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Original Article

Assessment of muscle and fat mass in type 2 diabetes patients by dual-energy X-ray absorptiometry

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Abstract

Objectives: The aim of this study was to assess the quantitative composition of muscle and adipose tissue in type 2 diabetes mellitus (T2DM) patients on the basis of dual-energy X-ray absorptiometry for the diagnosis of obesity and sarcopenia. **Methods**: Dual-energy X-ray absorptiometry was administered to 50 patients with T2DM. Evaluation of the composition of muscle and adipose tissue was performed. **Results**: The median of Appendicular Lean Mass Index (ALMI) in the general group was 8.04 [7.32; 8.97]. In general, there was a decrease in the appendicular muscle mass with increasing age. According to the results of T-score ALMI and Z-score ALMI, we did not identify patients with sarcopenia. However, the calculation of the T- and Z-criteria, adjusted for fat mass, led to a significant decrease of these parameters and in 98.0% it was possible to identify patients who meet the criteria of sarcopenia. **Conclusion**: We did not detect patients with sarcopenia on the basis of ALMI, T-ALMI. After revision of these criteria for fat mass, almost all patients started to meet the criteria of sarcopenia (98.0%).

Keywords: Body Composition, Dual-Energy X-Ray Absorptiometry, Fat Mass Index, Obesity, Sarcopenia

Introduction

Obesity is an important public health problem and challenge worldwide because it is associated with higher risk of cardiovascular and metabolic disorders.

To date, the severity of obesity is assessed according to the World Health Organization (WHO) classification by body mass index (BMI)[1], which takes into account the subject's weight-to-height ratio. Despite the simplicity of this method, there is a significant drawback: it is impossible to assess the body composition. It is known that body weight comprises not only adipose tissue, but also lean muscle mass, bone tissue, and weight of internal organs. In order to assess overweight, it is necessary to know the body composition, namely the fat-to-muscle ratio. Moreover, overweight may be accompanied by the muscle mass reduction, which may be a sign of sarcopenic obesity[2,3], characterized by significant fat deposition in muscle tissue, which leads to muscle weakness. Consequently, recommendations for such patients should include not only the change of eating habits in order to reduce the amount of adipose tissue, but also measures aimed at increasing the amount of muscle mass, as the weight loss in this case can lead to aggravation of sarcopenia. In the updated European consensus statement on definition and diagnosis of sarcopenia the European Working Group on Sarcopenia in Older People (EWGSOP) proposes to focus on low muscle strength to assess sarcopenia, but estimation of muscle quantity and quality is necessary to confirm diagnosis[4].

So, to assess the degree of obesity, it is important to use a method that would make it possible to determine the ratio of adipose and muscle tissue. One of such methods is dual-energy X-ray absorptiometry (DXA), which can be used to determine the fat mass index (FMI) and appendicular lean mass index (ALMI), as well as to calculate indicators (T-score and Z-score), which allow to diagnose sarcopenia or age-related muscle loss[5,6].

There is a number of studies, in which DXA with fat mass index was used to assess body composition together with the obesity classification[5]. This classification is more specific and makes it possible to make a diagnosis more accurately and

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develop individual recommendations for patients.

Patients with type 2 diabetes mellitus (T2DM) are, on the one hand, more likely to be overweight or obese, on the other hand, they have a higher risk of sarcopenia that may develop earlier than in people without type 2 diabetes[7].

Currently, there is a discussion in the literature about optimal methods for assessing body composition[8]. Existing methods do not allow to identify a relative decrease in muscle mass in patients with severe obesity. Using new approaches for assessing body composition may impact on sarcopenia diagnosis in special groups of patients, for example in patients with T2DM and obesity. The comparison of using different body mass indexes in special group of patients is important for the development of algorithms for sarcopenia diagnosis.

The study objective was to assess the quantitative composition of muscle and adipose tissue in patients with T2DM using the DXA method to diagnose obesity and sarcopenia.

Materials and methods: The study was conducted on the basis of the M. Vladimirsky Moscow Regional Research Clinical Institute (MONIKI).

The study enrolled patients with T2DM: men and women over 45 years old with BMI over 25 up to 50 kg/m^2, who signed the Informed Consent Form. Institutional review board approval was obtained before enrollment. The following patients were excluded: pregnant women, persons with missing limbs, having metal implants in the body, as well as those who have been tested with barium 2 weeks or less prior to the inclusion.

