

Original Article

Muscle Mass Reference Values of Greek Adult Population: A Cross-Sectional Study for Sarcopenia Definition in Greece

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Abstract

Objectives: Sarcopenia is a condition of the musculoskeletal system that has three distinctive dimensions: muscle strength, muscle mass and muscle performance. We need to accurately define it considering population particularities at national level. The aim of this study is measuring muscle mass variables in healthy young Greek population and set their reference values. **Methods:** Between June 2020 and June 2022, we recruited (convenience sampling) 185 healthy adults (103 males and 82 females) measured their body composition using two different methods. Bioelectrical Impedance Analysis (BIA) and Dual Energy X – Ray Absorptiometry (DXA). We calculated cut-off values as mean – 2 SDs. **Results:** Appendicular Lean Mass Index cut-off values for Greek males are 5.61 kg/m² and 4.06 kg/m² for females, Skeletal Muscle Mass Index cut-off values are 9.66 kg/m² for males and 7.83 kg/m² for females. **Conclusions:** We estimated cut-off values of normal skeletal muscle mass values in a rather selected sample of healthy Greek adult population. Since to our knowledge this is the first study of this type in Greece, these values are a useful tool towards better defining sarcopenia, but there is need to validate them in studies including rural and urban population and in sarcopenia studies in older people.

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Keywords: Appendicular Lean Mass Index, Reference values, Sarcopenia, Skeletal Muscle Mass Index

Introduction

When considering ageing one conceives the processes that refer to the changes brought as the time goes by. These alterations appear at different levels hierarchically organized namely at molecular, cellular, physiological and

functional dimensions respecting a temporal pattern¹. This is an observation that is valid for all the different organs and systems, including the muscular. Loss of mass and loss of strength and performance, basic ageing characteristics of the musculature, may lead to loss of functionality. But how much is little enough to suggest a health problem? This is the conceptual basis behind the definition of sarcopenia. Sarcopenia is a condition that involves loss of muscle mass and function that can arise across ageing or in the course of certain diseases. Originally, sarcopenia was only defined based on low muscle mass, but due to growing insights nowadays an emphasis is placed on muscle function as well. Clinical practice recognition is relatively new, considering that an ICD-10 code for sarcopenia was introduced in September 2016 but continuously rises in importance since it has been demonstrated to correlate with health

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outcomes². Several studies have attempted to calculate the prevalence of sarcopenia in community dwelling older people using more than one of the available diagnostic criteria [European Working Group of Sarcopenia in Older People (EWGSOP) 2010, updated EWGSOP 2019, the Foundation for National Institutes of Health criteria (FNIH)] in Poland³, and the International Working Group on Sarcopenia (IWGS) and Asia Working Group on Sarcopenia criteria (AWGS 2019, AWGS 2014, EWGSOP1, -EWGSOP2, IWGS, and FNIH in western China⁴. They concluded that the prevalence of sarcopenia for the same population differed depending on the tool used to estimate its presence. These differences and discrepancies make it urgent to develop a method to accurately estimate sarcopenia for different populations. Breakthrough publications, namely the EWGSOP 2⁵ and the earlier EWGSOP 1⁶ that have conceptually determined the field are suggesting measuring population specific reference values for the variables that define sarcopenia. International reference standards may fail to fit selected populations due to differences in genetic background, lifestyle variations. There is the need to tailor cut-off values in a country specific way. Based on this concept we tried to contribute useful knowledge towards defining sarcopenia in Greece.

Dual X-Ray absorptiometry (DXA) is the most commonly used technique to assess Appendicular lean soft tissue (ASM) which reflects the lean soft mass measured from both arms and legs while it also measures fat free mass (FFM) which reflects the sum of lean soft tissue plus bone mineral density or body weight minus Fat Mass (FM) as a proxy for Skeletal Muscle (SM). Another broadly used technique, noninvasive as well but easier to apply is the Bioelectrical Impedance Analysis (BIA), which depends on an algorithm that has been generated based on a reference method that calculates Fat Free Mass (FFM), Appendicular Skeletal Mass (ASM), and Skeletal Mass (SM)⁷.

It is of great importance to establish country specific muscle mass reference values using several accessible methods of muscle mass measurement, as it is suggested that results for Skeletal Mass can only be compared with the values of the appropriate reference population.

The aim of this study was to establish muscle mass reference values for the adult Greek population by using two different measurement techniques.

