FAT-FREE MASS INDEX AND FAT MASS INDEX OF INHABITANTS OF THE CITY OF BIALA PODLASKA

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Abstract. *Introduction:* A steady and considerable increase in the incidence of overweight and obesity is observed in the majority of developed countries. It affects every age group, regardless of sex and race. One of the causes of this negative trend, which has already reached an epidemic scale, is negative changes in lifestyle. We spend increasingly more time in front of a TV or a computer screen at the expense of other activities requiring energy expenditure. *Purpose:* The aim of this study was to analyze changes in body components of adult inhabitants of Biala Podlaska and determine the reference values for FFMI and FMI. *Materials and method:* The examined 668 women and 674 men (20 years old and older) inhabitants of Biala Podlaska. Values of somatic traits were evaluated on the basis of anthropometric measurements. Tissue composition was evaluated with the bioelectrical impedance method. *Results:* The reference values of FMI (25th-75th centile) in women ranged from 7.15 kg/m^2 to 12.93 kg/m^2, whereas in men from 4.94 kg/m^2 to 9.43 kg/m^2. In women the reference values FFMI ranged from 15.29 kg/m^2 to17.28 kg/m^2 and were similar in all calendar age groups. The reference values for all men ranged between 18.76 kg/m^2 and 22.01 kg/m^2 and were the lowest in the oldest category of age. *Conclusions:* The data presented in the following study might be useful for physicians and nutritionists as control values.

Keywords: body composition, fat-free mass index, fat mass index, norm references, BMI.

Introduction

A steady and considerable increase in the incidence of overweight and obesity is observed in the majority of developed countries. It affects every age group, regardless of sex and race [12,29]. One of the causes of this negative trend, which has already reached an epidemic scale, is negative changes in lifestyle. We spend increasingly more time in front of a TV or a computer screen at the expense of other activities requiring energy expenditure [9]. The spread of obesity is also attributable to the contemporary diet which is rich in fats and carbohydrates but deficient in vegetables, fruit and fiber [1,4]. According to the WHO, the number of obese adults has tripled over the span of the last two decades [10]. The percentage of obese individuals is higher in Eastern Europe and the Mediterranean countries than in Western or Northern European countries [3].

The majority of epidemiological surveys rely on BMI (body mass index) values to evaluate the level of excessive body mass. The major drawback of this method is that it does not account for the composition of body tissues. Hence, an above-average body mass may result from high fat mass (FM) as well as muscle hypertrophy. It may also be caused by sarcopenia, a deficiency of fat-free mass (FFM), with a concomitant increase in the content of fatty tissue [18]. Therefore, the proportions between fat-free mass and fat mass expressed by the BMI can vary significantly [17]. These values can also fluctuate depending on sex, age and place of residence [11,13,21]. For this reason, evaluations of overweight and obesity based solely on BMI values may not give a full picture of a person's health. The relationship between FFM and FM can be objectively evaluated based on the fat-free mass index (FFMI) and the fat mass index (FMI) proposed by van Itallia et al. [26]. In assessments performed with the use of the above indices, the influence of height on body tissue composition is eliminated, and changes in BMI values related to age, decreasing height or regressing FFM are taken into account, even if no increase is observed in FM. Hence, the aim of this study was to analyze changes in body fat composition of adult inhabitants of Biala Podlaska and to determine the reference values for FFMI and FMI.

Materials and methods

The research material comprised the results of a survey involving adult respondents (20 and older) residing in Biala Podlaska. The samples were selected based on the administrative division of the city, including 17 housing estates. A total of 1342 respondents, including 668 women and 674 men, participated in the survey. Individuals diagnosed with carbohydrate metabolism disorders, arterial hypertension, cancer and long-term users of medications that could affect body mass were excluded from the experiment. All respondents participated in the study voluntarily.

