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The impact of the age range of young healthy reference population on the cut-off points for low muscle mass necessary for the diagnosis of sarcopenia

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Abstract. – OBJECTIVE: According to the consensus report published by the European Working Group on Sarcopenia in Older People (EWGSOP), sarcopenia researchers should determine sex-specific cut-off points (COPs) for low muscle mass (LMM) in their respective countries. To this end, it is necessary to investigate young healthy adults' group (YHAG). As the EWGSOP hasn't specified any inclusion criteria for this group, there is a significant divergence in literature regarding the age range characterizing YHAG. Therefore, the primary aim of our study was to assess the impact of different YHAG age ranges on the calculated values of COPs for LMM. The secondary aims were to use the calculated COPs for evaluating the prevalence of sarcopenia among the older people from Poland.

MATERIALS AND METHODS: 1512 young healthy individuals were divided into six age subgroups: 20-30, 18-40, 18-39, 20-39, 20-40, and 20-35 years. The sex-specific COPs for LMM were calculated using the Appendicular Lean Mass index. The prevalence of sarcopenia was assessed in 468 older adults from Poland.

RESULTS: In the six age subgroups, six different COPs were obtained in the group of young women (ranging from 5.51 kg/m^2 to 5.60 kg/m^2), and three different COPs were found in the group of young men (ranging from 7.35 kg/m^2 to 7.40 kg/m^2). After applying the determined COPs, the overall prevalence of sarcopenia was found to range between 4.5% and 5.1%.

CONCLUSIONS: Since there are no guidelines establishing the YHAG age range, if multiple sex-specific COPs are obtained, the highest values should be applied in the diagnostic of sarcopenia to avoid the misclassification of patients with this disease.

Key Words:
Cut-off points, Sarcopenia, Elderly.

Introduction

Sarcopenia, defined as an age-related decline in muscle mass and strength, as well as physical performance, poses a serious threat to fit old age. Since sarcopenia causes an increased risk of disability, falls, morbidity and even mortality, it is important to recognize the condition early, so that treatment can be started earlier[1,2]. According to the Consensus report published in April 2010 by the European Working Group on Sarcopenia in Older People (EWGSOP), the diagnosis of sarcopenia requires the measurement of three variables: muscle mass, muscle strength, and physical performance[3]. The EWGSOP recommends using the presence of both low muscle mass and low muscle function (strength or performance) for the diagnosis of sarcopenia. To diagnose low muscle mass – or presarcopenia – in an older individual, cut-off points for the low muscle mass index used in the diagnostic work-up are necessary, so that the score achieved by the older adult can be compared to them. If the score is below the sex-specific cut-off point, the person is diagnosed with presarcopenia, which is a component of sarcopenia. In its consensus report, the EWGSOP recommends that researchers studying sarcopenia take steps to obtain good reference values (sex-specific cut-off points) for populations around the world[3]. In response to these Guidelines, cut-off points for

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low muscle mass have been determined in dozens of countries across the world over the past three decades. The cut-off points published between 1998 and 2013 are summarized in the study by Pagotto et al[4]. Their analysis shows that most researchers determine the cut-off thresholds for low muscle mass on the basis of young healthy adults (the so-called young healthy reference population). The approach is consistent with the guidelines proposed by the EWGSOP, recommending "the use of healthy young adults with cut-off points at two standard deviations below the mean reference value"[3]. However, based on a literature review, we noted that several researchers included in their studies young adults of varying ages, from different age ranges. For example, in our literature review, we identified three papers in which the cut-off points were determined on the basis of young adults aged 20-35 years[5-7]. There are also studies in which the young healthy reference population was within the age ranges of 19-30 years[8], 18-35 years[9], 20-42 years[10] or even 20-50 years[11]. A large number of analyses are based on adults aged 18-40 years[12-17], and equally common are studies with adults in the age range of 18-39 years[18-23]. Slightly less commonly used are the age ranges of 20-40 years[24-27], 20-39 years[28-31] or 20-30 years[32,33]. The last age range is consistent with the experts' recommendations from the Society of Sarcopenia, Cachexia and Wasting Disorders (SCWD). The authors of a document addressing the diagnosis of sarcopenia with limited mobility were the first and so far, the only ones to define the criteria for inclusion in/exclusion from the young reference population[34]. The discrepancies described above have encouraged us to set the primary aim of our study which is to assess the impact of different age ranges – within the same young healthy reference population – on the calculated values of cut-off points for low muscle mass. We speculate that different age ranges result in differences in the determined cut-off points. The secondary aim is to use all determined cut-off thresholds for muscle mass to assess the prevalence of presarcopenia and sarcopenia among the community-dwelling older people in Poland. As far as we know, it is the first analysis of this type.

Materials and Methods

Ethical Considerations

The study protocol was approved by the Bio-Ethical Committee of the Poznan University of Medical Sciences, Poland (approval No: 506/12).

