BODY COMPOSITION ASSESSMENT AND NUTRITIONAL STATUS EVALUATION IN MEN AND WOMEN PORTUGUESE CENTENARIANS

A. PEREIRA DA SILVA[1,2,3,4], A. MATOS[2], A. VALENTE[2,5], Â. GIL[2,6], I. ALONSO[2,7], R. RIBEIRO[2,8], M. BICHO[2,6], J. GORJÃO-CLARA[3,4]

1. Alameda Primary Care Health Center, Lisbon, Portugal; 2. Genetics Laboratory, Environmental Health Institute - ISAMB, Faculty of Medicine, University of Lisbon, Portugal; 3. Universitary Geriatric Unit of Faculty of Medicine of Lisbon, University of Lisbon, Portugal; 4. Academic Medical Center of Lisbon - North of Lisbon Hospital Center; 5. Department of Nutritional Science, Atlantica University, Barcarena, Portugal; 6. Instituto Rocha Cabral, Lisbon, Portugal; 7. Nutrition division St Louis Hospital, Lisbon, Portugal; 8. Molecular Oncology Group, Portuguese Institute of Oncology Porto Centre, Porto, Portugal. Corresponding author: Alda Pereira da Silva, Genetics Laboratory, Environmental Health Institute, ISAMB, Faculty of Medicine, University of Lisbon, Portugal, Av. Professor Egas Moniz, 1649-028, Lisboa, Portugal, Phone: +351 217 999 449; Mobile: +351 966649533; Email: alda_pereira@hotmail.com

Abstract: *Objectives:* To assess body composition, nutritional status and its differences between genders in a sample of Portuguese centenarians. *Design:* Observational cross-sectional study. *Setting:* Centenarians recruited in Portugal, able to give informed consent. *Participants:* A total of 252 subjects, with a median age of 100 years, mostly women (77.8%) who accepted to participate in the study, during the period of 2012 to 2014. *Measurements:* Anthropometric data collected (weight, height, BMI, waist circumference, hip and waist/hip ratio) were evaluated according to WHO criteria. A portable tetrapolar bioimpedance analyzer was used to calculate body composition and to assess resting metabolism. Nutritional status was evaluated according to three different criteria: BMI, waist circumference and body fat percentage using anthropometric equations and bioimpedance. *Results:* We observed an overall mean weight of 51.02±11.03Kg, height of 1.55±0.07m and a BMI of 21.07±3.69Kg/m2. For most of the evaluated parameters, we found substantial differences between genders. The prevalence of underweight and overweight were 25.3% and 13.3%, respectively. Only 5 subjects were obese. Overweight subjects were mostly men (W=10.6% vs. M=22.6%), whereas women were more underweight (W=28.7% vs. M=13.2%). When considering the waist circumference, 26.5% were above the cut-off value. Most of centenarians (72.9%) had a healthy level of visceral fat. This measurement was highly correlated with waist circumference (r= 0.687, p<0.001). The mean of body fat mass was 10.69±6.50Kg, fat-free mass 40.87±7.60Kg and total body water 27.54±6.25Kg. According to body fat mass criteria assessed by bioimpedance, the prevalence of obesity in study population was 6.0% with no gender differences (p = 0.225). Obesity prevalence using anthropometric equations was higher (Deurenberg: 77.7% and Gallagher: 42.8%) than the obtained value by bioimpedance analysis, although according to Bland-Altman analysis both equations showed a good agreement (Deurenberg: 95.8% and Gallagher: 97%) with bioimpedance method. The prevalence of hypohydration (12.9%) was tendentiously higher in women compared to men (W= 15.4% vs. M= 5.0%, p=0.087). Despite the frequency of osteoporosis was higher in women (W = 71.85% vs. M = 28.15%), 95% of men revealed criteria for osteoporosis. Resting metabolic rate (RMR) was significantly different between genders using bioimpedance analysis (W= 1123.33± 173.91; M= 1350.10± 188.88; p<0.001) or Harris Benedict equation (W= 934.92± 102.60; M= 1018.85± 171.68; p=0.001). Bland- Altman analysis between methods indicate that there was an agreement of 97.6%. The overall mean metabolic age obtained was 83.52±1.11 years, well below the chronologic age (p<0.001). *Conclusion:* In Portuguese centenarians, clinical and nutritional approach should be improved on the gender basis. In relation to nutritional status, centenarians were more frequently underweight than overweight. The thinness could be a natural process, contributing for the longevity being rather overweight a reducing factor in life expectancy. BMI and waist circumference showed a good correlation with body fat percentage. Despite the results of Bland- Altman analysis, Deurenberg and Gallagher equations are not suitable to evaluate obesity prevalence in centenarians. Harris Benedict equation seems to be a good option to measure RMR in centenaries, when BIA is not available. Body composition and nutritional characterization of Portuguese centenarians are relevant contribution in scientific evidence production for the action plan of healthy ageing in Europe (2012-2020) and also for clinical practice. .

Key words: Centenarians, body composition, bioelectrical impedance, anthropometry, nutritional status, genders.

Introduction

The most recent Portuguese population projections demonstrate that the number of very elderly individuals is increasing in agreement with other regions of the world (1, 2). In Portugal, trends on population growth of individuals with 100 years old or more, showed an index of increasing longevity from 39% in 1991, to 41% in 2001, and to 48% in 2011 (3). This rapidly growing very elderly population, which is not in scope of most studies on aging, conveys the need to understand and characterize this group from several perspectives with a purpose of to be able to give some input in the assessment of nutritional status foreseeing the wellbeing of the elderly and still be able to contribute to the knowledge of the phenomenon of longevity unrevealing some of its "secrets".

