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Body Composition and Selected Nutritional Indicators in Healthy Adults—A Cross-Sectional Study

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Abstract

Background: Body mass composition is subject to constant change and is multifactorially determined. Its analysis in different age groups allows a better understanding of the determinants of the human organism in health and disease.

Aim: The study was aimed to conduct cross-sectional assessment of body composition and selected nutritional indicators in healthy adults.

Methods: The cross-sectional study carried out from March 2016 to April 2018 was preceded by a monthly pilot study. All 1333 adults (women 795, 59.6%) aged 20–59 included in the study were from the urban and rural area of the Podkarpackie Province (Poland). These adults were classified into four 10-year age bands. To obtain reliable assessment, selected screening (anthropometry) and in-depth (bioelectrical impedance including phase angle and bioelectrical impedance vector analysis) methods were used.

Results: In women, the proportion of individuals affected by overweight and obesity increases significantly with age, with a less pronounced trend in men, as reflected in the observed differences in individual body composition components. A slight (0.45–0.60) correlation was also observed between body mass index (BMI) and percentage of fat mass (FM %) among men with an increasing strength of the association with age, decreasing in the 50–59 years group. In the female group, the correlations described are at a much higher level (0.80 or higher). The described changes in body composition were reflected in body type from athletic to obese, measured by means of the bioelectrical impedance vector analysis (BIVA) method.

Conclusions: Age and gender significantly differentiate body composition of the adult human body. The body composition analysis should be considered as complement screening assessment method, especially as a support for the assessment of nutritional status expressed by BMI.

Keywords

body composition, BMI, phase angle, BIVA, nutritional indicators, adults

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Background

The assessment of body composition is a very important element for describing the growth and development of the human body, from birth to old age, and for understanding the origins of health and disease. It is also essential in designing nutritional strategies and in monitoring therapeutic interventions.[1] The dynamics of body composition changes varies at different periods of life. Noticeable differences in selected indicators and

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components are observed in the healthy population. Lifestyle, age, gender, level of physical activity, body composition and ethnicity, may affect the level of fatness.[2,3] Numerous studies show an increase in body weight and body fat with age, as well as a decrease in FFM (fat free mass) after young adulthood.[4,5] Weight gain, characterised by a higher percentage of fat, is seen in men and women over 60 years of age[6] and is often associated with a decrease in physical activity.[7] Age-related changes in body composition can affect both fat mass (FM) and lean mass. On the one hand, losses in muscle and bone mass have a significant impact on functional, nutritional and endocrine status, as well as on the co-morbidity of many disease entities.[8,9] On the other hand, overweight and obesity (manifested by excess fat) represents a significant limitation in daily functioning and mobility.[10]

Recently, a number of reports analyzing the body composion and state of nutrition in health and disease have been published worldwide.[11–17] Their results indicating the occurrence of numerous disorders confirm the discussed social problem objectively. The World Health Organization (WHO) in the long-term strategy for action for 2015–2020 (European Food and Nutrition Action Plan 2015–2020) indicated nutrition disorders as the main reasons for the economic burden on individual European communities.[18] In Poland, according to the Multicentre National Survey on Population Health at the age of 20–74 from 2003–2005 (WOBASZ I) and 2013–2014 (WOBASZ II), obesity was observed in almost 22% in 2005 and 26% in 2014. There were no significant differences in the occurrence of obesity in both sexes in the given study periods, as well as significant differences between the overall results with and without gender breakdown.[19] A valuable source of knowledge are European multi-centre studies estimating obesity among Poles at 25.1%.[20] WHO data estimate overweight and obesity in 25.3% of Poles, 62.8% among men and 54.7% among women.[21]

Currently, access to various anthropometric indicators allows to estimate the nutritional status of the human body and, indirectly, also body composition. Their simplicity, low cost and easy access facilitate their use in everyday clinical practice. Body mass index (BMI), also referred to as the Quetelet index, is the most popular index for assessing nutritional status. It refers to the ratio of body mass and height according to the formula: BMI = body mass [kg]/body height [m^2]. In adults, the cut-off criteria are as follows: <18.5 (underweight), 18.5–24.9 (normal), 25.0–29.9 (overweight), 30.0–34.9 (obesity I °), 35.0–39.9 (obesity II °) and ≥ 40.0 (obesity III °).[22,23]

BIA is considered by many specialists a simple and safe method of assessing nutritional status and body composition in healthy people.[24–26] Mathematical equations for a given component validated for a given population play a significant role in the calculation of individual body composition components. A number of equations have been validated in adult populations.[27–29] Current research confirms the suitability of the above method in the assessment of nutritional status, in both hyperalimentation[30,31] and malnutrition.[32–34] The phase angle (PA), a valuable indicator of nutritional assessment based on BIA, is calculated by means of the formula $PA = \arctan(Xc/R) \times (180/\pi)$, where arctan – arctangent, Xc – reactance, R-resistance, π – 3.14.[25] Its biological significance is not completely understood, but it can be interpreted as an indicator of cell membrane sensitivity and water distribution between intracellular and extracellular compartments.[34] The above claim is justified in the very structure of the human body, where body is composed mostly of water with ions, through which an electric current can flow. The water in the body is localized in two compartments: extracellular water (ECW, approximately 45%) and intracellular water (ICW, approximately 55%).[35] There is a direct relationship between the concentrations of ions and the electrical conductivity and an indirect relationship exists between the ion concentration and the resistance of the solution.[3] The PA correlates significantly with the functional state. In healthy people, PA is in the range of 5 to 7 degrees.[36] Low PA values suggest cell death or a violation of their integrity, while high values indicate higher stability of cell membranes.[37]

