Nutrafoods (2019) 1:26-33. DOI 10.17470/NF-019-0004

Original Research

A comparison of in-field fat mass evaluation techniques: a practical perspective

Abstract

Nutritional status assessment of the individual is a key aspect in the monitoring of health status. In this context, body composition evaluation results are of fundamental importance. Several body composition techniques can be used depending on the information needed and the examined categories, and all the techniques are characterized by advantages and disadvantages. In this regard, this study aims to evaluate and compare the most commonly used techniques to evaluate body fat mass percentages in different situations.

Fifty subjects took part in the study. Anthropometric data were collected and the percentage of fat mass was estimated using three different techniques: circumference, skinfold and ultrasound. Correlation strength among techniques was evaluated and the level of agreement among techniques was determined. Inferential analysis was performed and the percentage error of each technique for each individual was calculated.

Correlation analysis revealed a stronger coefficient between skinfold and ultrasounds than between skinfold and circumferences (respectively, r=0.932 and r=0.686). Delta fat mass percentages were similar, approximately 5%, both when considering skinfold–ultrasound and skinfold–circumference. Stratifying the population by gender, it was observed that the correlation is worse in women than in men. In the case of stratification by BMI, in the 'Obese' grouping, the correlation coefficient was small, independent of the technique.

Comparing these techniques has highlighted some critical features of single methods, especially considering specific target populations.
This highlights the importance of the use of coupled techniques or the inadequacy of one with respect to another for particular categories.

Alexander Bertuccioli [1]
Giorgia Vici [2]
Roberto Ceci [2]
Leonardo Cesanelli [2]
Luca Belli [2]
Valeria Polzonetti [2]

[1] Dipartimento di Scienze
Biomolecolari (D.I.S.B.)
University of "Carlo Bo" Urbino, Italy

[2] Nutricam Food & Health
Schoold of Biosciences and Medicine
Veterinary Medicine
University of Camerino, Italy

Corresponding author:
Alexander Bertuccioli
alexander.bertuccioli@synalab.com

Keywords: body composition, nutraceuticals, diet, skinfolds, ultrasounds, body circumferences

Introduction

Body composition evaluation has a fundamental role in the assessment of an individual's nutritional status with a key role in monitoring the processes of growth, aging and also, of some diseases [1]. Reliable and valid body composition evaluation methods are important both in clinical and in research settings [2], providing important data regarding nutritional/supplementation interventions and physical exercise programmes [1].

Health benefits have been studied in relation to high dietary quality and providing tools that can improve dietary intake is a key aspect in the development of preventative strategies [3]. Moreover, the optimization of diet health-promoting effects can be achieved through the use of nutraceuticals that have been formulated to exploit health-promoting factors [4]. In this regard, nutraceuticals have been proposed as being key tools for the prevention and treatment of pathological conditions such as chronic disease [5]. However, one of the challenges to understanding the contribution of dietary factors is the ability to evaluate and 'measure' diet and diet impact [3].

In this regard, body composition could have a key role to play in monitoring the impact of nutritional and supplementation strategies (that is, diet optimization, nutraceutical impact and so on) as a tool to evaluate a possible response in terms of changes in body compartments related to specific nutrient or nutraceutical consumption/use [6-9]. Several body composition evaluation techniques can be used depending on the information needed and the examined categories and all the techniques are characterized by advantages and disadvantages [10]. In the study and assessment of obesity, several methods and/or techniques have been used to evaluate body composition and to categorize body weight, either for research or for clinical purposes [11].

The evaluation of fat mass is of fundamental importance. Indeed, an increase in body fat is associated with increased risk of various diseases, such as obesity, hypertension and cardiovascular disease, type 2 diabetes and others [1]. Body Mass Index (BMI) has some limitations, with BMI not differentiating between fat mass and free fat mass leading to difficulties in determining individual's overweight or obesity [12].

An important indicator of central obesity is waist circumference. Indeed, the circumference can be used as a supplementary method to evaluate adiposity [11]. Moreover, specific predictive equations can be used to estimate the percentage of fat mass using body circumference [13]. To estimate and monitor body composition, skinfold thickness is now commonly used [14]. The assessment of skinfold thickness provides an estimation of the fat mass percentage and the method is considered simple and inexpensive, even if it is strictly related to the investigator's experience [15].

