



## INVESTIGATION OF SOME FACTORS, INFLUENCING THE LEVEL OF PERFORMANCE AND RELATIVE PERFORMANCE OF TOP OLYMPIC WEIGHTLIFTERS

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### ABSTRACT

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For characterization of the performance level of top weightlifter the world records (achieved till 31.12.2016.) were used. The relative performance was determined as the ratio of the records and own bodyweight (category weight). It is demonstrated that both in case of male and female lifters the performance and the relative performance depend on the body-mass, however the tendency is opposite. Theoretically the performance is the function of body-mass on the  $2/3$  power, so it increases with the body-mass, but the relative performance decreases as a function of body-mass on the minus  $1/3$  power. Evaluating the results in the clean and jerk (C&J) we have to take into account the own bodyweight of the lifters, as well, because the lifters lift during the execution of the C&J attempt the barbell + the own body, standing up from squatting position. So the weightlifter lifts not only the barbell, but also his/her own bodyweight! The results with this correction show rather good agreement with the theoretically determined performance ratios for the different (8+7) weight categories.

**Contribution/Originality:** This study uses new estimation methodology for analysis of the relative performance of the top weight lifters, taking into account during the lifted the complex system of body+barbell.

## 1. INTRODUCTION

Analysis of weightlifting performances in the different weight categories can be really interesting from point of view of sport physiology, anthropometry and training methodology (Ajan, 1988; Nawrat, 1989; Hiskia, 1997;2002; Feher, 2006; Jones *et al.*, 2010). This topic is rather exciting, concerning the expectable and predictive performance for the future, as well. In the paper some factors are analyzed, helping to understand and mathematically describe and prove the practical facts, based on the world records.

Take e.g. the following statement, which is based on experimental results of the international scale elite lifters: the C&J result of the 62 kg lifter is 180 kg, however the result of the lifter in the 94 kg category (appr. 1.5 times higher bodyweight) is not  $1.5 \times 180 = 270$  kg, but „only” about 220 kg. Or a superheavyweight lifter (category +105 kg) with bodyweight 124 kg can lift in C&J not  $2 \times 180 = 360$  kg, but appr. only 240 kg.

So the question: what is the reason, that the relative performance (performance divided by the own bodyweight of the lifter) is in case of 94 kg and dominantly in case of 124 kg lifter is very far from the level of the 62 kg lifter? In case of 62 kg category the lifter can lift almost 3 times his bodyweight, although in case of 94 kg lifter this ratio

is only above 2 and in case of 124 kg lifter less than 2. This fact will be analysed and proved theoretically. If we take into account the valid biomechanical and physiological principles, we can even not expect better results in the heavier categories!

Let us mention that many former analysis were performed about the connection between the sport result and the bodyweight (Starodubcev, 1970; Vorobyev, 1978; Szabo *et al.*, 1979; Poletaev, 1981; Szabo, 2012; Ye *et al.*, 2013). The aim of application of the Sinclair-coefficients or formula – mathematical method for comparison of the achieved results in weightlifting – is also similar, giving an opportunity to evaluate the different results in the different categories for the estimation of the performance-level (IWF website). Based on this it is possible to determine e.g. what is the better result: the 300 kg total in the 62 kg category or the 400 kg total in the 105 kg one.

## 2. MATHERIAL AND METHOD

7 parameters were investigated, influencing dominantly the performance level of the lifters. In this analysis only those parameters were investigated, which have connection with biomechanics, physiology, anthropometry and the frequency-distribution of lifterse as a function of categories. So we paid attention only to the questions of fundamental importance, biological background, and not analysing such type of questions – of course important questions for the individual athletes - as e.g.the beginning age of the lifter, the number of weekly trainings, the qualification of the coach, the type of training method, the level of motivation, nutrition background, competitoion management, application of performace enhancement products etc. For the analysis appropriate mathematical methods were used.

For investigations the world records, achieved till 31.12. 2016. were applied – man and woman records in snatch, C&J and total – and the relative performances were calculated taking into account the different weight categories. The relative performance was determined as the ratio of the records and own bodyweight (category weight). Let us mention, that from 2017 the weight categories for female lifters were modified, new categories (90 kg and +90 kg)) were introduced, so today both male and female lifters compete in 8 categories. However it is true, the category limits are not identical.

Table 1 is for male and table 2 for female athletes. The relative performances were calculated based on the categories. You can see well, that the level of relative performance decreases significantly with the bodyweight. Let us mention, that in the highest categories for male competitors 150 kg, for female lifters 120 kg was used, as a typical average bodyweight, concerning the relative performance calculations. The reason is the following: in the last decade these values seem to be mean ones – for medal holders of the olympic games, world and contenintal championships – with a rather big standard deviation (the bodyweight range was for men between 110 and 190 kg, and for women between 80 and 160 kg).