Important information is also provided by the bioelectrical impedance vector analysis (BIVA) described for the first time by Piccoli et al. in 1994.[38] The method modelled on an electrocardiogram, allowed a different interpretation of the results of resistance (R) and reactance (XC) parameters normalized to body height (R/H; XC/H).[39] BIVA determines the hydration of the body based on the presentation of the total body water (TBW) value, i.e. the main component of body composition, exactly FFM. The length and angle of the vector, the range (centile) in which the single result is located (tolerance ellipses: 50%, 75% and 95% being percentile ranges) and the shape of the ellipse for the studied population are subjected to analysis.[40] The "y" axis represents the state of hydration (dehydration, overhydration) while the "x" axis represents body mass content (cell, muscle, FFM). On this basis, changes towards higher values of FM (obese type) or FFM, including muscular (athletic type), or lower FM and FFM (lean or cachectic) values in correlation to low/high hydration values of organism, presented in a given quadrant of the BIVA chart can be monitored.[32,38,41] For the purpose of statistical inference, a 95% confidence interval for the mean value of the vector drawn for a given population was adopted. BIVA gives the possibility of comparing single vectors and tolerance ellipses for examined groups with different characteristics (different for age, sex, ethnic group).[41,42]

To the best of our knowledge, the presented study is one of the first worldwide and the first in Poland, which compiles in an understandable way screening and in-depth assessment indicators (BMI, BIA, PA, BIVA) on a large population of healthy adults in different age bands, taking into account the change trend. The study shows the scale of the overweight and obesity, based on the analysis of FM and FFM as well as hydrated tissue drawn as BIVA tolerance ellipses represented by vector shift.

Methods

Ethics

The study was approved by the institutional Bioethics Committee at the University of Rzeszów (Resolution No. 11/10/2016) and by all appropriate administrative bodies. The study was conducted in accordance with ethical standards laid down in an appropriate version of the Declaration of Helsinki (64th WMA General Assembly, Fortaleza, Brazil, October 2013) and Polish national regulations.

Subjects

The study group consisted of 1333 adults (women 795, 59.6%) aged 20–59 residing in the urban and rural area of Poland. This cross-sectional study was carried out from March 2016 to April 2018, preceded by a monthly pilot study. The inclusion criteria were as follows: age 20 to 59 years, written consent to participate in the study, and lack of other chronic disease that may affect the nutritional status. None of them had musculoskeletal or functional mobility issues. Participants who were unwilling or unable to give informed consent or participating in another research project were not accepted. Potential participants were excluded during screening if their interview revealed any of the following conditions: kidney failure, heart failure, epilepsy, pregnancy, heart pacemaker, or leg swelling.

Participants were recruited via online advertisements, paper flyers, and snowball recruitment strategies, whereby participants referred others in their social network. Participation in the study was voluntary and anonymous. The purposes and procedures of the study were explained, and informed consent was obtained. The personal data of subjects were protected by assigning each participant with a code in the form of a digital number. All measurements were carried out in the Centre for Innovative Research in Medical and Natural Sciences (Rzeszów, Poland) and during a 2-day health promotion event named Festival of Health in the Heart of the City held in Rzeszów, which is designed to promote a healthy lifestyle.

The studied adults were classified in four 10-year age bands. The division carried out in this way enabled relating the obtained results to reference values for a given age. It also allowed to standardize their interpretation and compare them with the results of other authors. The flow chart demonstrating selection of the study group is presented in Figure 1.

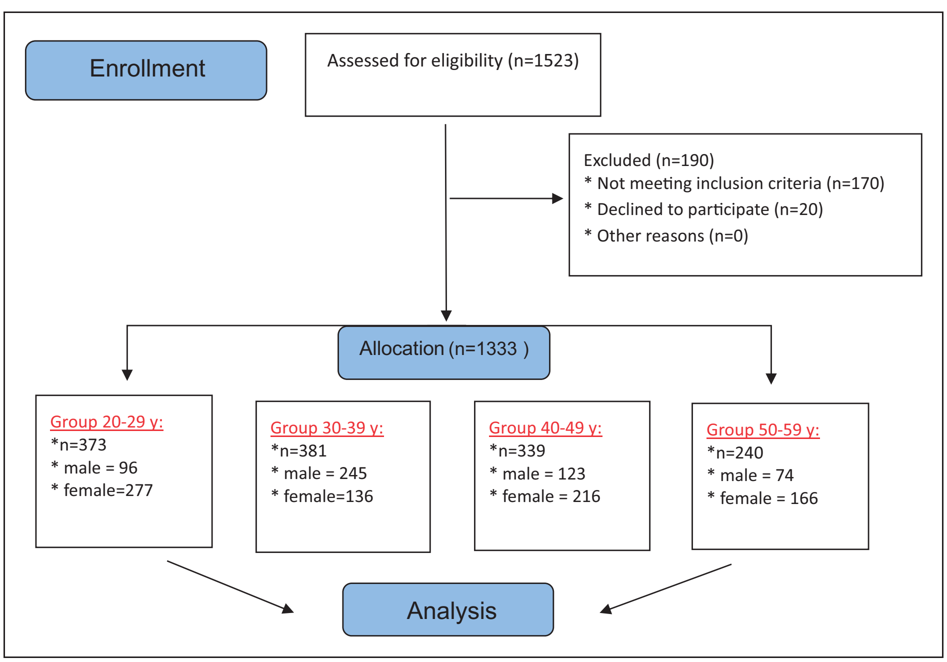

Figure 1. Flow Chart Demonstrating Study Participants Selection.

Assessment

Anthropometric measurements and body mass index. In all participants, body weight and height were measured, and BMI was calculated. The measurements were performed under standard conditions, in an upright position, barefoot, and in a fasting state. Body weight and height were assessed with an accuracy of 0.1 kg/0.1 cm using a digital scale (Radwag 100/200 OW, Radom, Poland). Body mass index (BMI) was calculated as weight (kg)/height (m2) [kg/m^2]. For all participants, BMI fell into one of the following categories (WHO recommendation): <18.5 (underweight), 18.5–24.9 (normal weight), 25.0–29.9 (pre-obesity) and >29.9 (obesity).[22,23] Anthropometric assessments were performed by trained nurses.