Skinfold thickness can be measured at different body sites, usually biceps, triceps, subscapular, suprailiac and thigh. Skinfold thickness measurement has been validated as being a good method to estimate body fat percentage in adults using standardized equations and it is now widely used to assess adiposity both in adults and in children [11].

An alternative approach to estimate body fat percentage is ultrasound [2]. This technique has the advantage of measuring obese subjects at anatomical locations where skinfold calipers cannot be applied [2]. However, with only a limited number of known studies conducted in this area, more validity and reliability studies are needed [16].

A critical understanding of the different techniques with regard to strengths and limitations is important to correctly evaluate and understand body composition [17]. Indeed, several conditions and subject characteristics lead to different requirements in relation to the preferred method for quantifying body composition [2]. In this regard, this study aims to assess and compare the most commonly used techniques for evaluating fat mass (circumference, skinfold and ultrasound) in different situations.

Materials and methods

Fifty healthy subjects took part in the study, 17 women and 33 men. Written informed consent was obtained from each participant before the study began. Anthropometric data were collected following standardized international procedures. Weight, Height, Body Circumferences and Skinfolds were collected for each subject. Weight was measured using a mechanical balance scale (Wunder RB200) with a precision of 0.01 kg. Every subject was evaluated shoeless and wearing underclothes. Height was measured shoeless using a stadiometer (Wunder HR1) with a precision of 0.1 cm.

The measure was taken while ensuring the correct position of the head, in the standard position of the reference Frankfurt plane, with the upper border of the external auditory meatus on a horizontal plane with the lower border of the eye.

BMI was calculated by dividing the measured weight by the squared height [18]. Body circumferences were taken using a non-stretchable fibreglass insertion tape with a precision of 0.1 mm at different sites: the waist, hip, wrist, forearm, upper arm, thigh and calf.

Fat mass percentage was estimated using the McArdle and Katch method [13]. Skinfold thickness was measured using a GIMA skinfold caliper with a precision of 0.2 mm, at different sites on the right side of the body: triceps, biceps, mid-axillary, chest, subscapular, abdominal, suprailiac, thigh.

The techniques and specific anatomical positions for measurements are described in many textbooks and in the open-access NHANES manual [17, 18]. The percentage of fat mass was estimated using the Jackson and Pollock equations (7-site) [19]. Ultrasound was performed using a BodyMetrix, BX2000, IntelaMetrix, Inc., Livermore, CA. Gel was placed on the head of the transducer at the site to be measured, at the same sites as the skinfolds (triceps, biceps, mid-axillary, chest, subscapular, abdominal, suprailiac, thigh). Body View IntelaMetrix software was used to estimate the percentage body fat.

The skinfold technique (Jackson and Pollock) was used as the reference technique because of its common use in practice, its convenience and availability.

Data analysis was performed using SPSS® and by using skinfold as the reference technique. Data are expressed as the mean±SD. Correlation strength among techniques was evaluated through the Pearson correlation coefficient. Moreover, Bland–Altman analysis [20] was performed to determine the level of agreement among techniques. Inferential analysis was carried out following Vidali et al [21] and the percentage error for each technique for each individual was calculated. Confidence limits of agreement were set at 95%. p<0.05 was considered statistically significant. The total group was stratified by sex, BMI, WHR (Waist-to-Hip Ratio), age and morphotype.

Results

The studied population is described in **Table 1**.

	Total (n= 50)				
	Mean			Range	
Age	34.26	±	16.47	15.00	76.00
Body Weight (kg)	73.05	±	15.31	38.00	110.00
Height (m)	1.69	±	0.09	1.50	1.90
BMI	25.63	±	4.76	14.80	35.10
Values are expressed as mean ± SD; BMI = Body Mass Index					

Table 1 Studied population characteristics

Pearson coefficients both for the total and stratified populations are summarized in **Table 2**.