**Table-1.** World records (kg) for men in 2016 for snatch, C&J and total, calculating the relative performances, as well

Category (kg)	Snatch	C&J	Total
56	139 2.48	171 3.05	307 5.48
62	154 2.48	183 2.95	333 5.37
69	166 2.41	198 2.87	359 5.20
77	177 2.30	214 2.78	380 4.94
85	187 2.20	220 2.59	396 4.66
94	188 2.00	232 2.47	412 4.38
105	200 1.90	246 2.34	437 4.16
+105 (appr.150)	216 1.44	263 1.75	473 3.15

**Table-2.** World records (kg) for women in 2016 for snatch, C&J and total, calculating the relative performances, as well

Category (kg)	Snatch	C&J	Total
48	98 2.04	121 2.52	217 4.52
53	103 1.94	134 2.53	233 4.40
58	112 1.94	141 2.43	252 4.34
63	117 1.86	147 2.33	262 4.16
69	128 1.86	158 2.29	286 4.14
75	135 1.80	164 2.19	296 3.95
+75 (appr. 120)	155 1.29	193 1.61	348 2.90

### 3. BIOLOGICAL AND BIOMECHANICAL PARAMETERS DETERMINING THE PERFORMANCE LEVEL

To our mind theoretically 7 different parameters can be analysed, these are the following:

- effect of body-mass on the performance level according to the law of biomechanics
- connection of the body-mass and the lifted weight as a function of categories
- effect of body composition (muscle ratio) on the performance
- effect of bodyheight on the dynamics of the movement (parameters of speed and acceleration)
- effect of bodyheight on the lifting of the barbell from point of view of energetics
- effect of body-mass and physique on the technical execution of the movement structure
- distribution of the lifters as a function of the body-mass.

In this paper we deal only with the 2 first parameters, the mathematical calculations are based on these 2 factors. The other 5 parameters were only mentioned, but for the time being not analysed and discussed.

### 4. CONNECTION OF BODY-MASS AND PERFORMANCE LEVEL AND RELATIVE PERFORMANCE, BASED ON BIOMECHANICAL CALCULATIONS

It is a rather wellknown fact, that the performance of the athlete or rather the musculature of the competitor is proportional to the cross-section of the muscles. It means to the second extent of the linear measurement. (Linear measurement is e.g. the height of the athlete or the diameter of the muscles.)

So, to the formula:

$$F = k_1 \cdot l^2 \quad (1)$$

F – force

l – a linear measurement

$k_1$  – constant (factor of proportionality)

In the same time it also known, that the volume of a body is proportional to the third extent of the linear measurement, and the mass of the athlete is the product of the volume and the density of the body.

To the formula:

$$V = k_2 \cdot l^3 \quad \text{and} \quad m = \rho \cdot V \quad (2)$$

V – volume

$k_2$  – constant (factor of proportionality)

l – a linear measurement

m - mass

$\rho$  - density

If the performance is characterized by the force (F), based on the mathematical equations of (1) and (2) we will get the following formula:

$$F = k \cdot m^{2/3} \quad (3)$$

So, the performance is proportional to the  $2/3$  extent of the body-mass. If the task is to determine the relative performance level, the performance should be divided by the body-mass of the athlete. The following formula shows this relationship:

$$F_{rel} = F/m = m^{2/3} : m = m^{-1/3} \quad (4)$$

The figures, according to the equations (3) and (4) show well, that the performance increases with the body-mass, however not proportionally, but to the  $2/3$  extent of the body-mass of the lifters. On the contrary, the relative performance decreases significantly with the increase of the body-mass. So in case of a lifter with small bodyweight the relative performance level is much higher, than in case of heavy lifters. Fig 1 shows the connection between performance and body-mass and Fig 2 shows the relative performance vs body-mass relationship.

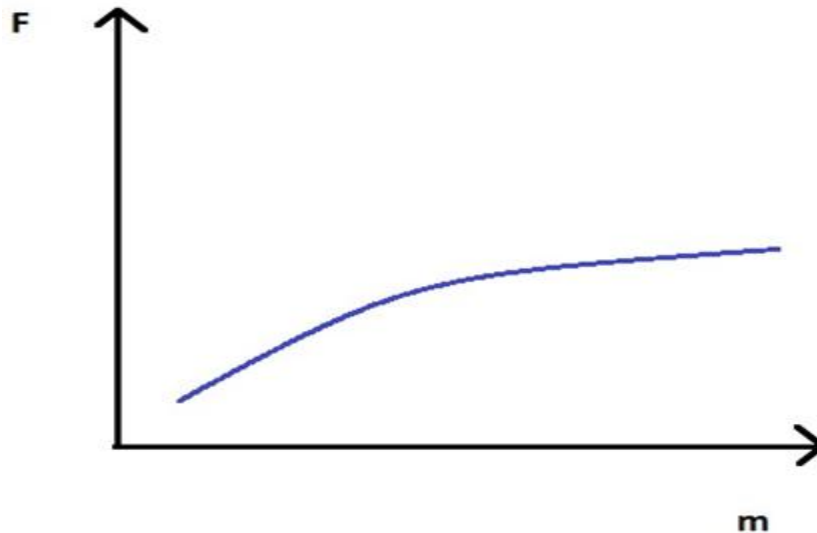


Fig-1. Performance (F) as a function of body-mass (m)