Study Population

A total of 1980 Caucasian adults (aged 18-97 years) were involved in the study. Among these, 1512 young healthy subjects (aged 18-40 years) were screened to determine cut-off points for low muscle mass necessary for the diagnosis of pre- and sarcopenia. In the group of the other 468 elderly subjects (aged 65-97 years), the prevalence of pre- and sarcopenia was assessed. A detailed description of both groups studied is presented below.

Determining Different Cut-Off Points for Low Muscle Mass

One thousand five hundred twelve (1512) volunteers from Poland (877 Caucasian women and 635 Caucasian men) aged 18-40 years were included in the young healthy reference population. The subjects were healthy and did not declare using any medications on a daily basis. They were recruited from the students and staff of the Poznan University of Medical Sciences, Stanislaw Wojciechowski Higher Vocational State School in Kalisz and Poznan University of Physical Education. Participants were recruited between January 2012 and December 2016. The exclusion criteria were as follows: 1) presence of contraindications to body composition test by means of the bioimpedance analysis (BIA) such as implanted artificial pacemaker, metal implants in the body, and pregnancy; 2) presence of acute or chronic diseases; 3) chronic drug usage; 4) body mass index (BMI) $\geq$ 30 kg/m^2 corresponding to obesity. At the beginning of the study, six age subgroups were identified separately within the groups of women and men: 20-30 years, 18-40 years, 18-39 years, 20-39 years, 20-40 years and 20-35 years. Each of the age ranges listed above had been used before, at least twice, by other researchers determining cut-off points for low muscle mass, and presented in the available literature. Next, the body height of each young adult person was measured with a mobile stadiometer (Tanita, Poland), and body composition was examined by the BIA method using an InBody 170 analyzer (Biospace Co., Ltd., Seoul, Korea). InBody 170 is a segmental impedance device, which uses a tetrapolar 8-point tactile electrode method. Ten impedance measurements are performed at two different frequencies (20 and 100 kHz) at each segment (right arm, left arm, trunk, right leg, and left leg). Before starting the exam, each person was asked to stand

barefoot in an upright position, with their feet placed on the electrodes on the machine platform, and their arms abducted, with hands gripping on to the electrodes on the handles. The subject's identification number, age, sex, and height were entered into the analyzer. After 15 s the device provided information about body composition including data on the segmental lean mass. Next, body height and segmental lean mass data were used to calculate the Appendicular Lean Mass (ALM) index, which is most commonly used in the diagnostics of low muscle mass (presarcopenia). The ALM index was expressed as the ratio of the lean muscle mass of the extremities (both lower and upper) and the squared height. The sex-specific cut-off points for the ALM index for six age subgroups of young healthy adults were calculated according to the method proposed by Baumgartner et al[12] by subtracting two standard deviations (-2SD) from the mean value of the ALM index. Then, the calculated cut-off points were used to identify the elderly with presarcopenia and sarcopenia according to the EWGSOP criteria.

Assessment of Presarcopenia and Sarcopenia According to EWGSOP

The prevalence of presarcopenia and sarcopenia was assessed in 468 community-dwelling elderly adults (382 women and 86 men) living in Poznan, the fifth largest city in Poland. All the studied subjects were of Caucasian origin. The following inclusion criteria were applied: 1) age (65 years or more); 2) ability to assume an upright posture, which was required to evaluate body composition with the BIA method due to the type of analyzer used. The exclusion criteria were: 1) cognitive impairment impeding contact with the subject; 2) presence of contraindications to body composition test by means of the BIA method, i.e., implanted artificial pacemaker or the presence of knee or hip endoprosthesis; 3) lack of possibility to perform the handgrip strength test and/or Timed Up and Go Test (TUG) necessary for the assessment of muscle function in the diagnostics of sarcopenia. The diagnosis of presarcopenia and sarcopenia was based on the criteria proposed by the EWGSOP[3]. Participants who had low muscle mass plus low handgrip strength, and/or low physical performance were considered to have sarcopenia. Presarcopenia was diagnosed when the participant showed only low muscle mass.

Assessment of Muscle Mass

As in younger subjects, segmental lean mass data for each elderly participant was obtained by the BIA method using the same InBody170 analyzer. Body height was measured with the same mobile stadiometer. The resulting parameters were used to calculate the ALM index. The score obtained by an older person was compared to all sex-specific cut-off points for low muscle mass got from the study of the six age subgroups within the same young healthy reference population. An elderly participant was considered to have low muscle mass (presarcopenia) if his ALM index was less than or equal to the sex-specific cut-off points.

Assessment of Muscle Strength

Muscle strength was assessed by a handgrip strength test using a hydraulic dynamometer (Saehan, South Korea). The participants performed the handgrip strength test in an upright position, with full elbow extension and 90° of shoulder flexion. Both the left and right hands were tested once. The mean value of both hands was used as the final score for each individual. Results were recorded in kilograms (kg). The older participants with handgrip strength < 30 kg for men and < 20 kg for women were considered to have low handgrip strength[3].

