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Lean body mass: reference values for Italian population between 18 to 88 years old

C. DE MESQUITA BARROS ALMEIDA LEITE[1], L. DI RENZO[2], P. SINIBALDI SALIMEI[2], P. GUALTIERI[2], M.E. MADALOZO SCHIEFERDECKER[3], R.M. VILELA[4], H.A. GHIZONI TEIVE[5], C. FREHNER[6], C.A. TACONELI[7], A. CABRAL[8], G. MERRA[9], A. DE LORENZO[2]

[1]Internal Medicine and Health Sciences CHC-UFPR, Curitiba, Brazil
[2]Section of Clinical Nutrition and Nutrigenomic, Department of Biomedicine and prevention University of Tor Vergata, Rome, Italy
[3]Nutrition Department, Federal University of Parana (UFPR), Curitiba, Brazil
[4]Postgraduate Program in Food and Nutrition Safety, Nutrition Department, Federal University of Parana (UFPR), Curitiba, Brazil
[5]Movement Disorders Unit, Neurology Service, Internal Medicine Department, Hospital de Clínicas, Federal University of Paraná (UFPR), Curitiba, Brazil
[6]Clinical Medicine Department of Federal University of Parana (UFPR), Curitiba, Brazil
[7]Statistical Department of Federal University of Paraná (UFPR), Curitiba, Brazil
[8]Laboratório de Estatística Aplicada. Federal University of Paraná (UFPR), Curitiba, Brazil
[9]Emergency Department, "Agostino Gemelli" General Hospital Foundation IRCCS, Catholic University of the Sacred Heart, Rome, Italy

Christiane de Mesquita Barros Almeida Leite and Laura Di Renzo contributed equally to this work

Abstract. – OBJECTIVE: Body's lean mass compartment is a strong predictor of morbidity and mortality risk in various clinical conditions. This paper proposes a simple and easily applied reference table for lean body mass (LBM) and lean body mass index (LBMI) for the Italian population.

PATIENTS AND METHODS: Retrospective analysis of a database containing anthropometric and DXA body composition measurements obtained from a cross-sectional study conducted between 2002 and 2009 with Italian individuals. Parametric and nonparametric tests were performed using R 3.1.1 and SPSS 22.0 software packages.

RESULTS: The 3712 study participants, 37.3% men and 62.7% women, aging from 18 to 88 years. Individuals with normal weight, overweight and obesity were evenly distributed in the sample. LBM and LBMI measures were significantly higher in males. In both genders, there was a significant and progressive decline in these measures associated with aging. Significant differences in LBMI between genders were found in all age groups except for individuals over 75 years.

CONCLUSIONS: Based on the participants LBM profile, a reference table for LBM values was proposed. This reference will be useful to detect changes in the LBM compartment of individuals from the South Central Region of Italy, supporting health professionals during the process of diagnosing sarcopenia.

Key Words:
Nutritional assessment, Body composition, Lean body mass, Dual-energy X-ray absorptiometry, Sarcopenia.

Introduction

Body's lean mass com a strong predictor of life quality, physical and functional capacity of individuals, as well as morbidity indicator and mortality risk in many clinical conditions[1,2]. Once lean body mass (LBM) measurements are obtained, these findings must be compared to reference values for the design of physical or dietetic interventions.

Biological and environmental characteristics such as gender, age, race, ethnicity and lifestyle habits can influence the body compartments composition, and should be considered both in individual care and population studies[3,4].

Other factors that can lead to misinterpretations during body composition assessment are differences in how the body's compartments are defined or how to differentiate various body compartments. Thus, it is important to consider the difference between lean body mass (LBM), fat-free mass (FFM) and skeletal muscle mass (SMM). LBM is

Corresponding Author: Giuseppe Merra, MD; e-mail: giuseppe.merra@policlinicogemelli.it

the sum of body water, total body protein, carbohydrates, non-adipose tissue lipids and soft mineral tissue, therefore excluding the adipose and bone compartments[2,5]. FFM represents the skeletal and non-skeletal muscles, the organs and the connective and bone tissues[2,5]. Conversely, SMM is a component of both systems and hence should not be used interchangeably with either LBM or FFM. Moreover, studies have demonstrated the importance of analyzing body composition data adjusted for height as opposed to the use of absolute values or percentages in order to reduce the risk of classifying individuals as either within or outside of reference standards simply because of varying heights[6-8].