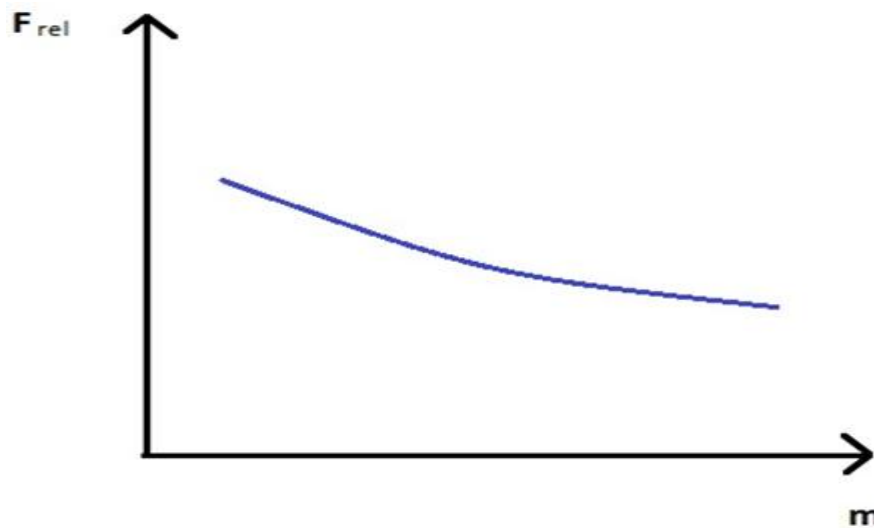


Fig-2. Relative performance (F<sub>rel</sub>) as a function of body-mass (m)

We should suppose, that the valid world records represent very well the maximum performance level of the best athletes, so it is a real fundament for comparison of the theoretically expected results and the real word records. The question, that what is the reason, that in the former decades (and in slightly modified categories) the records were

higher – with other level of doping-controls required – will be not analysed. But let us mention, that today the world record in the 85 kg category is 220 kg, however in 1986 the bulgarian lifter Asen Zlatev produced 225 kg in C&J, lifting in the 82.5 kg category. Or e.g. the best performance was produced by Leonid Taranenko in 1988 in the

superheavy category, however today the world record in C&J is 263 kg. And if we take into account the fantastic performance of Naim Suleymanoglu in 1988, lifting in C&J 190 kg in the 60 kg category, the difference is even bigger, since the valid world record today in the 62 kg category is „only” 183 kg.

Of course the reliability of our mathematical evaluation has an expectation – perfectly it is not possible to fulfil – the results level in the different categories should be appr. the same! This expectation is definitely not fulfilled in case of the snatch record in categories 85 and 94 kg, because the difference is only 1 kg. So, the performance level for snatch is much better in the 85 kg category, than in the next one.

Let us take 2 concrete cases for the comparison of the theory and the practice! First choose the C&J results of male lifters in the 56 and 105 kg categories! Of course it should be stressed, that theoretically the results of all categories could be used for comparison, but the analysis should be carried out with results of lifters of the same gender. The body composition is significantly different in case of female lifters, this is the main reason of lower level performance in comparison with male lifters, You can see, that in case of the same bodyweight the female lifters lift appr. 20 % less, than the male competitors. With similar bodyweight the best female lifters can produce appr. the same result in C&J as the male lifters in snatch (Szabo *et al.*, 2013) The average ratio of snatch results to the C&J results is appr. 80 % (Drewes, 2008).

For male lifters the world record in the 56 kg category is 171 kg, and in the 105kg category 246 kg. The ratio is 0.695, so the 56 kg lifter produces 69.5 % of the performance of the 105 kg competitor.

Theoretically – based on the former mentioned mathematical formula  $F = k \times m^{2/3}$  – with logarithmical calculation we can determine the performance-value for the 2 body-mass:

in case of  $\lg x = 2/3 \log 56$        $x = 14.6$

in case of  $\lg x = 2/3 \log 105$        $x = 22.3$

The ratio of these 2 values is 0.655, showing, that the difference between the theoretically determined result and the valid performance is significant, the level of the 56 kg performance is much higher, than the one in the 105 kg category.