Materials and Methods

This prospective, observational, cross-sectional study, was performed at the Center of Geriatric Assessment at Henry Dunant Hospital Center (ENHC), from June 2020 till June 2022, when it stopped because of the difficulties faced in terms of recruitment, related to COVID-19 restrictive measures, in Athens-Greece. The population of the study consisted of 185 healthy young adults between 20–44-year-old. We did not perform sample size estimation because of the difficulty of recruitment of

normal population. Our sample size of 185 participants is higher than the sample size suggested on literature^{8,9}. Study protocol has been approved by the Ethical Committee of the ENHC. Study fulfillment respected the World Medical Association Declaration of Helsinki -Ethical Principles for Medical Research Involving Human Subjects ethical standards. Convenience sampling was chosen as the method of choice for the sample recruitment.

Inclusion and exclusion criteria

Otherwise, healthy Greek male and female adults were recruited. The presence of any chronic condition (diabetes mellitus, autoimmune disease, neurological conditions) or medical history (bariatric surgery, serious injury and hospitalization to Intensive care Unit) that could affect the muscle mass, the presence of any metal material that could affect measurements led to exclusion of the subjects. People taking protein formulations and anabolic substances, as well as professional athletes, people with history of drug abuse were also excluded. We firstly invited people fulfilling the inclusion criteria among the personnel of the hospital and then we upload invitation banners on the official site of the hospital and we were urging participants to inform their social and working environment about the study.

Measurements

All participants were evaluated for demographic characteristics (gender, age, marital status, education, lifestyle habits (smoking, alcohol, nutrition, sleep etc.) and anthropometric measurements (height, weight). Full body composition analysis was performed with Bioelectric Impedance Analyzer (BIA) using the TANITA Body Composition Analyzer device, model BC-418MA. Skeletal Muscle Mass was calculated by the following equation: SMM (kg) = 0.566 * FFM (fat free mass) as in the literature¹⁰. Dual-Energy X-ray Absorptiometry-DXA was also performed using the QDR 4500 A fan Beam densitometer (Hologic, Inc., Bedford, MA) following standard procedures as a second technique for body composition measurement providing direct measurements of ALMI. For these measurements we could not have valid measurements for 2 males and 1 female participant.

Handgrip was measured using a CAMRY hand dynamometer in sitting position with the arm flexed at 90 degrees. We measured three times for each arm and we used the best value.

Statistical Analysis

All analyses were carried out using the statistical package SPSS 21.00 (IBM Corporation, Somers, NY, USA). Data was expressed using descriptive statistics including mean±SD (standard deviation), min and max for continuous variables and frequencies, percentages for categorical variables. The Kolmogorov—Smirnov test was used for normality analysis

Table 1. Demographic characteristics of study population.

		N	%
Age	mean \pm SD	30.85\pm6.32 (20-44)	
Age group	20-24 years	37	20.3
	25-29 years	43	23.6
	30-34 years	53	29.1
	35-39 years	26	14.3
	40-44 years	23	12.6
Gender	Male	103	55.7
	Female	82	44.3
Educational Status	Secondary	16	8.8
	University Degree	103	56.6
	Post Graduate	63	34.6
Working Conditions	Sedentary	136	74.7
	Manual	46	25.3
Smoking Status	Never	112	61.5
	Former	21	11.5
	Current	49	26.9
Aerobic Exercise	Never/seldom	85	46.7
	Sometimes	86	47.3
	Daily	11	6.0

Table 2. Mean values for several Body Composition Variables. All variables were presented as Mean \pm SD (Range).

	SMM	SMMI (BIA)	BMI	ALMI (DXA)
Males	N = 103 38.50 kg \pm 5.22 (27.56, 53.66)	N = 103 11.82 kg/m ² \pm 1.08 (9.43, 15.11)	N = 103 25.67 kg/m ² \pm 3.65 (17.40, 44.20)	N = 101 7.35 kg/m ² \pm 0.87 (5.65, 9.65)
Females	N = 82 25.24 kg \pm 2.49 (20.60, 33.17)	N = 82 9.13 kg/m ² \pm 0.65 (7.85, 11.08)	N = 82 22.35 kg/m ² \pm 3.14 (17.60, 33.70)	N = 81 5.30 kg/m ² \pm 0.62 (4.25, 7.13)

SMM: Skeletal Muscle Mass, SMMI (BIA): Skeletal Muscle Mass Index (BioImpedance Analysis), BMI: Body Mass Index, ALMI DXA: Appendicular Lean Mass Index Dual Energy X-Ray Absorptiometry.

of the parameters.

