IS BMI REALLY SUITABLE FOR CHARACTERIZATION OF PHYSIQUE (NOURISHED STATE, STATURE) AND OPTIMUM BODYWEIGHT OF ATHLETES?

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Abstract
Body Mass Index (BMI) is not perfectly (sometimes absolutely not) suitable for determination of the nourished state (physique) and optimum body-weight for athletes because of 3 reasons. 2 reasons are general and the third one is of specific character. The first one is, that the human bodymass is proportional to the third extent and not to the second one of the linear measurement (here height), that is proportional to the volume (and not the surface!) of the body. So instead of BMI the Rohrer-index is proposed to use. The second, still general reason, that only height and body-mass are not enough for appropriate characterization and estimation of the physique, figure and ideal bodymass, because as a function of body structure (e.g. parameters of width) the optimum bodymass can even show 20-25 kg difference among individuals having the same height. The third specific reason is that the athletes can have in general much higher muscle-ratio (instead of 43 % for average adult men even over 60 %) than normal human beings, non sportsmen, so BMI even more than 30 should be eventually evaluated as a normalweight, and not overweight or obesity.

Keywords: *body structure, muscle-ratio, nutrition, obesity, overweight, Rohrer index, stature*

INTRODUCTION

Recently – although the frequency of application of BMI determination is dominant, based on the simplicity – there is no generally accepted and unified method and qualification system for determination and characterization of physique (nourished state, stature), however the existence of a confident and reproducible technique (qualification method) is a necessity. In the paper information is given about the reasons, supporting the opinion, that BMI is not suitable for characterization of physique and body construction of athletes. And of course it is not applicable for estimation of the ideal bodymass of athletes, as well. For supporting this opinion we will shortly analyse the problems in case of application of different indices and methods for estimation of the ideal figure and bodymass. Let us mention that BMI is not suitable for characterization of physique neither for athletes, nor for children, the ratios between height and bodymass are different for adults and kids (Poskitt, 2000, Chinn, Rona 2002, Lobstein et al.2004, Neovius et al.2004).

ANTHROPOMETRY, BODY COMPOSITION
Based on the results of anthropometrical measurements – body structure, physique, body composition (e.g. muscle-ratio, fat-ratio) – it is possible to estimate the optimum bodymass for the individual human beings, and knowing the real (actual) weight we can have a proposition concerning the appropriate diet (daily intake of energy, nutrients etc.) of the athletes.

For anthropometrical characterization of people different data can be used – e.g. lean bodymass, fat-ratio – but the most simple calculations apply only 2 parameters, so only the height and bodymass data are taken into account. However, to get really characterizing parameters, which are applicable in the practice, as well – and based on these parameters to carry out a correct estimation of the optimum bodymass – we should take into consideration some other peculiarities (e.g. width of shoulder, hip, waist, skinfold thickness, bone ratio), as well. Popovic and coworkers (2009) used 20 anthropometric measures.

It is evident, that the data, characterizing the body structure and body composition have prognostic importance, as well, because besides the genetic determinity there is a specific adaptation of physique as a function of external conditions (e.g. long years intensive trainings). It is wellknown, that although the physique can be changed during the years in consequence of the influence of environment, surrounding conditions – nourishment, physical load - but in 13-14 years of age those peculiarities are generally formed, which are applicable for estimation of the expectable physique and stature of the athletes. Bjelica and Petkovic (2011) published interesting paper concerning the motoric abilities and morphological characteristics in the prediction of sport results.

Bodymass optimation is a basic requirement concerning the good physical and psychic state (quality of life, sport performance level) of the athletes. And the optimum bodymass can not be calculated correctly, using only height data, which gives information only about the longitudinal dimensionality of the skeleton. We should know the characteristics of physique (ectomorphic, mesomorphic or endomorphic type) and in any case the quantity of fat tissue in the body. Of course the diferrence can be significant also between the female and male athletes, one (important) reason of the performance-difference between the genders is the body-composition. To the data of Görner et al. (2009) for male PE students the mean bodyfat-ratio was 12.8 % (SD=5.0%), for female PE students this ratio was 23.9 % (SD=5.5%). The mean BMI for men was 23.7 (SD=2.8) and for women 21.4 (SD=3.0).