All patients received hypoglycemic drug therapy. Of these, 70% (35 from 50) patients were on insulin therapy (among them 18% (9 from 50) - on insulin monotherapy, 52% (26 from 50) - on the combination treatment with non-insulin medicines and insulin, 30% (15 of 50) received only non-insulin treatment. Metformin was prescribed to 70% of patients (35 of 50), sulfonylurea – to 20% (10 of 50), sodium-glucose co-transporter 2 (SGLT2) inhibitors – to 16% (8 of 50), dipeptidyl peptidase 4 – to 8% (4 of 50), glucagon like peptide 1 receptor agonist – to 2% (1 of 50).

Height was measured by height meter.

The Discovery A densitometer (Hologic, Inc., USA) was used to determine the body composition via the Whole Body program, which is a part of the host software of the device. According to the study data the quantitative composition of muscle and adipose tissue was assessed[9].

To assess muscle mass, the following features were calculated: appendicular lean mass index (ALMI), standard deviation relative to normal ALMI in younger (20-40 years old) people of a corresponding gender (T-ALMI)[6].

$$ALMI = (ULLM + LLLM\ (kg)) / height\ (m)^2,$$

where ULLM is the lean mass of the upper limbs, LLLM is the lean mass of the lower limbs.

$$T\text{-}ALMI = ALMI\text{-}\mu / \sigma,$$

where μ is the average deviation from ALMI in people aged 20–40 years of the corresponding gender enrolled in the National Health and Nutrition Examination Survey (NHANES); σ is the standard deviation from ALMI in people aged 20–40 years of the corresponding gender enrolled in the NHANES (Table 1).

The standard deviation was also estimated relative to normal ALMI in individuals of the same age and of the corresponding gender (Z-ALMI).

$$Z\text{-}ALMI = ALMI\text{-}\mu / \sigma,$$

where ALMI is the appendicular lean mass index, μ is the average deviation from ALMI among people of corresponding age and gender enrolled in the NHANES, σ is the standard deviation from ALMI among people of a corresponding age and gender enrolled in the NHANES (Table 2).

According to the EW GSOP 2019 criteria sarcopenia in the Caucasian population is diagnosed in ALMI <7.0 for men and <6.0 for women, and in T-ALMI ≤–2. Low fat-adjusted lean for age (risk of sarcopenia) was assessed at Z-ALMI ≤–1[4].

To fat adipose mass the following features were calculated: fat mass index, standard deviation of FMI relative to normal indicators in younger (20-40 years old) people of the corresponding gender (T-FMI) and standard deviation of FMI relative to normal values in persons of the same age of the corresponding gender (Z-FMI)[5].

$$FMI = fat\ mass\ (kg) / height\ (m)^2.$$

To assess normal body weight and the degree of obesity, the Kelly T. et al.[5] classification according to FMI was used (Table 3).

$$T\text{-}FMI = FMI\text{-}\mu/\sigma,$$

where FMI is the fat mass index, μ is the average deviation of FMI among people of a corresponding gender aged 20-40 years enrolled in the NHANES, σ is the standard deviation of FMI among people of a corresponding gender aged 20-40 years enrolled in the NHANES (Table 1).

$$Z\text{-}FMI = FMI\text{-}\mu/\sigma,$$

where FMI is the fat mass index, μ is the average deviation from FMI among people of a corresponding age and gender enrolled in the NHANES, σ is the standard deviation from FMI among people of a corresponding age and gender enrolled in the NHANES (Table 2).

Fat mass standardization of T-ALMI and Z-ALMI was provided according to Weber D. et al.[6]: T-ALMI (FMI) and Z-ALMI (FMI).

$$Z\text{-}ALMI\ (FMI) = (Z\text{-}ALMI - estimated\ Z\text{-}ALMI) \times (1 / SD),$$

$$estimated\ Z\text{-}ALMI = \beta_1\ (Z\text{-}FMI) + \beta_2\ (Z\text{-}FMI)^2 + constant;$$

where β_1, β_2 are coefficients, constant is a constant value, SD is the standard deviation calculated for people of corresponding gender and age.

$$T\text{-}ALMI\ (FMI) = (T\text{-}ALMI - estimated\ T\text{-}ALMI) \times (1 / SD),$$

$$estimated\ T\text{-}ALMI = \beta_1\ (T\text{-}FMI) + \beta_2\ (T\text{-}FMI)^2 + constant,$$

where β_1, β_2 are the coefficients, constant is a constant value, SD is the standard deviation calculated for people of a corresponding gender of a young age (20-40 years).

Fat-adjusted-sarcopenia was diagnosed at T-ALMI (FMI) ≤–2; low fat-adjusted lean for age muscle mass was diagnosed at Z-ALMI (FMI) ≤–1, according to reference 6[6].

The degree of obesity was also assessed by BMI according to the WHO classification[1].

$$BMI = weight\ (kg) / height\ (m)^2$$

Table 1. Average (μ) and standard deviation (σ) for T-ALMI and T-FMI depending on gender*.

