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The use of the fat-fat-free index (FFF) to assess changes in muscle mass depending on the training period in female weightlifters

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- **A** Study Design
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Abstract

Background and Study Aim: One of the most important elements in the training process is the "expansion" of muscle mass, which is a constituent a of fat-free component in the human body. The aim of the study was knowledge about the suitability of the fat-fat-free indicator for estimating changes in body composition during the training period in female weightlifters.

Material and Methods: Twenty two women were examined and divided into two groups: Group I women training weightlifting in the Student Sports Club Talent (n = 8); Group II (control) students of cosmetology (n = 14). The average age of the examined women was 22.2 ±2.2 years, average body height 162.4 ±4.4 cm, average body weight 59.1 ±5.3 kg, average BMI 22.4 ±1.9 kg/m2, and the average percentage of body fat 17.7 ±4.7 %. Body height was determined using the SECA 213 height meter and body composition using the analyser BC-418 MA (Tanita). Based on the values of fat mass in kg (FatM) and fat-free mass in kg (FFM) obtained from the analyser, the total fat and fat-free mass index (FFF) was calculated for five body segments.

Results: The value of the fat fat-free index in contestants (group I) during the first study differed in a statistically significant way from the values obtained after the training break as well as from the values obtained from the control group in both studies. The female athletes of Student Sports Club Talent in the period of reduced training load had statistically significantly lower levels of muscle tissue as observed through the increase of the FFF index value

Conclusions: The FFF index is an objective tool to assess changes in body composition during training and post-start period. The post-start period training should be structured in such a way as to counteract the muscle mass reduction with the simultaneous increase of fat tissue mass.

Key words: blood test • muscle tissue • Sinclair points • training intensity • training load

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Load – *noun* **1.** a weight or mass which is supported **2.** the force that a body part or structure is subjected to when it resists externally applied forces **3.** the amount of something, usually weight, that a body part can deal with at one time [37].

Blood test – *noun* a scientific analysis of a sample of blood [37].

Muscle tissue – *noun* the specialised type of tissue that forms the muscles and can contract and expand [37].

Training intensity – the effort of training. A number of methods are used to establish training intensities which give maximum benefits. These include the lactic acid method, minute ventilation method, and target heart-rate [38].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '***workload volume***'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of ***training load*** defined as the amount of workload. It is useful in analyses with a high level of generality. (...) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [39, p. 238].

Sinclair points – are the gold standard in Weightlifting for working out your rankings in the world. They are adjusted each Olympic Year and are based on the current world records in their respective body weight groups. All you

INTRODUCTION

One of the important elements of sports training is monitoring changes in the athlete's body. Most often, values relevant to the highest, best and instantaneous results are evaluated – maximum power [1], maximum energy production [2], training techniques [3-6], or changes at the biochemical level [7-9]. In addition, the overall performance of athletes or changes in muscle tissue are determined. Control, from a medical perspective, is carried out once a year as part of an athlete's examination, during which changes in body weight and height are determined, basic blood tests (morphology, blood sugar levels) are taken, and heart rate is monitored. However, these tests do not show changes at the tissue level, and in particular the ratio of fat to fat-free mass. One of the most important elements in the training process is the "expansion" of muscle mass, which is a constituent a of fat-free component in the human body [10-12].

Tamura et al. [13] observed changes in body composition during training, which were illustrated by an increase in muscle mass and a simultaneous decrease in body mass. We usually asses an increase in muscle mass by using measurements of the increase in muscle strength compared with the pre-training period. We then compare these results with other competitors or a peer group [14-16]. These types of measurements are performed using the isokinetic method (e.g. Biodex System Pro measuring stand) isometric [15, 17-19] as well as using performance tests [20]. Due to the assessment of the moment of muscle strength, the level of training in athletes is estimated in individual training phases. The increase in muscle strength is closely related to the increase in muscle mass or lean body mass. This can be achieved through weight gain or by the reduction of body fat at constant body weight. The indicator which enables the assessment of changes in the proportion of fat and fat-free components is the FFF (fat-fat-free) index [18]. The fat-fat-free index, based on the ratio of fat mass to fat-free, is sensitive to changes in the proportion of individual components without changing body weight [12, 21, 22]. This indicator allows us to estimate how the fat component changes in relation to the fat-free, which gives us a picture of the state of muscle mass during strength training.