Dual-energy x-ray absorptiometry (DXA) is considered the gold standard method for the evaluation of body compartments. DXA enables the analysis of these compartments to a molecular level, i.e., body mass and bone density, fat mass and soft lean mass, in parts or the whole body at once. It is a fast, non-invasive and safe method, in which radiation exposure is equivalent to between 1 and 10% of that emitted during a chest radiograph[2,9,10]. However, the cost of acquiring the DXA machine is still a limiting factor for its use in clinical practice, especially in small urban or rural centers. Thus, alternative tools to estimate LBM should be created and disseminated so that complete and reliable analyses of body composition could be routinely performed in all health services.

To guarantee reliability, during the assessment of individual body composition, the use of reference tables should take into consideration the population ethnic used to build the reference. Thus, when comparing data from multi-racial populations, such as the NHANES sample, against assessment findings from population groups of other geographical regions the healthcare professional should be cautious[11].

To our knowledge, publications providing comparative tables for total LBM and LBMI are currently unavailable for the Italian population. Thus, this study proposes a table of LBM and LBMI reference values for the South Central region of Italy population.

Patients and Methods

Study Design and Subjects

It was used data from a cross-sectional study conducted by the Human Nutrition Unit of a University with healthy Caucasian adults from the South Central region of Italy between 2002 and 2009. All study participants were volunteers, adults and elderly. Diagnosis of acute or chronic illness, physical disabilities, use of prostheses and medications such as steroids and diuretics were considered exclusion criteria for the study.

Study participants were categorized into 14 subgroups according to their respective gender and age for subsequent comparison of anthropometric and body composition measurements. Body fat percentage (%BF) values were classified by parameters proposed by De Lorenzo et al[12] according to age groups. LBM and LBMI values were compared with reference values Gould et al[13] and with the NHANES 1999-2004 values[11], respectively.

All participants in accordance with the principles of the Helsinki Declaration signed a statement of informed consent. The study was conducted according to the guidelines of the Medical Ethics Committee of the University Tor Vergata (Rome, Italy).

Anthropometric Measurements

After 12-hours of overnight fast, study participants underwent anthropometric assessment. Anthropometric measurements for all participants were performed according to Lohmann et al[14]. Participants were instructed to remove all their clothing, except for undergarments, including shoes, socks and metal objects prior to the assessment. Body weight (in kilograms) was measured to the nearest 0.1 kg, using a balanced beam scale (Invernizzi, Rome, Italy). Height (in meters) was measured using a stadiometer to the nearest 0.1 cm (Invernizzi, Rome, Italy). Body Mass Index (BMI) was calculated using the following formula: BMI (kg/m^2) = body weight (kg)/height (m^2).

Dual X-Ray Absorptiometry (DXA)

Total body composition was assessed by DXA (Lunar DPX and iDXA, G.E. Medical Systems, WI, USA), in accordance with the manufacturer's operation manual. The technique combined a total body scanner, an X-ray source, an internal wheel to calibrate the bone mineral compartment, and an external lucite/aluminium phantom to calibrate the fat compartment. Standard DXA quality control and calibration measures were performed prior to each testing session. Scans were performed with individuals in the supine position. The entire body was scanned starting from the top of the head and moving down the body in a rectilinear pattern towards the feet. The average measurement time was 20 min. The effective radiation dose from this procedure is about 0.01 mSv. The intra and inter subject coefficient of variation (CV%=100 × SD/mean) ranged from 1% to 5% respectively. The coefficient of variation for bone measurements was lower than 1%; data resulted from readings of five subjects scanned six times over a nine-month period were 2.2% for Total Body Fat (TBF) and 1.1% for LBM were found. LBMI was calculated by dividing LBM by height in meters squared[6,7].