Age / gender	Men 20-40 (n=2604)		Women 20-40 (n=2434)	
Coefficient	μ	Σ	μ	σ
For calculation T-ALMI	8.66	1.36	6.65	1.20
For calculation T-FMI	7.46	3.41	10.40	4.64
** All coefficients are for the Caucasians; T-ALMI – T-score of appendicular lean mass index; T-FMI – T-score of fat mass index.*				

Table 2. Average (μ) and standard deviation (σ) of Z-ALMI and Z-FMI depending on gender*.

Age	40-50 (n=1436)		50-60 (n=1115)		60-70 (n=1264)		70-90 (n=1098)	
Coefficient	μ	Σ	μ	Σ	μ	σ	μ	σ
For calculation Z-ALMI (men)	8.78	1.24	8.53	1.21	8.31	1.17	7.70	0.98
For calculation Z-ALMI (women)	6.79	1.35	6.62	1.24	6.50	1.20	6.17	1.02
For calculation Z-FMI (men)	8.48	3.12	8.87	3.25	9.34	2.95	8.87	2.75
For calculation Z-FMI (women)	11.60	4.95	12.37	4.75	12.92	4.49	11.82	3.61
** All coefficients are for the Caucasians; Z-ALMI – Z-score of appendicular lean mass index; Z-FMI – Z-score of fat mass index.*								

Table 3. Classification of obesity (FMI).

Gender/grade of obesity	Normal	Overweight	Obesity		
			Class 1	Class 2	Class 3
FMI (men)	3 – 6	>6 to 9	>9 to 12	>12 to 15	>15
FMI (women)	5 – 9	>9 to 13	>13 to 17	>17 to 21	>21
FMI – fat mass index.					

Table 4. General characteristics of the group and main indicators of the body composition.

Indicator	Overall	Men	Women	p*
Number of patients n (%)	50 (100%)	14 (28.0%)	36 (72.0%)	
Race	Caucasian (100%)			
Age (yrs)	63.50 [59.75; 69.00]	60.0 [56.75; 65.50]	65.5 [61.25; 69.00]	0.072
Duration of diabetes (yrs)	11.5 [7.00; 17.00]	11.50 [3.00; 21.50]	11.50 [9.00; 16.75]	0.948
BMI (kg/m^2)	32.33 [30.09; 36.17]	32.33 [28.56; 35.14]	32.30 [30.53; 36.28]	0.310
FMI (kg/m^2)	11.97 [10.55; 13.86]	8.90 [7.57; 12.78]	12.85 [11.46; 15.12]	<0.001
ALMI (kg/m^2)	8.04 [7.32; 8.97]	9.19 [8.61; 9.54]	7.58 [7.24; 8.67]	<0.001
Z- ALMI	2.23 [1.66; 3.55]	4.78 [1.61; 7.08]	2.06 [1.55; 3.31]	0.04
Z- FMI	8.93 [7.67; 11.17]	6.17 [4.73; 9.61]	10.00 [8.50; 11.99]	<0.001
T- ALMI	2.35 [1.73; 3.12]	2.82 [2.24; 3.17]	2.12 [1.69; 3.13]	0.070
T- FMI	9.96 [8.86; 11.62]	7.25 [5.47; 10.63]	10.67 [9.42; 12.88]	<0.001
Z- ALMI (FMI)	-17.14 [-24.55; -8.30]	-1.27 [-5.57; 2.71]	-22.63 [-31.30; -16.42]	<0.001
T- ALMI (FMI)	-33.24 [-46.05; -18.55]	-8.69 [-15.39; -5.60]	-40.87 [-47.10; -32.49]	<0.001
*The data are presented in the form Me[LQ;UQ], where Me – median, LQ – lower quartile; UQ – upper quartile. Groups were compared using the Mann-Whitney test *. BMI – body mass index; FMI – fat mass index; ALMI – appendicular lean mass index; T-ALMI – T-score of appendicular lean mass index; T-FMI – T-score of fat mass index; Z-ALMI – Z-score of appendicular lean mass index; Z-FMI – Z-score of fat mass index.*				