In case of male athletes the sport performance is in general higher (having similar bodyweight), becasue there is a significant difference in muscle-ratio. In case of women – in consequence of lower muscle-ratio - the fat-ratio is higher. In the age group 30-40 years the average fat-ratio for normal, only recreational level sport activity having men, but without overweight and obesity is appr. 13-19 %. In case of similar group of women the fat-ratio is 21-27 %. Of course in case of top athletes the fat-ratio can be much less, for top-bodybuilders even 3-4 %. Definitely the body constitution of body-builders is significantly different from the one of representatives of normal population, so the body-composition is also different.

PHYSIQUE, BODY-STRUCTURE, NOURISHED STATE, FIGURE, STATURE

It is known, that the physique of every individual human being can be considered as a combination of 3 different types, and these components (endomorphic, mesomorphic and ectomorphic ones) can be determined with well-documented scientific methods, like Sheldon-method or Heath-Carter method. E.g. in case of weightlifters in general the typical peculiarities are the following: moderated endomorphic, high mesomorphic and very low ectomorphic componensts of physique. Mesomorphic physique (dominated by the skeleton width and muscularity) means athletic body structure, wide shoulder, narrow hip, well-developed muscles, stocky figure. In case of the real (ideal?, normal?) type there is a balanced relation of the explicitness of the somatic typology factors (Biberovic et al., 2008). So the real type is a combination of ectomorph (dominated by the skeleton length), mesomorph and endomorph (dominated by the body size) components.

About the importance of physique in the sport-performance there are many references. In case of top Hungarian lifters a study was carried out for determination of the correlation between physique and performance (Farmosi, 1978). It was established that there is a close significant positive correlation between the result of lifters in snatch and clean&jerk and the mesomorphic component of physique. On the contrary it was also proven, that the correlation is negative between the result and the ectomorphic component of physique. However, let us mention that in some other sport branches – e.g. swimming, high jump, long distance running, fencing, soccer, basketball – the ectomorphic component of the physique can be significantly higher, than in case of top weightlifters. So a relatively high ectomorphy is not a difficulty to excellent sport performance in many sports. Of course – in consequence of long years active training – the physique and figure can be changed step by step, and the continous weightlifting training increases the mesomorphy of the athletes.

INDICES FOR CHARACTERIZATION OF PHYSIQUE

Quetelet index

This index is a very simple one, it is the qoutient of the bodymass (in g) and the height (in cm). This index gives some chance for comparison of people, having similar weight or similar height, but it is not suitable for comparison of athletes in different sport-branches or in different weight categories. A man having 64 kg bodymass and 160 cm height has the same 400 Quetelet-index as a man with 80 kg and 200 cm, although it is evident, that the body structure, the figure is perfectly different, the tall person is rather or very slim. In case of similar physique with increase of the height the Quetelet index increases significantly, e.g. for weightlifters in the lowest category (56 kg) in general is below 400, but for competitors in the super-heavyweight category (+105 kg) can be even above 800.

Table 1 shows the typical height (cm) of elite lifters as a function of the previously used 10 bodyweight-categories (today for men there are only 8 categories!), and the calculated Quetelet, Kaup and Rohrer indices. In the calculation for the typical super-heavyweight lifters 150 kg is taken into account as mean bodymass, which is appr. the average bodymass of the medalists of World Championships and Olympic Games in the last 20 years.

Table 1. Typical height data (cm) and the calculated Quetelet-, Kaup- and Rohrer indices for top olympic lifters as a function of bodyweight-categories

category (kg)	typical height (cm)	calculated indices		
		Quetlet	Kaup	Rohrer
52	150.0	347	2.31	1.54
56	154.5	362	2.35	1.52
60	158.0	380	2.40	1.52
67.5	163.0	414	2.54	1.56
75	166.8	450	2.70	1.62
82.5	169.9	486	2.86	1.68
90	172.5	522	3.02	1.75
100	175.5	570	3.25	1.85
110	178.0	618	3.47	1.95
+110	185.6	808	4.35	2.35

RBW index
We can mention that recently instead of Quetelet-index the RBW-index (relative bodyweight index) is in use, which is principally the same, as the Quetelet one. However in calculation of the RBW index the bodymass in kg and the height in m should be taken into account, so in case of 400 Quetelet index the RBW index is 40.

