADL: Instrumental activity of daily living, NRS-2002: Nutritional risk screening-2002.

Table 3. Multivariate logistic regression analysis of the factors that affect sarcopenia.

	p	Exp (B)	Odds ratio (95% CI)	
			Lower	Upper
Age	**0.002**	1.058	1.022	1.096
Presence of osteoporosis	0.094	1.715	0.906	3.532
Albumin (g/dL)	**0.023**	**0.891**	**0.773**	**0.981**
Immature granulocyte %	0.111	5.644	0.651	63.536

Variables included in the multivariable logistic regression model were selected based on statistical significance in univariate analyses and clinical relevance. Age, serum albumin level, osteoporosis status, and immature granulocyte percentage (IGr%) were simultaneously entered into the model using the ENTER method.
CI: Confidence Interval, dL: Deciliter, g: Gram.

Discussion

Sarcopenia's underlying processes are not fully understood, but it is recognized as a multifactorial condition. Among these, inflammation is considered to play a pivotal role. This study examined the association between sarcopenia and IGr%, a potential marker of systemic inflammation, among post-menopausal women evaluated in outpatient clinics. Significantly higher IGr% levels were observed in the sarcopenic group in the univariate analysis of the current study. In contrast, other inflammatory parameters such as CRP, WBC, NEUT, LYMPH, NLR, and PLR showed no significant group differences. While no significant differences were observed in other inflammatory markers, higher IGr% levels in the sarcopenic group suggest that this parameter may capture early inflammatory activity associated with sarcopenia.

In this study, 39.9% of post-menopausal participants were classified as probable sarcopenia, whereas 4% met the criteria for confirmed sarcopenia. By comparison, two studies conducted on post-menopausal women in Switzerland reported probable sarcopenia rates of 12.3% and 18.5%, respectively (32,33). Meanwhile, a study conducted in India that used the handgrip strength protocol recommended by the Asian Working Group for Sarcopenia 2019—which defines low grip strength as <18 kg—reported a probable sarcopenia prevalence of 45.3% (34). Such variability underscores that differences in diagnostic cut-off values, ethnic and demographic characteristics, and methodological approaches can markedly influence sarcopenia prevalence estimates across populations. Therefore, direct comparisons between studies should be interpreted with caution when reference standards or assessment protocols

differ. Our findings provide context-specific epidemiological data and further emphasize the need for standardized, population-appropriate diagnostic frameworks to enhance the accuracy of sarcopenia detection and enable more reliable comparisons across cohorts.

Several factors may account for the relatively higher prevalence observed in our cohort. First, our study utilized population-specific cut-off values for handgrip strength, as proposed by Bahat et al. (3) (22 kg for women), which likely increased the sensitivity of sarcopenia detection and consequently elevated the prevalence rate. Indeed, if the EWGSOP2-recommended cut-off of 16 kg had been applied, the prevalence of sarcopenia in our cohort would have been 10.1%. Second, our cohort consisted exclusively of post-menopausal women referred to an outpatient clinic, a population that may have a higher burden of metabolic or functional decline compared with community-dwelling samples. Although 92% of participants were functionally independent in ADL, this does not necessarily preclude early or subclinical sarcopenia, since declines in muscle strength may precede overt functional impairment. Similarly, Bahat et al. (3) reported that sarcopenia was associated with low nutritional status rather than with functional decline, suggesting that functional deterioration may emerge later in the disease course (35). Taken together, these findings underscore the importance of employing population- and sex-specific reference values to ensure accurate sarcopenia identification and to avoid underestimation in at-risk clinical groups.

The prevalence of sarcopenia was significantly higher in individuals aged 65 years and older. A prior study reported a markedly increased risk of sarcopenia with advancing age, with prevalence rates of 1.4%, 4.9%, and 12.5% in the 60-69, 70-79, and 80+ age groups, respectively (5). The risk of sarcopenia increases with age due to declines in SMM and muscle strength. Progressive muscle dysfunction results from this physiological process, which encompasses primary aging and the effects of chronic diseases. Early detection and prevention of sarcopenia are vital due to its increasing prevalence with age, especially among older adults and those with multiple conditions. Increasing evidence highlights the importance of developing age-specific diagnostic tools and health policies that are tailored to older adults.