The reference intervals were calculated using parametric approach with the 95% boundaries were specified by the mean \pm 2SD, because the data follow a normal distribution. Correlation between variables estimated by using the Pearson's and Spearman's correlation coefficient. All tests are two-sided, statistical significance was set at $p < 0.05$.

Results

The study sample included 185 young adults (mean age 30.85 \pm 6.32 years) of which 55.7% were males. Most of them attained higher educational level (university degree

56.6 %, post graduate studies 34.6%) working mainly in sedentary setting (74.7 %), were non-smokers (61.5%) with the majority abstaining or rarely participating in aerobic (46.7 % and 47.3% respectively) training activities as can be seen in Table 1.

BIA variables

Fat free mass (FFM) was measured by BIA and skeletal muscle mass (SMM) was calculated as in the literature⁹. SMM for males was 38.50 kg \pm 5.22 kg/ [27.56, 53.66] and for females 25.24 kg \pm 2.49 kg [20.60, 33.17] (Table 2). This value was then divided by height to estimate the Skeletal Muscle Mass Index (SMMI (BIA)) which was 11.82

Table 3. Reference intervals for muscle mass variables (Mean \pm 2SD).

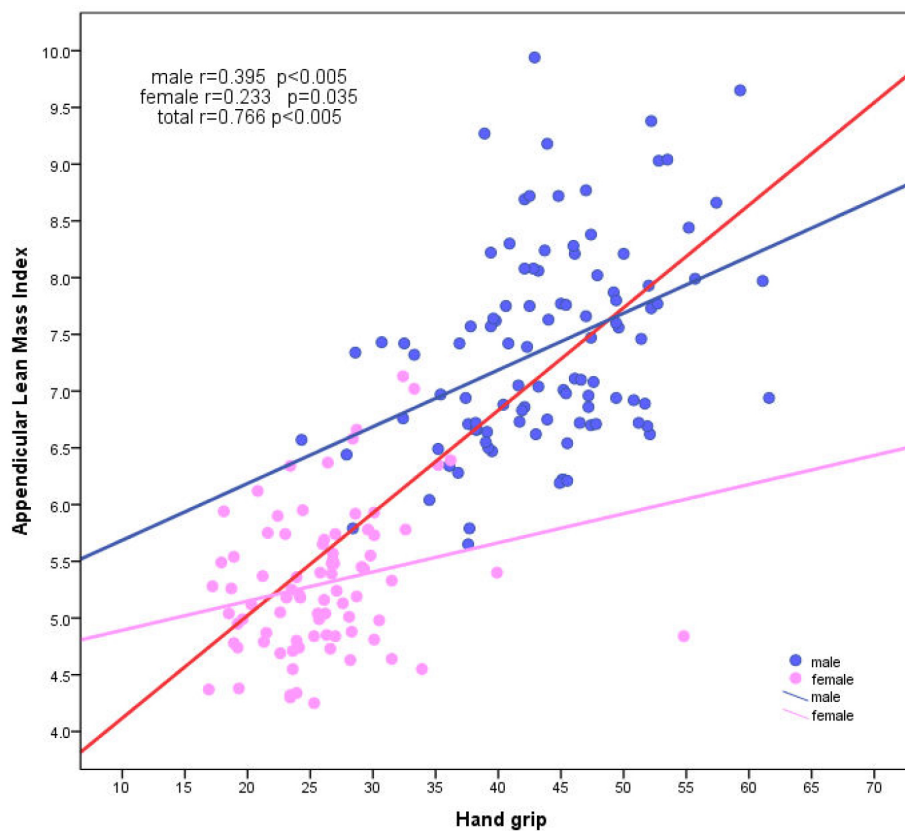
	SMM	SMMI (BIA)	ALMI (DXA)
Males	(28.06 - 48.94) kg	(9.66 - 13.98) kg/m ²	(5.61 - 9.09) kg/m ²
Females	(20.26 - 30.22) kg	(7.83 - 10.43) kg/m ²	(4.06 - 6.54) kg/m ²

SMM: Skeletal Muscle Mass, SMMI (BIA): Skeletal Muscle Mass Index, ALMI; Appendicular Lean Mass Index.

Table 4. Correlation between handgrip and muscle mass variables.