Using body composition data obtained through DXA, reference tables for LBM and LBMI values for various age groups of both genders were developed.

Statistical Analysis

R Core Team (2014), version 3.1.1. (R Foundation for Statistical Computing, Vienna, Austria, 2014) and SPSS for Windows, version 22.0 (IBM Corp., IBM SPSS Statistics for Windows, Armonk, NY, USA) software packages were used for statistical analyses. The Shapiro-Wilk test was used to assess the data normality, which were expressed as the median, minimum, and maximum values.

To compare the data between groups by gender, and between subgroups classified by gender and age, the Mann-Whitney test was applied, based on the distribution of the variables. In all data analyses, the level of significance was set at $p < 0.05$.

Results

The study population consisted of 3712 Caucasian Italian individuals, 37.3% male and 62.7% female, aged from 18 to 88 years.

The main anthropometric and body composition characteristics of the sample categorized by gender and age group are shown in Table I. Age was the only individual characteristic in which a statistically significant difference was not found between age subgroups classified by gender. Based on the observed BMI values, there was a high prevalence of overweight in both genders, and in most of the subgroups, the mean values remained at the upper limit line. However, no group was classified as obese. Only the two youngest female and male subgroup can be classified as within the normal weight range. On the other hand, according to %BF values were considered compatible with pre-obesity and obesity in all age groups of men, with the exception of the younger group that presented adequate values. The group of young women presented %BF equivalent to normality, but it was identified obesity in all other age groups.

LBM values were significantly higher in males, comparing to females**.** In both genders, a significant and progressive decline in LBM was associated with aging.

In the male group, median LBM was 57.3 kg, with minimum and maximum values of 26.9 and 122.2 kg, respectively. In the female group, median LBM was 38.9 kg with minimum and maximum values of 15.8 and 95.2 kg, respectively. The subgroup aging from 35 to 44 years had the highest median LBM value for both genders.

Similarly, significant differences in LBMI were found in all age groups when comparing genders, except among individuals older than 75 years. In males, LBMI values were similar in all age groups, and the highest value was observed in individuals aging from 45 to 54 years. This was the only subgroup where a significant difference was found compared to younger age groups. In females, there were small but continuous increases in LBMI associated with aging, with the highest values observed among older individuals. The two youngest female subgroups did not differ between each other, but were significantly different from all of the other subgroups.

All LBMI values were lower than those found in reference standards published by NHANES[11]. Significant differences were observed when comparing reference and measured LBMI values classified by gender and by gender and age subgroups.

The absolute values for LBM and LBMI categorized by gender and age, and distributed into percentile ranks are shown in Table II.

Discussion

In this work, it is proposed a reference patterns table for LBM and LBMI categorized by gender and age in the evaluation of adult and elderly population of a specific region of Italy.

Median values for BMI and BF% observed in the study population are within the mean ranges for these variables as reported by Coin et al[15] in a study of appendicular FFM in a different sample of Italian individuals.

The prevalence of overweight and obesity according to BF% values indicates that the nutrition status of this population is following global trends in obesity development[16].

Table I. Anthropometric and body composition characteristics of the population of the South Central Region of Italy.