Osteoporosis and sarcopenia together define the relatively new medical concept of osteosarcopenia. Although each condition has been studied extensively in isolation, epidemiological data on osteosarcopenia are limited (36). Research in the United Kingdom found sarcopenia in half of post-menopausal women with osteoporosis (37). The results of our study likewise confirm the possibility of these two conditions co-occurring. Sarcopenia occurred in 36.8% of people with osteoporosis, and conversely, 57% of sarcopenic individuals also had osteoporosis. Moreover, the sarcopenic group showed substantially reduced femoral neck T-scores and lumbar spine BMD, suggesting an increased risk of osteoporosis. Regarding prior falls or fractures, there were no statistically significant differences between the groups. Our results are consistent with the study by Zanchetta et al. (38), which reported decreased femoral neck BMD and a higher incidence of falls in the past year among sarcopenic women, but no significant difference in fracture rates. The relatively young study population could explain the lack of a statistically significant difference in fall and fracture rates. Our results indicate that osteosarcopenia is prevalent in post-menopausal women, underscoring the need for integrated bone and muscle health assessments in clinical settings. The close physiological relationship between muscle and bone is evidenced by their shared mechanical loading, biochemical pathways, and genetic controls.

Notwithstanding the unclear pathogenesis of sarcopenia, many studies associate its progression with dysregulated inflammation, resulting in loss of muscle mass and impaired physical performance. Muscle protein breakdown and inhibition of protein synthesis, driven by proinflammatory cytokines, are believed to contribute to sarcopenia. Inflammatory biomarkers may aid early diagnosis and prognosis of sarcopenia in this context (11). However, a consensus in the literature on the specific biomarkers or pathophysiological mechanisms driving the inflammatory processes of sarcopenia is currently lacking. Zhao et al. (10) found that higher levels of NLR, PLR, and systemic immune-inflammation index were significantly associated with a greater likelihood of sarcopenia in middle-aged and older adults. The findings suggest that regular monitoring of systemic inflammatory markers may be an effective strategy for screening and managing sarcopenia. In a similar vein, a Turkish study explored the SI as a potential biomarker in sarcopenia screening and management (39). The study by Can et al. (40) demonstrated an association between sarcopenia and inflammatory markers, including erythrocyte sedimentation rate, CRP, and adiponectin.

In addition, many studies have identified links between sarcopenia and elevated levels of proinflammatory cytokines, particularly TNF-α and IL-6 (41). However, measuring these cytokines in everyday clinical settings is rarely practical due to cost, technical difficulty, and the demands of laboratory infrastructure. Therefore, employing more practical, accessible, and cost-effective inflammatory biomarkers for sarcopenia screening and evaluation is vital.

CBCs readily measure IGr%s, providing an accessible laboratory parameter. Bone marrow regulates IGr% production in response to inflammation (13). In hospitalized patients who develop sepsis, IGr%s have been reported to be among the earliest biomarkers to rise (42). In a retrospective study of 84 patients with acute pancreatitis, IGr% levels were significantly higher in severe cases

and were suggested to be associated with prognosis. Similarly, another retrospective analysis found that both IGr% and IGr% count were markedly elevated in patients with complicated appendicitis compared with those with uncomplicated disease (43,44). Additionally, a recent study demonstrated that IGr% levels at admission could serve as an innovative, cost-effective, and readily accessible biomarker with predictive value in patients with coronavirus disease-2019 (45). Collectively, these findings highlight the potential of IGr% as an early diagnostic indicator and a prognostic biomarker across a range of acute inflammatory conditions.

Studies show that elevated IGr% levels occur not only in infections but also in various systemic inflammatory conditions, such as diabetic nephropathy, acute myocardial infarction, stroke, rheumatologic diseases, and metastatic cancers (15-18). In rheumatologic and autoinflammatory diseases, IGr%s hold potential as indicators of inflammation. In familial mediterranean fever, elevated IGr% levels during attack-free periods compared with those of healthy individuals reflect subclinical inflammation and may serve as predictive markers for future attacks (46). In patients with rheumatoid arthritis, IGr% levels are rapid, accessible, and cost-effective markers for assessing disease activity; peripheral blood IGr% levels also have potential value for prognostication and prediction of response to anti-TNF therapy (47). In addition, IGr%s, as quantified by both absolute IGr% count and IGr%, have consistently demonstrated robust sensitivity and specificity for identifying metastatic involvement in breast and colon cancers. In breast cancer, IGr% levels accurately predicted axillary metastases that were clinically occult but pathologically confirmed, whereas in colon cancer, both the IGr% count and percentage effectively discriminated metastatic from non-metastatic cases in the preoperative setting (18,48). These findings position IGr%s as readily accessible, cost-effective biomarkers that reflect early inflammatory responses and tumor-associated immune dysregulation and offer potential for monitoring acute and chronic inflammation. This dual functionality underscores its utility for patient stratification, early detection of metastasis, prognostic assessment across various malignancies, and evaluation of low-grade chronic inflammation that may contribute to sarcopenia in post-menopausal women.