Assessment of Physical Performance

Physical performance was assessed using the TUG test. A stopwatch (Stratos 2 Hanhart, Oakland, NJ, USA) was used to measure the time (in s). The TUG consists of the following tasks: transfer from a sitting to standing position followed by a fast, short-distance walk on a flat surface (3 m) and return to the sitting position. If a subject walks with a cane or crutch(es), he or she performs the test using the necessary aid(s). The elderly with results above 14 s were considered to have low physical performance[35].

Statistical Analysis

Statistical analysis was performed using the STATISTICA 12.5 software (StatSoft, Poland). For each parameter mean and standard deviation were calculated. The shape of the distribution of the sample data collected was checked using the Shapiro-Wilk test. Unpaired groups were compared to the Mann-Whitney test. $p < 0.05$ was considered to denote statistical significance.

Results

Characteristics of the Study Group

The young healthy reference population enrolled in the study included 877 Caucasian women and 635 Caucasian men aged 18-40 years, with the mean ages of 28.44±6.80 years and 24.22±5.30 years, respectively. The prevalence of presarcopenia and sarcopenia rated in the elderly group involved 382 women and 86 men, with the mean ages of 72.79±5.92 years and 75.57±6.23 years, respectively. The basic characteristics including demographic, anthropometric, and selected body composition variables of the young and elderly participants are shown in Table I. Comparing the young men to young women, men were significantly younger (24.22±5.30 *vs.* 28.44±6.80 years, $p < 0.001$), heavier (78.88±10.11 *vs.* 62.89±9.16 kg, $p<0.001$), taller (1.81±0.06 *vs.* 1.66±0.06 m, $p<0.001$), and had higher BMI (24.14±2.64 *vs.* 22.81±2.94 kg/m^2, $p<0.001$), with higher ALM values than women (28.29±3.35 *vs.* 18.51±2.38 kg, $p<0.001$). Similarly to younger group, elderly men were significantly heavier (75.70±12.43 *vs.* 71.12±12.21 kg, $p<0.001$) and taller (1.68±0.06 *vs.* 1.57±0.06 m, $p<0.001$), and had higher ALM values than elderly women (22.10±3.10 *vs.* 16.72±2.55 kg, $p<0.001$), although their BMI was significantly lower (26.93±3.92 *vs.* 29.04±4.76 kg/m^2, $p<0.001$). An additional assessment of muscle function in the elderly showed that elderly men were stronger than the elderly women (34.55±8.21 *vs.* 24.15±8.24 kg, respectively, $p<0.001$). However, both groups had a similar level of physical performance assessed by the TUG test (elderly men: 6.99±2.67 s *vs.* elderly women: 7.04±2.32 s, $p>0.05$).

Impact of the age range of the young healthy reference population on the cut-off points for low muscle mass

The basic characteristics including demographic, anthropometric, and selected body composition variables for the six age subgroups of young women and men are shown in Tables II and III, respectively. The tables also list two additional parameters: ALM index and sex-specific cut-off points. All age subgroups within a given sex were found to be characterized by similar body height. The highest values of weight, BMI index, and ALM index for both sexes were observed in the subgroup aged 20-40 years, and the lowest values of the same parameters were observed in the subgroup aged 20-30 years. In the group of young women, a large variation was found in the calculated cut-off points, with a separate cut-off point obtained in each of the six age subgroups. No such variation was observed in the group of young men, where only three different cut-off points were obtained. For example, the cut-off point of 7.38 kg/m^2 was determined in three age subgroups of young men: 18-40, 18-39, and 20-35 years. Both in group of women and men, the lowest cut-off point was found in the age subgroup of 20-30 years, whereas the highest was found in the age subgroup of 20-40 years (in men the same cut-off point was also obtained in the subgroup of 20-39 years).

Effect of different cut-off points on the prevalence of presarcopenia and sarcopenia in the examined group of elderly people

Based on several sex-specific cut-off points listed in Tables II and III, presarcopenia and sarcopenia were diagnosed in various percentages of older people, as shown in Figure 1 and Figure 2. However, the observed differences in the prevalence of both conditions were minor. After applying the EWGSOP diagnostic criteria to the cut-off points, the overall prevalence of presarcopenia was found to vary between 7.5% and 8.8%, and the prevalence of sarcopenia ranged from 4.5% to 5.1%. As expected, the prevalence of presarcopenia and sarcopenia increased with age both in women and in men (Figures 3 and 4). The incidence of presarcopenia ranged between 3.1% and 3.9% among all older women, and between 26.7% and 30.2% among all older men, according to the applied cut-off points. In turn, the prevalence of sarcopenia ranged from 2.1% to 2.6% among all older women, and from 15.1% to 16.3% among all older men, according to the applied cut-off points.

