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Original Research

The prevalence of sarcopenia and sarcopenic obesity in a German geriatric day clinic

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ABSTRACT

Purpose: Sarcopenia and sarcopenic obesity are defined by the loss of muscle strength and mass. Both diseases pose a growing global challenge. Their prevalences vary between studied populations. The aim of this study is to estimate the prevalences of sarcopenia and sarcopenic obesity in sample of community-dwelling older adults attending a geriatric day clinic.
Methods: A secondary analysis of the Paint-II Data (single-center randomized controlled trial on the effects of art therapy) was used to estimate the prevalence of sarcopenia and sarcopenic obesity. Furthermore, a machine learning model predicted factors associated with both diseases.
Results: We had body composition information on 255 of the 409 Paint-II participants. Their mean age was 81 ± 5 years and 78 % were female. Depending on the appendicular skeletal muscle mass (ASM) definition, the prevalence of sarcopenia ranged between 10 % and 24 % using ASM/height^2 or absolute ASM respectively. The prevalence of sarcopenic obesity was 15 %. Weight was the most influential predictor, with higher weight being linked to sarcopenic obesity and lower weight associated with sarcopenia.
Conclusions: The prevalence of sarcopenia and sarcopenic obesity among community-dwelling older adults attending geriatric day clinics is higher than among the general geriatric population. There is a significant discrepancy in sarcopenia prevalence depending on whether muscle mass is measured absolutely or adjusted for body size. Diagnosis is further complicated by varying recommended cut-offs. We support efforts to simplify and standardize the diagnostic criteria.

1. Introduction

Sarcopenia, defined as the pathological and generalized loss of skeletal muscle strength and mass, is an important disease in older age [1]. The international interest in sarcopenia is still limited despite its association with various negative outcomes such as impaired physical performance, falls, hospitalization and mortality [2,3]. Furthermore, sarcopenic obesity (SO) is a related condition where the synergic effect of sarcopenia and obesity increases the risk of metabolic diseases [4].

A variety of different working definitions and diagnostic criteria of sarcopenia coexist. As a consequence, big disparities can be noticed in the prevalences estimated ranging globally from 10 to 27 % among older adults [5]. The lack of a common definition may also result in a delay in diagnosis and adequate research. In order to tackle this problem the Global Leadership Initiative in Sarcopenia (GLIS) has recently developed the first global conceptual definition of sarcopenia including reduced muscle strength and muscle mass [1]. In a further step the GLIS aims a global operationalization of sarcopenia with shared terminology, measures and cut-off points.

The burden of sarcopenia and SO vary between studied populations. For instance, people living in nursing homes or hospital inpatients are more likely to suffer from these diseases compared to community-

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dwelling older adults [5,6]. Age is associated with a reduction in muscle protein synthesis as well as the loss of muscle mass and strength [7]. Therefore, older populations are at higher risk of sarcopenia and SO [1,4,8]. Inactivity, inflammation, malnutrition and chronic diseases are key risk factors as well [8,9].

Geriatric day clinics provide partial inpatient treatment, where patients receive care during the day while spending nights at home. Through a multidisciplinary approach involving physicians, therapists, and nurses, these clinics offer holistic treatment aimed at maintaining patients' independence and quality of life. Patients attending geriatric day clinics are community-dwelling older adults who live independently or with minimal external assistance. Given that common referrals include gait disorders, recurrent falls, and cognitive impairment, we hypothesize that these individuals are at high risk for sarcopenia and could therefore particularly benefit from appropriate treatment. The aim of our study is to estimate the prevalence of sarcopenia and sarcopenic obesity in community-dwelling older adults attending a geriatric day clinic. Additionally, we compare different diagnostic criteria based on the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) recommendations [8].

2. Methods

2.1. Data collection and participants

Our paper used data collected in the course of the Paint-II study. Paint II was a single-center intervention trial to investigate the effects of art therapy on the quality of life, pain intensity and well-being of multimorbid community-dwelling older adults admitted to the geriatric day clinic at Nuremberg hospital between September 2017 and August 2019. Paint-II inclusion criteria were age of $\geq$70 and having at least one of these diagnoses: depression, dementia or chronic pain syndrome. Patients with physical limitations that prevented independent participation in art therapy and patients with severe language barriers were excluded. Further details on methods and results of the Paint-II are discussed elsewhere [10]. All participants provided a written informed consent.

Paint-II participants underwent the diagnostics steps for sarcopenia and SO. Body composition was determined using bioimpedance analysis (BIA). Not all participants underwent a BIA. Reasons for the lack of bioelectrical impedance analysis included: missing consent to the examination, presence of a pacemaker, relevant leg edema, leg pain, presence of relevant leg injuries and wounds as well as early discharge.