In this study, none of the standard inflammatory indicators, including WBC, NEU, LYM, PLR, NLR, and CRP, demonstrated a statistically significant association with sarcopenia. Interestingly, IGr% were significantly higher among sarcopenic individuals in the univariate analysis; however, this association was no longer significant in the multivariate model adjusted for confounders. This finding aligns with previous reports indicating that systemic inflammation contributes to sarcopenia pathogenesis in post-menopausal women, yet the specific inflammatory pathways and their measurable biomarkers remain inconsistent across studies. Cesari et al. (49) showed that elevated blood IL-6 concentrations were linked to low muscle strength and poorer physical performance among older adults, underscoring the involvement of inflammatory pathways in age-related muscle decline. In contrast, a meta-analysis conducted by Bano et al. (50) in 2017 reported no significant difference in IL-6 levels between individuals with sarcopenia and their non-sarcopenic counterparts. These findings suggest that the detectable inflammatory profile in sarcopenia may differ across populations and study settings, potentially reflecting heterogeneity in underlying biological mechanisms or methodological factors. In this context, IGr% may serve as an early-phase indicator of subclinical inflammation, potentially preceding increases in traditional markers such as CRP or NLR. Although its independent predictive value was not confirmed in our sample, the observed elevation supports its possible role in the early detection of inflammation-related muscle deterioration. Future large-scale, longitudinal studies are warranted to validate these findings and clarify whether IGr% offers incremental predictive value beyond standard inflammatory markers in the stratification of sarcopenia risk.

Study Limitations

This study is pioneering in its evaluation of the relationship between IGr% and sarcopenia, significantly advancing current research. Furthermore, limiting participants to post-menopausal women allows for focused sarcopenia awareness campaigns within this population. This study may enhance our understanding of age-related muscle loss and women's health concerns following menopause. The generalizability of the findings to other populations is limited due to the study's single-center design and the exclusive use of Turkish participants. Furthermore, the exclusive inclusion of post-menopausal female participants restricts the applicability of the results to male populations. The cross-sectional study design prevents the determination of causality between IGr% levels and sarcopenia. Additionally, the relatively young mean age of our study population (59 years) should be taken into consideration when interpreting the findings. Most sarcopenia research and biomarker validation studies target older adults (≥65 years), in whom age-related muscle decline and inflammatory alterations are more pronounced. Therefore, the results of our study may not be directly generalizable to geriatric cohorts. Consequently, larger, more diverse, multicenter studies are required to establish causality.

Conclusion

The IGr%, an easily obtainable parameter from routine CBC testing, may be a promising biomarker for sarcopenia, reflecting early low-grade systemic inflammation. While these findings highlight its potential usefulness in clinical risk assessment, further validation through large-scale, prospective, multi-center studies is necessary before its routine clinical application can be recommended.

Ethics

Ethics Committee Approval: The study received ethical approval from Marmara University's Local Ethics Committee (decision number: 09.2025-25-0174, date: 21.03.2025).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Y.Y., N.Ş.D., A.Y., E.Ü., E.D.K., Z.B.Y., Ç.A., B.C., A.T., Concept: Y.Y., N.Ş.D., A.Y., E.Ü., E.D.K., Z.B.Y., Ç.A., B.C., A.T., Design: Y.Y., N.Ş.D., A.Y., E.Ü., E.D.K., Z.B.Y., Ç.A., B.C., A.T., Data Collection or Processing: Y.Y., N.Ş.D., A.Y., E.Ü., E.D.K., Z.B.Y., Ç.A., B.C., A.T., Analysis or Interpretation: Y.Y., N.Ş.D., E.Ü., B.C., A.T., Literature Search: Y.Y., N.Ş.D., A.T., Writing: Y.Y., N.Ş.D., A.T.,

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