Aging has been associated with significant changes in

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body composition, body fat distribution, and resting metabolic rate (RMR) (4–6), with a decline in fat-free mass (FFM) and an increase in body fat particularly in the trunk (4, 7, 8). Considering that the amount of FFM has functional significance in aging, the decline of FFM seems to be responsible for the age-related waning in RMR, a determinant of physical strength and independence in elderly people, and a modulator of immune competence (9, 10). However, even though body composition and sarcopenia in aging individuals have been subject of several studies, only limited data exists in extreme groups of age, such as centenarians.

Human body composition is an important factor in nutritional status, both at the individual and population level. Understanding the changes in body size, shape and composition with ageing and their health implications is important for the nutritional support, and pharmacologic treatment of elderly and for the development of appropriate health guidelines targeting the well being of the elderly (11, 12). Bioimpedance methods are innocuous, easy to handle, highly reliable and present good correlation with other more sensible methods to evaluate body composition (13–15).

Changes in body composition seem to be involved in decreased ability to perform daily life activities, often associated with aging. Notwithstanding, these features might be informative to allow the implementation of adapted programs to optimize centenarians quality of life. According to our knowledge this is the first epidemiological study, in Portuguese centenarians and seems to us a high-priority study given the population eldering. The present study aims to access body composition and nutritional status in men and women Portuguese centenarians.

Material and Methods

Population and enrollment

A sample of 252 individuals was studied being 196 women (W) and 56 men (M), with a mean age of 100.26±1.99 years old, recruited in Portugal. The identification of centenarians was done by consulting various editions of the Journal of Authorities and collection of elements from all districts of the country. Centenarian's contacts were obtained through the Presidents of the Parish Councils, namely telephone, email or addresses of Retirement Homes of Social and Parish Centers and Holy Houses of Mercy. Before enrollment, previous contacts were done with Authorities, Institutions of Elderly, Homes of Mercy and Health Centers, private charity and private social and health establishments, throughout the country, to confirm eligibility of centenarians to be included in the study. In a total of 3328 established contacts were identified 332 centenarians that met the study objectives and inclusion criteria and agreed to participate. Visits were, then, scheduled and subjects enrolled (n = 262) after giving authorization themselves and their caregivers, family and when applicable the institution. After scheduled, 10 individuals (3.69%) refused to participate. All Portuguese individuals that were able to communicate and give their informed consent were included. At the end of a two years period of recruitment and fieldwork, from 2012 to 2014, a sample of Portuguese centenarians living in Portugal, were finally included. Exclusion criteria for bioimpedance measurements were the presence of implanted electronic devices or body metal implants.

This study was approved by Scientific and Ethics Committees of the Lisbon Academic Medical Centre (Faculty of Medicine of the University of Lisbon and Santa Maria Hospital) and by the National Commission for Data Protection, and was conducted in agreement with the Helsinki Declaration (16).

Anthropometry and body composition measurements

Height data was obtained using ADE® ultrasonic stadiometer (ADE GmbH & Co,. Hamburg, Germany) with a precision of 5 mm. Waist circumference was measured, nearest 1 mm, using a non extensible metric tape. Waist circumference was measured at the midpoint between the lower rib margin and the iliac crest, normally umbilical level (17–19) and, for obese individuals, the assessment of measure was the level of the umbilicus at the end of the expiratory movement (20, 21). The hip circumference was obtained by measuring the level of trochanter points (left and right) through the gluteus prominence around the widest portion of the buttocks, with the tape parallel to the floor (18). The ratio between waist and hip was then calculated (waist-to-hip ratio) considering cut-off for abdominal obesity waist–hip ratio greater than or equal to 0.90 for males and 0.85 for females (18). Abdominal obesity, pre-obesity and obesity were defined according to WHO criteria (18, 22).

In order to determine centenarian's weight and body composition information, we used a portable tetrapolar bioelectrical impedance device Tanita® BC-420MA (Tanita corporation of America, Inc, Illinois, USA), which measures body composition using a constant current source (50kHz, 90μA) (23). At 50 kHz, the current passes through both intra- and extracellular fluid, although the proportion varies from tissue to tissue, allowing the determination body compartments in subjects without significant fluid and electrolyte abnormalities (24). The elderly were evaluated wearing light clothing and without shoes and socks.

This equipment provides estimated values for each measured value of body fat percentage, fat mass, fat-free mass, muscle mass and bone mass by the dual X-ray absorptiometry (DXA) method, estimated value for the total body water measured value by the dilution method and estimated value for the visceral fat rating by magnetic resonance imaging (MRI) method using the Bioelectrical Impedance Analysis (BIA) method (23). The following parameters were registered: weight (kg), body mass index (BMI) kg/m^2, fat mass (FM), kg and %, visceral fat score, fat-free mass (FFM) kg, muscle mass (MM) kg, total body water (TBW) kg and %, bone mineral mass (BMM) kg, resting metabolic rate (RMR) Kcal and KJ, metabolic age (based on standard value for muscle mass and metabolic rate) and impedance value. Using data from these measurements, we calculated for each subject the indexes of lean body mass [(FFM (kg)/height (m^2)] and of fat mass [FM (kg) /height (m^2)]. Resting metabolic rate was also calculated by application of Harris-Benedict formula (25) and these results were compared with BIA method values using Bland-Altman analysis (26). Deurenberg (27, 28) and Gallagher (29) anthropometric equations were used to evaluate obesity prevalence according to fat mass criteria. The results obtained were compared to bioimpedance. The cut-off values for fat mass, according to genders, were established with agreement to WHO guidelines (22).