AGES	18-88		18-24		25-34		35-44		45-54		55-64		65-74		75-88	
MALE																
N		1384		210		331		254		257		202		102		28
HEIGHT (cm)	175.0	(140.0-197.0)	176.1	(159.0-197.0)	176.5	(150.5-193.0)	176.5	(140.0-195.0)	174.0	(160.0-193.0)	172.0	(153.5-187.5)	170.0	(153.0-185.5)	165.0	(152.5-185.5)
WEIGHT (kg)	84.3	(44.7-195.0)	76.2	(46.7-136.0)	81.0	(44.7-152.0)	89.6	(47.5-181.0)	90.0	(60.3-195.0)	85.7	(50.6-163.2)	83.8	(55.6-142.0)	72.9	(49.0-118.0)
BMI (kg/m^2)	27.7	(16.1-61.5)	24.6	(16.5-44.6)	25.8	(16.1-52.8)	28.5	(17.9-50.1)	29.7	(20.4-61.5)	29.5	(16.3-53.9)	28.5	(18.5-48.0)	27.3	(17.6-38.9)
LBM (kg)	57.3*	(26.9-122.2)	56.9*	(39.5-86.4)	58.0*	(35.3-92.9)	59.3*	(26.9-122.2)	58.6*	(38.5-96.2)	55.5*	(39.2-95.5)	52.4*	(39.0-77.1)	47.4*	(40.2-78.2)
LBM %	66.9	(40.6-99.0)	75.9	(50.8-98.0)	70.7	(45.5-91.1)	65.4	(48.0-99.0)	64.2	(40.6-88.1)	64.2	(43.8-98.0)	64.3	(45.7-92.6)	67.2	(54.4-83.8)
LBMI (kg/m^2)	18.8^{*a}	(12.6-33.1)	18.5^{*b}	(13.9-26.7)	18.8^{*c}	(12.6-29.6)	19.1^{*d}	(13.7-33.1)	19.2^{*e}	(14.1-32.5)	18.8*	(13.5-32.0)	18.4*	(14.1-26.6)	17.7*	(14.3-27.4)
BF (kg)	25.0	(0.9-100.3)	15.6	(0.9-68.5)	19.7	(2.4-80.1)	26.9	(1.9-68.8)	28.7	(5.7-100.3)	28.6	(1.9-70.3)	26.7	(3.1-71.9)	24.4	(6.3-48.3)
BF %	29.6	(2.0-54.4)	20.3	(2.0-50.4)	25.6	(4.3-54.4)	30.7	(3.9-52.9)	32.0	(7.5-52.0)	32.3	(2.0-47.3)	32.5	(5.6-50.6)	32.1	(12.6-42.4)
FEMALE																
N		2328		373		502		405		508		347		142		51
HEIGHT (cm)	161.0	(139.0-196.5)	162.5	(140.0-183.0)	163.0	(145.0-194.0)	162.0	(140.0-182.5)	160.0	(142.5-196.5)	158.0	(139.0-178.5)	155.0	(142.0-173.0)	151.0	(142.0-163.0)
WEIGHT (kg)	68.3	(37.5-158.0)	60.1	(37.8-158.0)	64.3	(37.5-147.4)	71.9	(43.1-143.0)	71.0	(41.6-149.3)	72.7	(48.5-140.0)	71.8	(46.3-117.4)	67.3	(38.0-103.2)
BMI (kg/m^2)	26.4	(15.5-59.8)	22.6	(15.5-59.5)	24.0	(15.6-54.8)	27.9	(16.6-57.6)	27.6	(16.2-52.6)	28.9	(17.7-59.8)	29.6	(18.8-51.6)	29.8	(16.2-46.5)
LBM (kg)	38.9*	(15.8-95.2)	37.4*	(27.1-67.8)	38.7*	(15.8-69.3)	40.3*	(25.8-69.4)	39.4*	(27.8-90.2)	39.2*	(24.3-71.6)	38.3*	(29.7-95.2)	37.2*	(28.1-48.9)
LBM %	56.0	(24.8-159.5)	61.9	(37.4-86.8)	59.5	(24.8-104.0)	54.2	(37.8-89.9)	54.8	(36.0-87.4)	53.2	(33.2-87.3)	52.3	(37.4-159.5)	55.3	(44.6-80.1)
LBMI (kg/m^2)	15.0^{*f}	(5.8-39.4)	14.2^{*g}	(10.5-25.1)	14.5^{*h}	(5.8-27.2)	15.2^{*i}	(11.1-26.1)	15.3^{*l}	(10.6-28.7)	15.6^{*m}	(9.4-25.5)	15.5^{*n}	(11.8-39.4)	16.6^{*o}	(13.0-22.0)
BF (kg)	27.2	(2.5-119.0)	19.5	(5.5-93.4)	23.1	(2.5-79.9)	29.6	(2.9-80.0)	29.4	(7.2-78.5)	31.4	(6.9-119.0)	31.8	(11.7-67.6)	27.2	(4.1-54.6)
BF %	39.9	(5.2-74.2)	33.1	(10.9-59.1)	36.4	(6.2-74.2)	41.5	(5.2-58.7)	41.2	(13.0-56.1)	42.9	(12.6-67.0)	44.6	(23.0-57.7)	40.8	(10.8-52.9)