Bioelectrical impedance analysis. The bioimpedance parameters R (Ω) and Xc (Ω) were obtained using bioelectrical impedance analyzer AKERN BIA – 101 (Akern SRL, Pontassieve, Florence, Italy). The results were analyzed using dedicated software (Bodygram1_31 from AKERN, Pontassieve, Florence, Italy). The equations used by the software to assess the specific parameters are restricted property of the company, but to a significant degree, they are based on computed algorithms developed by Sun et al.[43]

The whole-body BIA device employed a tetrapolar method. After turning on the device, sinusoidal current with an amplitude of 800 μA and 50 kHz (imperceptible to the human body) passed through the body of the examined person and then was intercepted by the device giving the result of tissue resistance (resistance and reactance). The measurements were conducted between 7:00 and 12:00, in a fasting state (food or beverage consumption may decrease impedance by 4–15 Ω over a 2–4 h period after meals, representing an error smaller than 3%),[44] in supine position, with abducted upper (30°) and lower (45°) extremities, after at least 5 min of rest. To ensure reliability and repeatability of the results obtained, two measurements, one after another, were performed. Disposable electrodes were placed on the dorsal surface of the right upper (over the wrist) and right lower limb (on the ankle), as described by Lukaski et al.[44]

The following measurements were analyzed: fat mass (FM), fat free mass (FFM), total body water (TBW) and body cell mass (BCM).

Bioelectrical impedance vector analysis. R and Xc data were subsequently used to determine the PA and BIVA. The PA was calculated using the following formula: PA = tangent arc (Xc/R)*180/π.[45] The BIVA results were conducted using bioelectrical measurements adjusted for the height (R/H, Ohm/m, Xc/H, Ohm/m). R/H and Xc/H are plotted as a point on the probability graph (RXc graph), showing the 50%, 75%, and 95% tolerance ellipses of the reference population, according to Piccoli et al.[46] Detailed description of the methodology has been described elsewhere.[47,48] The use of dedicated software (Bodygram1_31 from AKERN, Pontassieve, Florence, Italy) and BIVA 2002 software,[51] allowed to plot tolerance ellipses with the indication of a specific vector shift. All BIVA measurements were performed by one operator.

Statistical Analysis

Statistical analyses were performed using StatSoft software (Statisctica package, version 13.1, SoftStat Corporation, Poland). Normality of distribution was assessed with the Shapiro-Wilk test. The continuous data are presented as mean ± standard deviation (SD). Differences between groups were analyzed with the two-tail student's t-test for independent variables in case of parametric distribution, while Mann–Whitney U Test was used in case on non-parametric distribution. The categorical data were compared using χ^2 test. The study also made use of a simple and multiple regression analysis test, assessing successively the impact of one quantitative variable on the subsequent one and the simultaneous impact of several quantitative variables on the subsequent one. A P value of <.05 was considered statistically significant.

Results

Table 1 presents anthropometric (body weight, height), impedance (R, XC) and nutritional status (BMI, PA) parameters in four age bands every 10 years. Additionally, a separate analysis was made for BMI and PA (Figure 2). In the females, a significant decrease in height, R, XC, normalized R and XC was observed, with a simultaneous stabilization in PA and decrease in the oldest age group. Both body weight and BMI increased significantly with age. In the group of males the distribution of results obtained between age groups was similar to that of the group of females, with the difference that in the oldest age group a decrease in BMI and body weight parameters was demonstrated. BMI and PA were higher in men than in women at all ages, with the exception of BMI in the 50–59 age group (slightly higher in women) (Figure 2). At the same time, it should be noted that the proportion of people affected with overweight and obesity increases significantly with age in women, while the trend is less pronounced in men (Figure 3 and Table 2).

BIA results of study participants are presented according to gender in Table 3. In the group of females, only FM [kg, %] increased significantly, other parameters were lower (FFM [%], BCM [kg and %], TBW [%])

Table 1. Anthropometric Parameters According to Age Separately for Females and Males—Mean With 95% Confidence Intervals for Each Group and Differences Between Neighboring Groups.