2.2. Measures and outcomes

2.2.1. Muscle strength

The upper extremities strength was measured by handgrip strength (HGS). Three measurements by a digital dynamometer were performed on both the dominant and the subdominant hand. The highest value was used for the analyses. For the lower extremities Chair-Stand-Test (CST) was conducted. The CST is the time needed to rise five times from a chair and sit down again without using the upper extremities.

2.2.2. Body composition

BIA analyses were performed using AKERN BIA 101. The appendicular skeletal muscle mass (ASM) was calculated using the cross validated regression equation from Sergi et al. [11]. The appendicular skeletal muscle mass index (ASMI) was calculated dividing the ASM on the squared height. The formula used for skeletal muscle mass (SMM) was the cross validated regression equation from Janssen et al. [12]. The fat mass (FM) and phase angle are obtained from proprietary manufacturer algorithms using the software Bodygram PLUS.

2.2.3. Sarcopenia and sarcopenic obesity (SO)

The prevalences of sarcopenia and severe sarcopenia were based on the criteria from the EWGSOP2 [8]. Participants were classified as probable sarcopenic based on reduced muscle strength measured by CST or HGS. To confirm the diagnosis of sarcopenia, participants with probable sarcopenia needed to have a reduced muscle mass (measured by ASM or ASMI). We evaluated sarcopenia prevalence by both muscle mass metrics separately. Severe sarcopenia was defined in patients with sarcopenia by additional presence of poor functional performance. Functional performance was measured by gait speed and the Timed Up and Go test (TUG).

The definition and diagnostic criteria for sarcopenic obesity followed the ESPEN and EASO Consensus Statement [9]. The diagnosis requires both, 1) reduced muscle strength measured by CST or HGS, and 2) altered body composition including relative reduction of skeletal muscle mass evaluated with SMM divided by weight as well as a relative increase of fat mass evaluated with FM divided by weight. The prevalences were provided separately for SO patients with a BMI of 25 kg/m^2 or higher and BMI of 30 kg/m^2 or higher.

EWGSOP2, ESPEN and EASO criteria are available in the supplementary materials.

2.3. Statistical analysis

For categorical variables we reported absolute values and proportions. Continuous variables were presented with mean and standard deviation as well as the median together with the first and third quartiles (Q1 and Q3). Completeness of the data is displayed in Tables 1–3.

The primary aim of our study was to estimate the prevalence of sarcopenia and sarcopenic obesity among community-dwelling older adults. As part of an exploratory analysis, we employed machine learning, i.e. Extreme Gradient Boosting (XGBoost) [13] models, to predict factors associated with presence of sarcopenia (diagnosed using the ASM metric) and presence of sarcopenic obesity (based on the BMI cut-off of 25 kg/m^2). Our selection of potential predicative factors

Table 1
Patient characteristics stratified by sex.

	Female (n = 200)	Male (n = 55)	Overall (n = 255)
Age in years			
Mean (SD)	81.2 (5)	81.3 (6)	81.2 (5)
Median [Q1, Q3]	81 [78, 85]	81.0 [77, 85]	81.0 [77, 85]
Height in cm			
Mean (SD)	158 (7)	171 (8)	161 (9)
Median [Q1, Q3]	158 [153, 163]	171 [167, 176]	160 [155, 167]
Weight in kg			
Mean (SD)	72 (16)	82 (12)	74 (16)
Median [Q1, Q3]	70 [60, 80]	80 [75, 90]	73 [63, 83]
BMI			
Mean (SD)	28.5 (6.3)	28.2 (3.5)	28.5 (5.8)
Median [Q1, Q3]	27.4 [24.4, 32.3]	27.8 [25.8, 30.0]	27.4 [24.8, 31.8]
CFS			
Mean (SD)	4.4 (0.9)	4.7 (0.8)	4.5 (0.9)
Median [Q1, Q3]	4 [4, 5]	5 [4, 5]	5 [4, 5]
Barthel-Index			
Mean (SD)	92.2 (9.2)	92.3 (10.1)	92.2 (9.4)
Median [Q1, Q3]	95 [90, 100]	95 [90, 100]	95 [90, 100]
PMS			
Mean (SD)	6.8 (1.7)	6.6 (2.0)	6.8 (1.8)
Median [Q1, Q3]	7 [6, 9]	6 [5, 9]	7 [5, 9]
MMSE			
Mean (SD)	24.8 (4.0)	25.1 (2.9)	24.9 (3.8)
Median [Q1, Q3]	26 [23, 28]	25 [24, 27]	26 [23, 27]
MNA-SF			
Mean (SD)	9.1 (2.1)	9.6 (1.9)	9.2 (2.1)
Median [Q1, Q3]	10 [8, 10]	10 [9, 11]	10 [8, 11]
Missing	1 (0.5 %)	0 (0 %)	1 (0.4 %)
Number of medications			
Mean (SD)	7.5 (3.5)	7.6 (4.4)	7.5 (3.7)
Median [Q1, Q3]	7.5 [5, 10]	7 [5, 10]	7 [5, 10]

CFS: Clinical Frailty Score, PMS: Parker Mobility Score, MMSE: Mini Mental State Examination MNA-SF: Mini Nutritional Assessment-Short Form.