The progressive period of ontogenesis is a life stage that proves to be one of the most difficult to assess when it comes to the impact of training on changes in body structure and composition. The authors attempting to verify the training focus primarily on changes in the child's motor skills, correlating it with age, sex, anthropometric values and the sports discipline [23, 24].

The sports discipline where maximum strength of the muscle is very important and its construction is the training basis, is weightlifting. Each sports discipline has developed training schemes. Meltzer in his publication showed that weightlifters are a rather homogeneous group in terms of physical activity and they maintain a relatively low level of total body fat [25]. This enables us to use the fat-fat-free indicator to assess changes in individual training phases. The preparatory and competitive seasons are a time of increased training and assessment in terms of maximum muscle strength.

The aim of the study was knowledge about the suitability of the fat-fat-free indicator for estimating changes in body composition during the training period in female weightlifters.

MATERIAL AND METHODS

Participants

Twenty two women were examined and divided into two groups: Group I women training weightlifting in the *Student Sports Club Talent*, School Complex No. 3, Wrocław (n = 8); Group II (control) students of cosmetology (n = 14), University School of Physical Education, Wrocław, Poland. The women have all been training for at least 3 years either individually or as a team are multiple Polish Weightlifting Champions (winning the title as recently as years 2016-2018).

The average age of the examined women was 22.2 ±2.2 (Gr I 20.9 ±3.1; Gr II 22.9 ±1.0) years, average body height 162.4 ±4.4 (Gr I 162,4 ±4.4; Gr II 167,6 ±7.8;) cm, average body weight 59.1 ±5.3 (Gr I 59,1 ±5,3; Gr II 63,6 ±5,9; p = 0.0221) kg, average BMI 22.4 ±1.9 (Gr I 22.4 ±1.9; Gr II 22,7 ±1.3) kg/m^2, and the average percentage of body fat 17.7 ±4.7 (Gr I 17.7 ±4.7; Gr II 28.6 ±2.9; p = 0.0003) %.

Study design

The tests were carried out twice. The first test – in October 2018 was immediately after the end of the direct start preparation (DSP) for the 25th Polish Weightlifting Championships (which ended with them winning the Polish Championship title). The second test – in December 2018, was at the beginning of the new training season. Between the tests, women from *Student Sports Club Talent* had 10 weeks of relaxation period after the competition and were in preparation for the next DSP.

During this period, training sessions took place 3-4 times a week and included specialised exercises with reduced intensity and weight of tools during exercise (kg) (Table 1). The basic training forms used in both training periods were mostly targeted and versatile exercises (long jump, triple jump, high jumps: running and standing jumps, hurdling, vaulting horse jumps, one and two handed medicine ball throws; many exercises for the shoulders – swinging, presses, twists, lying (horizontal) position and seated press, bent-over with barbell on the shoulders and on the training equipment with weights). The competitors during the research project did not get injured and did not have a significant training break with a complete suspension of the exercises. Students were examined over the same periods of time.

Percentage of Fat FatP norm for age 21-33%. In the group of women training weightlifting, two had the class NMC (National Master Class), one had first class, four second class, and one third class. The average value of *Sinclair's points* (see glossary) for this group was 194±29 (the individual sporting characteristics are presented in Table 2).

Body height was determined using the SECA 213 height meter and body composition using the TANITA 8-electrode body composition analyser BC-418 MA. Based on the values of fat mass in kg (FatM) and fat-free mass in kg (FFM) obtained from the analyser, the total fat and fat-free mass index (FFF) was calculated for five body segments: upper right limb (RAFFF), upper left limb (LAFFF), torso (TRFFF), lower right limb (RLFFF) and lower left limb (LLFFF). The indicator was calculated using the formula FFF = FatM [kg] / FFM [kg] [21].