Anthropometric Parameters	Age Group [Years]			
	20–29 (*N* = 277)	30–39 (*N* = 136)	40–49 (*N* = 216)	50–59 (*N* = 166)
Females				
Height [cm]	163.9 (163.1;164.6)	163.8 (162.8;164.8)	162.6 (161.8;163.3)	160.6 (159.7;161.5)
	−0.1 (−1.3;1.2)	−1.2 (−2.5;0.0)	−1.9 (−3.1; −0.7)*	
Body weight [kg]	61.5 (60.2;62.8)	67.7 (65.3;70.1)	70.3 (68.3;72.3)	72.5 (70.5;74.4)
	6.2 (3.5;8.9)*	2.6 (−0.2;5.4)	2.2 (−0.5;4.8)	
BMI [kg/m^2]	22.9 (22.4;23.3)	25.2 (24.4;26.0)	26.5 (25.9;27.2)	28.1 (27.3;28.8)
	2.4 (1.4;3.3)*	1.3 (0.4;2.3)*	1.6 (0.6;2.5)*	
R [Ohm]	603.5 (596.1;610.9)	572.6 (559.7;585.5)	543.5 (534.2;552.9)	530.0 (520.3;539.6)
	−30.9 (−44.7; −17.1)*	−29.1 (−43.5; −14.6)*	−13.6 (−27.2;0.0)	
XC [Ohm]	66.4 (65.5;67.4)	63.9 (62.3;65.4)	60.4 (59.3;61.6)	55.9 (54.7;57.2)
	−2.6 (−4.3; −0.8)*	−3.5 (−5.3; −1.7)*	−4.5 (−6.2; −2.8)*	
R/H [Ohm/m]	369.0 (364.0;373.9)	350.0 (341.9;358.1)	335.0 (328.8;341.2)	330.3 (324.1;336.5)
	−18.9 (−28.0; −9.9)*	−15.0 (−24.5; −5.6)*	−4.7 (−13.6;4.2)	
XC/H [Ohm/m]	40.6 (40.0;41.3)	39.1 (38.1;40.1)	37.3 (36.5;38.0)	34.9 (34.1;35.7)
	−1.6 (−2.7; −0.4)*	−1.8 (−3.0; −0.6)*	−2.4 (−3.5; −1.3)*	
PA [°]	6.30 (6.22;6.38)	6.40 (6.26;6.54)	6.35 (6.25;6.45)	6.04 (5.93;6.14)
		0.10 (−0.05;0.25)	−0.05 (−0.21;0.11)	−0.31 (−0.46; −0.16)*
Males				
Height [cm]	178.3 (177.0;179.6)	178.9 (178.1;179.7)	177.3 (176.1;178.4)	174.7 (173.2;176.3)
	0.6 (−0.9;2.1)	−1.6 (−3.0; −0.2)*	−2.5 (−4.4; −0.7)*	
Body weight [kg]	83.9 (81.4;86.5)	88.4 (86.8;89.9)	89.0 (86.5;91.5)	84.7 (81.5;87.9)
	4.4 (1.4;7.5)*	0.6 (−2.2;3.4)	−4.3 (−8.0; −0.6)*	
BMI [kg/m^2]	26.4 (25.6;27.2)	27.6 (27.2;28.0)	28.3 (27.6;29.0)	27.7 (26.8;28.6)
	1.2 (0.3;2.1)*	0.7 (−0.1;1.5)	−0.6 (−1.7;0.5)	
R [Ohm]	486.9 (473.5;500.2)	476.7 (468.9;484.5)	453.3 (442.9;463.6)	441.8 (424.7;458.8)
	−10.2 (−25.2;4.9)	−23.4 (−37.2; −9.6)*	−11.5 (−29.9;6.8)	
XC [Ohm]	62.6 (60.9;64.2)	61.6 (60.6;62.6)	58.5 (56.5;60.6)	54.1 (52.3;56.0)
	−0.9 (−3.0;1.2)	−3.1 (−5.0; −1.2)*	−4.4 (−7.0; −1.8)*	
R/H [Ohm/m]	273.1 (265.8;280.3)	266.8 (262.3;271.2)	255.9 (250.0;261.8)	253.2 (242.8;263.6)
	−6.3 (−14.9;2.3)	−10.9 (−18.8; −2.9)*	−2.7 (−13.2;7.9)	
XC/H [Ohm/m]	35.1 (34.2;36.1)	34.5 (33.9;35.1)	33.1 (31.9;34.2)	31.0 (29.9;32.1)
	−0.6 (−1.8;0.6)	−1.5 (−2.6; −0.4)*	−2.0 (−3.5; −0.6)*	
PA [°]	7.36 (7.19;7.52)	7.38 (7.27;7.49)	7.29 (7.11;7.48)	7.01 (6.81;7.21)
	0.02 (−0.19;0.24)	−0.09 (−0.28;0.11)	−0.28 (−0.54; −0.02)*	

Significates differences at $P < 0.05$ between neighboring groups was denoted by*.

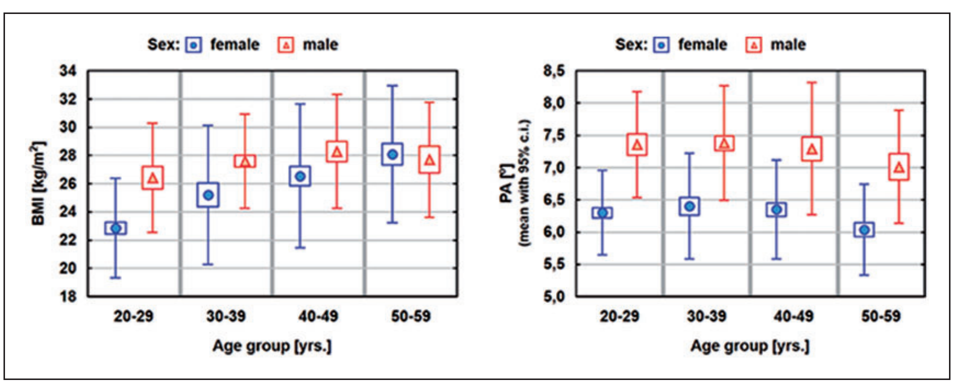

Figure 2. Mean With 95% C.I (Box) and Mean +/− Std. Dev. (Whiskers) for BMI and PA According to Group Separately for Females and Males.

or stable (FFM [kg], TBW [kg]) with age. In the group of males (except group 20–29 y), a decrease in FM [kg, %] with age was seen. A significant decrease in BCM% was also observed in the oldest group of males. FFM [%] and TBW [%] increased. The remaining measured parameters become slightly stabilized.

Interestingly, for females statistically significant trends were found for all body composition parameters, while for males insignificance was found for the trend of FM [kg], FFM [%] and BCM [kg]. Moreover, the correlations often have a different direction – e.g. FM [%] in women increases with age (increase in FM [%] by 0.186 each year) while in men it decreases, with each year by 0.096 on average. The above prognosis data indicate that in women in 10 years one can expect a percentage increase of FM by 1.86% while in men a decrease by 0.96%. Detailed trend analyses are presented in Table 4.