The values of somatic traits were evaluated by anthropometric measurements (height and body mass) using Martin’s technique [20]. Height was measured with an anthropometer with the accuracy of 0.1 cm. Body mass was measured with TP-150 WTL B electronic scales to the nearest 0.1 kg. The obtained results were used to calculate the body mass index (BMI), defined as the ratio of body mass to the square of the height (kg/m^2). According to the classification of the World Health Organization (WHO), BMI values below 18.50 kg/m^2 suggest that the person is underweight and values in the range of 18.50 to 24.99 kg/m^2 are indicative of optimal body mass. BMI values equal to or higher than 25 kg/m^2 imply that the person is overweight, whereas BMI of 30.00 kg/m^2 and higher suggests obesity [29]. Tissue composition was evaluated by bioelectrical impedance using an Akern BIA body composition analyzer. This device applies a high-frequency but low-voltage (12 V) alternating current to the body to produce a homogenous electric field with low voltage and high frequency [8]. The analyzer supported determinations of passive resistance, including its two components: resistance and reactance. Body composition was evaluated in the BODYSTAT 1.3 application based on the

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following input data: age, sex, height, body mass, resistance and reactance. The above data was analyzed by the program to produce information about fat mass and fat-free mass in the body. The fat-free mass index (FFMI), defined as the ratio of fat-free body mass to the square of the height (kg/m^2), and the fat mass index (FMI), the ratio of fat mass to the square of the height (kg/m^2), were calculated.

The research was conducted in line with the provisions of the Declaration of Helsinki, and it was approved by the Ethical Commission of the Senate of the University of Physical Education in Warsaw. The results were subjected to statistical analysis. The following descriptive statistics were used to characterize the variables: sample size (n), arithmetic mean ($\tilde{x}$) and standard deviation (SD). Differences in the values of the analyzed traits between age groups classified according to the calendar year were calculated by ANOVA and the LSD test.

Results

The surveyed respondents are characterized in Tables 1 and 2, subject to age and sex. Percentile ranks for FMI and FFMI are shown in Tables 3 and 4. Significant differences in height were observed between the examined groups. The youngest women were 6.70 cm taller than members of the oldest group, whereas in men, the corresponding difference was 6.79 cm. A reverse trend was reported for body mass. The value of this somatic trait in women older than 60 was 10.54 kg higher in comparison with women from the 20-39 age group. Among men, members of the 40-59 age group were by 4.40 kg heavier than younger subjects. A tendency to lower body mass was observed in respondents older than 60. Changes in body mass-height proportions were reflected in BMI values. In women, significant differences in the discussed index were observed between age groups classified according to the calendar year. The BMI of women from the 60+ group was 6.15 kg/m^2 higher in comparison with that of the youngest group (20-39 year-olds). In men, the difference in the BMI scores between the corresponding age groups reached 3.40 kg/m^2, and it was statistically significant.

Table 1.

Anthropometric and body composition characteristic by gender and age bracket

Women	All (n 668)		20-39 years (n 140)		40-59 years (n 348)		60 years old and older (n 180)	
	x	SD	x	SD	x	SD	x	SD
Height [cm]	162.17	6.60	166.00	5.67	162.10	6.48	159.30	5.99
Weight [kg]	69.03	13.13	62.36	13.23	69.62	12.58	72.90	12.02
FM [kg]	26.26	11.21	19.71	10.82	26.83	11.06	30.10	9.36
FM [%]	36.39	9.47	30.05	8.99	36.79	9.44	40.45	7.00
FFM [kg]	42.79	3.93	42.59	3.97	42.86	3.67	42.79	4.35
FFM [%]	63.61	9.36	69.95	8.99	63.21	9.28	59.55	6.90
BMI [kg/m²]	26.63	5.05	22.63	4.50	26.50	4.65	28.74	4.50
FMI [kg/m²]	10.04	4.31	7.14	3.88	10.23	4.20	11.87	3.62
FFMI [kg/m²]	16.21	1.48	15.49	0.96	16.27	1.54	16.87	1.40
Men	All (n 674)		20-39 years (n 214)		40-59 years (292)		60 years old and older (n 168)	
	x	SD	x	SD	x	SD	x	SD
Height [cm]	176.22	7.15	179.67	7.60	175.61	6.39	172.88	5.84
Weight [kg]	85.70	15.06	83.25	14.09	87.65	15.81	85.43	14.50
FM [kg]	22.28	10.42	17.25	6.97	21.52	8.90	30.03	11.99
FM [%]	25.16	8.46	20.10	5.05	23.69	6.02	34.17	8.68
FFM [kg]	63.42	9.08	65.78	8.26	66.26	7.57	55.45	7.79
FFM [%]	74.84	8.44	79.90	5.03	76.31	5.85	65.83	8.71
BMI [kg/m²]	27.60	4.39	25.79	3.71	28.43	4.53	28.60	4.28
FMI [kg/m²]	7.19	3.35	5.32	2.06	6.94	2.76	10.00	3.74
FFMI [kg/m²]	20.41	2.43	20.47	1.98	21.49	2.01	18.60	2.51