Table 2
Sarcopenia and SO prevalences stratified by sex.

	Female (n = 200)	Male (n = 55)	Overall (n = 255)
Reduced muscle strength			
No reduced muscle strength	44 (22.0 %)	15 (27.3 %)	59 (23.1 %)
Reduced muscle strength (HSG & CS)	62 (31.0 %)	19 (34.5 %)	81 (31.8 %)
Reduced muscle strength (CST solely)	79 (39.5 %)	16 (29.1 %)	95 (37.3 %)
Reduced muscle strength (HSG solely)	15 (7.5 %)	5 (9.1 %)	20 (7.8 %)
Sarcopenia (ASM)			
No Sarcopenia	44 (22.0 %)	15 (27.3 %)	59 (23.1 %)
Probable Sarcopenia	105 (52.5 %)	31 (56.4 %)	136 (53.3 %)
Sarcopenia	51 (25.5 %)	9 (16.4 %)	60 (23.5 %)
Sarcopenia (ASMI)			
No Sarcopenia	44 (22.0 %)	15 (27.3 %)	59 (23.1 %)
Probable Sarcopenia	137 (68.5 %)	33 (60.0 %)	170 (66.7 %)
Sarcopenic	19 (9.5 %)	7 (12.7 %)	26 (10.2 %)
Severe Sarcopenia (ASM)			
No Severe Sarcopenia	157 (78.5 %)	48 (87.3 %)	205 (80.4 %)
Severe Sarcopenia	43 (21.5 %)	7 (12.7 %)	50 (19.6 %)
Severe Sarcopenia (ASMI)			
No Severe Sarcopenia	185 (92.5 %)	49 (89.1 %)	234 (91.8 %)
Severe Sarcopenia	15 (7.5 %)	6 (10.9 %)	21 (8.2 %)
Sarcopenic Obesity (BMI 25)			
No Sarcopenic Obesity	165 (82.5 %)	42 (76.4 %)	207 (81.2 %)
Sarcopenic Obesity	35 (17.5 %)	13 (23.6 %)	48 (18.8 %)
Sarcopenic Obesity (BMI 30)			
No Sarcopenic Obesity	167 (83.5 %)	50 (90.9 %)	207 (85.1 %)
Sarcopenic Obesity	33 (16.5 %)	5 (9.1 %)	38 (14.9 %)

Table 3
Patient characteristics based on sarcopenia metrics.

Diagnosis by ASM	No Sarcopenia		Sarcopenia	
Diagnosis by ASMI	No Sarcopenia (n = 192)	Sarcopenia (n = 3)	No Sarcopenia (n = 37)	Sarcopenia (n = 23)
Age in years				
Mean (SD)	81 (5.3)	83 (0.6)	83 (4.7)	83 (6.4)
Median [Q1, Q3]	80 [77, 84]	83 [82, 83]	83 [80, 87]	82 [79, 87]
Sex				
Female	148 (77.1 %)	1 (33.3 %)	33 (89.2 %)	18 (78.3 %)
Male	44 (22.9 %)	2 (66.7 %)	4 (10.8 %)	5 (21.7 %)
Height in cm				
Mean (SD)	162 (8.4)	177 (10.0)	154 (4.7)	161 (7.5)
Median [Q1, Q3]	162 [156, 167]	173 [171, 181]	154 [151, 159]	161 [156, 166]
Weight in kg				
Mean (SD)	78.3 (14.7)	75.7 (12.5)	61.5 (6.9)	55.7 (10.7)
Median [Q1, Q3]	76.8 [68.7, 87.5]	74.7 [69.2, 81.7]	61.8 [55.4, 63.3]	54.1 [50.4, 57.5]
BMI				
Mean (SD)	29.9 (5.7)	24.1 (1.6)	25.8 (2.6)	21.4 (2.8)
Median [Q1, Q3]	29.3 [25.9, 33.0]	25.0 [23.6, 25.0]	25.6 [23.8, 28.1]	21.2 [20.2, 22.6]
Grip Strength Sub Dominant Arm				
Mean (SD)	17.8 (7.8)	25.6 (5.4)	14.1 (5.5)	14.0 (5.0)
Median [Q1, Q3]	17.0 [13.1, 21.1]	28.2 [23.8, 28.7]	13.0 [11.1, 15.6]	12.8 [11.0, 17.3]
Missing	2 (1.0 %)	0 (0 %)	0 (0 %)	0 (0 %)
Grip Strength Dominant Arm				
Mean (SD)	19.2 (7.8)	29.1 (11.1)	15.3 (6.7)	16.3 (6.4)
Median [Q1, Q3]	19.0 [14.7, 22.4]	35.0 [25.7, 35.6]	15.3 [11.7, 18.6]	15.5 [13.7, 19.3]
Missing	6 (3.1 %)	0 (0 %)	0 (0 %)	1 (4.3 %)
Chair Stand Test Possible				
Chair Stand Test not possible	45 (23.4 %)	2 (66.7 %)	12 (32.4 %)	11 (47.8 %)
Chair Stand Test possible	147 (76.6 %)	1 (33.3 %)	25 (67.6 %)	12 (52.2 %)
Chair Stand Test				
Mean (SD)	19.2 (13.9)	17.6 (0)	21.7 (10.8)	21.5 (9.82)
Median [Q1, Q3]	15.7 [12.0, 20.5]	17.6 [17.6, 17.6]	17.3 [15.2, 26.3]	18.2 [14.5, 25.7]
Missing	45 (23.4 %)	2 (66.7 %)	12 (32.4 %)	11 (47.8 %)
Timed Up and go test				
Mean (SD)	18.8 (10.5)	16.7 (3.2)	22.6 (12.5)	18.9 (8.1)
Median [Q1, Q3]	15.0 [12.0, 22.0]	18.0 [15.5, 18.5]	20.0 [13.0, 26.3]	17.0 [14.0, 21.8]
Missing	0 (0 %)	0 (0 %)	1 (2.7 %)	1 (4.3 %)
Gait Speed				
Mean (SD)	0.74 (0.23)	0.61 (0.23)	0.67 (0.20)	0.68 (0.18)
Median [Q1, Q3]	0.74 [0.60, 0.87]	0.52 [0.49, 0.69]	0.67 [0.54, 0.78]	0.68 [0.57, 0.79]
Phase Angle				
Mean (SD)	4.5 (1.1)	3.7 (0.5)	4.3 (1.1)	3.8 (0.6)
Median [Q1, Q3]	4.4 [3.9, 4.8]	3.7 [3.5, 4.0]	4.1 [3.8, 4.6]	3.7 [3.5, 4.2]