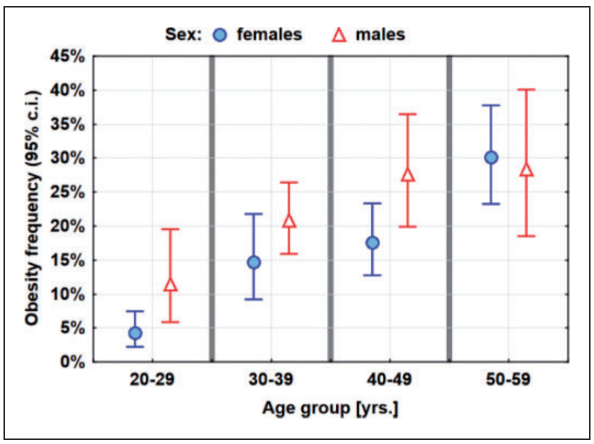

Figure 3. Obesity Frequency in Age Groups for Females and Males (Percent With 95% C.I. and Relative Risk).

Table 5 examines how selected percentage components of body composition are related to BMI using the linear correlation coefficient. A negligible (0.45–0.60) correlation of BMI with FM [%] was observed among men, the strength of the association increasing slightly with age, decreasing in the 50–59 years group. However, in the group of women, these correlations are much higher, reaching a level of 0.80 or higher.

The results from the BIVA are shown in Figures 4 and 5 for male and female, respectively. The athletic type (higher MM and BCM values, lower TBW values) predominated among young men (group 20–29 y and 30–39 y), with the majority of percentage values (65.3% and 56%, respectively) of BIVA vectors (upper left quadrant). With age a percentage shift of vectors was observed towards the obese type of build (higher FM values, higher TBW values) (group 40–49 y: 54.5% and group 50–59 y: 60.3%) (lower left quadrant). The same vector shift with age was also observed in women. In young women, the athletic type predominated (group 20–29 y: 61.4% and group 30–39 y: 52.8%), while the obese type predominated with age (group 40–49 y: 47.3% and group 50–59 y: 54.5%).

Discussion

Knowledge of the ontogenetic variability of body composition traits in the population contributes not only to a more accurate knowledge of the physiological and biochemical processes occurring in the body over time. It is also a valuable support in the treatment of diseases, including civilization diseases, as well as in their

Table 2. Nutritional Status (Expressed by BMI) According to Age for Females and Males.

	Age Group [Years]								
	20–29		30–39		40–49		50–59		
BMI WHO Classification	*N*	%	*N*	%	*N*	%	*N*	%	*P*
Females									
Underweight	14	5.1	3	2.2	3	1.4	0	0.0	.0053**
Normal weight	202	72.9	77	56.6	87	40.3	50	30.1	<.0001***
Pre-obesity	49	17.7	36	26.5	88	40.7	66	39.8	<.0001***
Obesity	12	4.3	20	14.7	38	17.6	50	30.1	<.0001***
Males									
Underweight	0	0.0	0	0.0	0	0.0	0	0.0	1.0000
Normal weight	33	34.4	61	24.9	23	18.7	17	23.0	.0634
Pre-obesity	52	54.2	133	54.3	66	53.7	36	48.6	.8557
Obesity	11	11.5	51	20.8	34	27.6	21	28.4	.0146*

P value was calculated using chi-square test of independence, separately for occurrence of each BMI category.
*, ** and *** denotes significant differences between group for $P<.05$; $P<.01$ and $P<.001$.

Table 3. Bioelectric Impedance Analysis Results According to Age Separately for Females and Males—Mean With 95% Confidence Intervals for Each Group and Differences Between Neighboring Groups.

Anthropometric Parameters	Age Group [Years]			
	20–29 (*N* = 277)	30–39 (*N* = 136)	40–49 (*N* = 216)	50–59 (*N* = 166)
Females				
FM [kg]	17.5 (16.6;18.5)	21.0 (19.4;22.6)	22.9 (21.4;24.4)	24.7 (23.2;26.2)
	3.5 (1.5;5.4)*	1.9 (−0.1;4.0)	1.8 (−0.2;3.7)	
FM [%]	27.2 (26.4;28.0)	29.7 (28.4;31.0)	30.9 (29.8;32.0)	32.8 (31.7;34.0)
	2.5 (1.0;4.1)*	1.2 (−0.4;2.8)	1.9 (0.4;3.4)*	
FFM [kg]	44.2 (43.6;44.8)	46.3 (45.4;47.3)	47.5 (46.7;48.3)	47.7 (46.9;48.5)
	2.1 (1.0;3.2)*	1.2 (0.0;2.4)*	0.2 (−0.9;1.3)	
FFM [%]	72.8 (72.0;73.6)	70.1 (68.8;71.4)	69.1 (68.0;70.2)	67.2 (66.0;68.3)
	−2.7 (−4.3; −1.2)*	−1.0 (−2.6;0.6)	−1.9 (−3.4; −0.4)*	
BCM [kg]	24.4 (24.0;24.8)	25.7 (25.1;26.3)	26.5 (25.9;27.1)	25.8 (25.3;26.4)
	1.3 (0.5;2.1)*	0.8 (0.0;1.6)	−0.7 (−1.4;0.1)	
BCM [%]	54.9 (54.6;55.3)	55.5 (54.8;56.1)	55.2 (54.8;55.7)	53.7 (53.2;54.2)
	0.6 (−0.1;1.2)	−0.2 (−1.0;0.5)	−1.5 (−2.2; −0.8)*	
TBW [kg]	32.3 (31.8;32.7)	34.0 (33.3;34.7)	34.9 (34.3;35.4)	35.0 (34.4;35.6)
	1.7 (0.9;2.5)*	0.9 (0.0;1.8)*	0.1 (−0.7;1.0)	
TBW [%]	53.2 (52.6;53.8)	51.3 (50.3;52.2)	50.7 (49.9;51.6)	49.3 (48.6;50.1)
	−1.9 (−3.0; −0.8)*	−0.6 (−1.8;0.6)	−1.4 (−2.5; −0.3)*	
Males				
FM [kg]	19.4 (17.8;21.1)	22.2 (21.0;23.3)	20.9 (19.4;22.5)	17.8 (16.1;19.6)
	2.7 (0.7;4.8)*	−1.2 (−3.1;0.6)	−3.1 (−5.6; −0.6)*	
FM [%]	22.7 (21.3;24.1)	24.3 (23.4;25.1)	23.1 (21.8;24.3)	20.3 (18.7;22.0)
	1.6 (0.0;3.2)	−1.2 (−2.7;0.3)	−2.7 (−4.7; −0.8)*	
FFM [kg]	63.9 (62.2;65.7)	66.3 (65.3;67.3)	67.6 (66.0;69.1)	66.7 (64.6;68.9)
	2.4 (0.4;4.4)*	1.2 (−0.6;3.1)	−0.8 (−3.3;1.6)	
FFM [%]	77.4 (76.0;78.7)	75.7 (74.9;76.5)	76.5 (75.2;77.7)	78.7 (76.7;80.8)
	−1.6 (−3.3;0.0)	0.8 (−0.8;2.3)	2.3 (0.2;4.3)*	
BCM [kg]	38.4 (37.2;39.6)	39.8 (39.1;40.6)	40.1 (38.9;41.2)	38.9 (37.3;40.5)
	1.4 (0.0;2.9)	0.2 (−1.1;1.6)	−1.2 (−3.0;0.6)	
BCM [%]	59.6 (58.9;60.3)	59.8 (59.3;60.2)	59.3 (58.5;60.1)	57.8 (56.5;59.0)
	0.2 (−0.8;1.2)	−0.5 (−1.3;0.4)	−1.6 (−2.7; −0.4)*	
TBW [kg]	47.0 (45.9;48.2)	48.4 (47.6;49.2)	49.7 (48.6;50.8)	49.0 (47.4;50.5)
	1.3 (−0.1;2.8)	1.3 (0.0;2.7)	−0.7 (−2.5;1.1)	
TBW [%]	56.6 (55.6;57.6)	55.4 (54.8;56.0)	56.3 (55.4;57.2)	58.1 (56.5;59.6)
	−1.2 (−2.5;0.0)*	0.9 (−0.2;2.1)	1.8 (0.3;3.3)*	