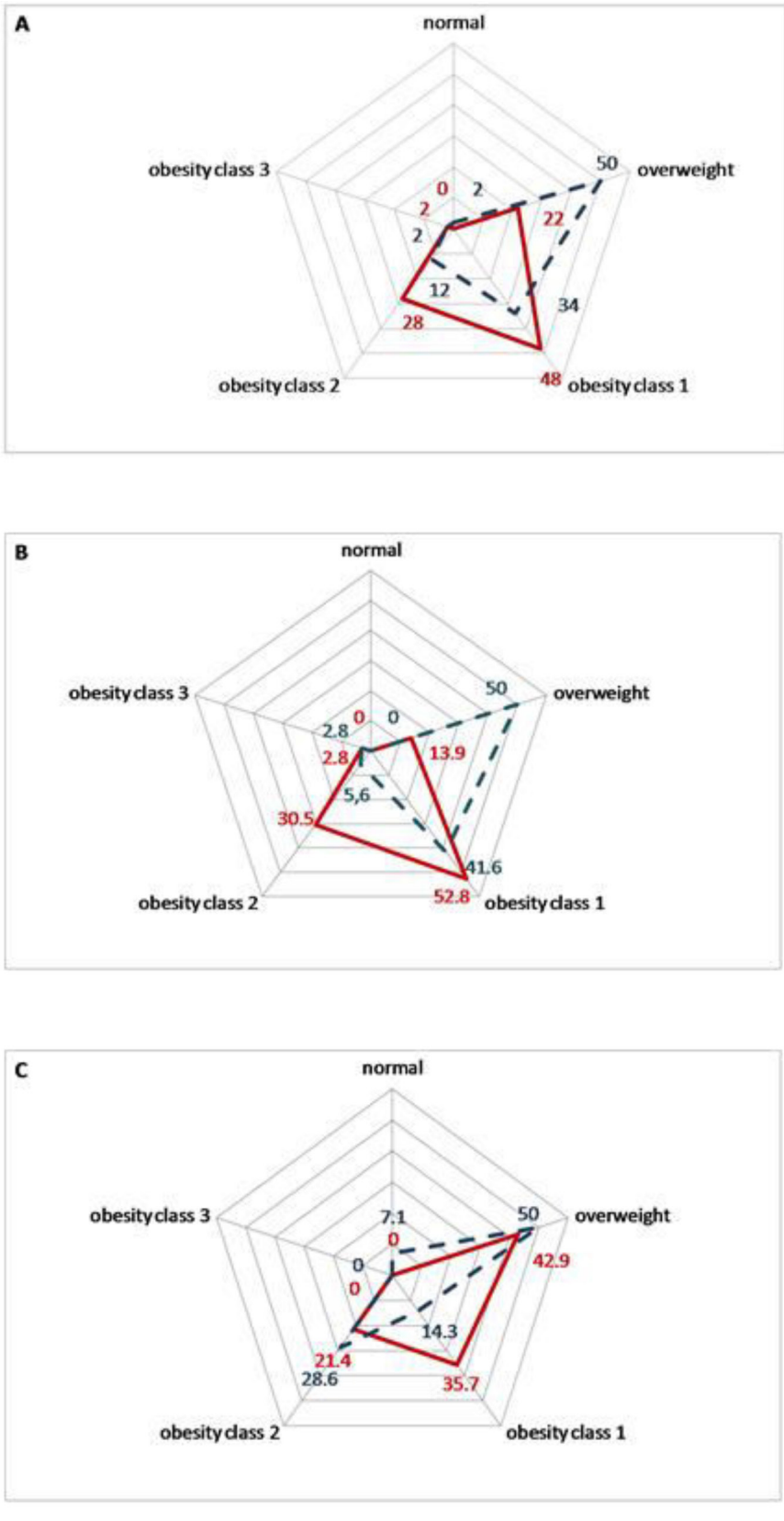

Figure 1. The distribution of T2DM patients normal, overweight, obese class 1, obese class 2, obese class 3 according to WHO BMI classifications (red solid line) and FMI classification (blue dashed line); A – overall, B – women, C – men.

Table 5. The distribution of T2DM patients according to WHO BMI and FMI classifications depending on gender.

	BMI (kg/m²)		FMI (kg/m²)	
	Men	Women	Men	Women
Normal	0	0	1 (7.1%)	0
overweight	6 (42.9%)	5 (13.9%)	7 (50.0%)	18 (50.0%)
Class I	5 (35.7%)	19 (52.8%)	2 (14.3%)	15 (41.6%)
Class II	3 (21.4%)	11 (30.5%)	4 (28.6%)	2 (5.6%)
Class III	0	1 (2.8%)	0	1 (2.8%)
Total	14	36	14	36

T2DM – type 2 diabetes mellitus; WHO BMI – World Health Organization body mass index; FMI – fat mass index.

Table 6. Spearman rank correlation test between variables.