The TBW is the total amount of body fluid expressed as a percentage of their total weight. The hypohydration was defined as the status being in negative water balance (a water deficit) (30). According with Tanita´s internal research references for hypohydration, were considered the following values: less than 45% or 50% for women and men, respectively (23).

For osteoporosis evaluation we take into account the criteria established by manufacture's instruction of Tanita Corporation based on bone mass estimated by bioimpedance analysis, depending on the weight and sex and was considered its presence in the case of being a woman, bone mass less than 1.95 /2.40/ 2.95Kg for weights < 50 / 50-75 / ≥75Kg respectively; being a man bone mass less than 2.66 /3.29/ 3.69Kg for weights < 65 / 65-95 / ≥95Kg respectively (31).

Subjects with difficulty to stand up or to stay stabilized on foot were excluded from the weight, and hip measurements. People with implanted electronic devices, were evaluated using a non-electric device BR2016 scale (Camry Electronic Co., Ltd, Guangdong).

Statistical analysis

Analysis were conducted with SPSS version 21.0 (SPSS Inc, Chicago) software. Data is presented as mean ± standard deviation (M ± SD) for quantitative variables and as number (percentage) for qualitative values. All variables were tested for normality using Kolmogorov-Smirnov. The adequate parametric or non-parametric tests were used to compare means and to correlate variables. The Chi-square test was used for categorical variables, whereas means comparisons between groups were achieved by application of the t-test or Mann-Whitney test. To evaluate correlation between normal continuous variables, a model of simple linear regression was used. Bivariate associations between non-normal numeric variables were assessed using Spearman correlation coefficient. All results were considered statistically significant when $p<0.05$.

Results

Two hundred and fifty two Portuguese centenarians have accepted to participate in this study, 196 (77.8 %) women (W) and 56 (22.2%) men (M).

Demographic data are depicted in Fig. 1 and Table 1. Note that, the province with the higher prevalence of centenarians was Beira Baixa (Castelo Branco district: 17.86% M vs. 14.29% W), followed by Estremadura (Lisbon district: 7.14% M vs. 13.27% W).

Figure 1
Portuguese map depicting the demographic placement of centenarians included in this study. Dots are representative of women and triangle of men. VC, Viana do Castelo; BRAG; Braga; BRÇ, Bragança; VR, Vila Real; GUA, Guarda; V, Viseu; OPORTO, OPorto; AV, Aveiro; COI, Coimbra; L, Leiria; CB, Castelo Branco; ST, Setúbal; LX, Lisboa; PL, Portalegre; E, Évora; B, Beja; S, Santarém; F, Faro

Global sample age ranged from 97 to 109 years with an average of 100.26±1.99, median of 100 years (mean age: W=100.32±1.95 years; M=100.07±2.12) (Table 2).

Noteworthy, 72.2% of the centenarians were observed in elderly homes (nursing homes), 19.8% at their residence with family, 4.4% in religious congregations, in host families and hospitals; and 3.6% were found living alone. At the time of our survey most centenarians were widowed (82.9%), albeit some were singles (13.5%), others married (2.4%) and only a few divorced (1.2%). Regarding the number of children per each

Table 1

Distribution of centenarians included in this study by gender and according to Portuguese districts and provinces. The total corresponds to the representatively of each district (N (%)). VC, Viana do Castelo; BRAG; Braga; BRÇ, Bragança; VR, Vila Real; GUA, Guarda; V, Viseu; OPORTO, OPorto; AV, Aveiro; COI, Coimbra; L, Leiria; CB, Castelo Branco; ST, Setúbal; LX, Lisboa; PL, Portalegre; E, Évora; B, Beja; S, Santarém; F, Faro

DISTRICT	LOCALLY	FEMALE N	MALE N	TOTAL N (%)	DISTRICT	LOCALLY	FEMALE N	MALE N	TOTAL N (%)
	PROVINCE OF MINHO					**PROVINCE OF BEIRA ALTA**			
VC	Viana Castelo	7		13 (5.2)	GUA	Guarda	2		18 (7.1)
	Guilhadeses	2				Dornelas	3		
	Arcos de Valdevez	1				Almeidinha	1		
	Vila Chã S João/	1				Lageosa do Mondego	2		
	Ponte da Barca	1				Sabugal	2		
	Lavradas/Lugar da Bemposta	1				Soito	1		
BRAG	Aveleda/Braga	1		3 (1.2)		Celorico da Beira	3	2	
	Sto Estevão/Bastuço/Barcelos	1				Moimenta da Serra	2		
	Estorãos	1			V	Mangualde	3	2	21 (8.3)
	PROVINCE OF TRÁS OS MONTES					Casais		1	
BRÇ	S. Pedro Silva	1		12 (4.8)		Freixiosa	1		
	Miranda do Douro		2			Santiago de Cassurães	2		
	Mirandela	3				Freixedo/Santa Comba Dão	1		
	Mogadouro	1	1			Covelo/Valadares	1		
	Paloçoulo	1				Ançada	1		
	Vila Flor	1	1			Farminhão		1	
	Ervedosa/Vinhais		1			Rojão Grande	1		
VR	Vila Seca		1	8 (3.2)		Castelo de Penalva	2		
	Casal de Além/Oliveira	1				Penalva do Castelo	2		
	Vila Real	1				Regada/Vila Maior	1		
	Alijó	1				Vila Mendo de Tavares	1		
	Sanfins do Douro		1			Sabugosa/Tondela	1		
	Boticas	1	1						
	Cerva	1							
	PROVINCE DOURO LITORAL					**PROVINCE OF ESTREMADURA**			
OPORTO	Vila Nova Gaia	1		14 (5.6)	ST	Pragal	1		7 (2.8)
	Porto	1	3			Almada	1		
	S. Miguel Souto		2			Alcácer do Sal	2		
	Leça do Balio	5				Lagoa de Albufeira		1	
	Santo Tirso	1	1			Cova da Piedade	2		