regarded in the analysis was primarily guided by clinical expertise and existing literature. We include: sex, age, weight, height, Clinical Frailty Score (CFS), Parker Mobility Score (PMS), Mini Nutritional Assessment-Short Form (MNA-SF), number of regular medication [3,5,6,14–19].

We also used SHapley Additive exPlanations (SHAP) to interpret our prediction model. SHAP helps break down the contribution of each variable, showing how much it influences the outcome [20,21]. Additionally, we include plots that show how each predictor affects the diagnosis of sarcopenia and sarcopenic obesity. The supplementary materials contain further information about the modeling.

The analyses were performed with the R programming language (ver. 4.2.1) [22]. For modeling and interpretation we used the xgboost package version 1.7.6.1 [23] and the SHAPforxgboost package version 0.1.3 [20].

3. Results

In total, the Paint-II study recruited 409 multimorbid community-dwelling participants aged 70 and over. Thereof 154 (37.65 %) patients were not eligible for the analysis due to missing BIA assessment. In total 255 participants had body composition information. The characteristics of participants with BIA are presented in Table 1.

3.1. Sarcopenia prevalence

The prevalence of probable sarcopenia in our sample was 76.9 % (95 %-CI [71.2, 81.9]). The prevalence of reduced HGS was 39.8 %, whereas the prevalence of reduced strength in the CST was 69 %.

The prevalence of sarcopenia using the EWGSOP2 criteria differed depending on the chosen muscle mass metric. The prevalence of sarcopenia using ASMI (ASM/height^2) was 10.2 % (95 %-CI [6.8, 14.9]), while using the absolute ASM it was 23.5 % (95 %-CI [18.6, 29.2]). A statistically significant difference in diagnosis using the different metrics was identified by McNemar's test ($p < 0.001$), and their agreement measured by Cohens Kappa was κ=0.41, indicating fair to moderate agreement of both metrics in diagnosing sarcopenia.

The prevalence of severe sarcopenia using the EWGSOP2 criteria differed as well depending on the chosen muscle mass metric: using ASMI the prevalence of severe sarcopenia was 8.2 % (95 %-CI [5.2, 12.3]) compared to 19.6 % (95 %-CI [14.9, 25]) using the ASM. A

statistically significant difference in diagnosis using the different metrics was identified by McNemar's test ($p < 0.001$), and their agreement measured by Cohens Kappa was κ=0.47, indicating moderate agreement.

3.2. Sarcopenic obesity prevalence

The prevalence of sarcopenic obesity was 18.8 % (95 %-CI [14.2, 24.2]) based on the BMI cut-off of 25 kg/m^2. Considering a BMI cut-off of 30 kg/m^2, 38 participants had SO with a total prevalence of 14.9 % (95 %-CI [10.8 %, 19.9 %]).