Comparison of ALM index and cut-off points for low muscle mass in this study with data from other studies

Since our analysis is the first one of its kind, it is difficult to compare its results with other analyses. However, we found in the available literature, several papers evaluating the effect of age on ALM[23,28,30,31]. The studies specify, among others, the mean values with standard deviations for the ALM index in several age subgroups covering 10 years (including young adults aged 20-29 years and 30-39 years, with a slight modification of these age ranges in the study by Marwaha et al[31] for 21-30 years and 31-40 years).

Table I. Characteristics of subjects from the young healthy reference population and older adults included in the analysis.

Characteristics	Young healthy reference population 18-40 years			Older study population 65+ years		
	Men (n=635)	Women (n=877)	*p*-values	Men (n=86)	Women (n=382)	*p*-values
Age (years)	24.22±5.30	28.44±6.80	<0.001	75.57±6.23	72.79±5.92	<0.001
Weight (kg)	78.88±10.11	62.89±9.16	<0.001	75.70±12.43	71.12±12.21	<0.001
Height (m)	1.81±0.06	1.66±0.06	<0.001	1.68±0.06	1.57±0.06	<0.001
BMI (kg/m^2)	24.14±2.64	22.81±2.94	<0.001	26.93±3.92	29.04±4.76	<0.001
Appendicular Lean Mass (kg)	28.29±3.35	18.51±2.38	<0.001	22.10±3.10	16.72±2.55	<0.001
Lean Mass of Arms (kg)	7.57±1.13	4.37±0.72	<0.001	6.25±1.17	4.50±0.81	<0.001
Lean Mass of Legs (kg)	20.72±2.42	14.14±1.78	<0.001	15.86±2.18	12.22±1.89	<0.001
ALM index (kg/m^2)	8.64±0.63	6.70±0.57	<0.001	7.85±0.80	6.80±0.75	<0.001
Muscle strength of right arm (kg)*				35.47±8.43	24.63±6.29	<0.001
Muscle strength of left arm (kg)*				33.63±8.70	23.07±6.20	<0.001
Timed Up and Go test (s)*				6.99±2.67	7.04±2.32	0.28

*these measurements were not performed in young healthy reference population.

Table II. Characteristics of selected parameters in different age subgroups of the young reference population of women.

	20-30 years (n=379)	18-40 years (n=877)	18-39 years (n=851)	20-39 years (n=736)	20-40 years (n=762)	20-35 years (n=591)
Age (years)	24.58±3.07	28.44±6.80	28.08±6.59	29.55±5.86	29.91±6.06	27.61±4.82
Weight (kg)	60.75±8.52	62.89±9.16	62.66±9.09	63.40±9.08	63.65±9.15	62.49±8.78
Height (m)	1.67±0.06	1.66±0.06	1.66±0.06	1.66±0.06	1.66±0.06	1.66±0.06
BMI (kg/m^2)	21.87±2.58	22.81±2.94	22.71±2.90	22.93±2.92	23.04±2.96	22.60±2.85
Appendicular Lean Mass (kg)	18.30±2.32	18.51±2.38	18.50±2.39	18.66±2.36	18.67±2.36	18.52±2.31
Lean Mass of Arms (kg)	4.23±0.66	4.37±0.72	4.36±0.72	4.43±0.71	4.44±0.71	4.36±0.68
Lean Mass of Legs (kg)	14.07±1.77	14.14±1.78	14.14±1.78	14.23±1.77	14.24±1.77	14.17±1.75
ALM index (kg/m^2)	6.57±0.53	6.70±0.57	6.69±0.58	6.73±0.57	6.74±0.57	6.68±0.55
Cut-off point for LMM	5.51	5.56	5.53	5.59	5.60	5.58