FM (fat mass). FFM (fat-free mass). BMI (body mass index). FMI (fat mass index). FFMI (fat-free mass index)

Table 2

ANOVA comparisons between age groups

	Women				
	F	p	I-II	I-III	II-III
Height [cm]	45.706	0.000*	*	*	*
Weight [kg]	28.324	0.000*	*	*	*
FM [kg]	38.754	0.000*	*	*	*
FM [%]	55.878	0.000*	*	*	*
FFM [kg]	0.232	0.792	-	-	-
FFM [%]	57.096	0.000*	*	*	*
BMI [kg/m²]	71.084	0.000*	*	*	*
FMI [kg/m²]	55.816	0.000*	*	*	*
FFMI [kg/m²]	40.427	0.000*	*	*	*
	Men				
	F	p	I-II	I-III	II-III
Height [cm]	50.463	0.000*	*	-	-
Weight [kg]	5.332	0.005*	*	*	*
FM [kg]	91.025	0.000*	*	*	*
FM [%]	230.428	0.000*	*	*	*
FFM [kg]	114.672	0.000*	*	*	*
FFM [%]	237.872	0.000*	*	*	*
BMI [kg/m²]	28.183	0.000*	*	*	*
FMI [kg/m²]	127.899	0.000*	*	*	*
FFMI [kg/m²]	98.378	0.000*	*	*	*

*statistically significant differences at the level of $p \leq 0.05$

Table 3

Percentiles for fat mass (FMI), fat-free mass (FFMI), fat mass as percentage of body weight (FM%) women

FMI								
age bracket	n	**5 th**	**10 th**	**25 th**	**50 th**	**75 th**	**90 th**	**95 th**
all	667	1.93	4.52	7.15	10.04	12.93	15.56	18.14
20-39 years	140	1.15	2.17	4.54	7.14	9.74	12.11	14.43
40-59 years	348	2.34	4.86	7.42	10.23	13.04	15.61	18.12
60 years old and older	180	5.05	5.05	9.44	11.87	14.30	16.51	18.68
FFMI								
age bracket	n	**5 th**	**10 th**	**25 th**	**50 th**	**75 th**	**90 th**	**95 th**
all	667	13.50	14.39	15.29	16.21	17.28	18.19	19.08
20-39 years	140	13.63	14.21	14.79	15.49	16.08	16.67	17.24
40-59 years	348	13.43	14.36	15.30	16.27	17.37	18.31	19.23
60 years old and older	180	14.22	14.22	15.92	16.87	17.80	18.65	19.50

Table 4

Percentiles for fat mass (FMI), fat-free mass (FFMI), fat mass as percentage of body weight (FM%) men

