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Reference values of surrogates of skeletal muscle mass, estimated by means of bioelectrical impedance analysis (bia), in a spanish adult sample with overweight or obesity: a cross-sectional study

Fernando Rojo (1), Ramón de Cangas (1), Jose Ramón Bahamonde (2).

(1) Dpto. Investigación en Nutrición de Precisión, Centro Salud Nutricional, Gijón (Asturias). (2) Facultad Padre Ossó, Universidad de Oviedo, Oviedo (Asturias).

E-mail: nutriciondeprecision@nutricionprecision.com

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Abstract:

The Skeletal Muscle Mass drivers the Resting Energy Expenditure and the metabolic flexibility and displays a large plasticity in response to various interventions. The heterogeneity of methods for its estimation comes with it a bias in the development of diagnostic criteria and consensus and hinders the comparison between studies. Besides its absolute values do not allow to compare individuals due to the lack of scaling, Our aim was to determine the percentiles of Fat Free Mass Index (FFMI), Appendicular Lean Mass Index (ALMI) and Skeletal Muscle Mass Index (SMMI) according to sex in a Spanish adult sample with overweight or obesity. Cross-sectional study [n=304; 102 males (M), 202 women (W), >18 years old, both sexes] and 0,36< Edema Index (EI)=ECW/TBW<0.39. Height (SECA 222) and % FM, FFM, FFMI, LM, LMI, SMM and EI (BIA Inbody 770) were measured. FFMI=18.08±2.35 (M: 20.47±1.90; W: 16.88±1.48) kg/m2, ALMI=7.52±1.10 (M: 8.65±0.84; W: 6.95±0.69) kg/m2 and SMMI= 10.02±1.48 (M: 11.55±1.16; W: 9.24±0.92) kg/m2. The P10 of FFMI, ALMI and SMMI was 18.56/15.02; 7.74/6.05; 10.41/8.12 kg/m2. The Biolectrical Impedance Analysis (BIA) measurements are device dependent. Therefore, it is recommended to resort to the values of FFMI, ALMI and SMMI escalated to height to the power of 2, only if Inbody 770 is used, It is worth noting that it leads to a systematic bias, overestimating FFM in 5.95±5.06 kg (CL: 0.89 to 11.02) against DEXA.

Keywords:

- Fat Free Mass (FFM)
- Lean Mass (LM)
- Skeletal Muscle-Mass (SSM)
- Allometry
- Scaling exponent

Introduction

The science of body composition looks into the combination of elements that make up the total mass of an individual at different levels (atomic, molecular, tissue and whole-body). A whole range of methods (Dual-Energy X-ray Absorptiometry –DEXA- Computerized Axial Tomography –CT-, Magnetic Resonance Imaging -MRI-) are available with this aim, based on different models according to the number of compartiments (2C, 3C, etc.) that present different grades of validity (1).

The most widespread methods in a clinical setting to estimate the body composition are the Biolectrical Impedance Analysis (BIA) and the Skinfold Method (SFM) due to their affordable price, user-friendly and non-invasiveness (1).

The estimation of the amount of Fat Mass (FM) and its distribution in Subcutaneous (SAT) and Visceral Adipose Tissue (VAT) has monopolized the biomedical research in nutrition and physical activity in health and disease, likely due to its involvement in the physiopathology of Non-Communicable Chronic Diseases (NCCD) (2), at the expense of the Fat Free Mass (FFM), Lean Mass (LM) and Skeletal Muscle Mass (SMM) (3).

Although 15 years ago Wolfe et al, already foresaw the relevance of SMM in health and disease and emphasized its underestimation, it was not until a lustrum that the study of the physiology and metabolism of SMM has stimulate the interest of scientific community for being an expression of Body Mass Cell (BMC), the main determinant of Resting Energy Expenditure (REE) in absolute values, for contributing to the metabolic flexibility, sinthesize and release miokines that allow the cross-talk with other peripheral organs such as liver and bone and display a large plasticity in response to nutritional, physical activity and pharmacological interventions (3).

The muscular tissue is classified in three kinds according to structure (histology) and function: smooth, heart and skeletal muscle mass. The latter, also known as striated or voluntary, takes part in locomotion, functional independence and intermediary metabolism.

The gold standard method to estimate SMM are the MRI and CT, and both are interchangeable (4). However, their high price, requirement of qualified personal and periodical calibration, restrict them to a research setting.

The BIA has been validated to estimate FFM (10), LM (11), Appendicular Lean Mass (ALM) (12) and SMM (13) in a wide range of healthy and sick population (e.g. colon cancer) with a variety of ages and grades of adiposity. (5-8).

Several surrogates of SMM have been suggested. The most widespread ones are FFM, LM, SMM and ALM. However, there is certain misunderstanding in the literature, where the FFM, LM and SMM are occasionally employed erroneously as synonymous hindering the comparison between studies.