Let us take an example also for the female lifters! In the 53 kg category the world record in C&J is 134 kg, in the 75 kg category 164 kg. The ratio is 0.817, so the 53 kg lifter produces 81.7 % of the performance of 75 kg lifter. Calculate with logarithm the performance-levels for the 2 body-mass!

in case of  $\lg x = 2/3 \log 53$        $x = 14.1$

in case of  $\lg x = 2/3 \log 75$        $x = 17.8$

The ratio of these 2 values is 0.792, showing again the fact, that the difference between the theoretically determined and the valid ratio is significant, the performance level in the 53 kg category is much higher, than in the 75 kg one.

You can ask the question: if the difference is significant, what is the reason? Did we have a mistake in the analysis? Well, there was not a mistake in the calculation, however we did not take into account a very important parameter in the prediction of the performance level! And this parameter is the second one of the previously mentioned 7 parameters, having an impact on the performance level of lifters.

## 5. RELATIONSHIP OF THE LIFTED WEIGHT AND THE BODYWEIGHT AS A FUNCTION OF THE CATEGORIES

During execution of the C&J attempt first the lifter has to perform the clean, and after it, standing up from the squatting position with the barbell on the chest, the lifter has to carry out the jerk. But during the finishing part of the clean, if the lifter stands up with the barbell, he/she has to lift not only the barbell, but his/her own bodyweight, as well! (More precisely not the total bodyweight, but the dominant part of it, because the lower legs below the knees the lifter does not lift practically. Anyway, this is less, than 10 % of the body-mass of the lifter.) So, if we

would like to explain and compare the real performances in the different categories – concerning the dynamics and energetics of the movements – we should not forget to take into account the body-mass, as well!

Let us analyse the 2 previously mentioned cases. The male lifter in the 56 kg category should lift not 171 kg, but appr.  $171+56 = 227$  kg in the gravitation space, and the 105 kg lifter lifts instead of 246 kg  $246+105=351$  kg. The ratio of the calculated results is 0.647, which is in rather good agreement with the theoretically determined ratio, 0.655, calculated using the laws of biomechanics.

In case of female competitors the 53 kg lifter lifts not the 134 kg barbell, but the lifted total weight is  $134+53=187$  kg, and for the 75 kg lifter the real weight is  $164+75=239$  kg. This corrected ratio is 0.782, which is close to the 0.792 theoretical ratio, determined mathematically, using the biomechanical law.

## 6. THE INFLUENCE OF OTHER FACTORS

It was mentioned, that also the other factors have an influence on the performance, but the dominant factors are the previously analysed 2 ones. Although obviously the lifter lifts the weight not with the whole body, but with his/her muscles, so the muscle-ratio is also a modifying factor. Today the muscle-ratio of the best male weightlifters is nearly 60 %, and the ratio is significantly less only in case of +105 kg lifters, because for them the fat-ratio is higher in general.

Influencing factor is the height of the lifter, as well, having an impact on the speedy and accelerating parameters of the lifted weight, on the dynamics of the movement. Another factor to consider is the height of the lifter that influences the way of the barbell from point of view of energetics. And finally let us mention the effect of the distribution difference of the amount of lifters as a function of body-mass. Surely the frequency in the middle categories is higher!

## 7. FINAL CONCLUSIONS

For characterization of the performance of weightlifters the world records, achieved till 31.12.2016. were used, and for the relative performance the records were divided by the body-mass (maximum weight of the categories) of the lifters. The values of performance and the relative performance depend on the body-mass, but – based on biomechanical calculations – this change shows an opposite tendency as a function of bodyweight of the lifters. Because the performance is a function of bodyweight on the  $2/3$  extent, so increases with the increasing bodyweight, definitely the relative performance decreases as a function of bodyweight, to the  $-1/3$  extent. Although the real evaluation of the results of top lifters in C&J needs a modification, as well, since the lifters – during the clean, standing up with the barbell from the squatting position – should lift not only the barbell, but their own bodyweight, as well.

If we calculate with the input data, mentioned in the introduction – 180 kg in C&J for the 62 kg lifter and 220 kg C&J for the 94 kg lifter – applying for the determination the formula  $m^{2/3}$ , the theoretical ratio is 0.754. But the ratio of the C&J results (180 és 220 kg) is 0.818. The explanation of this significant difference is the own bodyweight.

If we take into consideration also the 62kg and 94 kg plus weight, as the own body-mass of the lifters, the ratio of the so calculated 242 kg and 314 kg is 0.771. This corrected value shows a better agreement with the theoretically determined one. So, the conclusion is the following: the corrected (with bodyweight) performance shows a very good agreement with the theoretically determined ones between the categories.

In the same time – if the calculations are carried out for the highest category, both in cases of male and female lifters the real performances are significantly below the theoretically calculated ones. So, in this case we have to take into account other factors, as well. This will be the topic of the second part of the paper.

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