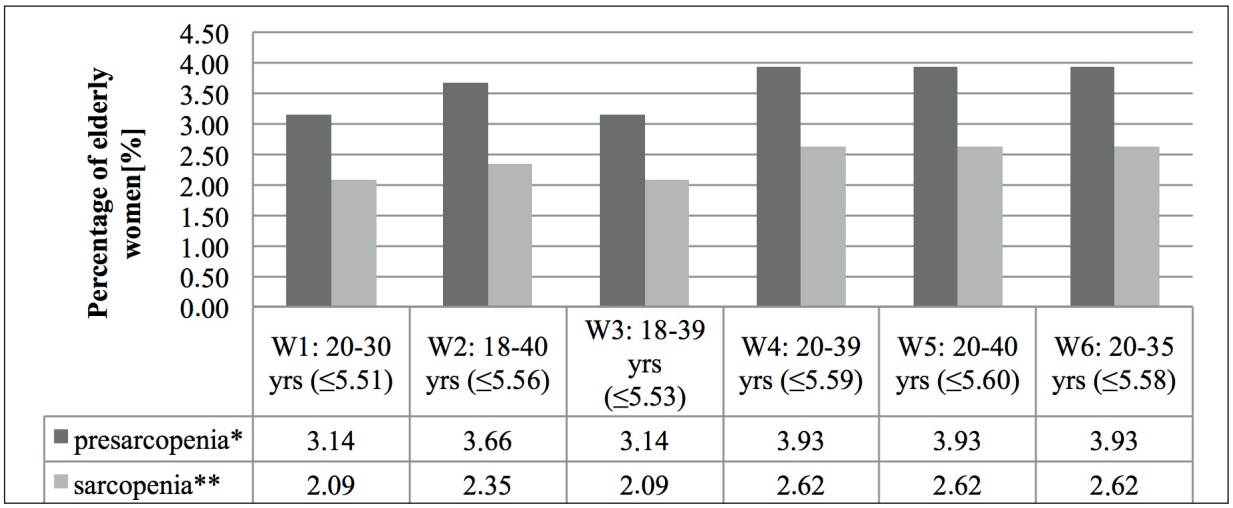

Figure 1. The percentage of elderly women with EWGSOP-defined sarcopenia. (W: women, *Low muscle mass only; **Low muscle mass + low muscle strength and/or low physical performance).

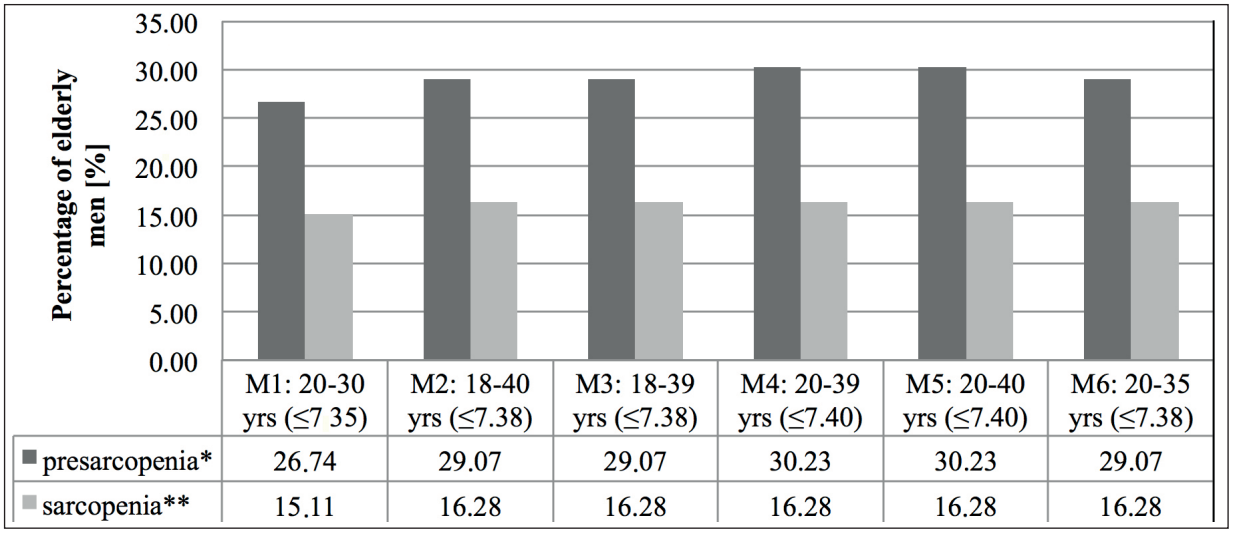

Figure 2. The percentage of elderly men with EWGSOP-defined sarcopenia. (M: men, *Low muscle mass only; **Low muscle mass + low muscle strength and/or low physical performance).

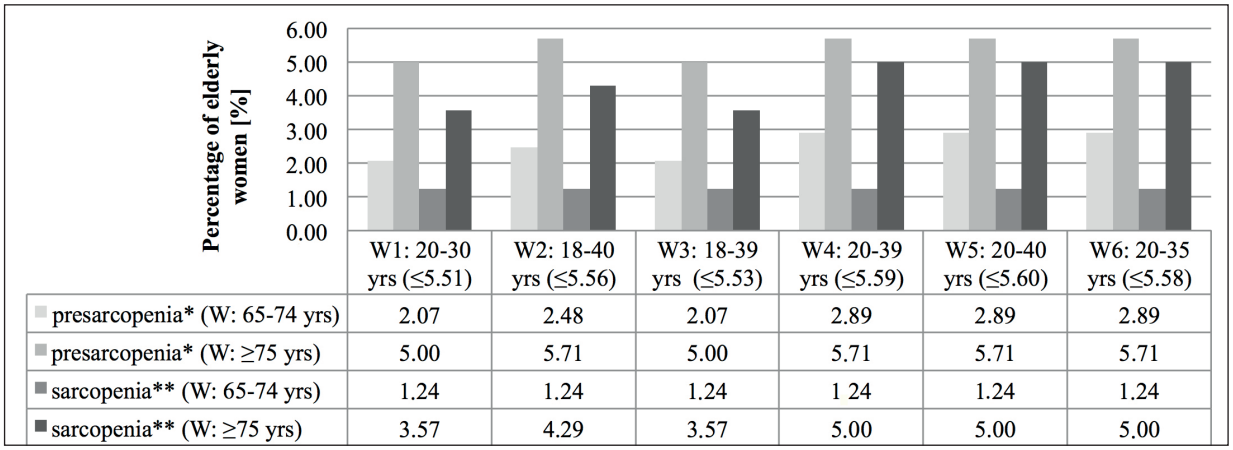

Figure 3. The percentage of elderly women with EWGSOP-defined sarcopenia divided into two age subgroups. (W: women, *Low muscle mass only; **Low muscle mass + low muscle strength and/or low physical performance).