need to do is supply your bodyweight and total (best Snatch + best Clean & Jerk) and points are generated from the information. Please note that **Sinclair Points** only count from your body weight and total in any one competition. **How do they work it out?** There are 8 body-weight categories for senior and junior men –56, 62, 69, 77, 85, 94, 105, 105+. And 8 (as of January 2017) for senior and junior women –48, 53, 58, 63, 69, 75, 90, 90+. For men, all bar the 105kg+ body-weight category has an upper limit and for women, all bar the 90kg+ body-weight category has an upper limit. The formula for working out **Sinclair Points** assumes the lifters who broke the World Records are at the top end of their body weight groups. However the 105kg+ category for men and 90kg+ category for women have no upper limits. The IWF (affiliated with Alberta Weightlifting Association) assign a body-weight for these two super-heavy weight categories. They use mathematical formula to plot a curve that best represents the class.

Table 1. The difference in training load between the (DSP) and the post-competitive season for *Student Sports Club Talent* Wrocław weightlifters.

Training load indicator	The (DSP) period	The post-competitive season period
Training kilogram (individually adapted to the athlete the weight of tools during exercise)	6-8 thousand kg	3-4 thousand kg
Number of trainings per week	5-6	3-4
Training intensity	Maximum, sub-maximal in specialised exercises	50-70 %

Table 2. Competitive characteristics of the surveyed women (n = 8) from the group I (ordinal variable sport class and the second criterion – year of birth).

	Sports class	Year of birth	Weight category	Throb +Clean and jerk	Sinclair points	Occupied place in the 2018
1	NMC	1994	58	86 + 96 = 182	252.7	2
2	NMC	1995	63	65 + 84 = 149	200.3	1
3	I	1995	53	65 + 79 = 144	212.3	2
4	II	1995	53	48 + 60 = 108	171.5	5
5	II	1997	58	55 + 70 = 125	175.9	9
6	II	2001	53	58 + 72 = 130	192.7	6
7	II	2002	75	72 + 83 = 155	187.9	5
8	III	1998	69	60 + 78= 138	172.7	3

The research project was conducted with the permission of the Commission of Bioethics (487/2006).

All participants gave written informed consent after thorough explanation of the procedures involved. The study was carried out in accordance with the tenets of the Declaration of Helsinki. The study was conducted in accordance with the CONSORT (Consolidated Standards of Reporting Trials) statement (Figure 1.)

Statistical analysis

The STATISTICA 13.1 program was used for statistical analysis. The estimation of the results is based on the following indicators: frequency (n); mean (M); standard deviation (SD or ±).

Using the Shapiro-Wilk test, the normality of the distribution of traits in the studied groups was examined. Due to the lack of normal distribution, non-parametric tests (Kruskal-Wallis test) were used for intergroup comparisons. Non-parametric Wilcoxon pairwise tests were used to evaluate western changes in the course of training. Spearman's rank correlation test was used to assess the dependence of the variables. The level of statistical significance was set at $p<0.05$.

RESULTS

The value of the fat fat-free index in contestants (Group I) during the first study differed in a statistically significant way from the values obtained after the training break as well as from the values obtained from the control group in both studies. The values of the index for all the examined in both studies were the highest for lower limbs which indicated increased fat deposition in those segments as compared to others (Table 3).

In control tests after the end of the post-competitive season a statistically significant decrease of muscle mass in group I was observed in the area of general muscle mass of upper limbs. The