	Ultrasound–Skinfold	*Skinfold Circumferences*
	Pearson Coefficient	Pearson Coefficient
Total Population	0.932**	0.686**
Sex		
Male	0.954**	0.898**
Female	0.788**	0.753**
Age		
15–25	0.963**	0.750**
26–50	0.887**	0.450*
51–76	0.856**	0.217
BMI		
Normal-weight	0.968**	0.479*
Over-weight	0.825**	0.504*
Obese	0.872**	0.023
WHR		
Android	0.746**	0.649*
Gynoid	0.957**	0.558**
Intermediate	0.943**	0.254
Morphotype		
Lean	0.878	0.904*
Medium	0.904**	0.686**
Burly	0.919**	0.579**

Table 2 Ultrasound–skinfold and skinfold–circumferences Pearson coefficients

The Pearson correlation coefficients were higher with the ultrasound technique than the circumference with the only exception seen with stratification by morphotype in the case of 'Lean' where a higher coefficient was found with circumferences rather than ultrasound.

Table 3 shows Bland–Altman statistics. In the total population, mean differences are close to each other and approximate 5 (% of Fat Mass). No statistically significant mean differences are observed with the exception of circumferences in the cases of the 'Female' and 'Lean morphotype' groups.

Through Bland–Altman analysis, differences were plotted against individual averages of % FM (Fat Mass) from skinfold. **Table 4** shows intercepts and slopes. To consider a comparison valid, it is necessary that 0 is included in the interval of the lower and upper limits in the case of intercepts and 1 is included in the interval of the lower and upper limits in the case of the slope. In cases where these conditions are both verified, the comparison is valid. From this study, the cases where the comparison was

		Skinfold–Ultrasounds				*Skinfold–Circumferences*			
		Mean average error	Δ (% FM)	p	Limits of agreement	Mean average error	Δ (% FM)	p	Limits of agreement
	Total	-19.80%	-4.60 ± 3.22	p < 0.01	-11.04, 1.80	-21.27%	-5.48 ± 5.93	p < 0.01	-17.7, 6.02
Sex	Male	-19.22%	-4.16 ± 2.64	p < 0.01	-9.44, 1.12	-19.97%	-8.27 ± 4.21	p < 0.01	-16.69, 0.15
	Female	-20.93%	-5.45 ± 4.07	p < 0.01	-13.59, 2.69	-23.81%	-0.06 ± 4.99	p=0.958	-10.04, 9.92
Age	15–25	-22.69%	-4.07 ± 3.05	p < 0.01	-10.17, 2.03	-18.51%	-3.51 ± 4.73	p < 0.01	-12.97, 5.95
	26–50	-16.73%	-3.46 ± 2.85	p < 0.01	-9.16, 2.24	-25.27%	-6.51 ± 6.18	p < 0.01	-18.87, 5.85
	51–76	-20.94%	-7.34 ± 3.17	p < 0.01	-13.68, -1.00	-18.16%	-6.50 ± 7.06	p < 0.05	-20.62, 7.62
BMI	Normal-weight	-19.15%	-3.64 ± 1.98	p < 0.01	-7.60, 0.32	-20.08%	-3.86 ± 5.07	p < 0.01	-14.00, 6.28
	Over-weight	-21.02%	-4.83 ± 4.26	p < 0.01	-13.35, 3.69	-22.18%	-6.13 ± 5.97	p < 0.01	-18.07, 5.81
	Obese	-19.45%	-6.86 ± 2.98	p < 0.01	-12.82, -0.90	-22.97%	-8.81 ± 7.05	p < 0.01	-22.91, 5.29
WHR	Android	-15.49%	-6.58 ± 4.89	p < 0.01	-16.36, 3.20	-22.76%	-8.42 ± 4.28	p < 0.01	-16.98, 0.14
	Gynoid	-20.37%	-3.58 ± 2.16	p < 0.01	-7.90, 0.74	-20.07%	-3.95 ± 4.99	p < 0.01	-13.93, 6.03
	Intermediate	-22.38%	-4.58 ± 2.25	p < 0.01	-9.08, -0.08	-21.92%	-5.48 ± 7.63	p < 0.05	-20.74, 9.78
Morpho-type	Lean	-21.50%	-3.16 ± 1.76	p < 0.05	-6.68, 0.36	-9.02%	-5.30 ± 6.27	p=0.132	-17.84, 7.24
	Medium	-16.07%	-3.65 ± 2.83	p < 0.01	-9.31, 2.01	-22.47%	-5.78 ± 5.03	p < 0.01	-15.84, 4.28
	Burly	-22.71%	-5.73 ± 3.46	p < 0.01	-12.65, 1.19	-22.77%	-5.26 ± 6.77	p < 0.01	-18.8, 8.28