Allometry is the biological science which studies the relative changes in the dimensions of the various parts that forms an organism, in relation to its size throughout its growth. The allometric relations arise from the form $y=\alpha x\beta$, where α and β are constants and known as allometric exponents. If $\beta=1$ it is said that the objects display geometrical similarity or that they are isometric. The allometric model $y=\alpha x\beta$ in its logarithmic form is employed to establish the exponents of scaling (9).

Allometry establishes that the gross values from any body composition parameter should not be compared. It is necessary to adjust it to compare individuals with different phenotypes of FFM. It requires to escalate the FFM and its surrogates, getting a relative FFM. The studies turn to weight, height, height squared, etc., although they are usually adjusted by the height squared and sometimes by the weight. There are a wide range of surrogates: Fat Free Mass Index (FFMI), Appendicular Lean Mass Index (ALMI), Skeletal Muscle Mass Index (SMMI) and relative SM. A standardization of the surrogates of FFM is required to reach a larger harmonization of the studies and make easier their comparison. In addition, it is needed studies that provide reference values from healthy and clinical Spanish adult samples.

The purpose of the study is to determine the percentiles of FFMI, ALMI and SMI according to sex in a Spanish adult sample suffering from overweight or obesity.

Material and Methods

Cross-sectional study in a sample of patients who attend to a private office to lose fat mass (n=304; H: 102, M: 202) and inclusion criteria (>18 years old, both sexes) and 0.36<Edema Index (EI)=ECW/TBW<0.39. In the first attendance Ht (SECA 222) and weight, % FM, FFM, FFMI, LM, LMI, SMM and EI (BIA Inbody 770, InBody Co., LTD, South Korea), were measured, where FFMI=FFM/T2, ALM=Σ(LMra+LMla+LMrl+LMll), ALMI=ALM/T2 and SMMI=SMM/T2. The statistical package was used (IBM SPSS V.25 (SPSS Inc, Chicago, USA).

Results

In Table 1 it is listed the descriptive statistics from the studied sample. In the Table 2 and Table 3 are recorded the percentils of FFM and its surrogates studied in men and women respectivelly.

VARIABLE (MEAN+SD)	TOTAL SAMPLE	MEN	WOMEN
N	304	102	202
AGE (YEARS-OLD)	42±12	40±13	43±12
WT (KG)	80±16,65	89,76±17,26	75,18±14,03
HT (M)	1,67±0,08	1,75±0,07	1,63±0,06
BMI (KG/M²)	28,55±5,15	29,29±5,17	28,18±5,11
%FM	35,41±9,84	28,60±9,33	38,84±8,18
FM (KG)	29,07±11,48	26,94±12,80	30,14±10,63
EI	0,379	0,376	0,381
FFM (KG)	51±10,58	62,82±8,07	45,04±5,41
FFMI (KG/M²)	18,08±2,35	20,47±1,90	16,88±1,48
LM (KG)	48,05±9,99	59,24±7,57	42,39±5,10
ALM (KG)	21,27±4,88	26,60±3,77	18,58±2,67
ALMI (KG/M²)	7,52±1,10	8,65±0,84	6,95±0,69
SMM (KG)	28,30±6,40	35,47±4,80	24,68±3,31
SMMI (KG/M²)	10,02±1,48	11,55±1,16	9,24±0,92

SD: Standard Deviation. Wt: Weight. Ht: Height. BMI: Body Mass Index. FM: Fat Mass. EI: Edema Index. FFM: Fat-Free Mass. FFMI: Fat-Free Mass Index. LM: Lean Mass. ALM: Appendicular Lean Mass. ALMI: Appendicular Lean Mass Index. SMM: Skeletal Muscle Mass. SMMI: Skeletal Muscle Mass Index

Table 1. Descriptive statistics of the variables

VARIABLE	P10	P25	P50	P75	P90
FFM	54,35	57,92	61,80	67,72	74,79
FFMI	18,56	19,52	20,23	21,64	22,66
LM	51,28	54,62	58,35	63,92	70,50
ALM	22,43	24,36	26,22	28,64	32,55
ALMI	7,74	8,17	8,67	9,16	9,78
SMM	30,45	32,5	34,85	38,50	42,54
SMMI	10,41	10,98	11,39	12,34	12,91

FFM: Fat-Free Mass. FFMI: Fat-Free Mass Index. LM: Lean Mass. ALM: Apendicular Lean Mass. ALMI: Apendicular Lean Mass Index. SMM: Skeletal Muscle Mass. SMMI: Skeletal Muscle Mass Index