Significates differences at $P < .05$ between neighboring groups was denoted by *.

prevention. In the present study, selected body composition components and nutritional indicators were assessed in 1333 healthy adults, in four age subgroups.

A common way to define and measure obesity, as well as to estimate disease risk, is to determine the BMI. Our study, based on the aforementioned index, showed excessive body weight in 57% of the study population, suggesting the presence of excessive fat mass. Both overweight and obesity, in each age group, affected men more often than women. Additionally, similar to other reports[4,5] our research has shown a trend of increasing body weight and percentage overweight and obesity (expressed by BMI) with age, particularly pronounced in the female group. However, a high BMI does not always correspond to an increased amount of body fat and vice versa, as BMI does not differentiate between fat mass and fat-free mass.[49] The composition of body mass changes with age, and a characteristic feature of the ageing process is both an increase in body fat and a loss of total water, bone mass and muscle mass, among others.[50] In older people, deficits in FFM, often masked by excessive body fat, like obesity, are a major health problem and a public health challenge.[51] Early detection of changes – including significant imbalances, in FM and FFM content at older ages – can prevent the onset of serious illness, malnutrition as well as disability.[8]

Detailed analysis of the body composition of the subjects showed a definite trend of changes. In women, a gradual increase in FM with age was observed, with a

Table 4. Analysis of the Trend of Changes in Individual Body Composition Components With Age Calculated Separately for Females and Males.

Body Composition Components	Changes in Body Composition Components With Age			
	Females		Males	
	B (95% C.I.)	*P*	*B* (95% C.I.)	*P*
FM [kg]	0.249 (0.192; 0.306)	<.0001	−0.069 (−0.150; 0.012)	.0937
FM [%]	0.186 (0.142; 0.230)	<.0001	−0.096 (−0.160; −0.033)	.0029**
FFM [kg]	0.132 (0.099; 0.164)	<.0001	0.104 (0.025; 0.183)	.0097**
FFM [%]	−0.185 (−0.229; −0.141)	<.0001	0.058 (−0.009; 0.124)	.0890
BCM [kg]	0.061 (0.038; 0.083)	<.0001	0.018 (−0.039; 0.075)	.5394
BCM [%]	−0.030 (−0.050; −0.010)	.0035**	−0.066 (−0.105; −0.028)	.0007***
TBW [kg]	0.102 (0.078; 0.126)	<.0001	0.078 (0.020; 0.136)	.0090**
TBW [%]	−0.126 (−0.158; −0.093)	<.0001	0.062 (0.013; 0.111)	.0125*

Regression analysis results with age as independent variable: *B* – regression coefficient.
*, ** and *** denotes statistically significant trends ($B \neq 0$) for $P < .05$; $P < .01$ and $P < .001$.

Table 5. Correlation Between Body Composition and BMI (Linear Correlation Coefficient) for Females and Males, According to Age Group.

Body Composition Components	BMI							
	Females				Males			
	Age Group [Years]							
	20–29	30–39	40–49	50–59	20–29	30–39	40–49	50–59
FM [%]	0.81*	0.78*	0.84*	0.86*	0.45*	0.53*	0.60*	0.49*
FFM [%]	−0.81*	−0.78*	−0.84*	−0.86*	−0.45*	−0.53*	−0.60*	−0.49*
BCM [%]	0.17*	0.26*	0.20*	0.18*	0.19	0.10	0.12	0.10
TBW [%]	−0.79*	−0.81*	−0.82*	−0.86*	−0.45*	−0.54*	−0.59*	−0.55*

* denotes statistically significant linear correlation coefficient ($P < .05$).