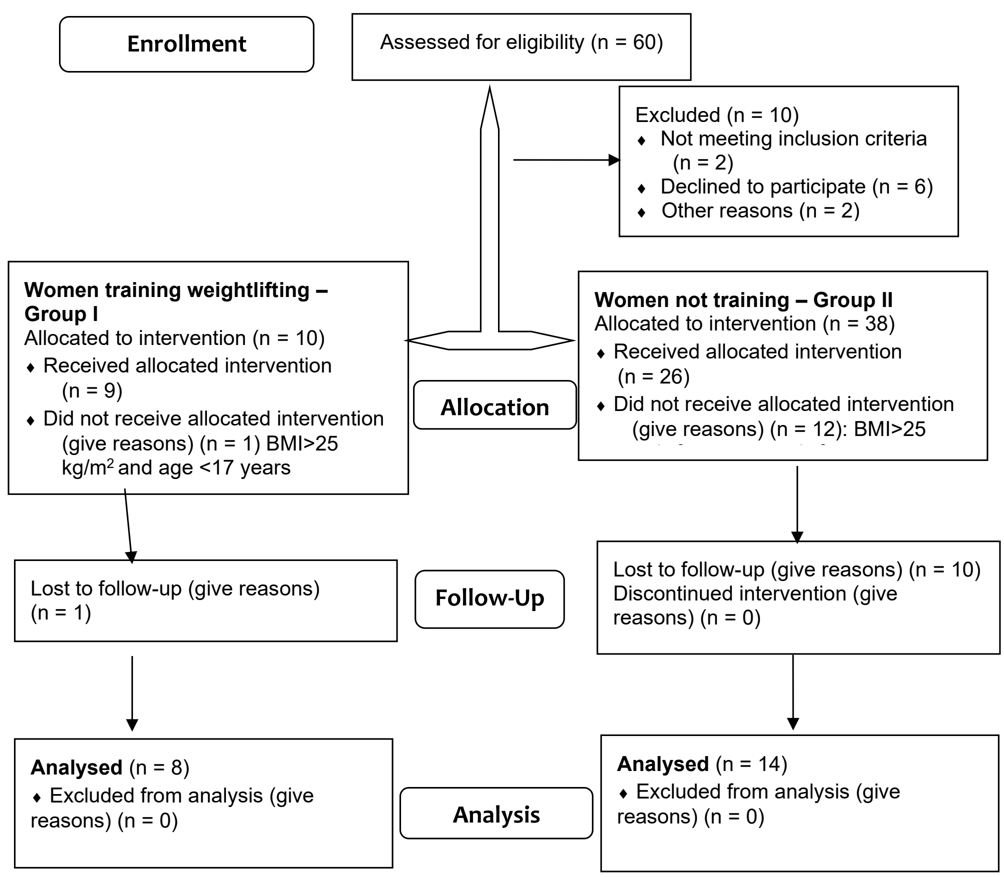

Figure 1. Consort flow diagram

Table 3. The FFF index value depending on groups and study.

Variable	Period of study	Group I (n = 8)	Group II (n = 14)	Group I vs Group II
		M & SD	M & SD	p
FFF	I	0.219 ±0.072	0.402 ±0.057	**0.0003**
	II	0.325 ±0.115	0.451 ±0.059	**0.0185**
	p	**0.012**	**0.002**	
RA FFF	I	0.186 ±0.123	0.408 ±0.081	**0.0019**
	II	0.254 ±0.150	0.410 ±0.063	**0.0105**
	p	**0.012**	0.875	
LA FFF	I	0.183 ±0.117	0.439 ±0.075	**0.0015**
	II	0.260 ±0.152	0.432 ±0.066	**0.0154**
	p	**0.012**	0.552	
TR FFF	I	0.159 ±0.062	0.354 ±0.064	**0.0002**
	II	0.287 ±0.109	0.414 ±0.069	**0.0185**
	p	**0.012**	**0.004**	
RL FFF	I	0.330 ±0.080	0.481 ±0.059	**0.0019**
	II	0.392 ±0.120	0.528 ±0.059	**0.0105**
	p	**0.025**	**0.002**	
LL FFF	I	0.322 ±0.089	0.472 ±0.062	**0.0030**
	II	0.398 ±0.121	0.527 ±0.044	**0.0127**
	p	**0.017**	**0.001**	

values of expected muscle mass are presented in Table 4. The female athletes of *Student Sports Club Talent* in the period of reduced training load had statistically significantly lower levels of muscle tissue as observed through the increase of the FFF index value (Tab.4). The greatest differences were observed within the area of torso where the value of the fat fat-free index. as compared to the first study, increased in the group of athletes by 120% whilst in the control group by 47%. In students from the control group a statistically significant increase of the general FFF index value as well as FFF index value in lower limbs and torso was observed. The fat fat-free index in torso in the athlete group of the second study showed a significantly higher abdominal fat deposition (TR FFF) (Table 4).

