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Development of an equation to estimate fat-free mass in mountain Guides and Porters

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ABSTRACT

Body composition (BC) is a crucial component in the monitoring of athletes, not only as a variable related to physical performance, but also as a follow-up of dietary intervention and training.

Objective: To propose regression equations from body surface area (BSA) to estimate fat-free mass (FFM) of mountain guides and porters using deuterium oxide dilution (MDD) as a criterion method.

Methods: Cross-sectional study in 23 young and adult men working as mountain guides and porters on Aconcagua (Argentina). The volunteers ranged in age from 20 to 50 years. Weight, height, body mass index (BMI) and BSA were assessed by eight regression equations.

Results: Three linear regression equations were generated considering chronological age and ASC as predictors: Model 1 (FFM = - 25.287 - (0.260 * age) + (49.014 * ASC1), R^2 = 63.0%), model 2 (FFM = -20.736 - (0.191 * age) + (45.523 * ASC2), R^2 = 62.0%) and model 3 (FFM = -28.592 - (0.244 * age) + (52.499 * ASC3), R^2 = 63.0). The three equations presented tolerance indices (T) and variance inflation values (VIF) within limits; more evidence of absence of autocorrelation.

Conclusion: Three predictive models based on age and BSA were generated that allow estimating the FFM in a valid and reliable way. The results suggest their use and application for monitoring before, during and after expeditions.

KEYWORD

Body Composition; equation development; Body Surface Area; Hipobaric Hipoxia; High Altitude workers.

INTRODUCTION

Mountaineering is the sport of mountain climbing and often incorporates the skills of alpine rock and ice climbing[1], and is characterized by hiking, trekking and high mountain climbing activities[2]. Its objective is to ascend the mountain as a whole rather than individual rock formations or rock walls. To do this, it is necessary to organize a detailed planned expedition that involves organizing the ascent and descent of the summit at regular and efficient intervals[3]. This involves activities such as camping, facing geographical difficulties (crevasses, avalanches, rock falls and ice, among others), oxygen depletion due to altitude, low temperatures and extreme weather conditions[4].

In general, this sport is characterized as high risk and is associated with deaths, frequent physical injuries, often severe[5]. Despite this, in recent years the practice of mountaineering[1] has grown rapidly and there has even been an increased interest in research in this area[6].

In this context, body composition (BC) assessment is a crucial component in the follow-up of athletes, not only as a vari-

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able related to physical performance, but also as a follow-up of dietary and training intervention[7,8].

In fact, it is widely known that ostensible changes in BC and body weight occur during high mountain expeditions[8-10]. So, the possible mechanisms responsible could have to do with increased energy expenditure because of increased basal metabolic rate and/or high levels of physical activity, inadequate energy intake, fluid loss and gastrointestinal malabsorption[11-13].

From this perspective, taking into account the environment in which mountaineering takes place, the length of stay and the physical demands at high altitude, health professionals are obliged to constantly monitor the BC[14], especially the fat-free mass (FFM), since this compartment is an important component in the regulation of energy metabolism as a reservoir of glucogenic amino acids and nitrogen[15,16]. Indeed, the gradual loss of FFM in altitude conditions compromises physical performance and musculoskeletal adaptations[17].

Therefore, the assessment, monitoring and control of FFM in mountain guides and porters is extremely important, as maintaining adequate levels of FFM can improve physical performance (such as strength and endurance) for carrying heavy equipment, overcoming rough and steep terrain in hypoxic conditions[14]. Under this context, different equations have been validated in young and adult population, one of the oldest and most used being that of Du Bois and Du Bois[18] and more currently the equation of Kuehnapfel et al. (2017)[19]; however, to our knowledge, there are no studies on equations that predict GLM from anthropometric indicators in young and adult mountaineers, so in recent years several studies have suggested that body surface area (BSA) could be an appropriate indicator to estimate FFM in young and adults[16,20].