FMI								
age bracket	n	**5 th**	**10 th**	**25 th**	**50 th**	**75 th**	**90 th**	**95 th**
all	671	0.89	2.90	4.94	7.19	9.43	11.47	13.48
20-39 years	213	1.44	2.68	3.94	5.32	6.70	7.95	9.19
40-59 years	291	1.75	3.41	5.09	6.94	8.79	10.47	12.13
60 years old and older	167	2.97	2.97	7.49	10.00	12.50	14.78	17.03
FFMI								
age bracket	n	**5 th**	**10 th**	**25 th**	**50 th**	**75 th**	**90 th**	**95 th**
all	671	15.83	17.28	18.76	20.41	22.01	23.49	24.95
20-39 years	213	16.63	17.82	19.02	20.47	21.67	22.87	24.06
40-59 years	291	17.69	18.89	20.12	21.49	22.82	24.05	25.25
60 years old and older	167	13.84	13.84	16.88	18.60	20.24	21.77	23.28

The analysis of body tissue composition revealed considerable differences between the sexes as regards the fatty tissue content of the examined age groups, both in terms of absolute values and percentage content, which reached 10.39 kg and 10.40% in women and 12.78 kg and 14.07% in men, respectively. The observed variations in fatty tissue content were also confirmed by FMI values. In subjects older than 60, those differences reached 4.73 kg/m^2 in women and 4.68 kg/m^2 in men in comparison with the youngest respondents. The reference values of FMI (25th-75th centile) ranged from 7.15 kg/m^2 to 12.93 kg/m^2 for women and from 4.94 kg/m^2 to 9.43 kg/m^2 for men, and they were observed to increase with age. The variations in FFM percentages in total body mass were consistent with changes in fatty tissue content. An analysis of changes in the absolute value of FFM revealed a difference of only 0.20 kg in women, whereas in men, the difference reached 10.33 kg, and it was statistically significant. Based on FFMI values, the difference in fat-free body mass was determined at 1.38 kg in women. The reference values of the analyzed index ranged from 15.29 kg/m^2 to 17.28 kg/m^2, and they were similar across all age groups. In men, FFMI values decreased by 1.87 kg/m^2. The reference values for all men (25th-75th centile) ranged between 18.76 kg/m^2 and 22.01 kg/m^2, and the lowest values were reported in the group of oldest respondents.

Discussion

The dimensions and proportions of the human body change with age. Increased spinal curvature, the flattening of intervertebral discs and greater bending force on lower limbs' joints lead to reduction in height of seniors, in comparison with the value of this somatic trait of adolescents. A person's height is determined by genetic factors in approximately 70% [19)] and the level to which phenotypic traits are manifested is largely influenced by the external environment. The height of the contemporary man continues to increase across various populations, and the rate of intergenerational changes in height is determined by socioeconomic status and standard of living [2,14,28]. This trend is clearly visible in eastern Poland, and the observed changes are greater than in other regions of the country [24], which could suggest that differences in height between the youngest and the oldest respondents are less attributable to ageing, but are more likely to be caused by intergenerational variability in the analyzed region. At the same time, body mass increases with age, that results in higher BMI values. The average BMI for the entire examined population, both men and women, is indicative of overweight. It is worth noting that BMI values higher than 25 kg/m^2 were observed in the group of women older than 40, whereas in men, reference values were exceeded in all age groups. When BMI values are compared with the reference values for fatty tissue content in Caucasians, as proposed by Heo et al. [7], the percentage of fatty tissue in all female age groups exceeded the reference limit. In men, the above correlation was noted only in the 60+ group. This suggests that high BMI values can be largely attributed to a high contribution of fat-free mass in body composition. A higher content of fatty tissue, in terms of both absolute values and body mass percentages, an increase in body mass and BMI values with a concomitant decrease in FFM indicate that the increase in body mass results mainly from fatty tissue deposition. This dependency was confirmed by FMI values which were found to increase with age. FMI and BMI values calculated for the inhabitants of Biala Podlaska were higher than those reported for the European population [5,25], which indicates that women and men surveyed in this study were characterized by higher adiposity than their European peers. The variations in the extent of the reported changes and the age at which they occurred could be attributed to the use of different methods (BIA, DEXA, hydrodensiometry) in evaluations of body composition as well as ethnic differences.