Values are presented as the median (minimum-maximum) N = number of individuals; BMI = Body Mass Index; LBM= Lean Body Mass; LBMI= Lean Body Mass Index; BF = Body Fat.
Mann-Whitney test between groups and between subgroups: $p<0.001$. * indicates significant differences between gender groups for same parameter; e compared respectively with a, b, c, d has $p<0.001$; f compared respectively with h, i, l, m, n, o has $p<0.001$; g compared respectively with h, i, l, m, n, o has $p<0.001$;

It is important to mention that the categorization of the BMI and %BF values did not agree with each other. Men and women can be classified as being overweight based on BMI results. On the other hand, if the parameter considered is %BF, these same individuals are classified as pre-obese and obese. These findings reaffirm the definitions "metabolically-obese" normal weight (MONW) that represents individuals with normal BMI but with excess body fat, and may develop, or already present, comorbidities related to the metabolic syndrome[17]. De Lorenzo et al[18] in turn, described the Normal Weight Obese (NWO) syndrome, in which the subjects did not present symptoms of the metabolic syndrome, differing from MONW.

In the meantime, the classification of overweight based on BMI in some age groups coincided with higher values of LBM in both men and women. This finding demonstrates one of the shortcomings of classifying nutritional status based only on the weight/height relation, since it does not distinguish body compartments, and may lead to misinterpretations[2,19].

Several authors have reported the influence of age on muscle mass[20,21], LBM[5] and FFM[16,20]. However, in this study, age had a slightly significant effect on the model. This finding confirms reports by Schutz et al[22] that FFM remained constant across age groups, consequently avoiding the need to adjust their reference values for age. Likewise, Kyle et al[20] and Coin et al[15] found that in men and women younger than 60 and 70 years, respectively, the effect of age interfered minimally on the determination of FFM. In a study by Hansen et al[23], age influenced muscle mass values only in women, and the difference was more significant in the assessment based on total body potassium than through DXA.

Inconsistent reports on the role of age in the reduction of LBM can be attributed to several factors. These include lack of standardization in defining tissue compartments, lack of clarification regarding the inclusion of bone tissue affected by osteoporosis in the assessment, small sample sizes affecting the results of statistical analyses, multiracial study populations, and the difference in techniques used to measure LBM. It is notable that our predictive equation, although developed from a small number of easily obtained variables, showed a strong correlation with DXA.

Higher LBMI values in the male group suggest the influence of sexual hormones on the phenotypes of men and women[24,25]. Male LBMI values peaked in the 44 to 55 years age group. In the older age categories lean body mass declined progressively with increasing age. This finding confirms studies reporting that in men, the prevalence of sarcopenia increases during their sixth decade of life[26].

The relationship between hormone levels and LBM in males is a topic of intense investigation[27]. Some authors have detected strong positive associations between testosterone levels and LBM[28,29] while others have suggested that other hormones, such as the thyroid growth hormone (GH) and insulin-like growth factors (IGF-1) also seem to have an anabolic effect that contributes to maintaining LBM[25,30,31].

In females we expected a decline in absolute values of LBM associated with aging, as sarcopenia usually begins by age 50 in parallel with the decline in estrogen levels during menopause[26]. However, the LBMI values we found did not decrease with age. This finding may indicate inaccurate height measurements, as women with osteoporosis can have orthopedic problems that interfere with their posture. This measurement error was also observed by Schultz et al[22] and Coin et al[15], who suggested that decreases in height observed in the elderly population are a challenge in calculating their FFMI. Barlett et al[8] observed increased FFM values, after adjusting for height, with increasing body fatness, and suggested that lean body tissue increases to provide support for excess fat. Nevertheless, it is important to perform LBM analyses adjusting for height in order to avoid inaccurate diagnoses[7]. The differences observed in LBMI values between the Italian sample and the American sample of the 1999-2004 NHANES study[11] underscores the role of ethnic and demographic factors in determining a population's body composition. The American study included Caucasian, Black and Hispanic individuals, and several authors have reported increased LBM in Black individuals[32,33]. It is important to emphasize that the differences in BMI values between these two samples were not statistically significant, which could be explained by variations in the body composition of their respective study participants. BMI impacts, furthermore, on major clinical eventis in patients with other pathologies[34].