Table 1 (cont.)

	PROVINCE OF BEIRA LITORAL				LX	Lisboa	20	2	
AV	Aveiro	2		7 (2.8)		Restelo	1		30 (11.9)
	Oliveira de Azeméis	1				Vila Franca de Xira	2		
	Branca/Albergaria-a-Velha	1				Campolide	2		
	Mealhada	1				Azambuja		2	
	Luso		1			Rocha Forte/Lamas	1		
	Estarreja	1							
						PROVINCE OF BEIRA BAIXA			
COI	Semide	2		12 (4.8)	CB	Covilhã	1	2	38 (15.1)
	Miranda do Corvo	2				Ourondo	3		
	Arganil		1			Teixoso	1		
	Salgueiro/Folques	1				Proença-a-Nova	3		
	Côja	1				Castelo Branco	5	1	
	Coimbra	2				Monsanto	3	1	
	São Pedro de Alva	2				Póvoa de Rio de Moinhos	1		
	Penacova		1			Belmonte	1		
	PROVINCE OF ESTREMADURA					Maçainhas	1		
L	Salir de Matos	1		12 (4.8)		Maçainhas/Belmonte	1		
	Mira de Aire/Minde	1				Gaia	1	1	
	Pombal	2	1			Paúl	2	1	
	Vergieiras/Marinha Grande	1				Proença-a-Velha	2	2	
	Vidais/Caldas da Rainha	1				Alcains		1	
	Casal Celão /Serra do Bouro		1			Vila de Rei	3	1	
	Alcobaça	2							
	Benedita	1							
	Alfeizerão	1							
	PROVINCE OF ALTO ALENTEJO					**PROVINCE OF RIBATEJO**			
PL	Cabeças	1		5 (2.0)	S	Santarém	3		10 (4.0)
	Aldeia da Mata	2				Entroncamento	1		
	Santiago de Urra	2				Alpiarça	1	1	
E	Vendas Novas	4		14 (5.6)		Chamusca	1		
	Mora	2	1			Golegã	1		
	Brotas	1				Delongo	1		
	Cabeção	2				Grou / Asseiceira /Tomar		1	
						PROVINCE OF ALGARVE			
	Évora		5		F	Tavira	1	1	21 (8.3)
	PROVINCE OF BAIXO ALENTEJO					Faro	4		
B	Baleizão/Beja	1		6 (2.4)		Albufeira		1	
	Albernoa	1	1			Armação de Pêra	2	1	
	S. João Negrilhos/Montes Velhos	1				Portimão	3		
	Mértola	1	1			São Braz de Alportel	1	3	
						Paderne	2		
						Alcantarilha	2		

Table 2
Anthropometric and body composition characteristics of Portuguese centenarians, overall and compared by gender

	N	Min. – Max.	Overall mean ± SD	N	Women mean ± SD	N	Men mean ± SD	p value
Age (years)	252	97-109	100.26±1.99	196	100.32±1.95	56	100.07±2.12	0.417
Weight (Kg)	241	29.3-89.3	51.02±11.03	188	48.69±9.83	53	59.28±11.18	<0.001
Height (m)	252	1.38-1.78	1.55±0.07	196	1.53±0.06	56	1.62±0.07	<0.001†
BMI (kg/m2)	241	12.29-34.03	21.07±3.69	188	20.70±3.55	53	22.41±3.88	0.018
Waist (cm)	227	56-120	85.30±10.85	177	82.99±9.66	50	93.48±10.98	<0.001†
Hip (cm)	199	76-137	97.43±9.24	153	97.52±9.42	46	97.15±8.74	0.586
Waist/ Hip	199	0.68-1.09	0.88±0.08	153	0.86±0.06	46	0.96±0.06	<0.001
Fat Mass (kg)	166	0.9-40.9	10.69±6.50	126	10.56±6.90	40	11.10±5.07	0.717
Fat Mass (%)	166	3-45.8	19.60±9.50	126	20.06±10.39	40	18.20±5.71	0.235
Deurenberg (%)	241	19.90-55.30	36.78±5.99	188	38.75±4.52	53	29.76±5.24	<0.001
Gallagher (%)	241	14.10-53.30	32.31±6.46	188	34.25±5.15	53	25.40±5.90	<0.001
Muscle Mass (kg)	166	24.5-59.8	38.78±7.23	126	36.77±6.27	40	45.11±6.40	<0.001
Muscle Mass Index (kg/m^2)	166	10.75- 23.07	15.910±2.35	126	15.55±2.29	40	17.04±2.20	<0.001
Fat-free Mass (kg)	166	25.8-63	40.87±7.60	126	38.75±6.60	40	47.54±6.40	<0.001
Lean Mass Index (kg/m^2)	166	11.36-24.30	16.76±2.47	126	16.39±2.41	40	17.95±2.31	0.001
Fat Mass Index (kg/m^2)	166	0.37-15.58	4.38±2.64	126	4.42±2.81	40	4.23±2.03	0.513
Bone Mass (kg)	166	1.3-3.2	2.09±0.37	126	1.98±0.32	40	2.43±0.32	<0.001†
Bone Mass Index (kg/m^2)	166	0.61-1.23	0.86±0.12	126	0.84±0.12	40	0.92±0.11	<0.001
Total Water (%)	163	38-84.6	53.77±7.96	123	52.37±7.75	40	58.06±7.12	<0.001
Total Water (kg)	163	15.4-44.7	27.54±6.25	123	25.54±5.07	40	33.70±5.20	<0.001
TBW/FFM (%)	163	59.69-88.35	67.03±4.38	123	65.80±3.23	40	70.82±5.24	<0.001†
RMR (Kcal)	166	793-1776.0	1177.97±202.01	126	1123.33±173.91	40	1350.10±188.88	<0.001
RMR (KJ)	166	3318.0-7431.0	4928.70±845.18	126	4700.10±727.63	40	5648.800±790.30	<0.001
Harris & Benedict (Kcal/day RMR)	241	678.11- 1436.72	953.38± 125.71	188	934.92±102.60	53	1018.85±171.68	0.001
Impedance (Ω)	166	171-846.7	439.01±119.90	126	451.76±124.89	40	398.84±93.00	<0.001
Visceral Fat Score	166	6-22	10.83±3.56	126	9.27±2.05	40	15.75±2.73	<0.001†
Metabolic Age (years)	166	80-90	83.52±1.11	126	83.53±1.17	40	83.48±0.88	0.707