In general, the use and application of the BSA could be useful for predicting the FFM of mountain guides and porters; moreover, it is expected to serve as an easy-to-use tool during expeditions[21], as often most of the tools normally used to assess BC require a laboratory and/or field environment, where specific protocols, equipment and resources are needed, making their use difficult and limiting their use during expeditions[22].

Therefore, this study aims to propose regression equations based on the BSA to estimate the FFM of mountain guides and porters. For this purpose, we used nine equations that estimate the BSA as possible predictors of the FFM.

MATERIALS AND METHODS

A cross-sectional descriptive study was carried out on 23 young and adult men who work as mountain guides and porters during the 2017 season on Mount Aconcagua.

The sample selection was non-probabilistic (accidental). The volunteers ranged in age from 20 to 50 years. All participants worked on the traditional ascent route called Plaza de Mulas (Mount Aconcagua, Argentina) and had an average of 3.2 ± 1.5 years of experience in mountain ascents.

All guides and porters of Argentinean nationality and with at least three years of experience in ascents of Mount Aconcagua were included in the study. Participants of other nationalities were excluded (there were two mountaineers), those over 50 years of age and those who ingested acetazolamide or another diuretic at least four days prior to sample collection for the deuterium dilution method (MDD).

The study was conducted in accordance with the Declaration of Helsinki for human subjects[23] and in compliance with the ethical Committee of the Institute of Nutrition and Foods Technology approved this study, for the use of isotopic dilution.

TECHNIQUES AND PROCEDURES

The anthropometric evaluations and use of the deuterium oxide dilution method (MDD) were carried out at the "Plaza de Mulas" base camp, located at 4,300 meters above sea level (masl), with an average barometric pressure of 444 millimeters of mercury (mmHg). Field work included an anthropometric assessment, followed by MDD sampling. Both assessments were performed early in the morning, between 7:00 and 8:00 hr, during the mountaineers' rest day.

Weight and height were evaluated with the least amount of clothing possible (barefoot and light clothing), according to the suggestions described by Ross, Marffel-Jones[24]. For weight, a brand name electronic scale (Tanita, United Kingdom) with a scale of 0 to 150 kg and an accuracy of 100 g was used. Height was measured using a Seca portable stadiometer (Seca Gmbh & Co. KG, Hamburg, Germany) with an accuracy of 0.1 mm.

Body mass index (BMI) was calculated using the formula: BMI = weight (kg)/height2 (m). Body surface area (BSA) was calculated using nine equations (proposed for adult men), these being the most used today for determining BSA.

The equations are shown in Table 1.

The MDD measurement was performed following the recommendations of the International Atomic Energy Agency (IAEA)[25]. Volunteers were instructed to empty their bladder. Then saliva sample was collected on cotton placed under the tongue. The saliva sample was used to determine the natural deuterium abundance of each participant. The wet cotton ball was transferred from the mouth into a 20 ml syringe and the saliva was squeezed into a 2 ml vial. Subsequently, 3.5 g of 99% deuterium was given to each person to ingest. Once the deuterium was administered, the participants lay down again in their respective sleeping bags for a period of 3.5 hr, so that the ingested deuterium could equilibrate with the rest of the body water. Once the equilibration time had elapsed, the first step for saliva col-

Table 1. BSA equations for young and adult males

Authors	Equations BSA
Du Bois and Du Bois[18]	$0.007184 \cdot Hei^{0.725} \cdot Wei^{0.425}$
Boyd[26]	$0.0003207 \cdot Hei^{0.3} \cdot (1000 \cdot Wei)^{0.7285 - 0.0188 \cdot \log_{10}(1000 \cdot Peso)}$
Fujimoto et al.[27]	$0.008883 \cdot Hei^{0.663} \cdot Wei^{0.444}$
Haycock et al.[29]	$0.024265 \cdot Hei^{0.3964} \cdot Wei^{0.5378}$
Livingston and Lee[30]	$0.1173 \cdot Wei^{0.6466}$
Mattar[31]	(Hei + Wei - 60) / 100
Meeh[35]	$0.1053 \cdot Wei^{2/3}$
Mosteller[28]	√ Hei · Wei / 3600
Kuehnapfel et al.[19]	$0.0051 \cdot Hei^{0.8516} \cdot Wei^{0.3262} \cdot e^{0.0036 \cdot BMI} \cdot e^{-0.0120}$