The proposed reference values, besides indicating the metabolically active tissue, cover the body extension as a whole, thus facilitating its use in clinical practice.

This work conducted a retrospective analysis of an existing database, and hence, is subject to the

Table II. Percentiles for Lean Body Mass and Lean Body Mass Index categorized by gender and age.

	P5		P10		P25		P50		P75		P90		P95	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
LBM														
18-24	45,54	30,50	49,17	31,80	52,90	34,30	56,90	37,40	62,70	41,90	67,46	47,96	70,97	51,78
25-34	46,45	30,91	48,30	32,90	53,10	35,20	58,00	38,70	64,80	43,70	73,10	49,19	76,75	52,30
35-44	46,67	31,80	49,26	33,44	53,83	35,60	59,35	40,30	65,60	47,10	73,84	52,72	78,31	56,98
45-54	48,00	32,30	49,70	33,27	53,60	36,10	58,60	39,40	65,20	44,90	71,14	50,20	74,50	53,67
55-64	46,31	31,36	47,90	32,90	51,63	35,15	55,50	39,20	61,10	43,95	67,98	49,94	75,58	54,18
65-74	42,82	31,61	44,49	32,64	48,48	34,10	52,45	38,30	58,20	42,05	64,37	48,31	68,00	52,88
75-88	41,44	30,80	41,91	32,10	43,35	33,80	47,40	37,20	60,23	40,40	64,65	45,60	69,21	46,05
LBMI														
18-24	15,55	12,10	16,10	12,50	17,10	13,20	18,20	14,20	19,60	15,50	21,01	17,20	22,77	18,54
25-34	15,35	12,10	16,00	12,60	17,15	13,40	18,80	14,50	20,50	16,30	22,60	18,00	23,85	19,50
35-44	15,70	12,40	16,10	12,90	17,30	13,90	19,10	15,20	20,70	17,70	23,24	19,90	24,87	21,30
45-54	16,30	12,60	16,86	13,07	18,00	14,10	19,20	15,30	1,30	17,40	23,24	19,60	24,84	20,83
55-64	16,11	12,90	16,80	13,10	17,80	14,20	18,85	15,60	20,60	17,60	22,85	19,54	23,97	21,14
65-74	15,50	13,20	15,91	13,51	16,93	14,43	18,40	15,50	19,90	17,30	21,99	19,96	22,98	21,08
75-88	14,80	13,35	15,85	13,90	16,95	14,60	17,70	16,60	18,93	17,45	22,52	18,70	25,34	20,10

P= Percentil; M = Male; F = Female; LBM = Lean Body Mass; LBMI = Lean Body Mass Index limitations inherent to this research design. These include the disproportion between the number of male and female individuals, the small number of elderlies and the lack of information on eating habits, physical activity and hormone levels of the sample.

The impact of decreases in the lean body compartment on an individual's immune competence and physical and functional capacities justifies the need for establishing and disseminating reference standards for normality. The lack of specific references populations affects the validity of comparative study findings, as these may not consider genetic and environmental factors.

In light of this need, the data analysis of this large sample enabled us to describe the quantitative LBM profile of study participants and to generate a proposed reference table. These tools can be useful for detecting decreases in LBM, and in turn assist in the diagnosis of sarcopenia both in individual clinical care and in population studies in the South Central Region of Italy.

Statement of Authorship

All authors contributed to the conception/design of the work; contributed to the acquisition, analysis, or interpretation of the data; drafted the manuscript; critically revised the manuscript; agree to be fully accountable for ensuring the integrity and accuracy of the work; and read and approved the final manuscript.

Conflict of Interest

The Authors declare that they have no conflict of interest.

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