simultaneous decrease in FFM, TBW and BCM. Men, on the other hand, showed a statistically significant decrease in FM (after 40 years of age) and BCM (in the oldest age group) with a simultaneous increase in FFM and TBW. The gender differences in body composition are also illustrated by the different direction of the trend in the percentage of FM content. In contrast to women, a decrease in body FM content was observed among men. This may be related to the fact that in men, the peak of body weight increase with age occurs much earlier, followed by normalization or decrease.[9,50] An interesting observation is also the occurrence of statistically significant trends for all body composition parameters among women, as opposed to men. The results obtained unequivocally confirm the current knowledge of human physiology, indicating a higher value of FM in the female body and a lower one in the male. An inverse proportion occurs in FFM composition (including total body water), with higher FFM in men and lower FFM in women. Fat accumulation in both sexes proceeds with different intensity, depending on the type of nutrition or physical activity undertaken. There is also a gradual regression of metabolically active tissue mass. At geriatric ages, it is masked by the increase in body fat and overgrowth of connective tissue in muscle mass. In large epidemiological studies assessing the body composition of the adult population of Italy, an increase in weight and percentage fat mass with age was demonstrated. The presented study, similar to our study, shows higher values of women's fat mass vs. men's fat mass in each of the studied age groups. In addition, a similar average percentage of FM was obtained in men (22.1%) and women (33.6%).[52] The above observations were also shown in other population studies of adults,[53,54] with particular emphasis on the percentage higher average median of FM in women.[54,55] Our observations also showed a high correlation of BMI with FM in the female group, which somewhat complements the results of previous studies in this area in adults[56] and children.[57]

Changes in body composition with age are further confirmed by PA and BIVA analysis. Previous studies

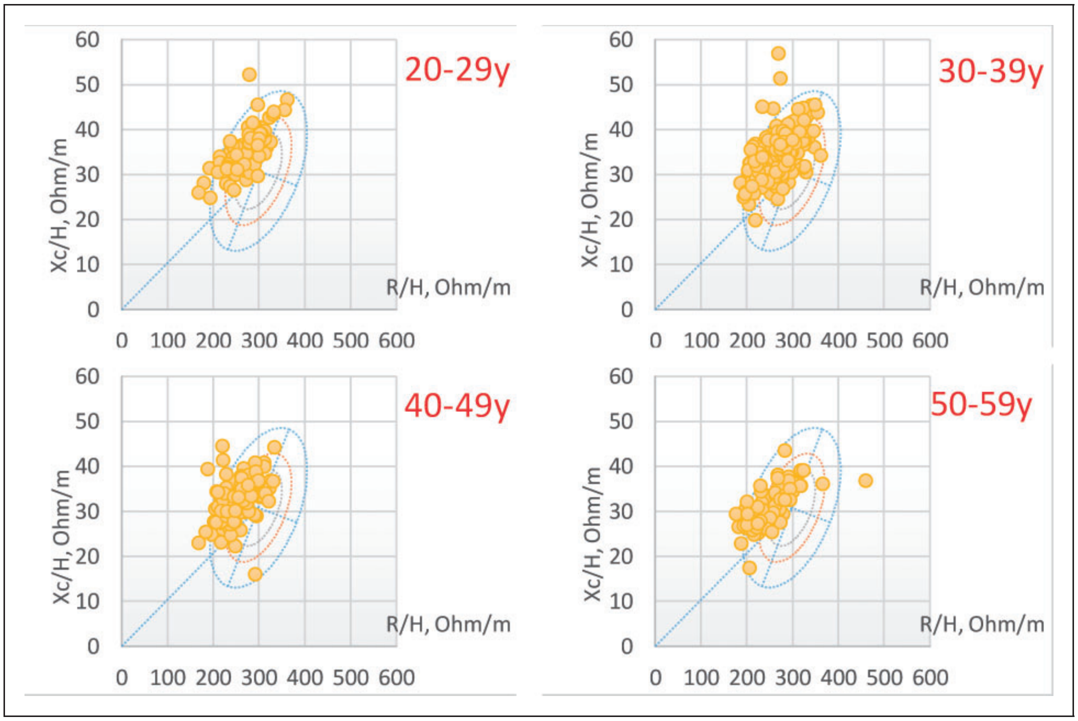

Figure 4. Bioelectrical Impedance Vector Analysis in Man Participants in Relationship to a Reference Population. Solid squares represent individual vectors of four groups (20–29 years; 30–39 years; 40–49 years; 50–59 years). The circles on the graph showing the 50%, 75%, and 95% tolerance ellipses of the reference population.