Legend: BSA: body surface area, Hei: Height. Wei: Weight.

lection was repeated again, determining a second saliva or contrast collection. All samples were collected in sterilized polypropylene tubes, sealed and stored in a safety transport case for subsequent laboratory analysis, where they were stored at -20 degrees Celsius and subsequently analyzed using an Esiorbitrap and Maldi-tof mass spectrometer, according to IAEA protocol[25].

Before analysis, saliva samples were thawed at room temperature and centrifuged to remove solid particles. Each participant's sample was analyzed twice. Finally, body compartments were calculated: % fat, fat mass FM (kg), fat-free mass FFM (kg) and total body water (TBW) (%) (IAEA 2010)[25].

Statistics

The Shapiro-Wilk test was used to contrast the normality of the study data. Descriptive analysis of arithmetic mean, standard deviation, confidence interval (CI) was performed. One-way Anova and Tukey's test of specificity were used to determine the differences between BSA equations. Pearson's correlation was used to relate the variables.

Three simple and multiple stepwise regression models were developed. The criteria used for the models generated were: explanatory power (R^2), standard error of estimation (SEE), Durbin-Watson contrast test, Tolerance and variance inflation factor (VIF). In all cases, $p<0.05$ was considered significant. Calculations were performed in SPSS 26.0 and MedCalc 11.1.0.

RESULTS

The descriptive values of the anthropometric indicators, body composition and the BSA of the young and adult mountaineers (guides and porters) are shown in Table 2. In the BSA there were no significant differences between the nine equations proposed for adult men (p>0.05).

The relationships between age and BSA values with FFM (criterion MDD) are shown in Table 3. The relationships between FFM (MDD criterion) with BSA values (nine methods), ranged from (r= 0.72 to 0.76), meanwhile, with age with FFM, the relationship was positive and low (r= 0.29, p=1.82).

Table 2. Anthropometric and body composition indicators of the sample studied

Variables	Mean	SD	CI	
			Lower limit	Upper limit
Age (years)	30.35	6.60	27.5	33.2
Weight (kg)	70.25	6.86	67.3	73.2
Hieght (cm)	175.17	6.31	172.4	177.9
BMI (kg/m^2)	22.89	1.93	22.1	23.7
Body Composition (MDD)				
MDD Fat Mass (%)	17.9	5.6	15.4	20.3
MDD FM (kg)	12.7	4.8	10.6	14.8
MDD FFM (kg)	57.6	5.7	55.1	60.0
MDD TBW (%)	60.1	4.1	58.3	61.9
BSA (equations)				
Du Bois and Du Bois[18]	1.85	0.11	1.8	1.9
Boyd[26]	1.85	0.11	1.8	1.9
Fujimoto et al.[27]	1.80	0.11	1.8	1.8
Haycock et al.[29]	1.85	0.11	1.8	1.9
Livingston and Lee[30]	1.83	0.12	1.8	1.9
Mattar[31]	1.86	0.11	1.8	1.9
Meeh[35]	1.79	0.12	1.7	1.8
Mosteller[28]	1.85	0.11	1.8	1.9
Kuehnapfel et al.[19]	1.78	0.10	1.7	1.8

Legend: SD: standard deviation. CI: confidence interval, L: limit, MDD: deuterium oxide dilution method: %: percentage, FM: fat mass, FFM: fat-free mass, TBW: total body water, BSA: body surface area.