Limits of agreement are mean difference ± 2 SD

BMI = Body Mass Index; WHR = Waist-to-Hip Ratio

Table 3 Bland–Altman analysis, using skinfold as reference

			Intercept	*Lower Limit 95% I*	*Upper Limit 95% I*	*p*	*Slope*	*Lower Limit 95% I*	*Upper Limit 95% I*	*p*
Total Population		Ultrasounds	0.60	-1.48	2.68	>0.05	0.77	0.68	0.86	<0.05
		Circumferences	9.67	5.16	14.18	<0.05	0.77	0.53	1.00	>0.05
Sex	Male	Ultrasounds	1.83	0.28	3.38	<0.05	0.68	0.60	0.76	>0.05
		Circumferences	1.43	-2.61	5.46	>0.05	1.47	1.21	1.73	<0.05
	Female	**Ultrasounds**	**2.49**	**-7.09**	**12.06**	**>0.05**	**0.73**	**0.42**	**1.05**	**>0.05**
		Circumferences	**1.23**	**-10.20**	**12.66**	**>0.05**	**0.95**	**0.49**	**1.41**	**>0.05**
Age	15–25	Ultrasounds	1.27	-0.87	3.40	>0.05	0.71	0.60	0.82	<0.05
		Circumferences	6.69	0.94	12.43	<0.05	0.79	0.42	1.16	>0.05
	26–50	**Ultrasounds**	**-0.52**	**-5.11**	**4.08**	**>0.05**	**0.85**	**0.64**	**1.06**	**>0.05**
		Circumferences	14.93	6.09	23.78	<0.05	0.51	0.02	1.00	<0.05
	51–76	**Ultrasounds**	**-7.83**	**-22.79**	**7.13**	**>0.05**	**1.01**	**0.55**	**1.48**	**>0.05**
		Circumferences	26.78	11.31	42.25	<0.05	0.18	-0.43	0.79	>0.05
BMI	Normal-weight	Ultrasounds	0.70	-0.80	2.20	>0.05	0.76	0.68	0.84	<0.05
		Circumferences	9.46	4.69	14.23	<0.05	0.53	0.22	0.85	<0.05
	Over-weight	Ultrasounds	2.93	-4.33	10.19	>0.05	0.70	0.42	0.97	<0.05
		Circumferences	17.89	8.56	27.23	<0.05	0.43	0.01	0.86	<0.05
	Obese	Ultrasounds	-4.34	-18.83	10.15	>0.05	0.92	0.46	1.38	>0.05
		Circumferences	32.61	18.53	46.70	>0.05	0.01	-0.55	0.58	<0.05
WHR	Android	Ultrasounds	7.57	-2.25	17.39	>0.05	0.52	0.19	0.84	<0.05
		Circumferences	16.25	3.63	28.86	<0.05	0.66	0.11	1.20	>0.05
	Gynoid	Ultrasounds	0.17	-1.80	2.14	>0.05	0.78	0.67	0.89	<0.05
		Circumferences	10.27	5.10	15.45	<0.05	0.53	0.17	0.89	<0.05
	Intermediate	**Ultrasounds**	**-3.25**	**-8.46**	**1.95**	**>0.05**	**0.95**	**0.75**	**1.15**	**>0.05**
		Circumferences	**21.65**	**10.91**	**32.39**	**<0.05**	**0.22**	**-0.28**	**0.71**	**<0.05**
Morphotype	Lean	Ultrasounds	1.59	-10.08	13.25	>0.05	0.71	-0.01	1.41	>0.05
		Circumferences	-17.07	-48.41	14.28	>0.05	2.72	0.36	5.09	<0.05
	Medium	Ultrasounds	0.04	-3.61	3.70	<0.05	0.80	0.62	0.99	<0.05
		Circumferences	9.13	2.66	15.59	<0.05	0.78	0.38	1.18	>0.05
	Burly	Ultrasounds	0.64	-3.44	4.71	>0.05	0.76	0.62	0.91	<0.05
		Circumferences	13.32	4.73	21.91	<0.05	0.62	0.23	1.00	>0.05

Verified comparisons are shown in bold *BMI = Body Mass Index; WHR = Waist-to-Hip Ratio*

Table 4 Intercept and slope analysis

found to be valid both for ultrasounds and for circumferences were 'Female' in terms of sex and 'Lean' in terms of morphotype. Moreover, ultrasound comparison was found to be valid in the case of 'Medium' in terms of WHR and for the age ranges 26–50 and 51–76. (**Table 4**).