3.3. Overlap between sarcopenia and sarcopenic obesity

Only six participants (2.4 %, four males and two females) fulfilled both diagnostic criteria for sarcopenia (ASM metric) and Sarcopenic Obesity (BMI ≥25). In the more restrictive metrics sarcopenia (ASMI metric) and Sarcopenic Obesity (BMI ≥30) there was no overlap between the two diagnoses.

3.4. Discrepancy in sarcopenia metrics

We observed a difference in prevalence of sarcopenia for the male and female depending on the metric used. While 9.5 % of females and 12.7 % of males showed sarcopenia using the metric ASMI (ASM/height^2), 25.5 % of females and 16.4 % of males were sarcopenic using ASM. We also observed a difference in height distribution in males diagnosed with sarcopenia depending on the metric. The average height for male patients diagnosed with sarcopenia with ASMI was 172 cm (SD 10), while the average height for male patients diagnosed with ASM was 164 cm (SD 7). The average height for female patients diagnosed with sarcopenia with ASMI was 159 cm (SD 6), whereas with ASM it was 156 cm (SD 6).

We also noted the differences in heights in the 40 participants with discrepancies in sarcopenia diagnoses. We observed an average height of 177 cm in patients ($n = 3$, one female) diagnosed sarcopenic with the ASMI metric but not with ASM. In contrast, the mean height of patients ($n = 37$, 33 females) having sarcopenia using ASM but not ASMI was 154 cm. Table 3 provides detailed participants characteristics comparing sarcopenia diagnosis based on the two metrics.

3.5. Sarcopenia predictors

The prediction model had an average AUC of 0.88 (95 %-CI [0.86, 0.90]). The dependence plots (Fig. 1) summaries the relationship between each single predictor and sarcopenia. The predictors are ordered by their predictive importance in descending order from left to right. Further summary plots are available in the supplementary materials. The most influential factors for predicting sarcopenia were weight, PMS and height. We observed that the probability of being diagnosed with sarcopenia decreased with weight, height, PMS. The probability of sarcopenia was higher in males compared to females. We observed a linearly increasing probability of sarcopenia with older age, a slight increase in patients with higher clinical frailty scores and a general increase with the number of medications used by patients and a decrease with higher MNA-SF scores.

3.6. Sarcopenic obesity predictors

The prediction model for sarcopenic obesity has an average AUC of 0.83 (95 %-CI [0.77 0.88]). Fig. 2 presents dependence plots that illustrate the relationship between each individual predictor and sarcopenic obesity. The predictors are arranged in descending order of predictive importance from left to right. Additional summary plots can be found in the supplementary materials. In contrast to the observation for sarcopenia we observed an increase in sarcopenic obesity diagnoses with increase in weight. In addition, we observed that the probability of being diagnosed with sarcopenic obesity decreased with height, PMS, and MNA-SF. There was little to no difference in the probability of sarcopenic obesity diagnosis in males compared to females. We observed a general increase in the probability of sarcopenic obesity with the number of medications taken.