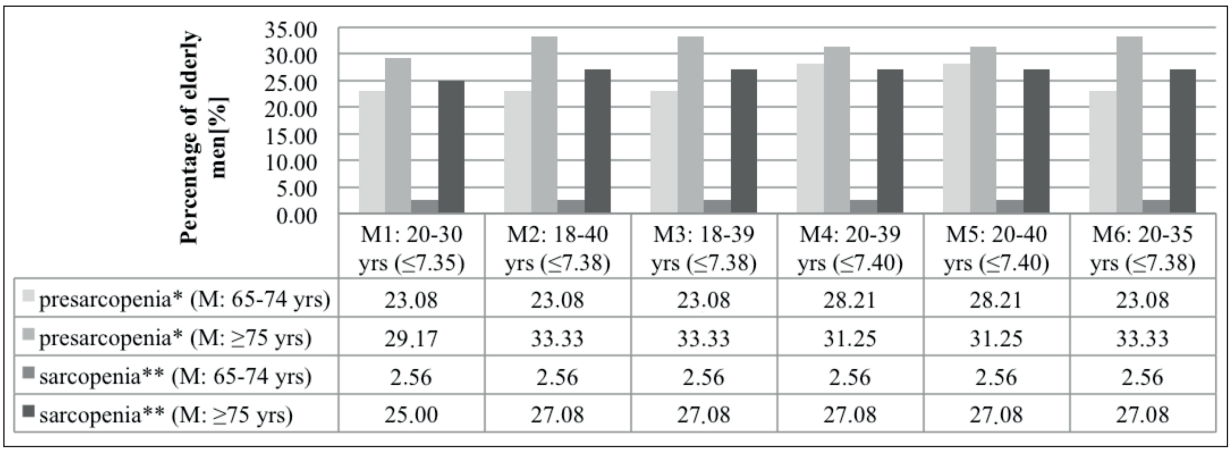

Figure 4. The percentage of elderly men with EWGSOP-defined sarcopenia divided into two age subgroups. (M: men *Low muscle mass only; **Low muscle mass + low muscle strength and/or low physical performance).

The results presented allow us to calculate the cut-off points in each age subgroup according to the method proposed by Baumgartner et al[12] (mean of ALM index -2SD) and compare them, as shown in Table IV. A comparison of the data listed in Table IV demonstrates that our cut-off points are the highest in both sexes. It should be noted that, except the work by Marwaha et al[31] which investigated representatives of the Indian, other authors have conducted their researches on Caucasian people, similarly to us. We also found that younger age groups (i.e., 20-29 or 21-30 years) generated lower cut-off points more frequently than the age sub-groups of 30-39 and 31-40 years, even if the differences between them were minor. This observation is consistent with our findings. Table IV also lists the cut-off points recommended by the authors of different publications for the diagnosis of sarcopenia in the respective countries. They were usually calculated for the young healthy reference populations aged between 20 and 39 years.

Discussion

This investigation was an attempt to assess the effect of the age range of the young healthy reference population on the calculated cut-off points required for the diagnosis of sarcopenia. According to the EWGSOP consensus report[3], which is the standard protocol in Europe, cut-off points for low muscle mass should be determined by examining the group of healthy young adults. However, the age range for young adults has not been precisely defined. It is generally recognized that a young adult is a person in the age range of 18 to 40, although definitions and opinions vary, especially in the field of psychology[36]. The lower limit of the range usually coincides with the age at which, in most societies, an individual acquires certain privileges together with civil and legal obligations. The upper limit is even more arbitrary and refers to the period when a person achieves stability in professional and family life, and when the first signs of biological aging of the body appear[37]. At this point, it should be noted that the age range of 18-40 years was employed for calculating the sex-specific cut-off points for low muscle mass by Baumgartner, who is recognized as a pioneer in this field[12]. However, many researchers didn't follow Baumgartner's initial approach when determining the cut-off points for their countries, setting different age ranges for young adults. Evaluation of the significance of the age range in calculating the cut-off points for low muscle mass seems to be particularly interesting in the light of the recommendations issued by the SCWD for the diagnosis of sarcopenia with limited mobility[34]. According to the recommendations, a healthy reference population should consist of at least 100 individuals aged between 20 and 30 years, of the same sex and the same ethnic/racial origin. Individuals included in this group should not experience limb pain or substantial balance problems. Interestingly, the SCWD has not provided any justification for the recommended age range of 20-30 years, which would be reasonable, given the fact that it differs significantly from the range first proposed by Baumgartner et al[12]. It should be emphasized that in literature we found only two papers in which the young reference population was within the age range recommended by the SCWD[32,33].