Table 3. Relationship between age and ASC equations with MDD

Equations BSA	r	p
Age (years)	0.29	0,182
Du Bois y Du Bois[18]	0.76	<0.001
Boyd[26]	0.75	<0.001
Fujimoto et al.[27]	0.75	<0.001
Haycock et al.[29]	0.75	<0.001
Livingston and Lee[30]	0.72	<0.001
Mattar[31]	0.75	<0.001
Meeh[35]	0.72	<0.001
Mosteller[28]	0.76	<0.001
Kuehnapfel et al.[19]	0.76	<0.001

Legend: BSA: body surface area, MDD: deuterium dilution method.

In general, the BSA equations proposed by Du Bois and Du Bois[18], Boyd[26], Fujimoto et al.[27], Mosteller[28] and Kuehnapfel et al.[19] showed the strongest correlations with the MDD.

Table 4 shows the models generated to propose the equations that predict the FFM. These models use age and BSA. In general, we identified three predictive models: model 1 uses the BSA calculated by Du Bois and Du Bois, model 2 the BSA calculated by Mosteller and model 3 uses the BSA calculated by Kuehnapfel. The best models were models 1 and 3, whose percentage of explanation was 63% and model 2 62%. In the three models the SES ranged from 1.98 to 2.12, the tolerance was from 0.61 to 0.67 and the IFV from 1.49 to 1.64.

The FFM comparisons between the criterion method (MDD) with the three predictive models based on age and BSA are shown in Figure 1. There was no difference between the three models vs. the criterion (p>0.05). The FFM values by criterion MDD was 57.57 ± 5.7 kg, model 1 (Dubois) 57.56 ± 4.9kg, model 2 (Mosteller) 57.57 ± 4.4kg and model 3 (Kuehnapfel) 57.57 ± 4.5 kg.

DISCUSSION

The aim of the study was to propose regression equations to estimate the FFM of mountain guides and porters from the BSA. For this purpose, we used as a contrast criterion method, Deuterium Oxide dilution (MDD), a technique recognized as the gold standard for determining total body water[25].

These results indicate that of the nine BSA equations used as predictors of the FFM, three equations[18,19,27] and chronological age are the ones that reflected a higher percentage of explanation (R^2 = 62 to 63%) compared to the rest of the BSA equations, with SES lower than 4% in the three models. Both tolerance and IFV in the three models evidenced values within the limits established by the literature[29]; evidencing a controlled multicollinearity of age and BSA, thus demonstrating the relevance of these two variables in the models constructed; with absence of autocorrelation (independence of the residuals measured with Durbin-Watson~2 test). Furthermore, there were no significant differences between the averages and ± DE of the MDD with the three predictive models.