BMI, body mass index; TBW, total body water; FFM, fat-free mass; RMR, resting metabolic rate; SD, standard deviation; Independent samples t–test was used to compare differences between genders, except for variables marked with † (Mann–Whitney test was used).

individual of the sample (median±SE of 2±0.136) we found a considerable number of individuals without children (n = 54; 21.4%) and, of these, 12 (22.2%) were men and 42 (77.8%) women. From the total sample individuals, 63.5% had 2 or less children.

Concerning anthropometric and body composition of the participants and according with selected criteria described in methodology, 11 centenarians did not meet the criteria for inclusion in the weight, 86 to bioimpedance, 25 for waist circumference and 53 for the hip measurement. Table 2 shows overall data, that evidences a mean weight of 51.02±11.03kg, range 29.3-89.3Kg and a height of 1.55±0.07m, range 1.38-1.78m. According to the evaluation of BMI, circumferences of waist and hip and fat mass, a low adiposity phenotype was observed in this very elderly population (Table 2).

Comparison of the evaluated parameters between genders is also shown in table 2. Notably, almost all anthropometric and body composition variables differed significantly between genders namely, measures that inform about localized fat depots (waist, waist-to-hip ratio and visceral fat score), that showed higher abdominal fat in very elderly men, compared with women ($p < 0.001$) (Table 2). While 91.3% of men had waist-hip ratio greater than the cut-off value, only 53.6% of the women presented this condition (Table 3).

We noticed differences in the distribution of BMI subclasses between gender ($p = 0.014$). Most underweight individuals (BMI <18.5, n=61) were women (88.5%). Only 5 individuals in the sample were obese (class I), 3 of them were men (Table 3).

According to body fat mass criteria assessed by bioimpedance, the prevalence of obesity in study population

Table 3
Gender distribution of anthropometric and body composition characteristics of Portuguese centenarians, according to standard cut-offs

	Overall N (%)	Women N (%)	Men N (%)	p value
TBW <45% (♀) or <50% (♂)	21 (12.9)	19 (15.4)	2 (5.0)	0.087
Body fat mass >35% (♀) or >25 (♂)	Deurenberg: 129 (77.7)	97 (77.0)	32 (80.0)	0.690
	Gallagher: 71 (42.8)	54 (42.9)	17 (42.5)	0.968
	Bioimpedance: 10 (6.0)	6 (4.8)	4 (10.0)	0.225
Osteoporosis Criteria- Presence†	135 (81.3)	97 (77.0)	38 (95.0)	0.011
Visceral fat score >12	45 (27.1)	7(5.6)	38(95.0)	<0.001
Waist circumference >88 (♀) or >102 (♂)	60 (26.5)	49 (27.8)	11 (22.0)	0.409
Waist/Hip ratio ≥0.85 (♀) or ≥0.90 (♂)	124 (62.3)	82(53.6)	42 (91.3)	<0.001
Underweight (BMI<18.5)	61 (25.3)	54 (28.8)	7 (13.2)	0.014
Normal weight (BMI≥18.5 and <25)	148 (61.4)	114 (60.6)	34 (64.2)	
Overweight (BMI≥25)	32 (13.3)	20 (10.6)	12 (22.6)	
Pre-Obesity (BMI≥25 and <30)	27 (11.2)	18 (9.6)	9 (17.0)	0.527
Obesity (BMI≥30)	5 (2.1)	2 (1.1)	3 (5.7)	

TBW, total body water; ♀, woman; ♀, man; † osteoporosis criteria – being a woman, bone mineral mass (BMM) less than 1.95 /2.40/ 2.95Kg for weights < 50/50-75/≥75Kg, respectively; being a man, BMM less than 2.66/3.29/3.69Kg for weights <65/65-95/≥95Kg, respectively; BMI, body mass index; The values showed refer to absolute frequencies (relative frequencies). The p values refer to differences in the distributions of categorical variables between genders.

was 6.0%, with no gender difference (p = 0.225). Obesity prevalence using anthropometric equations, however, was higher (Deurenberg: 77.7% and Gallagher: 42.8%) than the achieved value obtained by bioimpedance analysis (Table 2). Nevertheless, according to Bland-Altman analysis, both equations showed a good agreement (Deurenberg: 95.8% and Gallagher: 97%) with bioimpedance method (Fig. 2a and 2b, respectively).