Table III. Characteristics of selected parameters in different age subgroups of the young reference population of men.

	20-30 years (n=483)	18-40 years (n=635)	18-39 years (n=630)	20-39 years (n=576)	20-40 years (n=581)	20-35 years (n=544)
Age (years)	22.73±2.78	24.22±5.30	24.07±5.10	24.58±5.04	24.74±5.25	23.86±4.15
Weight (kg)	78.21±9.90	78.88±10.11	78.85±10.12	79.32±9.98	79.35±9.97	78.91±9.95
Height (m)	1.81±0.06	1.81±0.06	1.81±0.06	1.81±0.06	1.81±0.06	1.81±0.07
BMI (kg/m^2)	23.85±2.48	24.14±2.64	24.12±2.63	24.25±2.58	24.27±2.58	24.09±2.52
Appendicular Lean Mass (kg)	28.35±3.44	28.29±3.35	28.29±3.36	28.40±3.37	28.39±3.37	28.38±3.42
Lean Mass of Arms (kg)	7.55±1.14	7.57±1.13	7.57±1.13	7.62±1.13	7.62±1.13	7.59±1.14
Lean Mass of Legs (kg)	20.80±2.48	20.72±2.42	20.72±2.42	20.78±2.43	20.78±2.43	20.79±2.47
ALM index (kg/m^2)	8.63±0.64	8.64±0.63	8.64±0.63	8.66±0.63	8.66±0.63	8.64±0.63
Cut-off point for LMM	7.35	7.38	7.38	7.40	7.40	7.38

Table IV. Comparison of ALM Index and Cut-off point for Low Muscle Mass for women and men in the present study with data from other studies.

Age group (years)	Coin et al. 2013, Italy Mean ±SD (n)		Gould et al. 2014, Australia Mean ±SD (n)		Imboden et al. 2017, USA Mean ±SD (n)		Present study Mean ±SD (n)		Marwaha et al. 2014, India Mean ±SD (n)
	Women	Men	Women	Men	Women	Men	Women	Men	Women only
ALM INDEX (KG/M^2)									
20-29	6.23±0.63 (n=57)	8.77±1.08 (n=83)	6.84±0.80 (n=176)	8.67±0.90 (n=180)	6.96±0.97 (n=562)	9.47±1.56 (n=384)	6.57±0.53 (n=358)	8.63±0.63 (n=467)	5.73±0.60* (n=179)
30-39	6.44±0.94 (n=26)	8.81±1.21 (n=33)	6.83±0.74 (n=132)	8.92±0.95 (n=194)	6.95±1.10 (n=196)	8.94±1.20 (n=104)	6.87±0.57 (n=378)	8.79±0.61 (n=108)	5.98±0.57** (n=290)
CUT-OFF POINT FOR LOW MUSCLE MASS									
20-29	4.97	6.61	5.24	6.87	5.02	6.35	5.51	7.37	4.53*
30-39	4.56	6.39	5.35	7.02	4.75	6.54	5.73	7.57	4.84**
Age group used to calculate the recommended cut-off point	4.82#	6.54#	5.30#	6.94#	4.92##	6.35##	5.60#	7.40#	4.42#

n= number of participants, * for the age group of 21-30 years, ** for the age group of 31-40 years, # for age group 20-39 years, ## for age group 18-39 years.