Table 2. Percentils of FFM and its surrogates in men

VARIABLE	P10	P25	P50	P75	P90
FFM	38,43	41,30	44,80	48,75	52,40
FFMI	15,02	15,82	16,81	17,78	19,06
LM	35,96	38,97	42,15	45,92	49,20
ALM	15,22	16,72	18,28	20,33	22,05
ALMI	6,05	6,53	6,91	7,38	7,88
SMM	20,5	22,45	24,60	26,72	29,01
SMMI	8,12	8,59	9,22	9,79	10,60

SMMI 8.12 8.59 9.22 9.79 10.60

FFM: Fat-Free Mass. FFMI: Fat-Free Mass Index. LM: Lean Mass. ALM: Appendicular Lean Mass. ALMI: Apendicular Lean Mass Index. SMM: Skeletal Muscle Mass. SMMI: Skeletal Muscle Mass Index

Table 3. Percentils of FFM and its surrogates in women

Discussion

The studies which have evaluated the FFMI and its surrogates in Spanish adult samples either healthy or clinic are fairly scarce and their main limitations are their little sample size and that the estimation of those ones are not the primary outcome of the study, but their relation with specific physiological variables (e.g. arterial stiffness, transcriptomic and/or proteomic profiling of certain tissues and sleep quality) in diseases that usually accompany with a decrease in the FFM or its surrogates (e.g. bronchiectasis, cancer, chronic obstructive pulmonary disease and particularly sarcopenia) or nutritional interventions (e.g. glutamine). The most widespread surrogate of FFM is the ALMI, employed in the diagnosis of sarcopenia.

This is the first study we are aware of, which evaluates the FFM and its surrogates in a Spanish adult sample with overweight or obesity. The SM is structurally and functionally joined together to the bone either in animals or human being. Although the SMM seems to scale isometrically to the weight in mammals, it has been found an allometry slightly positive in primates (power=1.05) and non-primates (power=0.99). These structural relations of scaling are consistent with studies in human beings that points out that bigger individuals (defined by height) present a less Basal Energy Expenditure (BEE) that their smaller counterparts. The height is a phenotypical feature of body size. The Quetelet Index (QI) or Body Mass Index (BMI) highlights the mathematical relation between the weight (W) and height (H). The weight increases as the height squared raises, after adjusting by age and adiposity: W (kg)= α x H (m)2 where α=constant=BMI. One of the theories that supports this hypothesis is that the tallest individuals exhibit more structural frame, that is SMM. Heymsfield SB et al performed a preliminary study in a sample of 1,757 subjects extracted from several studies and found that the FFM scaled to the height with powers of 2.05 and 1.86, the Adipose Tissue Free Mass (ATFM) with powers of 2.20 and 2.09 and the SMM with powers of 2.08 and 1.98 in women and men, respectively (10).

The same authors analyzed the relation of scaling between the FFM and the height in a cohort of 13,186 adults non-Hispanic white (NHW), non-Hispanic black (NHB), and Mexican American from the National Health and Nutrition Examination Survey (NHANES) 1999-2004 and found scaling exponents of 2.09 and 1.86 in men and women NHW irrespective of the sex and adiposity (11). Also, de same authors examined the scaling relation between the LM and the height in a larger sample from the NHANES 1999-2006 (17,126 individuals) and discovered that the LM scaled to the height with powers substantially higher that 2: 2.87 and 2.4 in NHW men and women respectively. The finding was more pronounced in the lower extremities (12).

The main drawback of our study is the small size of the sample, just as the value of the scaling exponent employed. The FFM and LM is normally scale with a power of 2. Nevertheless, Benn RT et al suggested to adjust the weight (the FFM and LM in our case) to the height raised to a specific value of the scaling exponent, that should have been previously obtained from the population of interest, as illustrated by the data from the NHANES study (10). An optimal methodological design would have been to establish the scaling exponent a priori in our population of interest. However, Benn RT study was looked up a posteriori. Another choice would be to analyze again these data using the β values from the NHANES, but we would commit the mistake to extrapolate them from a North American population to a Spanish one. The high variability of β values, that are population-specific, prevent this approach on a large scale.

Conclusions

The estimation of FFM, LM, SMM and ASM should be part of the routine in the monitoring of body composition, just like happens with FM and VAT in daily clinic. The comparison of values of FFM and its surrogates require their adjustment to the height raised to an a priori unknown exponent of scaling. Therefore, previous studies which determine the allometric relation between body weight and its components (FM, FFM, LM, etc.) are required to unveil the exponent of scaling, in a large sample from the studied population. Besides reference values of FFM and its surrogates are needed in either healthy or clinical samples, with the purpose to contribute to precision medicine. It will allow the comparison of values from body composition studies in Spain and other countries. It is worth noting the absence of a standardization concerning the nomenclature of FFM and its surrogates in the literature, where acronyms such as ALMI and SMMI are usually interchanged erroneously. For this reason, the harmonization of terminology is imperative.

Conflict of interest

The authors declare no conflict of interest.

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