Kaup index
The applicability of Kaup index is a little better than the Quetelet index, because in case of comparison of 2 persons, it depends less from the height. The Kaup index is the quotient of weight and the second extent of height. Using the previous example, the Kaup index for a man having 160 cm height and 64 kg bodymass is 2.50, and for man with 200 cm and 80 kg is 2.00. If the physique (figure) is similar, with increase of height the measure of Kaup index increses, as well, but not so dramatically as in case of Quetelet index. So, if we would like to compare the physique and body structure of people with rather different height or significantly different bodymass, the application of Kaup index for characterization is not suitable. However in case of average height interval (170-180 cm for men and 160-170 cm for women) the comparison seems to be acceptable. But in case of athletes is definitely not, it depends from the sport-branch, as well. Surely the optimum bodymass for a competitor in modern pentathlon and a shot-puttter with the same height is terrible different.

BMI
The principle of calculation method for determination of the body mass index is the same as for the Kaup index, only the applied units are different. In case of BMI the bodymass (in kg) is divided by the second extent of height (in m). So practically we will get the BMI index if we multiply the Kaup index by 10. Coming back to the previous case, the BMI values are 25.0 and 20.0. The BMI calculation method is simple, easy and very popular, even specialists, scientific organisations and international bodies refer to BMI, concerning the correct or optimum parameters of nourished state. To the proposition of WHO the optimum range should be between 20 and 25, and this interval is valid both for female and male population. To Neumann (2001) the normal (optimum) BMI index is appr. 22 for females and 24 for males. There are many propositions in the scientific literature, in general for females 18.5-24.0 and for males 20.0-25.0 values are accepted as normal BMI ones.

In general the medical specialists agree that in those cases, when the real bodymass is more than 20 % above the optimum bodyweight, the healthy risk is significant. Of course it should be mentioned that not only the overweight but also the too small weight (e.g. representatives of female gymnastics, rhythmic sport gymnastics, long distance running and people with anorexia) can have negative impact on the healthy status, so it is a minimum requirement to have BMI over 18. In case of general normal adult people (not athletes) we have the following categories based on the BMI index values: BMI below 20 means malnutrition, ideal range is 20-25, the 25-30 BMI means overweight (first category of obesity), 30-35 BMI is the second category of obesity, 35-40 is the third category of obesity and over 40 is the fourth category (very dangerous) of obesity. The last one means that the bodymass is significantly over the optimum, and this has a very high level risk. Let us mention that in case of an athlete with 175 cm height (this is the typical average height for men, recently accepted for anthropometrical calculations in biological sciences) in case of 30 BMI the weight is 91.9 kg, in case of 35 BMI the bodymass is 107.2 kg and the 40 BMI equal with 122.5 kg bodyweight.

Of course the given (calculated) BMI indices are far not suitable for representatives of many sport branches, e g. top power lifters, body-builders, olympic lifters, other strength athletes like competitors of throwing events. The reason is multiple. First principally, surely the application of BMI for people having high bodyheight (and bodyweight) is theoretically not suitable. Secondly, the width parameters are not taken into account. And on the other hand in case of top athletes the muscle ratio is significantly more than for normal people. For average normal men the muscle ratio is appr. 42-43 %, but for top athletes it can even reach 60 %. In consequence of higher muscle-ratio of course the bodyweight will be also higher, even in case of rather lown fat %.

However the optimim bodymass is a function not only of the height, therefore – in dependence of body structure, parameters of width – the difference between the optimum masses with the same height can be even 20-25 kg. Table 2 shows the optimum weight of a man, having 175 cm height, differentiated into the following 5 structures (Neumann, 2001):

Physique type 1: very slim, very little active body muscle
Physique type 2: relatively slim, little active muscle mass
Physique type 3: medium stature, balanced muscle mass
Physique type 4: relatively stocky, great deal of active muscle mass
Physique type 5: very stocky, athletic, very much active muscle mass.

Table 2. Optimum weight (kg) of a 175 cm tall man

physique	optimum average weight (kg)	weight interval (kg)
slim	63	57-70
relatively slim	68	61-74
medium physical stature	70	63-77
relatively stocky	74	67-81
very stocky	78	70-86

This fact can be evaluated also from the other side: the height difference can be even 10-15 cm between 2 persons, both having optimum bodyweight. In case of elite weigthtlifters practically the BMI is never below 25, many lifters are in the range between 30-35 BMI value, and – mainly the superheavyweight lifters, who are really corpulent – not a few ones have even above 35 BMI value. (The sumo-wrestlers have a special category, and not only from point of wiev of BMI value.) However it is a fact, that BMI over 40 – independently from height, fat ratio, parameters of width, performance level – is absolutely unhealthy, the risk of health-damage is really very high, it is a serious mistake to load the body (tendons, joints, cardio-vascular system etc.) with such huge bodyweight. In this case it is evident, that the expectable life period and even the quality of life decreases significantly. It is not by chance that the life expectancy of sumo wrestlers, having unusually high bodymass is in general rather short. It is also true, that the nutrition habits and methods of such type wrestlers are also different from the nourishment of normal population.