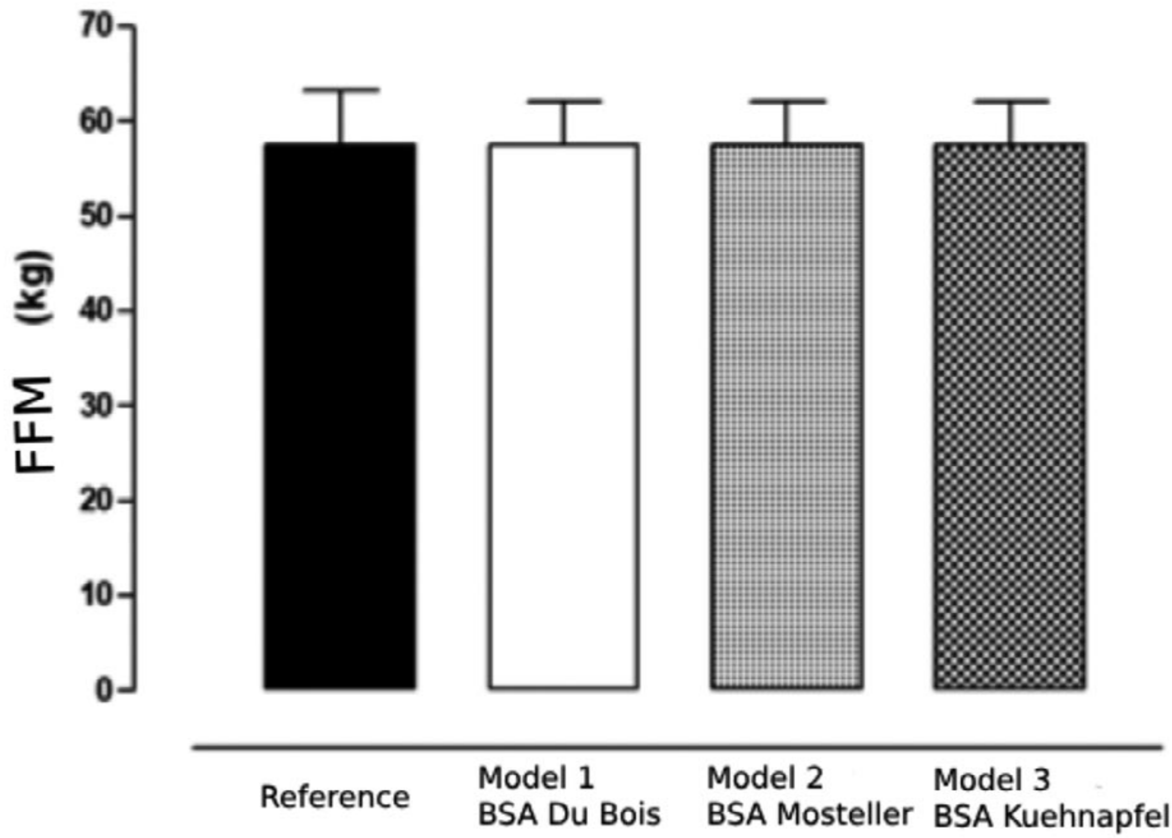
These findings indicate that these new, easily applied, low-cost equations that integrated age and BSA play a relevant role in determining the FFM of young and adult mountain porters, where weight loss and changes in BC often occur frequently during high-altitude mountaineering expeditions[30].

In fact, it has been evidenced that BSA represents human dimensionality and predicts metabolic activity in clinical applications and metabolic heat production in physiology[31]. Even

Table 4. Equations predicting Free Fat Mass for young and adult mountain guides and porters

Model	Equations	R^2	SEE	Durbin-Watson	Predictor	T	IFV
1	FFM = -25.287-(0.260*age)+(49.014*BSA1)	0.632	3.60	2.02	Age	0.61	1.64
					Du Bois	0.61	1.64
2	FFM = -20.736-(0.191*age)+(45.523*BSA2)	0.623	3.64	2.12	Age	0.67	1.49
					Mosteller	0.67	1.49
3	FFM = -28.592-(0.244*age)+(52.499*BSA3)	0.630	3.60	1.98	Age	0.63	1.60
					Kuehnapfel	0.63	1.60

Legend: FFM: fat-free mass, SEE: standard error of estimation, T: Tolerance, IFV: inflation values, BSA1: Du Bois and Du Bois, BSA2: Mosteller, BSA3: Kuehnapfel.



FFM = Fat-Free mass.

Figure 1. Comparison of the equations predicting free fat mass, with the three anthropometric prediction models

its use and application could contribute to identify the limits of performance due to strenuous physical work, especially in extreme temperatures, where climatic and ecological sources produce considerable biological variations[32], especially in regions of high altitudes.

Thus, the main reason for this relationship is that BSA provides a better representation of FFM in mountain guides and porters, as this component in adult men is represented by 80% of total body weight that includes bone, muscle, extracellular water, nerve tissue, and non-fat cells[32]; This can serve as a non-invasive tool for monitoring health status and disease in diverse populations, especially in those who often experience physiological mechanisms associated with acute and chronic adaptation to nutrition and physical exercise[33,34], as is the case of mountain guides and porters.

The equations proposed here allow estimation of the FFM, which information is useful for mountaineers, scientists and multidisciplinary teams planning high-altitude expeditions. Therefore, it is necessary to present adequate FFM levels, as this has an important impact on the performance and adaptation of the body to a challenging environment[30].