DISCUSSION

One of the most important training elements, irrespective of the type of physical activity. is the continuity of the application of methods to increase the athlete's capabilities. Each training cycle is composed of (DSP) and relaxation of training. Both stages are very significant not only in order to achieve desired sport results but also for the athlete's health. The DSP connected with the intensification of efforts and increasing of the athlete's capabilities was described on numerous occasions both in reference to sportsmen with and without disabilities [25, 1-11, 14, 13, 26, 28, 27]. In this period measurements are taken both in terms of increased strength, endurance or speed [1-6, 23, 24] as well as of changes on biochemical level [7-9].

Rutkowski et al. [12, 22] proved that during karate training conducted for 10 weeks we can observe changes occurring at the level of tissue components [12, 22]. In my own research on a group of persons with body mass irregularities participating in classes of increased intensity, the reduction of fat tissue mass occurred with simultaneous stabilisation of body mass. This proves "reconstruction" of body composition [29, 23]. For training continuity, what is also

Table 4. The value of expected muscle mass depending on group and study

Variable	Period of study	Group I (n = 8)	Group II (n = 14)	Group I vs Group II
		M & SD	M & SD	P
PMM	I	46.06 ±3.53	43.14 ±3.94	0.0987
	II	41.83 ±4.23	42.05 ±3.74	0.8982
	p	**0.0117**	**0.0064**	
RA PMM	I	2.39 ±0.23	2.01 ±0.26	**0.0024**
	II	2.10 ±0.36	1.99 ±0.24	0.3838
	p	0.0117	0.6784	
LA PMM	I	2.36 ±0.27	2.01 ±0.24	**0.0052**
	II	2.04 ±0.38	1.89 ±0.20	0.2279
	p	**0.0117**	**0.0064**	
TR PMM	I	25.68 ±2.20	24.48 ±2.16	0.2287
	II	21.34 ±0.88	24.54 ±2.27	**0. 0011**
	p	**0.0117**	0.7776	
RL PMM	I	7.85 ±0.51	7.39 ±0.67	0.1077
	II	8.30 ±1.59	6.84 ±0.58	**0.0050**
	p	0.4008	**0.0064**	
LL PMM	I	7.79 ±0.43	7.26 ±0.65	0.0529
	II	8.05 ±1.53	6.80 ±0.58	**0.0132**
	p	0.6744	**0.0009**	

significant is the period of post-start relaxation. The change in intensity and training load directly affects the physical and mental state of the athletes. Noce at al. [30] when assessing the mental state of athletes before and after competition concluded that older (over 18) judokas had experienced less fear during the post-start period as compared to younger contestants.

During studies, group I displayed statistically significant changes in body composition in all segments. A similar tendency, excluding upper limbs, was shown by non-training persons examined in the same period. It is important that female athletes after the end of start period and before the commencement of another preparatory cycle did not have different fat fat-free index from non-training women. The FFF index, that is the ratio of fat to fat-free tissue indicated the condition of muscle mass in the examined. The lower the index, the better the musculature of a given body segment. Group 1 in the DSP period showed significantly higher musculature in particular in the torso (TR FFF) and upper limbs area (RA FFF, LA FFF) and it differed in a statistically significant way from the values obtained in non-training women. The period of post-start relaxation, lower intensity and training load affected negatively all the FFF values of athletes. At the same time no statistically significant changes in body mass were observed, hence there were no significant increases of fat tissue.

The application of fat fat-free index makes it possible to assess changes on tissue level which are more significant than just the change of body mass. Results obtained in the study indicate that athletes enter a new training period with similar body composition as non-training persons do. The FFF index marked in tests during the DSP period indicated a lower limit of normative body mass for a given age while after the end of post-start period indicated a lower limit of normative body mass. In the control group the difference between the marked general FFF index in studies I and II is statistically significant but much lower than in the competitor's group (Figure 2).