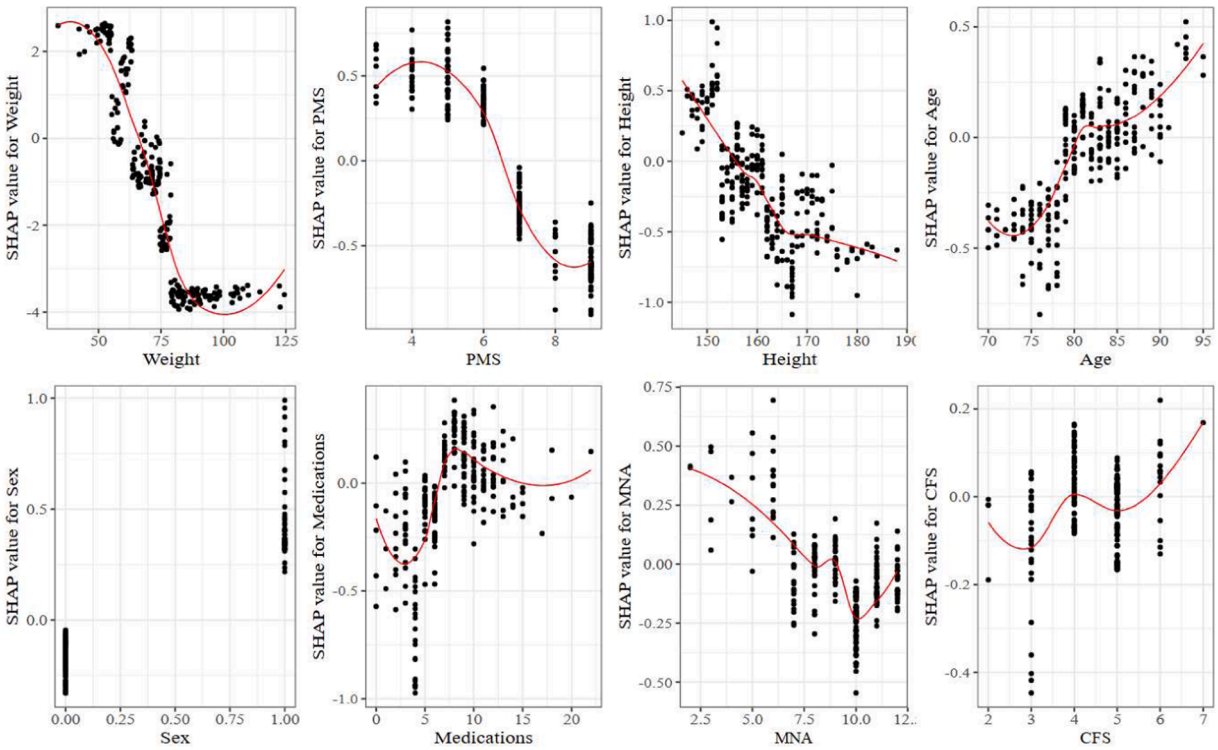

Fig. 1. Dependence plot showing the relationship between a predictors and log Odds for Sarcopenia.

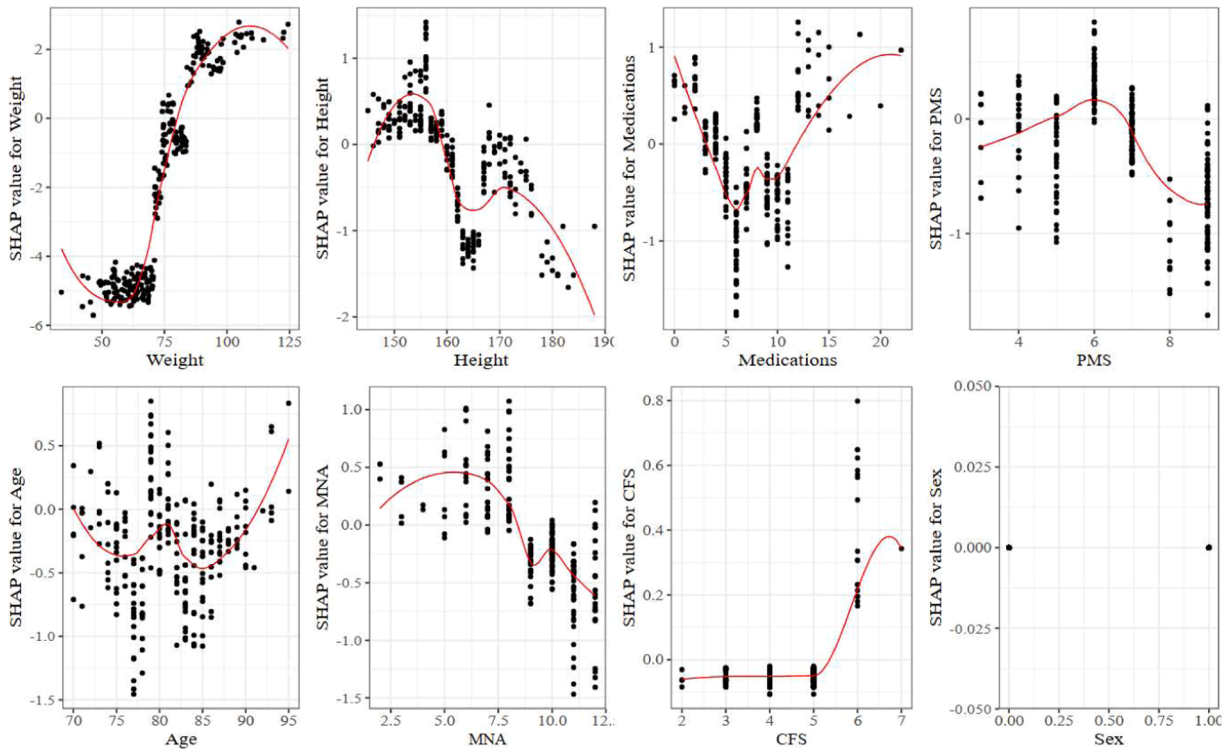

Fig. 2. Dependence plot showing the relationship between a predictors and log Odds for Sarcopenic obesity.

4. Discussion

Our data showed a high prevalence of both sarcopenia and sarcopenic obesity. This evaluated sample had a sarcopenia prevalence of 10 % defined by ASMI (ASM/height^2) and 24 % defined by absolute ASM. Our estimate is higher than the 7 % prevalence seen in the KORA-Age study (a population-based study in Germany), which used ASMI for sarcopenia diagnosis [9]. In different studies using the older EWGSOP definition of sarcopenia, sarcopenia prevalence in community-dwelling older adults in Germany was 4.5 % in females [24] and 4.9 % in males [25]. Furthermore, in the multinational DO—Health study, which was conducted with healthy independent seniors, the prevalence of sarcopenia in the German sample was 1.1 % [26].