Rohrer index

The Rohrer index – giving precise information about the connection between height and mass – has an important advantage if we compare it with Quetelet and Kaup indices. The Rohrer index is invariable for the height, so it gives good comparable results also in cases, when the height-difference between the human beings is significant. The mathematical background of the correct calculation is the fact, that the bodymass is proportional to the volume of the body, and the volume is proportional to the third extent (and not to the second one!) of the linear measure (in this case the height.) In case of calculation of Rohrer index the bodymass (in g) is multiplied wit 100 and devided by the third extent of the height, given in cm. (Or the weight is taken into account in kg, and divided by the third extent of height (in m) and by 10.)

So the BMI is principially not suitable for correct characterization of the height-bodymass ratio, because the volume of the body is proportional to the third extent of the height. And the Rohrer index does not have the disadvantege of BMI, it is invariant to the height. Let us mention that the mass is calculated as the multiplication of volume and specific gravity, and the increase of fat ratio slightly decreases the specific gravity. Some data concerning this connection are given in table 3.

Table 3. Connection between density of human body (g/cm^3) and fat %, based on the Pace-Rathburn

density	fat %
1.09	4.6
1.08	9.3
1.07	14.1
1.06	19.0
1.05	24.0
1.04	29.1
1.03	34.2

formula:

$$\text{fat\%} = 100 \times \left(\frac{5.548}{\text{density}} - 5.044 \right)$$

If we come back again to the previous examples, the Rohrer index for a man with 160 cm and 64 kg is 1.56, and for a man with 200 cm and 80 kg only 1.00. It is evident the huge difference in physique between the 2 persons, however for both is the Quetelet index the same and even the difference in Kaup (and BMI) indices is not so big. To imagine the huge difference in physique of these 2 persons we would like to mention, that the 200 cm tall athlete, having the similar physique (body structure, figure and nourished state) as the person with 64 kg and 160 cm, should have a bodyweight 125 kg, having the same 1.56 Rohrer index. This 125 kg is the adequate bodymass, belonging to the 200 cm height, if the Rohrer index is 1.56, and not 80 kg! It is an interesting observation, that the top professional basketball players and the top weightlifters in the lowest categories have appr. similar Rohrer index values, and a similar body constitution. Let us mention that the professional basketball players in USA have in general stocky, athletic physique, their height is above 2 m and their bodymass is between 110 and 140 kg.

To our earlier measurements the typical Rohrer index is 1.5-1.6 for the top lifters in the lower categories, 1.6-1.8 for the medium categories and in general is over2.00 in the super-heavyweight category (Szabo, 1989). If the super-heavyweight lifters with a typical 150 kg bodyweight would have the similar physique and stature as the lifters in the lower categories, they should have appr. 210-215 cm height! The difference in physique and figure between the lifters of the lower and the highest categories is evident, if we take into account that the typical height in the +105 kg category is appr. 185 cm for top lifters and the number of lifters above 190 cm height is really very-very limited.

If we would like to carry out a comparison between the lifters and representatives of other sport branches, we have to establish that e.g. in case of kayak-canoe and modern pentathlon sports the typical value of Rohrer index is only 1.2-1.3. In case of track and field athletes for the representatives of throwing events in general it is between 1.5 and 1.8, and in wrestling in the lower categories it is dominantly in the range of 1.3-1.5 and for the higher categories between 1.5 and 1.9 . If we do a comparison between top wrestlers and weightlifters, the difference is significant, the wrestlers are slimmer, and the Rohrer index is for the same weight appr. 0.2 value more for lifters. From the other side we can say that having the same bodyweight the wrestlers are in general 6-8 cm taller, than the lifters. Or in case of the same bodyheight the difference in the bodymass is in general 8-15 kg. In super-heavyweight the difference can be even significantly more, because today in wrestling the maximum tolerable weight of the competitors is 120 kg, but in weightlifting there is no limit recently. In the +105 kg category some top lifters even have 160-170 kg bodyweight, winning on world and Olympic championships gold medals. And the huge bodyweight is a typical case also for female lifters in the +75 kg category; some top ladies have bodyweight 140-160 kg. (Let us mention that within the special committees of IWF since many years serious discussions and debates are about the limitation of the upper categories, different for men and women, of course. One of the propositions is 140 kg for men and 100 kg for women as maximum admissible weight.)