It seems, therefore, that the recommendations have not been accepted by researchers to determine the cut-off points for low muscle mass. Despite this, we decided to include the age range proposed by the SCWD in our analysis. Notably, compared to other age ranges, the cut-off points calculated for the young adults aged 20-30 years of both sexes were the lowest of all, resulting in the diagnosis of presarcopenia and sarcopenia in the lowest percentage of the elderly. As we have shown, the value of the cut-off points is crucial in the diagnosis of low muscle mass, and variation between different cut-off thresholds results in differences in the frequency of diagnosing presarcopenia and sarcopenia. It must be stressed, however, that the application of extreme cut-off points (i.e., the highest *vs.* the lowest) was associated with a small discrepancy in the assessed frequency of both conditions in the general population (1.3% for presarcopenia and 0.6% for sarcopenia, respectively). More interesting results were obtained in the sex-based analysis. Although in the group of the elderly women the extreme cut-off points did not lead to a large discrepancy in the prevalence of presarcopenia and sarcopenia (0.7% for presarcopenia and 0.5% for sarcopenia, respectively), in the group of the elderly men the discrepancy was greater, amounting to 3.5% and 1.2% for presarcopenia and sarcopenia, respectively. It is difficult to explain this difference, especially that the discrepancy between the extreme cut-off points calculated in the group of young men was smaller (precisely 0.05, i.e., the difference between the 7.40 kg/m^2 and 7.35 kg/m^2 cut-off points) than in group of young women (precisely 0.09, i.e., the difference between the 5.60 kg/m^2 and 5.51 kg/m^2 cut-off points). Since our analysis is pioneering, it is hard to compare its results to other findings. Nevertheless, we made such an attempt, as shown in Table IV. The results listed there show that, generally, the value of the ALM index increased with age in the compared age subgroups (except for the findings reported by Imboden et al[23]). Furthermore, the results demonstrate that for the same age ranges several researchers obtained different cut-off points for the diagnosis of sarcopenia. For example, in Table IV for women (for the 20-39 age subgroup), the lowest cut-off point was that determined for Indian women (4.42 kg/m^2)[33], and the highest was that determined for Polish women (5.59 kg/m^2). However, the cut-off point calculated for Italian women (4.82 kg/m^2)[28] was higher than that determined for Indian women, but lower than ours and the one determined for Australian females[30]. Generally, the literature confirms that the cut-off points in representatives of the Caucasian race are higher than in Mexican[27] or Indian adults[31], which is a consequence of the larger body height and a higher percentage of skeletal muscles in body composition that are characteristic for Caucasian people[27,31]. In our opinion, the differences shown confirm the validity of calculating the cut-off points applicable to the population of the country in which studies on presarcopenia and sarcopenia are conducted. It cannot be assumed that the cut-off points determined in representatives of the same race are similar although they can be. It is worth noting that the Polish cut-off points for low muscle mass are very similar to the American ones calculated by Baumgartner et al[12] in the study mentioned above[12], equal to 5.45 kg/m^2 for women and 7.26 kg/m^2 for men. The researchers examined non-Hispanic white American men and women aged 18-40 years. Our cut-off points for the same age range were, 5.56 kg/m^2 in women and 7.38 kg/m^2 in men, and were also determined by analyzing young Caucasian people, but from Poland. When comparing different cut-off points determined for various populations (even of the same ethnicity, though from different geographical areas), it needs to be noted that the value of calculated cut-off points is affected by a number of factors which have been discussed in literature[27,31]. In addition to the ethnic/racial background, another key factor is lifestyle, including diet and physical activity which also affects the level of muscle mass. The age range of the young healthy reference population does not seem to play an equally significant role, although we think it is worth investigating. However, a crucial factor is the measurement method used for muscle mass evaluation (Dual Energy X-ray absorptiometry, DEXA *vs.* BIA). The aspect is discussed in greater detail in the section on study limitations. As far as we know, this is the first analysis concerning using Polish cut-off points for low muscle mass to examine the prevalence of sarcopenia among community-dwelling older adults from Poland. The result obtained for sarcopenia - approximately 5% for the general population - is assessed as relatively low. In other developed countries, the prevalence of EWGSOP-defined sarcopenia was reported to vary widely, across the range of 1 to 29%, among elderly adults living in the community[38]. This diversity may result from different methods applied to evaluate muscle mass (including different cut-off points), muscle strength, and physical performance, or from real differences in the

prevalence of sarcopenia. A similar prevalence of EWGSOP-defined sarcopenia was reported in the United Kingdom (6.5%)[39], in Germany (4.1%)[40] or Italy (7.5%)[41].

Study Limitations

Our study has one limitation that is the application of the BIA method for the assessment of ALM. However, in Poland, it is still very challenging to measure muscle mass by computed tomography (CT) or magnetic resonance imaging (MRI), or DEXA, which are more reliable methods. At present, given the fact that CT and MRI are expensive techniques, the DEXA method is the preferred alternative for research and clinical applications[3,42]. However, BIA is a more practical screening method to be used in large samples, especially in a community setting. Also, there are papers confirming a high level of agreement with the newest generation BIA devices (i.e., those using the 8-point tactile electrode method with more than one frequency, as in our study) with the DEXA method[43-45].

Conclusions

The cut-off points for low muscle mass determined in different age ranges of the same young healthy reference population may vary.

The application of varying cut-off points for the diagnosis of presarcopenia and sarcopenia results in the identification of these conditions in various percentages of the elderly, although the spread of results obtained in our study was small.

In the absence of consistent Guidelines regarding the age range of the young healthy reference population, the cut-off points for a given country can be determined for several age ranges by applying the study model proposed in this paper. If different cut-off points are obtained, to prevent the misclassification of subjects with sarcopenia, we advise using the highest cut-off points for low muscle mass.

We recommend the highest cut-off points, i.e., 5.60 kg/m^2 in women and 7.40 kg/m^2 in men, for the diagnosis of presarcopenia and sarcopenia in Poland.

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Conflict of Interests

The Authors declared that they have no conflict of interests.

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