	Correlation Coefficient (p-values)		
	Age Total	≤60 yrs n-12	> 60 yrs n-38
	Age (yrs)		
BMI (kg/m²)	-0.249 (0.081)	-0.074(0.793)	-0.373 (0.027)*
FMI (kg/m²)	-0.013 (0.927)	-0.146(0.603)	-0.299 (0.081)
ALMI (kg/m²)	-0.388 (0.005)*	0.088 (0.754)	-0.284(0.098)
Z- ALMI	-0.627 (<0.001)*	-0.258(0.353)	-0.507 (0.002)*
T- ALMI	-0.328 (0.020)*	0.013(0.964)	-0.310 (0.070)
Z- ALMI (FMI)	0.046 (0.750)	0.209(0.454)	0.386 (0.022)*
	BMI (kg/m²)		
FMI (kg/m²)	0.776 (<0.001)*	0.818 (<0.001)*	0.783 (<0.001)*
ALMI (kg/m²)	0.576 (<0.001)*	0.389(0.152)	0.683 (<0.001)*
Z- ALMI	0.466 (<0.001)*	-0.307(0.265)	0.771 (<0.001)*
Z- FMI	0.788 (<0.001)*	0.828 (<0.001)*	0.802 (<0.001)*
T- ALMI	0.729 (<0.001)*	0.604(0.017)*	0.795 (<0.001)*
T- FMI	0.695 (<0.001)*	0.818 (<0.001)*	0.704 (<0.001)*
Z-ALMI (FMI)	-0.544(<0.001)*	-0.643 (0.010)*	-0.552 (0.001)*
T- ALMI (FMI)	-0.530 (<0.001)*	-0.682 (0.005)*	-0.521 (0.001)*
	FMI (kg/m²)		
Z- ALMI	0.179 (0.213)	-0.579 (0.024)*	0.576 (<0.001)*
T- ALMI	0.400 (0.004)*	0.289(0.296)	0.479 (0.004)*
Z- ALMI (FMI)	-0.878 (<0.001)*	-0.943 (<0.001)*	-0.875 (<0.001)*
T- ALMI (FMI)	-0.873 (<0.001)*	-0.954 (<0.001)*	-0.853 (<0.001)*
	ALMI (kg/m²)		
Z- FMI	0.175 (0.225)	-0.009(0.975)	0.327 (0.055)*
T- FMI	0.161 (0.264)	-0.032(0.909)	0.386 (0.022)*
	Z- ALMI		
Z- FMI	0.194 (0.177)	-0.570(0.026)*	0.615(<0.001)*
Duration of diabetes (yrs)	-0.310 (0.028)*	0.225 (0.210)	-0.296(0.084)
	Z- FMI		
Z- ALMI (FMI)	-0.887 (<0.001)*	-0.942 (<0.001)*	-0.885 (<0.001)*
	T- ALMI		
T- FMI	0.383 (0.006)*	0.289(0.296)	0.522 (0.001)*
	T- FMI		
T- ALMI (FMI)	-0.905 (<0.001)*	-0.968 (<0.001)*	-0.838 (<0.001)*

Significant correlations are noted; FMI – fat mass index; BMI – body mass index; ALMI – appendicular lean mass index; T-ALMI – T-score of appendicular lean mass index; T-FMI – T-score of fat mass index; Z-ALMI – Z-score of appendicular lean mass index; Z-FMI – Z-score of fat mass index.*

Statistical analysis was performed using SPSS 22.0 Windows software using standard methods of variation statistics. Data are presented as median and interquartile range [25%; 75%]. The Spearman rank correlation coefficient was used to identify the correlation between the indicators in the group as a whole, in people ≤60 years of age and in people 61 years and older. The Mann-Whitney U test was used to compare quantitative data in two groups. The critical level of significance (p) in testing statistical hypotheses was taken to be 0.05 (95% level of significance), the trend was determined at a level of p ranging from 0.05 to 0.08.

Results

Fifty patients with T2DM were included. General characteristics of the group and the main indicators of the body composition are shown in Table 4. Almost the same BMI in men and women, significant differences in body composition are noted. In women, the average ALMI is lower and FMI is higher, which indicates a higher tendency of women to sarcopenic obesity.

All of the patients were overweight or obese according to the inclusion criteria. The median BMI was 32.33 [30.09; 36.17] kg/m^2. Obesity of the Class 1 (according to WHO) was detected in 48.0% (24 out of 50). Obesity of Classes 2 and 3 was diagnosed 1.5 times more often in women than in men, 42.9% of men (6 out of 14) and only 13.9% (5 out of 36) women had overweight, but not obesity.

There were some differences in the assessment of the normal weight, excess body weight and Class of obesity according to the FMI classification and BMI classification. One patient had normal body weight according to the FMI classification and was overweight according to the BMI classification. Some patients were reclassified from obesity to excess body mass after using FMI classification (Figure 1).