In sum, this study presents some strengths that we highlight below. It is one of the first studies carried out on Aconcagua Mountain in Argentina in young and adult mountaineers, and we used a standard method, recognized as the gold standard for the determination of body composition, for the validation of the equations that estimate the FFM. We also highlight some limitations, since it was not possible to measure other anthropometric variables (circumferences and bone diameters) or physical variables (such as muscle strength), which could have contributed to generate other models and analyze which one best models FFM. Future studies should control for these variables and expand the sample size used.

CONCLUSIONS

This se we verified that the body surface area is a predictor of the fat-free mass of mountain guides and porters.

Three predictive models based on age and body surface area were generated that allow us to estimate fat-free mass in a valid and reliable way. The results suggest their use and application for monitoring before, during and after high-altitude mountain expeditions.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of the Institute of Nutrition and Food Technology, INTA U. de Chile for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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REFERENCES

1. Monasterio E, Alamri YA, Mei-Dan O. Personality characteristics in a population of mountain climbers. Wilderness. Wilderness Environ Med. 2014;25 (02):214–9.
2. Apollo M. The true accessibility of mountaineering: the case of the High Himalaya. Journal of Outdoor Recreation and Tourism. 2017;17:29–43.
3. Crust L. Personality and mountaineering: A critical review and directions for future research. Personality and Individual Differences. 2020;163(110073).
4. Jackman PC, Hawkins RM, Burke SM, Swann C, Crust L. The psychology of mountaineering: a systematic review. Int Rev Sport Exerc Psychol. 2023 31;16(1):27–65.
5. Monasterio ME. Accident and fatality characteristics in a population of mountain climbers in New Zealand. N Z Med J. 2005; 118(1208):U1249.
6. Crust L, Swann C, Allen-Collinson J. Crust, L, Swann, C & Allen-Collinson, J (2018) Mentally tough behaviour in extreme environments: perceptions of elite high-altitude mountaineers, Qualitative Research in Sport, Exercise & Health. Qual Res Sport Exerc. 2018;1–14.
7. Arias MJ, Carrasco F, España V, Inostroza J, Bustamante A, Solar I. A comparison of body composition assessment methods in climbers: Which is better? PLoS One. 2019;14(11):e0224291.
8. Zamboni M, Armellini F, Turcato E, Robbi R, Micciolo R, Todesco T, et al. Effect of Altitude on Body Composition during Mountaineering Expeditions: Interrelationships with Changes in Dietary Habits. Ann Nutr Metab. 1996;40(6):315–24.
9. Boyer SJ, Blume FD. Weight loss and changes in body composition at high altitude. J Appl Physiol. 1984 Nov 1;57(5):1580–5.
10. Sitko S, Cirer-Sastre R, López Laval I. Effects of high altitude mountaineering on body composition: a systematic review. Nutr Hosp. 2019; 36(5): 1189-95
11. Westerterp KR, Meijer EP, Rubbens M, Robach P, Richalet JP. Operation Everest III: energy and water balance. Pflugers Arch. 2000;439(4):483–8.
12. Dünnwald T, Gatterer H, Faulhaber M, Arvandi M, Schobersberger W. Body Composition and Body Weight Changes at Different Altitude Levels: A Systematic Review and Meta-Analysis. Front Physiol. 2019;10:430.
13. Fuentes-López J, Callata-Gallegos Z, Mamani-Luque O, Ibáñez-Quispe V, Canqui-Flores B, Mendoza-Mollocondo C, et al. Aplicabilidad de la superficie corporal e índices antropométricos para valorar el tamaño corporal en adolescentes que viven a gran altitud. Nutr Clín Diet Hosp. 2022;42(2):117-22.
14. Torres-Mejías J, Rivarola E, López-Espinoza MA, Loyola J, Vargas R, Luna R, et al. Somatotipo y composición corporal de porteadores y guías del monte Aconcagua, Argentina. Rev Fac Cien Med Univ Nac Córdoba. 2018;29–30.
15. Wing-Gaia S. Nutritional Strategies for the Preservation of Fat Free Mass at High Altitude. Nutrients. 2014;6(2):665–81.
16. Fulco CS, Rock PB, Cymerman A. Maximal and submaximal exercise performance at altitude. Aviat Space Environ Med. 1998; 69(8):793–801.
17. Sergi G, Imoscopi A, Sarti S, Perissinotto E, Coin A, Inelmen EM, et al. Changes in total body and limb composition and muscle strength after a 6-8 weeks sojourn at extreme altitude (5000-8000 m). J Sports Med Phys Fitness. 2010;50(4):450–5.
18. Du Bois D, Du Bois EF. A formula to estimate the approximate surface area if height and weight be known. 1916. Nutrition. 1989;5(5):303–11; discussion 312-3.
19. Kuehnapfel A, Ahnert P, Loeffler M, Scholz M. Body surface assessment with 3D laser-based anthropometry: reliability, validation, and improvement of empirical surface formulae. Eur J Appl Physiol. 2017;117(2):371–80.
20. Wells JCK. Measuring body composition. Arch Dis Child. 2005 Jun 14;91(7):612–7.
21. Burmeister W. Human body composition as related to surface area. Eur J Pediatr. 1980;135(2):147–51.
22. Duren DL, Sherwood RJ, Czerwinski SA, Lee M, Choh AC, Siervogel RM, et al. Body Composition Methods: Comparisons and Interpretation. J Diabetes Sci Technol. 2008;2(6):1139–46.
23. Czarkowski M. Kolejna nowelizacja Deklaracj Helsińskiej [Helsinki Declaration—next version]. Pol Merkur Lekarski. 2014;36 (215): 298–301.