In our sample, 19 % of the participants were sarcopenic obese based on the BMI cut-off of ≥25 kg/m^2 and 15 % had SO based on the BMI cut-off of ≥30 kg/m^2. In comparison 4.5 % of the KORA-Age sample had SO [9]. Compared to the KORA-Age sample our patients were on average 5 years older and mostly female. Our higher prevalences seem consistent with findings that inpatients are more susceptible to both diseases. The global prevalence for sarcopenia ranges from 10 to 27 % and about 11 % for SO in older adults [5,6]. In persons 75 years or older, SO prevalence was reported as high as 23 % [6]. Among inpatients, the prevalence of sarcopenia rates for men and women are 31 % and 24 % respectively [5]. Since the common reasons for day clinic referrals include gait disorders, recurrent falls and cognitive impairment, our patients are more at risk of sarcopenia and SO.

Another reason for higher prevalences in our sample was the simultaneous use of HGS and CST tests to define reduced muscle strength. Other studies tend to use only one of these two tests [9,27]. In the case of SO we provided two prevalences based on the BMI cut-off 25 kg/m^2 and 30 kg/m^2. Both are considered valid, however the cut-off of 30 is usually recommended [4]. We opted to use BMI cut-off of 25 kg/m^2 in our statistical model as it includes patients with reduced muscle strength and altered body composition (relative reduction of skeletal muscle mass and relative increase of fat mass). Due to the small overlap between SO and sarcopenia [25], these patients are partially excluded from both diagnoses. In the case of SO they are excluded due to a BMI lower than 30 kg/m^2 and excluded from sarcopenia due to a higher absolute skeletal muscle mass on the base of having larger body size.

Additionally, we noticed a high discrepancy between sarcopenia prevalences. When using the ASMI to assess muscle mass sarcopenia prevalence was around 10 % compared to 24 % using absolute ASM. A recent study on 161 community-dwelling older Brazilian women showed similar results, i.e. sarcopenia prevalence was higher using the ASM compared to ASMI [27]. In our sample the mismatch was due to:

(1) 37 participants were sarcopenic only by ASM. These participants were on average shorter with a mean height of 154 cm (SD 5). The overall sample mean height was 161 cm (SD 9). This group had a similar HGS, CST and gait speed compared to those who are sarcopenic in both metrics. They had on average a slightly worse TUG of 23 (SD 13) seconds compared to 19 (SD 8) seconds to those who are sarcopenic in both metrics.
(2) 3 participants were sarcopenic only in ASMI. These participants were taller with a mean height of 177 cm (SD 10). Comparing the muscle strength and function in this group is limited due to the small sample size. These participants had in general a better HGS and TUG compared to those who were sarcopenic in both metrics. However, 2 participants were unable to perform the CST, and the gait speed of was one of the lowest with a mean of 0.61m/s (SD 0.2).

Our data suggested that shorter patients were less likely to be diagnosed with sarcopenia using the ASMI metric compared to ASM, Table 2 provides a detailed comparison between the groups.

These findings show that adjusting ASM to height may lead to an underestimation of sarcopenia diagnosis. This is especially important in a geriatric setting where loss of height is common and is known to be associated with frailty and sarcopenia [28]. In this scenario, the burden of false negatives disproportionately affects shorter adults. In contrast, ASM without height adjustment may underestimate sarcopenia prevalence among taller person, as larger bodies are expected to have more

muscle mass. There are several methods to adjust muscle mass based on body size, such as the ASMI, which is calculated by dividing muscle mass by height squared (ASM/height^2), relative muscle mass (ASM/weight), or muscle mass adjusted for BMI (ASM/BMI). However, there is ongoing debate about the most suitable way to make these adjustments [8,29,30].

In the case of sarcopenia the cost of false negative results seem to be higher for the patients and for the society. In other words, we consider the costs of current therapy options using resistance training and nutritional interventions lower compared to the various negative outcomes associated with sarcopenia, such as falls, hospitalization and loss of independence [3,31–33]. Therefore, we recommend using the metric detecting higher prevalence, in our case ASM. Further empirical evidence on sarcopenia therapy and health economics is needed to support this hypothesis.

Both, height and weight are known muscle mass predictors [14]. PMS was a more important predictor for sarcopenia than SO. This lines up with different studies that looked into the association between sarcopenia and physical activity [15]. Obesity in older individuals with sarcopenia seems to be a protective factor against functional decline [16]. Other predictive parameters followed the expected course: age, malnutrition and polypharmacy were positively associated with sarcopenia and SO [3,5,6,17]. In our models males were more likely to have sarcopenia. However, on a global scale it is not clear which sex is more susceptible [5]. Aligned with a systematic review and meta-analysis from 2021, there were no relevant differences in SO prevalence based on sex [6].