Tables 4 and 5 show evidently, that to the same BMI values belong rather different Rohrer index ones, so for comparison of nourished state and physique of persons with significantly different height is the BMI determination and characterization not applicable, far not suitable (Szabo, Tolnay, 2004). In the table 4 the Rohrer index values of 1.33 and 0.95 mean perfectly different physique, however the BMI is in both cases equal to 20.

Table 4. Bodymass and Rohrer index values, belonging to the same (20 and 25) BMI values

Height (cm)	BMI = 20		BMI = 25	
	Bodymass (kg)	Rohrer - index	Bodymass (kg)	Rohrer - index
150	45,00	1,333	56,25	1,667
160	51,20	1,250	64,00	1,563
170	57,80	1,176	72,25	1,471
180	64,80	1,111	81,00	1,389
190	72,00	1,053	90,25	1,316
200	80,00	1,000	100,00	1,250
210	88,20	0,952	110,25	1,190

Table 5. Bodymass and BMI values belonging to the 1.431 Rohrer index as a function of height (cm)

type of data	fictive	fictive	fictive	real parameter	fictive	fictive	fictive	fictive
height (cm)	146	156	166	176	186	196	206	216
bodymass	44,530	54,330	65,460	78,000	92,090	107,750	125,100	144,210
BMI	20,890	22,320	23,750	25,180	26,230	28,050	29,480	30,910
Rohrer-index	1,431	1,431	1,431	1,431	1,431	1,431	1,431	1,431

The conclusion is similar also based on the results of the table 5. The real parameter belongs to the first author of the paper, based on his height and bodymass data were the BMI and Rohrer indices calculated. The fictive data represent those bodymass and BMI data, which are calculated based on the real Rohrer index values, belonging to different (10-10 cm higher and lower) height data. Obviously that using BMI is not correct, it is not suitable for comparison. In case of very tall persons – if the Rohrer index is still 1.431 - the BMI is over 30, so it shows the second category of obesity, however for short people is only slightly above the malnutrition limit!

Broca index

This calculation method is also very simple, easily giving answer to the question: do we have overweight, or not? For determination of the Broca index we have to divide the bodymass (in kg) with the height (cm) reduced by 100 cm. The optimum Broca index value is appr. 1.00 . It means, that in case of 170 cm height the optimum weight is about 70 kg. The healthy risk is significant in those cases, if the calculated Broca index is over 1.2-1.3 value. Let us mention that for ladies the so called modified Broca index is proposed to apply. It means, that the calculated bodymass value should be reduced by 10 %. It means that e.g. for a voman with 170 cm height not 70 kg, but 70-7 = 63 kg seems to be the ideal weight. (This index is also incomplete, taking into account only the longitudinal dimensionality!)

Bernhardt formula

To the Bernhardt formula the ideal (normal) weight (in kg) can be calculated as multiplication of height (cm) and chest outline (cm) divided by 240. And based on this formula we can determine also the level of obesity (obesity is the quotient of actual weight and ideal – calculated - weight). If this parameter is below 1.00 it is the case of malnutrition, if between 1.00 and 1.10 this is an acceptable (slight) overweight. In case of 1.10-1.25 we speak about obesity, in case of 1.25-1.50 about a serious obesity. If it is over 1.50 this is a very significant obesity state, showing high level of health risk (e.g. cardiovascular disease (CVD), coronary heart disease (CHD), diabetes type 2, high level of LDL (low density lipoproteins) in the blood).

Waist-hip ratio, information about stature, body constitution

We should stress that for characterization of the physique and estimation of the optimum weight the waist-hip ratio determination is also one of the possibilities. In ideal case for female persons this ratio is below 0.8 and for men below 0.9. If the ratio is over 1.0 this is the symptom of obesity. But if we would like to get useful and real information about the physique and optimum bodyweight only based on the bodymass index values – this can be e.g. BMI, Rohrer index – we will not get satisfactory answer as a minimum to 3 questions:

- what are the width parameters of the person?
- what is the body composition (e.g. muscle ratio, fat ratio), does the human being have a significant amount of unnecessary fluid (oedema in consequence of water retention) in the body?
- where is fat located in the body, what about the fat-distribution?