	ALMI		FFM	
Total Population	PCC	0.766	SCC	0.811
	p-value	<0.005	p-value	<0.005
Female	PCC	0.233	PCC	0.268
	p-value	0.035	p-value	0.015
Males	PCC	0.395	PCC	0.466
	p-value	<0.005	p-value	<0.005

PCC: Pearson's Correlation Coefficient; SCC: Spearman's Correlation Coefficient. ALMI: Appendicular Lean Mass Index; Fat Free Mass.

**Figure 1.** Correlation between Appendicular Lean Mass Index and Hand Grip.

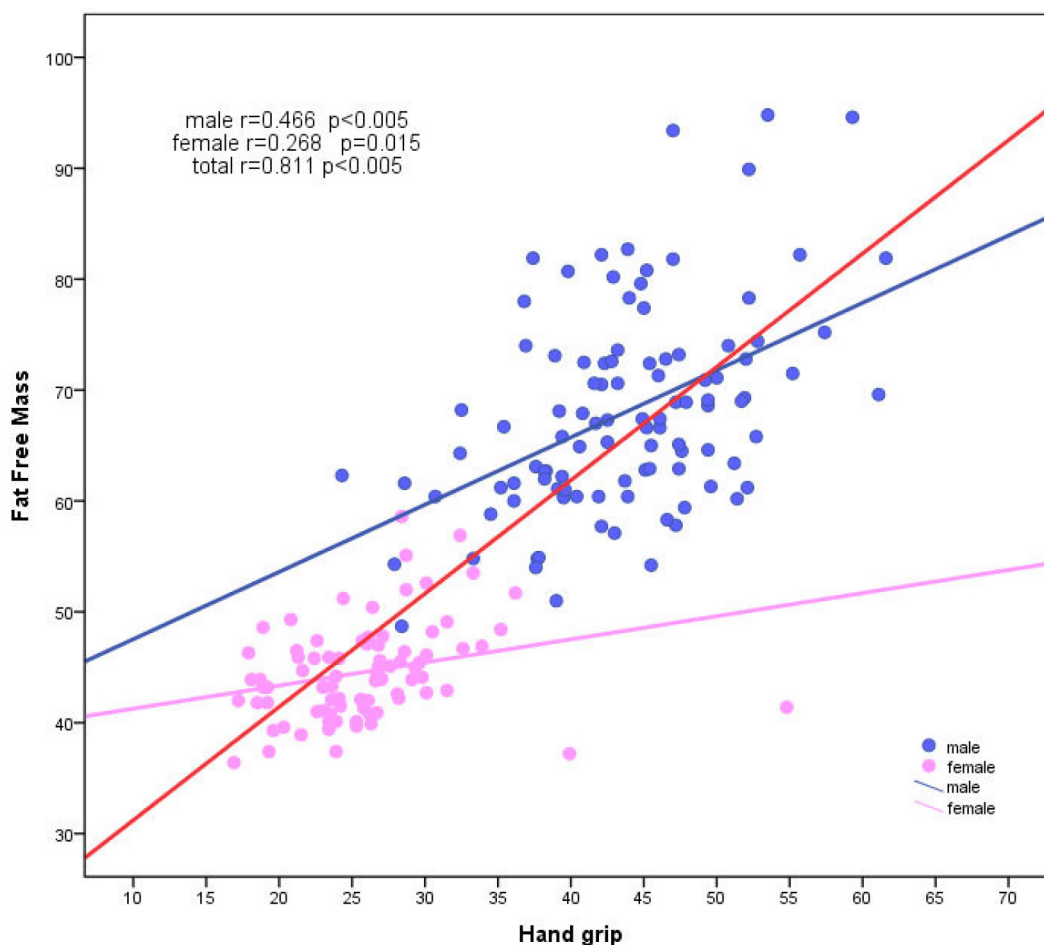


Figure 2. Correlation between Fat Free Mass and Hand Grip.

$\text{kg/m}^2 \pm 1.08 \text{ kg/m}^2$ [9.43,15.11] for males and $9.13 \text{ kg/m}^2 \pm 0.65 \text{ kg/m}^2$ [7.85, 11.08] for females (Table 2).

Muscle mass variables, namely Skeletal Muscle Mass Index (SMMI (BIA)) and their cut-offs that are proposed to be used to set the lower value for the sarcopenia definition in terms of muscle quantity are 9.66 kg/m^2 for males and 7.83 kg/m^2 for females (Table 3).