A key limitation of the study is the use of secondary data. The original data collection focused on evaluating the effects of art therapy in older patients. It focused on diagnoses such as depression, dementia, or chronic pain syndrome. Other comorbidities that could potentially influence the development of sarcopenia or obesity, such as inflammatory diseases like cancer or metabolic disorders, were not specifically recorded or categorized. Since we relied on secondary data, we had no control over the sample size. XGBoost generally performs better with larger datasets. There is however no single, universally accepted formula for calculating sample size for machine learning models like XGBoost [34]. We assessed the sample size adequacy in a data-driven approach, as presented in the supplementary materials. The primary objective of this study is to estimate prevalence; the analysis of potential predictors is exploratory and serves as a secondary aim. As such, any interpretation should be made with caution, given the limited sample size, risk of overfitting and the use of data not originally collected for this specific purpose.

Additionally, the study was conducted at a single center, which may limit the generalizability of the findings to other populations and settings. We performed nested repeated cross-validation in this study as internal validation. This provides an estimate of how the model will perform on new patients from the same underlying population. However, it provides no information about how the model will perform in different populations. The study was also conducted in Germany, which implies the sample was likely predominantly of white European ancestry. There is a large body of evidence demonstrating that clinical prediction models, particularly complex machine learning algorithms, can exhibit biased performance across different ethnic groups [35,36]. Our sample may be more prone to sarcopenia or sarcopenic obesity, as it was drawn from a geriatric day clinic. Additionally, the sample consists predominantly of females, which limits the generalizability of the findings. Generalizability can only be assessed through external validation. Any future validation efforts must prioritize assessing performance across diverse populations.

Another major limitation is the exclusion of 154 out of 409 (37.7 %) potential participants due to missing BIA data. Reasons for missingness included for example the presence of a pacemaker, relevant leg edema, and early discharge. This suggests that the excluded population was likely more frail, functionally impaired, and had a higher burden of comorbidity than the 255 patients included in the analysis. This introduces a risk of selection bias, which may lead to an underestimation of the prevalence. Consequently, the reported performance of our model might be biased.

Paint-II participants did not undergo the recommended screening (SARC-F: Strength, Assistance in walking, Rise from a chair, Climb stairs, and Falls questionnaire). However, a recent systematic review highlighted that SARC-F has a low to moderate sensitivity for sarcopenia and recommended initiating the diagnostic tests without screening [37]. Our predictive models regarded weight and height separately instead of BMI. We opted for this as our results showed that the diagnosis of sarcopenia is affected by adjustment to height and because BMI provides limited information about body composition [38,39].

The strength of our study is that we examined a group of susceptible community-dwelling older adults. The higher prevalences emphasize the necessity to test for SO and sarcopenia routinely in geriatric day clinics or similar partial inpatient treatment institutions. Furthermore, we studied the diagnosis of SO and sarcopenia based on different metrics. In general, the different cut-offs complicate the diagnostic process. The current recommendations apply absolute ASM or ASMI in the diagnosis of sarcopenia and relative muscle mass in SO. Another example is that there are different cut-offs for the CST, which for SO is more than 17 s compared to more than 15 s for sarcopenia [4,8].

5. Conclusion

Geriatric day clinic patients have a high prevalence of both sarcopenia and sarcopenic obesity. Furthermore, we observed a big discrepancy in sarcopenia prevalence based on the method used to estimate muscle mass (absolute or adjusted to body size). The diagnoses are complicated through the different recommended metrics. We therefore encourage the efforts to simplify and unify the diagnostic criteria for sarcopenia and sarcopenic obesity. We also support further research on optimizing the cut-offs for BMI screening in sarcopenic obesity, as setting the BMI cut-off at 30 kg/m^2 may result in higher false negatives results.

Ethical statement

The Paint-II study was conducted in accordance with the Declaration of Helsinki and was approved by the Freiburg international ethics committee (Freiburger Ethik Kommission International, Code 017/150). The study is listed in the German Clinical Trials Register under the ID DRKS00012417. Written informed consent was obtained from all participants prior to their inclusion in the study. The retrospective data analysis for this study was approved by the Institutional Review board at the Paracelsus Medical University, Nürnberg (IRB-2025–04).

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CRediT authorship contribution statement

Basel Habboub: Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Emmanuel Oludowole:** Writing – original draft, Visualization, Software, Methodology, Formal analysis. **Robert Speer:** Writing – review & editing, Methodology. **Johanna Masuch:** Writing – review & editing, Funding acquisition, Data curation. **Ursula Berger:** Writing – review & editing, Supervision, Methodology. **Markus Gosch:** Writing – review & editing, Supervision. **Katrin Singler:** Writing – review & editing, Supervision, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Basel Habboub reports financial support and travel were provided by Manfred Roth Stiftung and by Schöller Stiftung. Emmanuel Oludowole reports financial support was provided by Schöller Stiftung and Manfred Roth Stiftung. Markus Gosch & Katrin Singler reports a relationship with German Geriatric Society that includes: board membership. Robert Speer reports a relationship with Danone that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjfa.2025.100072.

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