The prevalence of hypohydration (12.9%), was tendentiously higher in women compared to men (W= 15.4% vs. M= 5.0%, p=0.087) (Table 3).

Resting metabolic rate were significantly different between genders using bioimpedance analysis (W= 1123.33± 173.91; M= 1350.10± 188.88; p<0.001) or Harris Benedict equation (W= 934.92± 102.60; M= 1018.85± 171.68; p=0.001). Bland Altman analysis between methods indicate that there was an agreement of 97.6% (Fig. 2c).

We observed a direct linear correlation between waist circumference and body fat mass (r= 0.652; p <0.001) (Fig. 3a) and with visceral fat (r= 0.687; p <0.001) (Fig. 3b) in both women (r= 0.643, p <0.001) and men (r= 0.868, p <0.001); body fat mass also correlates with BMI (r=0.793, p <0.001) (Fig. 3c). The RMR showed a strong correlation with FFM (r= 0.993, p<0.001) (Fig. 3d).

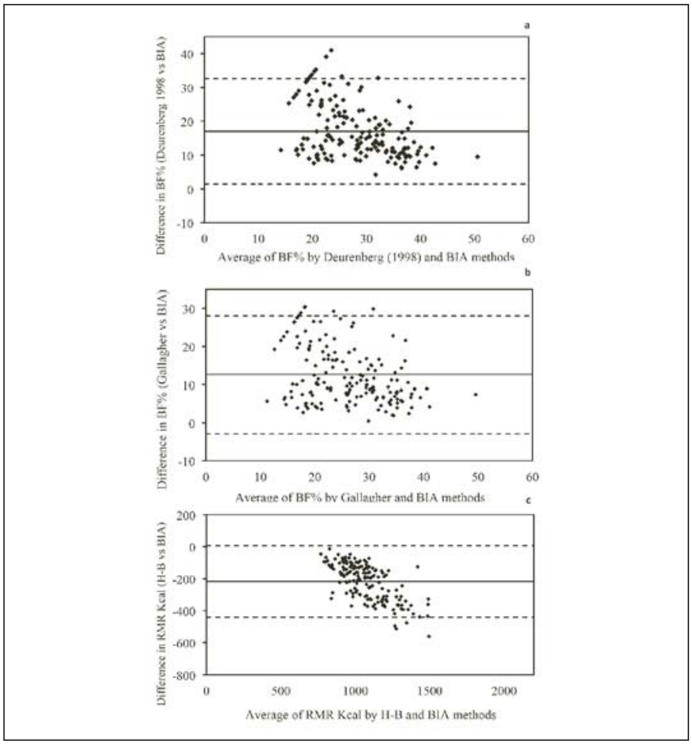
In this population the average of metabolic age (83.52±1.11 years, range 80-90) was well below the chronologic age (100.26±1.99 years, range 97-109), p<0.001 (Table 2). We observed that the age was inversely correlated with weight (r= -0.187 p= 0.004), BMI (r= -0.149 p= 0.021), RMR (r= -0.232 p= 0.003), TBW (r= -0.242 p= 0.002), MM index (r= -0.249 p= 0.001) and BMM index (r= -0.251 p= 0.001).

Despite frequency of osteoporosis criteria had been significantly higher in women (W = 71.85% vs. M = 28.15%, (p=0.011), 95% of total men showed osteoporosis criteria (Table 3). Muscle and bone mass indexes showed a direct correlation each other (r=0.989, p<0.001).

Discussion

This paper describes the body composition and nutritional status of a centenarians sample of the Portuguese population, residents in Portugal. Few studies are available in centenarian individuals body composition status and, according with our knowledge, this is the first study that evaluates body composition and nutritional status in Portuguese centenarians. There are in the world, yet few studies in this area but, given the existence of an increasing number of people in this age group, an aging population, it is necessary to make this assessment, in order to find action plans that will meeting the needs of older, with an intervening action at this level. The sample of our work consists of 252 elderly, where the average of age is 100.26±1.99, median of 100 years. Of the total sample, 38.6% has in fact less than 100 years and 39.0% were beyond the age of 100 years with a range of amplitude of 12 years. Given the difficulty of recruitment and assessment of the elderly, we understand to accept in our study centenarians and near centenarian's individuals, namely over 97 and less than 110 years, but mostly with 100 years old, that we expect they can translate the behavior of the centenarian population of our country.