Evaluations of changes in the composition of bodily tissues which are based only on percentages or absolute values of fat mass and fat-free body mass are increasingly often regarded as ambiguous and inaccurate. The proportions between FM and FFM change with age, even if body mass remains constant. The use of FMI and FFMI eliminates the influence of age and height loss on tissue components. Although the absolute value of fat-free body mass was found to decrease in the oldest group of female respondents, FFMI levels increased significantly in successive age groups. In males, the changes in FFM values were also confirmed by the direction of changes in FFMI. The lowest fat-free mass values were noted in the 60+ group. Our results are consistent with the findings of Schultz et al. [25]. Physiologically appropriate proportions between fat-free body mass and height are maintained by the human body at every age to prevent multiple organ failure. The discussed mechanism was less clearly manifested in men than in women. The above could result from greater loss of fat-free body mass relative to height. According to Forbs [6], an increase in body mass by 2.30 kg per decade counteracts the loss of FFM during the ageing process. Kyle et al. [16] demonstrated that the same effect can be achieved by a 1.40 kg increase in body mass per decade. In the examined population of men, the average difference in body mass amounted to 2.18 kg, and it contributed to adverse changes in fat-free body mass. In the female population, changes in body mass were estimated at 10.54 kg, which undoubtedly counteracted the loss of FFM.

Unlike BMI, FMI and FFMI are highly sensitive to minor changes in body composition, which makes those indexes very useful in evaluations of nutritional status. To date, both indexes were used in assessments of small populations requiring regular medical supervision [22,27]. Further work is needed to develop reference values based on large populations of healthy subjects. BMI is the sum of FMI and FFMI, therefore an increase or a decrease in BMI could be accounted for by a rise or a drop in one or both indices. It is generally assumed that an increase in FFMI is accompanied by a drop in FMI values. For this reason, the two indices should be evaluated jointly to determine whether drop or increase in body mass results from changes in one or both tissue components. The reference range between the 25^{th} and 75^{th} centile for FFMI of 15.29-17.29 kg/m^2 in women and 18.76-20.01 kg/m^2 in men may be regarded as clinically normal. Similar reference values were given by Schultz et al. [25], Coin et al. [5] and Kim et al. [15]. Values below the 25^{th} centile are indicative of disease, malnutrition or considerable loss of fat-free body mass, which could be both: physiological (sarcopenia) or pathological (emaciation). In FMI, the normal reference range was determined at 7.15 to 12.93 kg/m^2 for women and 4.94 to 9.43 kg/m^2 for men. Values above the 75^{th} centile point to excessive accumulation of fatty tissue. According to Pichard et al. [23], low FFMI accompanied by high values of FMI necessitate hospital treatment. In practice, FMI supports the identification of subjects with a high BMI, individuals without excessive fatty tissue and subjects who are characterized by an optimal BMI as well as high adiposity. The BMI of a person with the height of 1.70 m and weight of 85.00 kg is 29.41 kg/m^2, which, according to WHO standards, falls into the overweight category on the verge of obesity. This would be true if that person's FMI were above the reference limit without a concomitant increase in the value of FFMI. When nutritional status is evaluated solely based on BMI, short people are more likely to be classified as obese or overweight than tall individuals. The application of normalized values supports a comparison between subjects characterized by different height. In healthy and physically active people with an optimal BMI, the values of FFMI and FMI fall into the same category. In subjects who have a medical condition and are not physically active, FFMI and FMI reference values are often exceeded even at normal BMI levels [16].

Conclusions

The results of our study provide reference limits for physicians and nutritionists evaluating age-related changes in the bodily tissue composition of subjects residing in Biała Podlaska. The reported values should not be universally applied to all inhabitants of our country because environmental factors exert diverse effects on residents of different regions and lead to variations in tissue composition.

Conflict interests

The authors declare they have no conflict interests.

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