DXA variables

Appendicular Lean Mass Index for men was (Mean \pm SD (range) $7.35 \text{ kg/m}^2 \pm 0.87 \text{ kg/m}^2$ [5.65, 9.65] and for women $5.30 \text{ kg/m}^2 \pm 0.62 \text{ kg/m}^2$ [4.25, 7.13] (Table 2). Cut-off point of low muscle mass to be used in sarcopenia definition for Appendicular Lean Mass Index (ALMI) are 5.61 kg/m^2 for Greek males and 4.06 kg/m^2 for Greek females (Table 3).

Hand Grip

Males performed better across all age groups and had $43.6 \text{ kg} \pm 7.10 \text{ kg}$ while females had a mean value of $25.92 \text{ kg} \pm 5.65$.

Correlation of variables

We observed a statistically significant high positive correlation between the direct muscle measurements, namely Appendicular Lean Mass Index measured by DXA and Fat Free Mass measured by BIA with hand grip strength for the total population ($r = 0.766$, $p < 0.005$ for ALMI (DXA) and $r = 0.811$, $p < 0.005$ for FFM) (Table 4). When we observed the different subpopulations, this correlation remained statistically significant for both males $r = 0.395$, $p < 0.005$ for ALMI (DXA) and $r = 0.466$, $p < 0.005$ for FFM) and females $r = 0.233$, $p = 0.015$ for ALMI (DXA) and $r = 0.268$, $p < 0.005$ for FFM) as can be seen in Figures 1 and 2.

Discussion

When trying to assume representativeness of a cohort especially in a single center study it is always challenging. Especially when the values measured are used as reference values for an older population as is the case for the definition of cut-off values using an adult sample as normal

control and extrapolate its use for elderly population. We recognize this particularity but if we do not accept this bias we are risking of excluding several similar single center studies used to define reference values in other countries¹⁰. This cohort consists of young adults with higher education that are mainly working in sedentary occupations, in the majority non-smokers with only half of them performing regularly aerobic training and only a small proportion anaerobic training. The percentage of smokers is somehow lower to that reported for Greek adult population by Michas et al. in 2022 where smokers represent 40.9 % of the 18-39 age group of population examined and matches the age our sample while ex-smokers for this age group was 10.2 % similar to our finding¹¹. According to the findings of this study this lower smoking behavior of our sample may be related to the fact that half of the population is moderately active and they are in good health¹¹. Only a small percentage of our population did not attain tertiary education. In 2023, 44.5% of Greeks aged 25-34 held a tertiary education degree, above the EU average of 43.1%¹². Despite the fact that Greece has among the highest rates in Europe of tertiary education attainment for ages 30-34 with, 44.5% of Greeks aged 25-34 holding a tertiary education degree in 2023 as previously reported by the European Commission¹², still our sample is relatively well educated. This may be due to the recruitment approach, where we spread the information about this study firstly to our hospital, and later to offices close to our site and to higher education institutes and the participation to this study was promoted within a specific context. The banner to our hospital site somehow attracted also people of higher education attainment as well. The exercise profile of our population differs from the one described for Greece in the 2022 Eurobarometer report, where 61% of males and 64% of females aged 25-39 are never or seldom having any exercise or sport¹³. In our population only 46.7 % never or seldom have any aerobic exercise. Still though, physical activity level of our population does not significantly differ from that of the Hellenic National Nutrition and Health Survey, that included rural and urban population across Greece and they observed for the ages included in our sample that 35.7 % of people 19-30 years old and 43,1 of people 31-50 years old have low Physical Activity level¹⁴. Sedentarity at work is very high (74.7%) and it is similar to the finding of the same report where 55% of Greeks spend > 5.30 hours sitting¹³.

Despite ethical considerations that discourage classifying ageing as a disease, some authors propose the opposite by arguing that this would facilitate the development of programs and projects that maximize Quality Adjusted Life Years (QALYs) and Healthy Years Equivalent (HYEs) and the existence of multiple actionable disease codes in classifying ageing, including codes for sarcopenia, can be used to target therapeutic interventions¹⁵. In order to fulfill this classification need, it becomes extremely relevant to define sarcopenia in a very accurate and precise way. When compared to those of neighboring countries calculated also