The percentage error was calculated using skinfold as the reference.

Figure 1 shows the percentage error results for individual % fat mass. Ultrasound showed a mean overestimation of approximately 19.80% and circumferences of approximately 21.27%.

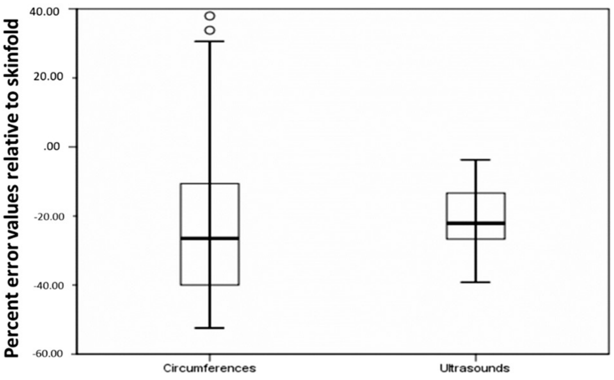
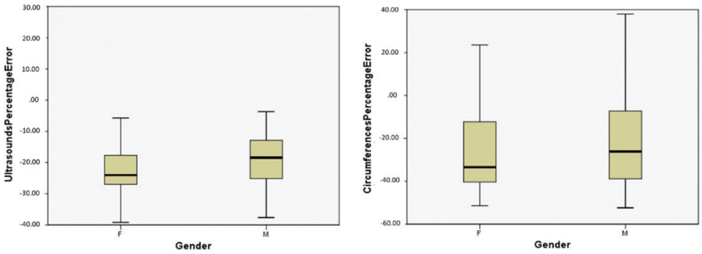


Figure 1 Percentage error for ultrasounds and circumferences relative to skinfold in the total population

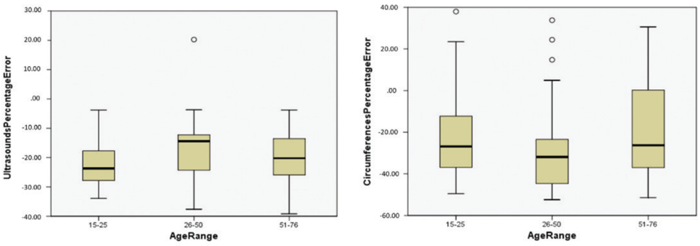
Figure 2 shows percentage error for ultrasound and circumferences with respect to skinfold in the stratified population.

Figure 2 Percentage error for ultrasound and circumference relative to skinfold in the stratified population.
BMI = Body Mass Index; WHR = Waist-to-Hip Ratio

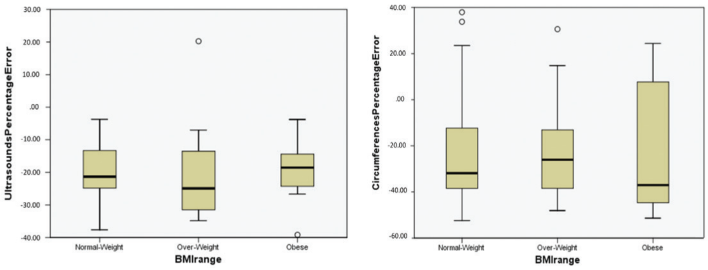
SEX	
Ultrasound medium error percentage	
Female	**Male**
-20.93%	-19.22%
Circumferences medium error percentage	
-23.81%	-19.97%



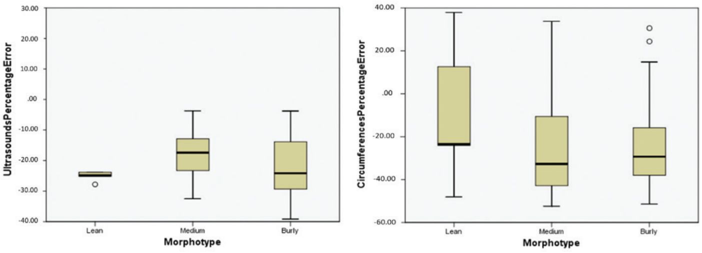
AGE		
Ultrasound medium error percentage		
15–25	**26–50**	**51–76**
-22.69%	-16.73%	-20.94%
-15.49%	-20.37%	-22.38%
Circumferences medium error percentage		
-18.51%	-25.27%	-18.16%
-22.76%	-20.07%	-21.92%