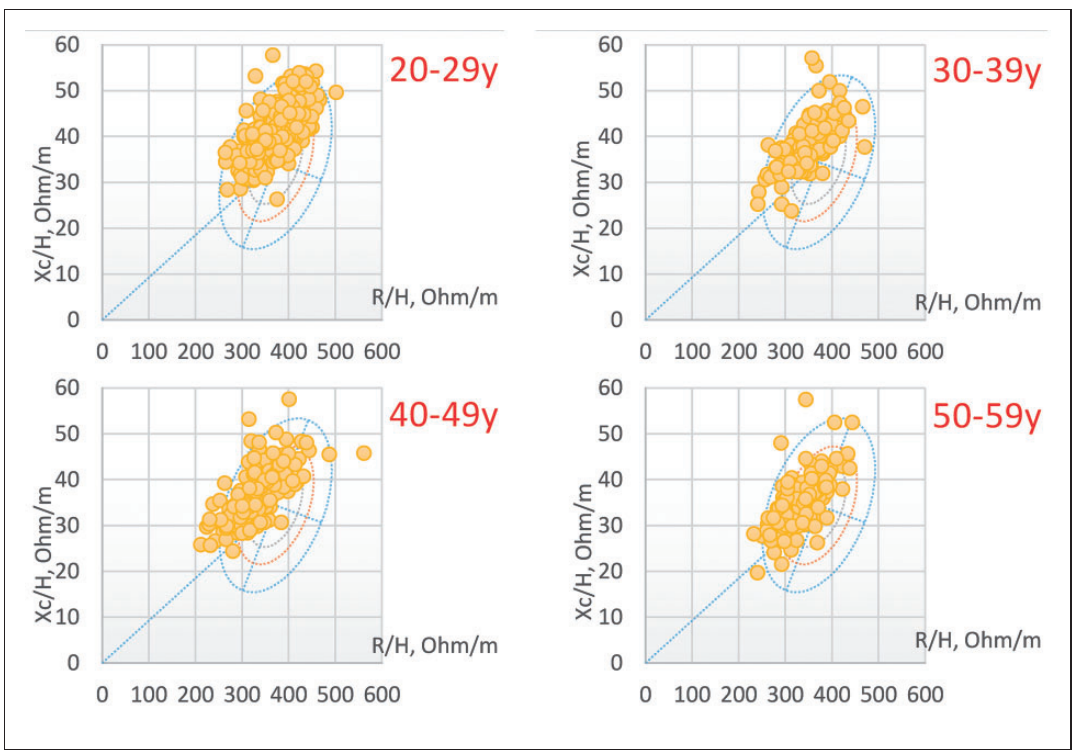

Figure 5. Bioelectrical Impedance Vector Analysis in Women Participants in Relationship to a Reference Population. Solid squares represent individual vectors of four groups (20–29 years; 30–39 years; 40–49 years; 50–59 years). The circles on the graph showing the 50%, 75%, and 95% tolerance ellipses of the reference population.

related to the phase angle have described its cyclical decrease with age. The reason was a decrease in reactance caused by the loss of muscle mass and thus an increase in resistance associated with a decrease in the proportion of water at the expense of body fat.[25] In our study, generally in each age group, higher PA values (by an average of 1.0 degree) were found among men than among women. Relating the results obtained to the broad standard of 5.0-7.0 degrees, the stability of cell membranes, and thus the normal functional state of the organism, should be concluded. In line with previous reports, our study showed a decrease in phase angle with age for both men and women, indeed the greatest in the oldest age group. A study by Barbarosa-Silva et al. analyzed the body composition and phase angle of nearly 2,000 healthy Brazilians aged 18–94 years. Statistically significant ($P < .001$) lower phase angle values were found in women as compared to men in each of the examined age groups. In addition, researchers obtained the trend of cyclical phase angle decrease with age for both sexes.[58] Lower PA values in women were also confirmed in other world reports,[59,60] in various ethnic groups.[61]

Analysis of BIVA vectors showed the advantage of an athletic type (more BCM) in women and men up to 40 years of age. The higher the age of the respondents, the higher the migration of vectors towards an obese body type (more FM). The above observations were also confirmed by trend analysis of changes in body composition components. The percentage of BCM (in both men and women) decreased significantly after the age of 40. An additional confirmation of these changes, in the female group, is the result of the BCM-BMI correlation analysis.

In terms of hydration, despite most results within the 50–75% percentile of the confidence ellipse, single values indicated potential dehydration (in the age groups up to 40 years of age for both sexes) or overhydration (over 40 years of age). The results should be unequivocally interpreted as a consequence of the aging of the body, superstructure of fat mass at the expense of cellular and muscle mass and different distribution of water in the body with age. Our study also proved a significant difference in the distribution of individual ellipses of tolerance for the examined age groups as well as in relation to reference values being part of the BIVA software. The difference from the reference values relates to the lower values of resistance and reactance vectors for the examined group. The above observation is consistent with the results of the study by Nescolarde et al. that assessed BIVA values in more than 4,000 Cubans in various age groups. The cited study clearly shows a decrease in confidence ellipses for the population aged 13–59 with a stable phase angle and a significant decrease in BIVA ellipses and phase angle after 60 years of age.[62] Slovak researchers also observed the downward trend in BIVA vectors in a large cross-sectional study. Noteworthy are higher resistance and reactance values in each of the examined age groups.[63] One should remember there are coexisting BIVA differences for sex in different ethnic groups has been well-illustrated in studies.[64]

Our study is obviously not free from limitations. As this is a cross-sectional study, we cannot determine if the changes by age are related to age or to other factors such as generation differences. The next limitation of our study is the lack of analysis in the geriatric age group. The analysis of basic anthropometric and body composition parameters in the 7th and 8th decade of life would significantly complement the assessment of body composition changes progressing with age. Another limitation of the study was the inverse ratio of men to women in group 30–39 y. In order to obtain the objectivity of the results obtained, from the beginning, there was no interference in the proportions of people enrolling in the study, the inverse ratio is the result of a larger number of men aged 30–39 (this number entered the study and could not be rejected since they met the inclusion criteria). The only exclusion criteria were health contraindications or lack of consent to participate in the study. The inverse proportion in the described group may be the result of the specifics of the work of the respondents voluntarily reporting for the study. A large part of them were drivers. Despite the inverted proportion and the hypothetical risk of obtaining different results with the inverse proportion of women to men, in the author's opinion (based on the observed trend of individual components of the body composition together and separately) this does not change the overall result trend.

In view of the cyclical increase in the global trend of disorders whose substrate is related to body mass composition, further exploration of changes and search for patterns in this area seems to be a priority.

Conclusions

Age and gender significantly differentiate the body composition of the adult human body. According to our findings and specialist recommendations, we suggest that body composition analysis should be considered as complement screening assessment method, especially as a support for the assessment of nutritional status expressed by BMI. The prognostic value of our results needs to be determined in further, long-term prospective studies to assess the nutritional status and associated disease risks of a healthy adult population.

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Authors' Contributions

Conceptualization, PW; methodology, PW and DB; formal analysis, PW, MS and IS; investigation, PW; resources, DB and IS; data curation, MS, IS and ZC; writing—original draft preparation, PW; writing—review and editing, PW, ZC, and IS; visualization and supervision, IS and ZC; and project administration, PW. All authors have read and agreed to the published version of the manuscript.

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