by using BIA, like Türkiye where Bahat et al 2020 found for young men SMM 33.6 ± 3.6 kg [24.1, 44.7] and SMMI 11 ± 0.9 kg/m² (8.4–13.5) and for young women SMM 23.5 ± 1.7 kg/m² [19.7,29.5] and SMMI 9 ± 0.8 (7.4–11.6), our results seem to lay within the same range. In terms of BMI, the same comparison demonstrates similar values. Our male population BMI is 25.67 kg/m² ± 3.65 and the population in the study of Bahat 25.5 ± 3.6 while for female population in our study BMI is 22.35 kg/m² ± 3.14 and in the case of Türkiye 22.4 ± 3.4 ¹⁶. The values of ALMI measured by DXA are similar to those found in a Polish healthy adult sample were low muscle mass cut-off points (2 SDs below) were 6 kg/m² and 4.3 kg/m² (ALMI (DXA) for men and women, respectively¹⁷. When compared to the respective values suggested by the emblematic publication of Cruz-Jentoft et al (2019) we observe different cut-off values. They define the cut-off values for ASMI for males < 7.0 kg/m² and for women < 5.5 kg/m². This is not something that is not observed before. Similarly to our findings where cut-off values are lower than the ones suggested by EWGSOP in a population of 1290 older people from the northeastern part of Brazil they similarly observed that the cut-off values were also lower and for this reason specific cut-off points for muscle mass seems the best approach to accurately assess sarcopenia¹⁸. The fact that the reference values defined in our study differs from the one suggested by EWGSOP2 and the fact that our values do not differ from those estimated in Türkiye in 2020 or in Poland in 2025 and in Brazil in 2021 does not undervalue our study. In the EWGSOP2 consensus paper⁶ reference values for ASM/height² are based on one publication that concerns non European population (namely Australian) back in 2014¹⁹.

In order to establish the validity of our study sample a correlation analysis between the different variables of body composition was performed, namely ALMI that is measured by DXA and FFM that is measured by BIA with hand grip as an index of muscle performance. As the variables related to muscle mass (ALMI by DXA, and FFM by BIA) are increasing the handgrip increased as well.

We provide here reference values of Appendicular Lean mass Index (ALMI (DXA) and Skeletal Muscle Mass Index (SMMI (BIA) to be used for the Greek population aiming to facilitate professionals to better estimate body composition in their everyday clinical practice. We set cut-off points for all measured values at -2 SD as previously described aiming to propose a reference value to evaluate low muscle mass for Greek population. The values for the Appendicular lean mass index (ALMI (DXA) cut-offs are 5.61 kg/m² for males and 4.06 kg/m² for females, which are in the lower range of the values recognized by Walowski et al that published cut-off values measured by DXA between 5.86 – 7.40 kg/m² in men and 4.42 – 5.67 kg/m² in women⁷. The cut-off values for SMMI (BIA) are 9.66 kg/m² for males and 7.83 kg/m² for females.

This is the first study in Greece that evaluates muscle mass variables of healthy male and female young adults aiming to establish cut-off values for the definition of

sarcopenia. Despite the fact that our study sample slightly differs in certain dimensions compared to general population in Greece (educational attainment, smoking habits, physical exercise) it can be considered as a reference sample since our results when compared with respective population samples from neighboring countries or from other European countries they seem to resemble in terms of body composition and performance^{10,17}. This renders our analysis adequate and valid for the purpose of setting reference values for sarcopenia. As internal control of the validity of our sample handgrip strength correlated well with the muscle mass variables of the study population. Another important advantage of this study is that we used two different techniques to evaluate muscle mass of the same population, providing valid measurements that can be applied both in research and in everyday practice. We can claim that our study is representative for a selected population, namely highly educated urban population, non-smokers having sedentary occupation with medium physical activity levels. Further research is needed: 1) in order to verify that our suggested values are true for rural population in Greece, 2) to use these values in sarcopenia prevalence studies in older people and validate them.

Conclusion

Proposed cut-off values for the definition of sarcopenia in Greek population when muscle mass is measured by using DXA are for ALMI 5.61 kg/m² for males and 4.06 kg/m² for females and when measured by using BIA are for SMMI 9.66 kg/m² for males and 7.83 kg/m² for females.

Ethics Approval

The study was approved by the Ethics Committee of Henry Dunant Hospital Center. ID: 3080234A.

Consent to Participate

All participants signed a written informed consent form fully explaining the procedures and the aim of this study prior to their enrollment.

Authors' Contributions

GS, NK conceptualized the study, GS, NK, EZ designed the study protocol, GS, EZ, AM, KA and EG collected the data, AG performed the statistical analysis of the data, GS, EZ, SP, NK interpreted the data, GS made the first draft and EZ, NK, SP, AG, AM, EG, KA revised the document. All authors read and approved the final version of the manuscript.

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