It is a wellknown fact, that the figure or stature of human beings is the joint interaction of somatic and psychic peculiarities, and

Hippocrates even in the antiquity (B.C. 5th century) tried to perform a classification of human beings into various types of stature. Later the typology of stature was represented by trends with the names of Kretschmer and Conrad. The different types of figures are characterized by the indices of anthropometric parameters (metric index, plastic index), which are able to give real information concerning the development of bone and muscle systems of the investigated persons, as well. However the determination of these indices is not so easy as e.g. in case of BMI.

Metric index

The metric index is a linear function of the diameters (width and depth) of the chest, corrigated with the height of the person. In other words this is the parameter of corpulency, the typical characteristic of roundness. The value of the index shows the peculiarity of the picnic (endomorphy) or leptosom (ectomorphy) character of the body. If the measure of the index – the determination can be carried out by using nomograms or regression equations - is positive or only slightly negative, the picnomorph character is dominant. The definetely negative range shows leptomorph charcter. If the measure of index is about 1.00, we say the stature is transitional, this is the metromorph character. Of course – taken into account the sexual dimorphysm – there are differtent scales, different graduations for determination of the metric indices for men and women.

Plastic index

The measure of plastic index is a parameter giving real information about the development of bone and muscle systems of the body. Practically this parameter is the sum of peculiarities of the bone system (width of shoulder, outline – circumference - of hand) and the muscle sytem (outline of the forearm). For determination of plastic index we take into account the sexual dimorphysm, so we should use different scales for men and women. A lot of investigations proved that the good physical performance needs a high plastic index measure, and this connection is valid vica versa, as well.

NOURISHED STATE, BODY COMPOSITION

In general the quantity of the total fat in the body of athletes in different sport-branches is in the range: 8-15 kg. However, in special cases the difference can be significant, up and down, as well, as a function of bodyweight and bodyweight-categories. For top lifters the typical fat ratio in the lower categories is below 10 %, in general between 7 and 10 %.

Some data about the body composition of elite lifters are shown in table 6 (Herm et al., 1987). So the amount of the fat quantity in the body of a top 56 kg lifter is only 4-5 kg. However in the highest categories (+105 kg for men and +75 kg for women) the fat-ratio can be significantly above 20 %, for female lifters even above 30 %. So the fat quantity in the body of a 150 kg lifter (we mentioned earlier, that the bodyweight can be even significantly more than 150 kg!) can be 30-40 kg.

Table 6. Fatty tissue % of elite lifters

category (kg)	fat tissue %	
	Average	SD
52	8.7	2.0
56	9.0	1.2
60	8.5	2.5
67.5	9.3	0.6
75	11.1	1.6
82.5	11.6	2.4
90	12.1	1.8
100	14.8	1.8
110	15.0	2.7
+110	18.4	2.5

There is a huge amount of data in the literature about the body composition parameters of top athletes. Let us mention, that in case of elite male weightlifters – without the representatives of the super-heavyweight category – the muscle ratio was between 48.5 and 63.3 %, and the fat-ratio in the 5.5-20.9 % range. In the highest category the muscle-ratio was in the interval 43.9-59.3 %, and the fat-ratio in the 9.5-26.2 % range. And we have data about the body composition of the selected Hungarian weighlifting teams, as well, based on our own measurements and by others (Szabo, 2003). E.g. for male lifters the average fat -ratio was 8.9 %, for female lifters 13.9 % to the measurements, carried out by M. Petrekanits (2002) in the exercise-physiology laboratory of the Department of Health Sciences and Sport Medicines of the Semmelweis University in Budapest. These and our measurements were carried out using the „fat gun" equipment (Isorobic Skinfold Caliper) for measurement of skinfold thickness.

So, if we would like to evaluate the nourished state and figure of athletes, it is necessary to take into consideration not only the height and bodymass, but the parameters of width and body-composition, as well. In case of body-composition we should emphasize the importance of fat-ratio determination, because the improvement of performance is in strong correlation with the decrease of fat-ratio within the same category. E.g. if the fat% in the middle categories of Olympic lifting exceeds the 13-14 % ratio, we should think about the optimation of bodymass and body-composition, the change of category to the previous one. E.g. to compete instead of 85 kg category in the 77 kg one. Of course it needs a real and scientifically supported change of the body-composition and change of the diet (e.g. reduce the fat and carbohydrate intake, apply fat-burners etc.).