In men and women, there was a change in the severity of overweight and obesity when assessed by FMI in comparison with that of BMI. Much larger number of women are overweight according to FMI, compared with using BMI (50.0% (18 out of 36) and 13.9% (5 out of 36), correspondently). At the same time, the number of patients with obesity Class 2 by BMI was higher than the one estimated by FMI (30.5% (11 out of 36) and 5.6% (1 out of 36), respectively) (Figure 1 B).

In men, there was also some redistribution of obesity degrees, although it was less pronounced than in women. The proportion of patients with overweight did not change significantly. At the same time, the number of men with the obesity Class 1 decreased significantly, and with obesity Class 2 rose slightly. In addition, according to the FMI classification, 7.1% of men (1 out of 12) turned out to belong to the group of normal body weight (Figure 1 C).

Based on obesity BMI criteria, it was found that a greater number of women in comparison with men had obesity (86.1% and 57.1%, respectively) (Table 5) and it was more pronounced in women. Prevalence of obesity Class 2 and 3 was observed more than 1.5 times often in women than in men: 33.3% and 21.4%, respectively. In case with FMI criterion, the prevalence of women with obesity was higher than that of men (50.0% and 42.9%, respectively), but at the same time, obesity Classes 2 and 3 were rarer in women than in men (8.4 % and 28.6%, respectively) (Table 5).

A correlation analysis in the total group revealed a direct correlation between BMI and FMI, ALMI, T- and Z-criteria, as well as an inverse correlation with the T- and Z-criteria adjusted for fat mass. In patients under 60 years old there was no correlation between BMI and indexes reflecting the amount of appendicular muscle mass (with the exception of Z-ALMI (FMI) and T-ALMI (FMI)) (Table 6).

It was noted that there is no link between age and BMI in the total group, however, in patients older than 60 years, there was an inverse correlation between these indicators (r=-0.373, p=0.027). In younger patients, age did not correlate with indicators of the body composition. There was an inverse correlation between age and Z-ALMI that reflected age-related muscle mass loss in the studied sample in comparison with population normal ALMI for the appropriate age.

The ALMI median was 8.04 [7.32; 8.97] kg/m^2 in the total group. It was naturally higher in men than in women: 9.19 [8.61; 9.54] kg/m^2 and 7.58 [7.24; 8.67] kg/m^2, respectively.

The median T-ALMI was 2.35 [1.73; 3.12], median Z-ALMI - 2.23 [1.66; 3.55]. In the studied sample there were no patients that met the criteria for sarcopenia (T-ALMI <–2.0), as well as the criteria for age-related muscle loss (Z-ALMI <–1.0). However, the calculation of T-and Z-criteria, adjusted for fat mass, led to a significant decrease in the median of these indicators (T-ALMI (FMI) = -33.24 [-46.05; -18.55], Z-ALMI (FMI) = -17.14 [-24.55; -8.3]) and allowed to identify a group of patients who meet the criteria for sarcopenia (98.0%, 49 out of 50). So, after T-ALMI was adjusted for fat mass, only in one patient (a man) T-ALMI (FMI) did not meet the criteria for sarcopenia. After Z-ALMI was adjusted for fat mass, 86.0% of the examined patients (43 out of 50) showed significant age-related muscle loss, and in 14.0% (7 out of 50) this figure corresponded to reference values.

The decrease in the appendicular muscle mass, assessed by both the T-score and the Z-score, was noted with increasing age: an inverse correlation was revealed between age and T-score, as well as between age and Z-score (Table 6). When the division by age groups was carried out, the correlation between age and Z-score was observed only in people older than 60 years, which may be associated with a progressive muscle loss since this age. At the same time, correlations between age and T-score were not observed in any age group.

In the total group, there was a weak but statistically significant inverse correlation between Z-ALMI and duration of diabetes (r=-0.310 (p=0.028)), reflecting a more pronounced age-related muscle loss as the diabetes duration increased.

Discussion

The identification of patients at high risk of cardiovascular disease and premature death is an extremely important task of modern health care. According to a large number of studies, an increase in body weight is associated with the risk of cardiovascular diseases, disability, and mortality[10,11]. At the same time, there is an obesity paradox (lower risk of mortality in persons with obesity compared with persons with normal body weight). There is some evidence of increase of cardiovascular and all-cause mortality after weigh loss in T2D patients[12]. Skeletal muscle mass reduction during weight loss can be a negative factor that worsens metabolism and may increase the risk of death. Therefore, the assessment of body composition in patients with T2DM is becoming increasingly important for the multifactorial control of the disease.