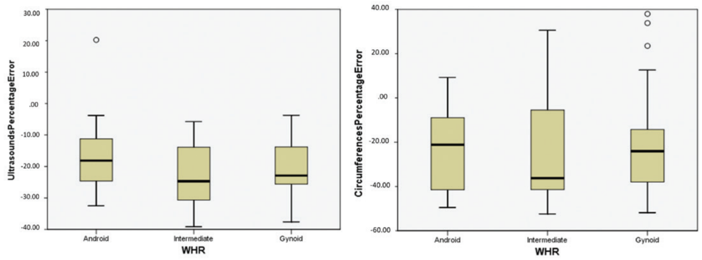
BMI		
Ultrasound medium error percentage		
Normal-Weight	**Over-Weight**	**Obese**
-19.15%	-21.02%	-19.45%
Circumferences medium error percentage		
-20.08%	-22.18%	-22.97%



MORPHOTYPE		
Ultrasound medium error percentage		
Lean	**Medium**	**Burly**
-21.50%	-16.07%	-22.71%
Circumferences medium error percentage		
-9.02%	-22.47%	-22.77%



WHR		
Ultrasound medium error percentage		
Android	Gynoid	Intermediate
-15.49%	-20.37%	-22.38%
Circumferences medium error percentage		
-22.76%	-20.07%	-21.92%



Conclusions

Several methods and/or techniques have been used to evaluate body composition either for research or for clinical purposes [11]. It has been demonstrated that the evaluation of body compartments and, in particular, of fat mass, is of fundamental importance in order to monitor the nutritional status of individuals and to better understand the impact of specific dietary strategies [10, 22]. Several studies are now focusing attention on the impact of nutraceuticals on health status utilizing body composition as one of the key monitoring tools [6-9]. There are many factors that can create different needs and preferred methods [1]. The use of standardized equations involves some limitations that can lead to erroneous estimation.

In this study, the three most easily and commonly used techniques are taken into account, comparing ultrasound and body circumferences to skinfold. The use of skinfold thickness to estimate the percentage of body fat is based on the implicit assumption that there is a fixed relationship between subcutaneous adipose tissue in predefined anatomical locations and total body fat. This relationship is dependent on various factors such as age, sex and health status [23]. The measurement of skinfold thickness may appear simple to perform, but substantial intra- and interobserver variability has been reported [1]. Using skinfold as the reference, both ultrasound and body circumferences showed a difference with respect to the measurement of percentage fat mass of approximately 5%.

Stratifying the population by sex, it was possible to observe that the correlation is worse in women than in men. This could be related to physical conformation, constitutional bio-typing and other variables such as water retention and hormonal asset.

In the case of stratification by BMI, in the 'Obese' grouping, the correlation coefficient was small, independent of the technique, underlining the fact that the evaluation of body composition in obese individuals is still difficult and is the focus of many studies. Moreover, it is possible to observe that in the case of obesity, circumferences showed a wide confidence interval with respect to ultrasounds. This could suggest a better application of ultrasounds rather than circumferences for this category.

Borkan et al demonstrated that skinfolds correlated better with fat weight than ultrasound, concluding that skinfolds were a good method to assess subcutaneous fat [24]. In this study, some discrepancies were found. In general, the comparison ultrasounds–skinfold resulted in the highest correlation coefficients with an overestimation for ultrasound with respect to skinfold of approximately +5% in the total population. Moreover, it was possible to observe that circumferences resulted in the highest percentage of fat mass.

Comparing these techniques has therefore highlighted some critical features of the single method, especially considering specific target populations, suggesting the use of coupled techniques (that is, in obesity) or the inadequacy of one with respect to the other for particular categories. This can be considered the first evaluation to study and understand not only the single methods, but the important connections between these, taking into account different situations (that is, gender, BMI and so on).