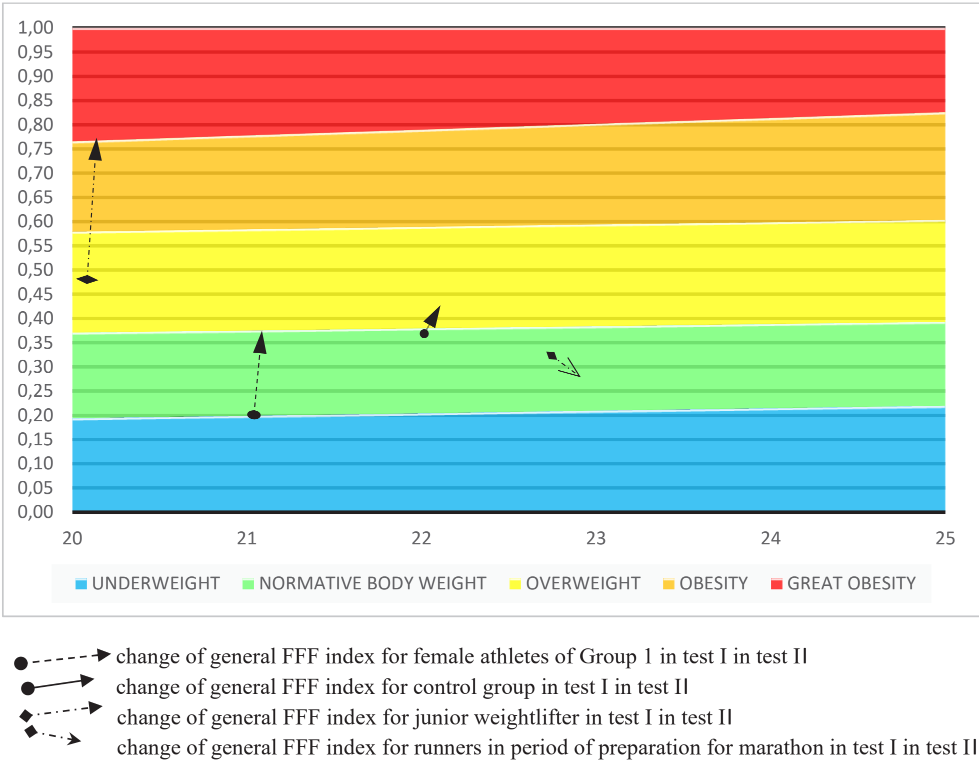

Figure 2. Growth chart for the FFF index [21].

When assessing only body mass or BMI we do not obtain the information about muscle mass which is more important in the case of competitors. The application of the FFF index makes it possible to monitor the changes occurring at the level of tissue mass.

Many authors emphasise that the application of only BMI to assess the changes occurring in result of physical activity is insufficient [31-33, 21, 13]. In my own studies on a group of overweight and obese children the lack of change in body mass was observed in the examined after the application of prophylactic scheme (additional physical activity) while significant differences were observed in terms of the FFF index [29, 34]. This index was also used to assess the effect of karate training on younger school children [12, 22]. In both presented studies no change in body mass was observed. similarly to the contestants. only the assessment of body composition. and in particular the FFF index. showed changes at the level of the contestant's internal composition. In the training process the monitoring of fat-free tissue. and in consequence muscle tissue. is significant in terms of exercise selection. The FFF index seems necessary as a tool supporting the training process. Sterkowicz et al. [35] and Jagiełło et al. [36] emphasise the meaning of qualification and control tests in the case of classification for a given sport discipline and according to them the results achieved by athletes in tests depend on training experience. Looking at training from a long-term perspective we cannot forget about appropriate management of contestants between the DSP, the competition period and the next season. As shown from the conducted studies, in the post-start season female weightlifters "lose" the form achieved in DSP and they start the new season with lower physical fitness due to muscle mass loss.

CONCLUSIONS

The FFF index is an objective tool to assess changes in body composition during training and post-start period. The following empirical data show such a recommendation: the female weightlifters' body composition in post-start period changes in a statistically significant way. the fat fat-free (FFF) index increases significantly. which translates to the level of fat tissue with a simultaneous decrease of fat-free mass; The period of relaxation in examined competitors negatively affects the level of muscle tissue due to the increased fat fat-free index.

The post-start period training should be structured in such a way as to counteract the muscle mass reduction with the simultaneous increase of fat tissue mass.

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