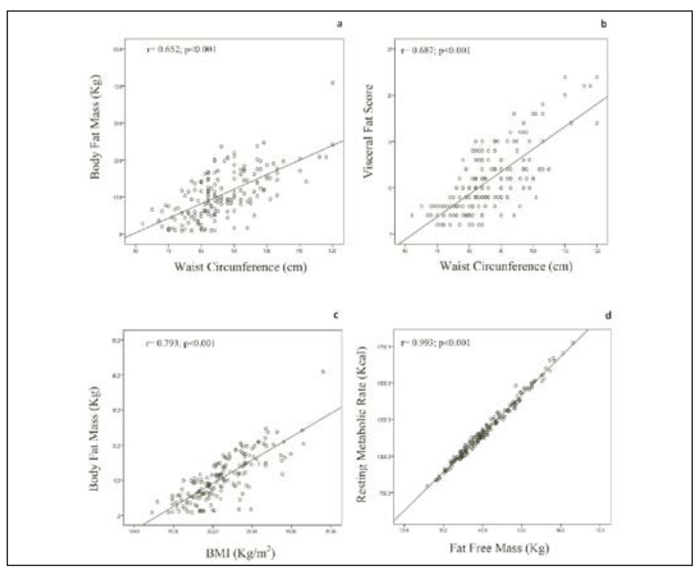
Figure 2
Bland-Altman analysis between methods Deurenberg and Gallagher with bioimpedance (figure 2a and 2b, respectively) and Harris Benedict (H-B) with bioimpedance (figure 2c)



We found in our study a predominance of 3.5 more times centenarian women over men being our sample, representative of the Portuguese population, according to the last census (3). We also verified higher density of centenarians in the metropolis, consistent with Italian studies, showing that urban centers may support extreme longevity, eventually by providing better sanitary care, as well as by yielding technological, cultural and economic resources (32). Similarly in the innermost region of the country, the higher frequency of centenarians observed can be explained by the lifestyle of the inhabitants, calmer and less stressful, living in this quiet area of hills (Serra da Estrela, Serra da Malcata and Açor).

Concerning anthropometric measurements, in our sample, is interesting to note that obesity was rare. Most individuals were within a normal (61.4%), or underweight (25.3%) BMI category for WHO, as observed in other studies reporting that centenarians are usually thin (2,14,15). It is known that obesity increases the risk of mortality (33) and reduces life expectancy (34,35). This is in accordance with the obese rarity observed in our sample. In fact we found that the centenarians from Portugal presented an height, within the expected range for the Portuguese born in the first decades of the twentieth century, but low average weight (36). Height and weight of Portuguese centenarians are similar to reported anthropometric characteristics in Italian centenarians (13,37,38). If the thinness seems to be a favorable factor to longevity cannot be, however, neglected the possibility of malnutrition, which should be considered in the clinical approach in elderly. It should be noted that, for older populations, being overweight was not found to be associated with an increased risk of mortality, quite the contrary, there was an increased risk for those at the lower end of the recommended BMI range for adults. Despite much controversy, studies have supported the idea that a BMI <23 or> 33 Kg/m2, is considered a mortality risk for an elderly population, and that the WHO healthy weight range (BMI: 18.5-24.9) may not be suitable for older adults (39). According to this criterion, 71% of our population would be at risk, since it has a BMI< 23 and possibly present malnutrition, especially women, the most affected (W = 74.5 vs. M = 58.5%) being important the monitoring weight status in these individuals, addressing modifiable causes. Instead, only one woman had a BMI> 33. From another perspective, however, the thinness could be a natural process, contributing for the longevity of our sample subjects, being rather overweight a reducing factor in life expectancy.

Figure 3
Correlations between body fat mass and waist circumference (a); body fat mass and visceral fat score (b); body fat mass and body mass index (c); fat-free mass and resting metabolic rate (d)



Regardless of BMI, studies point to the importance of waist circumference. It was found in a meta-analysis that the WHO cut-off points of 102cm in men and 88cm in women were associated with all-cause mortality relative risks for elderly people even across BMI categories (18,40). Interestingly, findings from the present study show that

Portuguese centenarian both genders, were below that cut-offs. In this sample, women have low waist (82.99±9.66 cm) and slightly above waist-hip ratio (0.86±0.06), which are considered for increased risk, and that are comparable with Italian centenarians (38,41). The values found for very-elderly men differed from women but, likewise, were below (waist circumference) or slightly above (waist hip ratio) of reference values considered of risk (Table 3). In this way, our work suggests that, due to the changes in the distribution of body fat with fat mass loss in the hips, particularly in women, the cut-off of 0.85 for cardiovascular risk given by the conventional waist-hip ratio may be adjusted for this age group and gender.

On the other hand, it is known that the benefit of caloric restriction on longevity may be due to the attenuation of visceral fat (42). This overextension of abdominal girth may correspond to a critical accumulation of visceral adipose tissue and increased risk for cardiovascular diseases (43, 44). In agreement, it was shown that surgical removal of visceral fat can improve lifespan (45). Waist circumference is a good indicator of visceral fat for both genders (46, 47), indeed, we obtained a good correlation of visceral fat score with waist circumference, that confirm the previous observation (Fig. 3b).

Therefore, Portuguese centenarian men seem to have a worst adiposity profile than women, which may confer them with higher morbidity and risk to develop fatal diseases. This hypothesis seems to be corroborated by the relative frequency of genders in the Portuguese centenarian population, where women clearly prevail over men (77.6% vs. 22.4%) (3). Our data from visceral fat score, confirmed the healthiest level of abdominal fat in women compared to men (median 9 vs. 15, respectively). From a maximum score of 59 in visceral fat (23), we observed that Portuguese centenarians had at the most the visceral fat score of 17 in women and 22 in men, representing a very low value that reduces the risks for coronary artery disease, stroke, and death (48). Taken together, these findings seem to corroborate the extreme longevity of individuals in our study.