The assessment of the severity of obesity is carried out according the WHO classification based on BMI[1]. It does not consider the amount and distribution of fat mass, as well as the amount of muscle mass, which play a significant role in maintaining metabolic health. Sarcopenic obesity increases the risk of cardiovascular disease, calculated according to the Framingham scale, more than the presence of only obesity or only sarcopenia[13]. An in-depth analysis of the body composition and distribution of fat mass provides more opportunities to identify groups of the maximum risk of complications associated with metabolic disorders in comparison with the BMI estimation.

The method of the body composition assessment based on DXA has been used for a long time; however, there are still no unified approaches to its use for diagnosing obesity and age-related muscle loss. However, now alternative approaches to the diagnosis of obesity are proposed based on the study of the amount of fat mass (according to the FMI). For example, Kelly et al. proposed a classification of obesity by FMI, which we used in our study. This classification is based on the NHANES database[5]. Our comparative analysis of the classification of patients based on measurements of BMI and FMI showed that with a similar distribution in groups as a whole, a number of differences are revealed. Some men had no abnormalities according to FMI (7.1%, 1 out of 14), while by the BMI assessment, overweight was diagnosed. At the same time, other men had more severe levels of obesity by FMI than by BMI. Some women were diagnosed with obesity by BMI, and with overweight by FMI. The obtained results can be explained specific gender differences in reference values in the classification of obesity by FMI, whereas in the classification by BMI, the degree of obesity is estimated without regard to gender. Perhaps the diagnosis by FMI would allow a more accurate assessment of the risks of cardiovascular diseases in different age groups in men and women, and the correction of treatment on this basis.

At the same time, a very important factor determining the state of metabolism is the quantity and quality of muscle tissue. In the routine practice of the endocrinologists and the general practitioners, this parameter is almost never evaluated. A sedentary lifestyle and aging lead to muscle mass loss, while overeating and high blood glucose can lead to impaired myocyte recovery and an increase in adipocyte synthesis, that is, fatty muscle infiltration.

To assess skeletal muscle mass according to DXA, the measurement of the appendicular muscle mass is used. It is calculated as the sum of the muscle mass of upper and lower limbs, without including fat and bone mass. ALMI, as well as T-ALMI, is used to diagnose sarcopenia, and Z-ALMI is used to diagnose age-related muscle loss as a risk factor for sarcopenia. ALMI reduces significantly in people over 70 years old and it can be observed earlier in patients with T2DM, mainly due to pronounced insulin resistance [14]. At the same time, there is a very large variation in the prevalence of sarcopenia, depending on the diagnostic criteria used. The average age of the studied patients was 63.50 [59.75; 69.00] years old, so the prevalence of sarcopenia was expected to be low, since they were younger than 70 years. At the same time, the presence of T2DM increased a risk factor for sarcopenia, it was expected to detect cases of sarcopenia in such patients.

A new consensus of sarcopenia diagnosis published by EWGSOP focused on low muscle strength as a key characteristic of sarcopenia using low muscle quantity to confirm the diagnosis[4]. Therefore, sarcopenia can be diagnosed in patients with normal amount of muscle mass in case of positive physical tests for sarcopenia and decreased muscle strength[2]. In this case, muscle quality may decrease due to fat infiltration. Indirectly, this process can be assessed by using the adjusted T-ALMI (FMI), that is, after the fat mass standardization of T-ALMI. In our study, when using the adjusted T-ALMI (FMI) as a criterion for sarcopenia, 98.0% of the examined patients (49 out of 50) met the sarcopenia criterion. An increase in the prevalence of sarcopenia when using the adjusted T-ALMI (FMI) compared to the unadjusted T-ALMI was also noted by other researchers[6]. Direct correlations between T-ALMI and T-FMI were obtained in our study, which indicated that an increase in fat mass was accompanied by an increase in muscle mass. However, T-ALMI standardized by FMI was inversely correlated with T-FMI. The same patterns are found for Z-ALMI and Z-ALMI (FMI). The increase in fat mass may mask the sarcopenic manifestations in these patients due to the relative increase in muscle mass due to fat infiltration. So standardization T-ALMI by FMI allows to obtain a more objective indicator of the deviation of muscle volume from the normal range.

Opportunities for using T-ALMI (FMI) as a criterion for sarcopenia should be confirmed in other studies with the participation of large number of patients, and studies are needed to confirm the association of a decrease in T-ALMI (FMI) <2 with increased mortality and deterioration in quality of life, as it was confirmed for T-ALMI and ALMI[2].

The analysis of BMI, which is the main indicator by which today the severity of obesity is determined in routine practice, interrelations with the indicators obtained by means of DXA revealed some correlations. Thus, in the total group of patients, a direct correlation was obtained between BMI and

indexes of fat and muscle mass. This correlation is obvious, since BMI takes into account body weight in general, including both fatty and muscle tissue. The inverse correlation between BMI and T- ALMI and Z-ALMI adjusted for fat mass can be related to the fact that the increase of the fat mass leads to a more pronounced correction of the calculated T- ALMI /Z-ALMI and their greater decrease.