It is known, that the location and distribution of fat within the body can be determined by anthropometrical measurements. There are 2 typical cases of unnecessary fat-deposition: on the waist and on the hip. The first one is mainly typical for men – this is the apple-type or android obesity – the second one (pear-type or ginoid obesity) can be observed dominantly by women. For characterization of the waist obesity it seems to be sufficient the measurement of waist (outline, circumference of belly). For normal population the optimum measure is below 94 cm. The 94-102 cm range shows overweigtht and still low level risk. If the waist parameter is over 102 cm, the healthy risk increases and this is the case of obesity. For women the parameters: below 80 cm, 80-88 cm, over 88 cm. (Let us mention, that these limit parameters are valid for people with average height. In case of a 190 cm tall man we should have a correction. If the average height is 175 cm, the difference is is 15 cm, which is 8.6 %. So the corrected waist for this man is not 94 cm, but 102 cm.)

There are many techniques, which are widely used for determination of fat% of the body. Relatively simple method is the skin calipers (in general 9 folds) technique, for determination of the skinfold thickness, the subcutaneous adipose tissue. But there are many others, as well, e.g. bioimpedance method (determination of bioelectrical complex resistance and conductivity) or NIR-NIT optical method (determination of near infrared reflectance and near infrared transmittance). These techniques are non-destructive and non-invasive methods (measuring the physical properties) and using some of these modern, up-to-date analytical tools – like NMR (nuclear magnetic resonance) and CT (computer tomography) or spectral image processing equipments – it is possible to get information also about the distribution of fat within the body (Firtha, 2005)(Szabo et al., 2012). The type of obesity can be characterized by the quotient of the visceral (within the belly) and subcutaneous (under the skin) fat quantity. For adult men the beginning of obesity is appr. 22-23 fat%, the critical limit between ideal weigtht and overweight is estimated as 15-16 %. For women the critical limit for obesity is 30-31 fat%, and the limit of overweight is appr. 23-24 %.

Of course in case of athletes the optimum fat% is much less, but the differencies – as a function of sportbranch, weight-category, and qualification level –can be really huge. Even between top athletes of different sport branches. E.g. to the publication of Meszaros et al.(2001) the difference in muscle and fat ratio of elite representatives of kayak-canoe and water polo sports is statistically significant. Because of different physiological and other (e.g. hydrodynamic resistance) reasons the optimum body-composition is different in the different sport branches. So, with a muscle-ratio, which seems to be optimum (suitable) for swimmers and water-polo players, the athletes in kayak-canoe or weightlifting can not reach top results, they have to have higher muscle-ratio. Bodyfat estimation will help coaches to indirectly evaluate the fitness level of tested players and competitors (Ismet et al., 2009).

PRACTICAL ASPECTS AND CONCLUSION

Based on the previously mentioned facts it is obvious that only BMI is not suitable for characterization of physique and nourished state. The reason is party principal: the bodymass is proportional to the third extent of the linear measurement, partly based on the lack of information about the parameters of width, body composition and fat-distribution. In case of athletes with optimation of nutrition – adequate planning and control of the diet of individual competitors as a function of sport-branch and training load – it is possible to reach optimum body-composition and higher results-level, as well.

Anyway, we should stress, that the various national and international medical societies and programs (e.g. Hungarian Scientific Society of Obesity, propositions of European Medical Society in 1998, 2003 and 2008, International Cholesterol Education Program, definition of obesity by the WHO Expert Committee) apply for estimation of healthy risk, the target and indication of treatment to take into account the

BMI and the waist parameter. It is evident, that knowing these parameters the medical doctor can make a correct decision about the treatments to use in case of multirisk patient.

For athletes to recognise a significant overweight or degree of obesity in general seems not to difficult. So, based on sufficient experience a physician, a human biologist or an educated coach can carry out a correct and useful investigation, based on some simple measurements and visual observation. Of course to create an effective therapy, to change the body-composition, to reduce the bodyweight to the ideal one, is a much more complicated task!

So, we have to declare that we can not expect maximum correctness and applicability for estimation of physique and body constitution based only on BMI parameter. For normal people (population level) in general yes, but in case of special segments (e.g. very short or very tall human beings, athletes with well developed musculature) definitely not.

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