24. Ross WD., Marfell-Jones MJ. Physiological testing of elite athlete. 2nd ed. MacDougall JD. - Wenger HA. - Geeny HJ., editor. Vol. 14. London; 1991. 223–308 p.

25. International Atomic Energy Agency. Introduction to Body Composition Assessment Using the Deuterium Dilution Technique with Analysis of Saliva Samples by Fourier Transform Infrared Spectrometry. IAEA Human Health Series. 2011;12.

26. Edith Boyd. The Growth of the Surface Area of the Human Body. University of Minnesota Press 1935, editor. Michigan; 1935.

27. Fujimoto S, Watanabe T, Sakamoto A, Yukawa K, Morimoto K. Studies on the Physical Surface Area of Japanese. Nippon Eiseigaku Zasshi (Japanese Journal of Hygiene). 1968;23(5):443–50.

28. Mosteller RD. Simplified Calculation of Body-Surface Area. New England Journal of Medicine. 1987;317(17):1098–1098.

29. Haycock GB, Schwartz GJ, Wisotsky DH. Geometric method for measuring body surface area: A height-weight formula validated in infants, children, and adults. J Pediatr. 1978;93(1):62–6.

30. Livingston EH, Lee S. Body surface area prediction in normal-weight and obese patients. American Journal of Physiology-Endocrinology and Metabolism. 2001;281(3): E586–91.

31. Mattar JA. A Simple Calculation to Estimate Body Surface Area in Adults and Its Correlation with the Du Bois Formula. Crit Care Med. 1989;17(8):846.

32. Tanner DA, Stager JM. Partitioned weight loss and body composition changes during a mountaineering expedition: a field study. Wilderness Environ Med. 1998;9(3):143–52.

33. Looney DP, Potter AW, Arcidiacono DM, Santee WR, Friedl KE. Body surface area equations for physically active men and women. American Journal of Human Biology. 2023;35(2).

34. Pietrobelli A, Heymsfield S, Wang Z, Gallagher D. Multi-component body composition models: recent advances and future directions. Eur J Clin Nutr. 2001;55(2):69–75.

35. Meeh K. Oberflächenmessungen des menschlichen Körpers. Z Biol. 1879;15:425–85.