In future studies, increasing the number of techniques and of subjects will add other information that can contribute to the further analysis of body composition evaluation techniques.

Acknowledgements

This work was not supported by any source of funding.

Ethical standards

This article does not contain any studies with animal subjects performed by any of the authors. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000(5). Informed consent was obtained from all patients included in the study.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

1. Langer RD, Borges JH, Pascoa MA, Cirolini VX, Guerra-Junior G, Gonçalves EM (2016) Validity of bioelectrical impedance analysis to estimation fat-free mass in the Army cadets. Nutrients 8:121
2. Fosbol MO, Zerahn B (2015) Contemporary methods of body composition measurement. Clin Physiol Funct Imaging 35:81–97
3. Solah VA et al (2017) Effect of fibre supplementation on body weight and composition, frequency of eating and dietary choice in overweight individuals. Nutrients 9:149
4. Keservani RK, Kesharwani RK, Vyas N, Jain S, Raghuvanshi R, Sharma AK(2010) Nutraceutical and functional food as future food: a review. Der Pharmacia Lettre 2:106–116
5. Santini A, Novellino E (2017) Nutraceuticals in hypercholesterolaemia: an overview. Br J Pharmacol 174:1450–1463
6. Liu YJ et al (2015) A dietary supplement containing cinnamon, chromium and carnosine decreases fasting plasma glucose and increases lean mass in overweight or obese pre-diabetic subjects: a randomized, placebo-controlled trial. Plos One 10: e0138646
7. Galvão CF, Xavier VF, da Silva LE, Gonçalves LCO, Gouveia Peluzio MDC, Gonçalves Alfenas RC (2018) Consumption of extra virgin olive oil improves body composition and blood pressure in women with excess body fat: a randomized, double-blinded, placebo-controlled clinical trial. Eur J Nutr 57:2445–2455
8. Joy JM et al (2013) The effects of 8 weeks of whey or rice protein supplementation on body composition and exercise performance. Nutr J 12:86
9. Panahi S et al (2018) Yogurt consumption, body composition, and metabolic health in the Quebec Family Study. Eur J Nutr 57:1591–1603
10. Andreoli A, Garaci F, Cafarelli FP, Guglielmi G(2016) Body composition in clinical practice. Eur J Radiol 85:1461–1468
11. Horan M, Gibney E, Molloy E, McAuliffe F. (2015) Methodologies to assess paediatric adiposity. Ir J Med Sci 184:53–68
12. Buss J (2014) Limitations of body mass index to assess body fat. Workplace Health Saf 62: 264
13. Katch FI (1977) Nutrition, weight control and exercise. Houghton Mifflin, Boston
14. Porto LG et al (2016) Agreement between BMI and body fat obesity definitions in a physically active population. Arch Endocrinol Metab 60:515–525
15. Rymarz A, Szamotulska K, Niemczyk S (2017) Comparison of skinfold thicknesses and bioimpedance spectroscopy to dual-energy X-ray absorptiometry for the body fat measurement in patients with chronic kidney disease. Nutr Clin Pract 32:533–538
16. Wagner DR (2013) Ultrasound as a tool to assess body fat. J Obes 2013:280713
17. Madden AM, Smith S (2016) Body composition and morphological assessment of nutritional status in adults: a review of anthropometric variables. J Hum Nutr Diet 29:7–25
18. National Center for Health Statistics (2011) The NHANES anthropometry procedures manual. Center for Disease Control. https://www.cdc.gov/nchs/data/nhanes/nhanes_07_08/manual_an.pdf
19. Jackson AS, Pollock ML (1978) Generalized equations for predicting body density of men. Br J Nutr 40:497–504
20. Bland JM, Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1:307–310
21. Vidali M, Tronchin M, Dittadi R (2016) Protocol for the comparison of two laboratory methods. Biochimica Clinica 40:129–142
22. Aragon AA et al (2017) International society of sports nutrition position stand: diets and body composition. J Int Soc Sports Nutr 14:16
23. Lukaski HC (2017) Body composition: health and performance in exercise and sport. CRC Press
24. Borkan GA, Hults DE, Cardarelli J, Burrows BA (1982) Comparison of ultrasound and skinfold measurements in assessment of subcutaneous and total fatness. Am J Phys Anthropol 58:307–313