According to body fat mass criteria assessed by bioimpedance, the prevalence of obesity in study population was 6.0% with no gender difference (p = 0.225). However, obesity prevalence using anthropometric equations was higher (Deurenberg: 77.7% and Gallagher: 42.8%) than the obtained value by bioimpedance analysis, although according to Bland-Altman analysis both equations showed a good agreement (Deurenberg: 95.8% and Gallagher: 97%) with bioimpedance method. The assessment of BF% from BMI, sex and age can estimate body composition (27–29). However, according to our results, do not appear to be an alternative to the use of bioimpedance, since over-estimate the results determined by the latter.

As for the body water, we note that hypohydration was found in 12.9% of the sample subjects, similar results (11.2%) were found by Buffa et al. (2010) (38). We found it tendentiously more prevalent in women compared to man (15.4 vs. 5.0%) (Table 3).

Changes in body composition during the aging process involve, besides the decrease in total body water, a decrease in bone and muscle mass (49). Indeed, the relative amount of fat-free mass decreases with advancing age (50). Aging is associated with involuntary loss of weight, largely due to involuntary loss of fat-free mass (muscle, organ, tissue, skin and bone), of body cell mass (cachexia), and of skeletal muscle mass (sarcopenia) (51), being important the development of appropriate physical exercise habits, to improve the health of this population (52). Sedentary lifestyle may not be the only cause, since hormonal, neural and cytokine activities also seem to play a role (8,53). Skeletal muscle waste leads to reduced mobility and increased disability contributing to the frailty syndrome of aging (54, 55). We found lower muscle mass, bone mass and FFM in women as compared to men, with values similar to those reported in other studies namely as regards the fat-free mass (13, 41, 56). The contribution of women for osteoporosis prevalence in the centenarians studied was greater than men (W = 71.85% vs. M = 28.15%), but 95% of them had osteoporosis (Table 3). Male osteoporosis with ageing is a reality and should be treated and prevented (57), despite men has been significantly undertreated in all age groups, compared to women (58). Future studies could assess the levels of vitamin D in this age group and the implementation of appropriate measures to musculoskeletal health.

The resting metabolic rate (RMR) was significantly different between genders using either bioimpedance analysis or Harris Benedict equation and Bland Altman analysis between methods indicate that there was an agreement of 97.6%. This fact suggests that Harris Benedict equation seems to be a good option to measure RMR in centenaries, when BIA is not available.

In our study we observed that the RMR was lower in women which may be due to a decrease in the FFM, since these two parameters were highly correlated (Fig. 3d). Similarly, absolute RMR was observed higher in men than women and can be explained primarily by greater lean body mass in men, but fat mass may explained, in part, this variation, especially in women (59).

Centenarians studied had a metabolic age lower than the chronological age. The estimated metabolic age, considering the muscle mass and RMR shows that globally our sample of centenarians exhibits a successful ageing for both genders.

There are several methodologies that can be used to evaluate the nutritional status in elderly. In our study we choose to use the bioimpedance method instead of anthropometric measurements like, arm and calf circumferences (60). With the application of the electrical bioimpedance it was possible to obtain body composition data of centenarians and simultaneously to evaluate the presence of malnutrition. The MNA® is one of the several screening tools (61) commonly used to help identify elderly persons who are malnourished or at risk of malnutrition, but do not give any information on body composition. The application of this tool in addition to bioimpedance method it was initially considered for this study but unfortunately was not possible to apply the MNA® questionnaire to centenarians, so the researchers decided to performed the bioimpedance method that shows to be relatively simple (portable equipment), quick (takes only a few minutes), non-invasive and gives reliable and immediately available results of body composition with an excellent reproducibility (less than 1% error) in repeated measurements.

Bioimpedance analysis may be a useful tool, for establish a nutritional plan adjusted to the daily dietary needs of elderly, contributing to their healthy living style and should be considered in clinical approach.

Conclusions

Our work is pioneered for the evaluation of body composition and nutritional status of centenarians in Portugal. We concluded that the majority of Portuguese centenarians are normal weight, have a metabolic age lower than the chronological age and displayed a healthy level of visceral fat score, according to waist circumference. In relation to that, these facts may have a protective role in longevity of centenarians. Concerning the nutritional status, the differences between men and women, can justify clinical and nutritional different approaches. Women centenarian were more frequently underweight than overweight, unlike men. If this fact may explain longevity nevertheless we cannot forget nutritional needs. BMI and waist circumference showed a good correlation with body fat percentage. According to this, and despite the results of Bland-Altman analysis, Deurenberg and Gallagher equations are not suitable to evaluate obesity prevalence in centenarians compared to bioimpedance. Harris Benedict equation, however, seems to be a good option to measure RMR in centenarians, when BIA is not available. Body composition and nutritional characterization of Portuguese centenarians are relevant contribution in scientific evidence production for the action plan of healthy ageing in Europe (2012-2020) and also for clinical practice.

It is of paramount importance to assess nutritional status by bioimpedance for the global assessment of centenarians, in order to infer the global health needs, enabling orientation their caregivers to improve the nutritional and fluid intake that should be improved on the gender basis. The evaluation of the eating habits of centenarians may, in the future, complete the assessment of nutritional status, and allowed compensate eventual deficient food consumption and improve the condition of health and well-being of this population.

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Ethical Standards Declaration: The experiments comply with the current laws of Portugal in which the work was performed.

Conflict of interest: The authors declare no conflict of interest.

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