We found some differences in age: for example, if BMI is inversely correlated with ALMI in the whole group and the tendency for an inverse correlation of these parameters persists in people over 60 years old, but there is no correlation at all in younger patients. This can be explained by a more pronounced decrease in muscle mass in older obese patients, while in younger patients, the contribution of muscle mass to total weight, and therefore to BMI, remains high.

The body composition in patients with T2DM is different from the body composition of people of the same age without T2DM. According to Heshka et al., patients with T2DM (BMI= 35.3 ± 5.3 k/m^2, aged 58.5 ± 6.6 years) had a lower total fat mass and fat mass of the legs, while fat mass of the torso was higher than in the control group without T2DM (BMI= 30.7 ± 4.2 kg/m^2, aged 55.3 ± 8.6 years)[15]. At the same time, the muscle mass of the legs was also less in patients with T2DM. It can be assumed that the body composition in T2DM changes as the disease progresses. In our study, in women older than 60 years old, there was a decrease in total fat mass, determined by FMI, and muscle mass, measured in terms of ALMI, Z-ALMI, T-ALMI, with an increase in T2DM duration. This can be explained by the increased activity of catabolic processes and the following decrease in the mass of muscle and fatty tissue with an increase in the duration of diabetes. In the younger group, these patterns were not observed; it can be assumed that this process deteriorates in patients with type 2 diabetes with age. In men, there was no correlation between the duration of T2DM and the body composition, which can be explained by the small number of men in the sample, although some gender differences in the body composition in T2DM cannot be ruled out.

Based on the assessment of muscle mass according to the existing criteria of sarcopenia, on the basis of ALMI and T-ALMI, this diagnosis was not revealed in any patient nor was a patient with muscle mass loss relative to the norm for the corresponding age group. After the above criteria were adjusted for fat mass, almost all enrolled patients (98.0% (49 out of 50)) met the criteria for sarcopenia and in 86.0% (43 out of 50) of patients age-related muscle loss in relation to the age norm was diagnosed. In obese persons the amount of muscle mass increases along with an increase in fat mass. Most likely this is due to the infiltration of muscle by fat. This leads to a decrease in the quality characteristics of the muscles and their functionality. However, the increased volume of muscles in obese persons does not exclude sarcopenia.

Conclusion

Currently, new parameters have been proposed for the assessment of the body composition, calculated on the basis of DXA results. It is an interesting opportunity to use it for assessing the ratio of fat and muscle mass, diagnosis of sarcopenia, as well as degrees of obesity in T2DM patients. In our study, the use of FMI for the classification of obesity revealed differences in the severity of overweight and obesity in comparison with the classification by BMI in men and women.

The possibility of using the adjusted T-ALMI (FMI) and Z-ALMI (FMI) indicators as criteria for sarcopenia and muscle mass loss relative to the age norm should be studied in large epidemiological studies in various populations, including patients with T2D to confirm the association of T-ALMI (FMI) <2 with an increase in mortality.

Our study has several limitations. First of all, there was the small number of patients included in the study. Larger studies are needed to determine the role of various parameters, including FMI and standardized ALMI by FMI in assessing body composition and the presence of sarcopenic obesity using densitometry. We limited our study to an assessment of body composition without determining the functional state of the muscles for the diagnosis of sarcopenia. Determination of muscle mass according to densitometry is only one of the criteria for sarcopenia; functional tests should be used to verify the diagnosis. The type of glucose-lowering therapy may possibly affect muscle mass, but it was not evaluated in our study due to the small sample size.

A comprehensive assessment of body composition will allow not only to assess the effectiveness of therapeutic and surgical methods for treating patients with obesity, but also to assess the sarcopenia risk during weight loss.

Ethics approval

Local ethics committee of Moscow Regional Research and Clinical Institute approved the protocol on 16/03/2017. 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 1964, as revised in 2013.

Consent to Participate

Informed consent was obtained from all patients for being included in the study.

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Authors' contributions

Inna V. Misnikova contributed to the conception, study design, data analysis, interpretation and writing the manuscript. Yulia A. Kovaleva contributed to the conception, data collection, analysis and interpretation, writing the manuscript. Elena Yu. Polyakova contributed to the conception, study design, data collection and revision of drafts for submission. Alexsander V. Dreval contributed to data collection, data analysis, writing of the manuscript and revision of drafts for submission. All authors read approved final version for publication and are accountable for all aspects of this work.

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