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The Influence of the Age, the Years of Training, and the BMI on the Average Muscle Power in Male and Female Rowers

Mate Moguš[1], Vlasta Oršić Frič[1,2], Bruno Atalić[2]

[1] Medical School Osijek, Osijek
[2] Clinical Hospital Center Osijek, Osijek

ABSTRACT

The aim of the study was to evaluate the influence of the age, the body mass index (BMI), and the years of training on the average muscle power in male and female rowers. The analysis of the testing results of the members of the Rowing club Iktus from Osijek in Croatia was performed. Results were obtained during the regular yearly testing on the rowing ergometer for the rowing season of 2009. Members of the Rowing club Iktus were divided into two subgroups according to their sex. The obtained results were analysed in accordance with the age, the BMI, and the years of training independently for the each of the two subgroups. The results have showed that the average muscle power is independent of all the three parameters in the male rowers, while it is dependent on the age and the years of training in the female rowers. It seems that the BMI does not play any role at all in the average muscle power. As a conclusion, it could be stated that while one can suggest to female rowers to improve their performance with prolonged training, there is a need for a further research in order to formulate a suitable advice for male rowers.

Key words: *rowing, age, body mass index, years of training, average muscle power*

Introduction

Rowing is a sport in which rowers race against each other in the boats propelled by the reaction forces on the oar blades as they are pushed against the water. While rowing, the rower sits in the boat facing backwards, and uses the oars which are held in place by the oarlocks to propel the boat forward. It is a demanding sport requiring strong core balance as well as physical strength and cardiovascular endurance. The rower begins by placing the blade in the water at the catch, after which the rower applies pressure to the oar while simultaneously moving the seat towards the bow of the boat firstly by extending the legs, then by extending the back towards the bow of the boat, and then finally by pulling the arms towards the chest. After the drive has been completed, the rower then pushes down on the oar handle to remove the oar from the water at the release. After feathering, the rower begins the recovery phase of the stroke in which the arms, body, and finally the legs and seat are moved towards the stern of the boat. Once the rower has reached the end of the recovery, the rower squares the blade and then repeats the stroke again, beginning with the catch[1].

Rowing is a cyclic form of propulsion such that in the quasi steady-state, which describes the movement of the upper body, but not the lower body as well, the motion of the system is repeated regularly. In order to maintain the steady-state propulsion of the system without either accelerating or decelerating the system, the sum of all the external forces on the system, averaged over the cycle must be zero. Thus, the average drag or retarding force on the system must equal the average propulsion force on the system. The drag forces consist of aerodynamic drag on the superstructure of the system (components of the boat situated above the waterline), as well as the hydrodynamic drag on the submerged portion of the system. The propulsion forces are the forward reaction of the water on the oars while in the water. Rowing is one of the few non-weight bearing sports that exercise all the major muscle groups. Rowing improves cardiovascular endurance and muscular strength. High-performance rowers tend to be tall and muscular, although extra weight does increase

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the drag on the boat, the larger athlete's increased power tends to be more significant, which is achieved through increased length of leverage on the oar through longer limbs of the athlete[2].

The aim of this study was to evaluate the influence of the age, the body mass index (BMI), and the years of training on the average muscle power. The working hypothesis was that the rowing fitness decreases with the age after the age of 23 when the growth and development stop, increases with the years of training regardless of age, and is related with the BMI according to the Gauss curve, meaning that it is the highest with the normal range values, and decreases accordingly with the smaller and the bigger values than the mentioned normal range.

Subjects, Materials and Methods

According to the presented sources the observed group of rowers who are members of the rowing club Iktus Osijek was already in the beginning divided into male and female subgroups, in order to avoid the influence of sex differences on one hand, and to create two independent comparable groups on the other hand. Their average age was average ± standard deviation (range 15 to 23 years) for male rowers and average ± standard deviation (range 14 to 34 years) for female rowers. They were measured for their body height, body mass and average muscle power, while their ages, sex, and years of training were taken from their club records, which was done with their consent as a part of their regular training program. BMI was calculated according to a formula: BMI= body mass (kg) / body height $(m)^2$. Average muscle power was calculated according to a formula: power (W) = 2.8/(time (s)/distance (m))[3].

Testing equipment was the rowing ergo meter Concept 2 model D. It is used for simulating of the rowing action. It is achieved by training on land and could be used for measuring rowing fitness. It does not stimulate the lateral balance changes, the exact resistance of water, or the exact motions of true rowing including the sweep of the oar handles. However, it can still allow a comparable workout to those experienced on the water[1]. The Performance Monitor measures the drag factor on the recovery phase of each stroke and uses it to calculate rower's average speed on 500 m (avg 500). This method of self-calibration compensates for local conditions and damper settings, making scores on different indoor rowers comparable. Indoor racing and the online community are made possible by this method of self-calibration. Speed that rower generates on ergo meter is expressed as average time necessary for to pass 500m (for example if avg 500 at the moment is 2:00 it means that rower is going to pass distance of 500m in 2 minutes). Drag factor setting on ergo meter during this test was chosen on recommendations of manufacturer, and it was set 120–125 for male rowers and 115–120 for female rowers. Test was conducted in intervals of 4 minutes with the 2 min rest between each interval.

Initial speed for each rower was individualized and it was set by the rower's previous individual speed during the extensive training on the ergo meter, and it was calculated as a sum of speed of 6km test plus additional 12sec. 6km test is a standard test and it is conducted during the winter season, when male and female rowers are maximally trained. It represents a sum of average avg/500m during 6 s plus additional 12 s. It is a part of extensive training conducted on ergo meter for six kilometres[2]. In every following series rower would be speeding average avg/500m of previous series for three to four second. With the aim of achieving relevant middle values we have determined time values between 1.41,5–1.51,5 s for male rowers, and 2.00,5–2.10,5 s for female rowers. The average score of muscle power was 300.395 W for the male rowers (median of two rowers with 300.741 W) in the interval between 274,815 W and 350 W, while for the female rowers was 159,310 W (median of one rower with 159,565 W) in the interval from 132,191 to 181,593.

The t-test, normal test, standard variance equation test and Mann-Whitney Rank Sum Test were used for data analysis. The level of statistical significance of difference was set at $p<0.05$.

Results

The correlation between the age, the BMI, and the years of training on one hand, and the average muscle power on the other hand were analysed between male and female rowers. Regarding the sex the mean male average muscle power was around 300 J, and the female one around 150 J. As previously mentioned both sex groups were analysed independently (Tables 1 and 2). Normality test and the equal variance test of both groups showed passing results with the standard deviations of 0.209 and 0.077. The difference in the mean values of the two groups was greater than would be expected by chance, with 95 percent confidence interval for the difference of means (0.377–4.875). There was a statistically significant difference between the input groups with the standard deviation of 0.024, while the power of the performed test with the alpha of 0.050 was 0.546. The strength comparison between the two groups showed similar results. Normality test and the equal variance test of both groups again showed passing results with the standard deviations of 0.062 and 0.790. The difference in the mean values of the two groups was also greater than would be expected by chance, with 95 percent confidence interval for difference of means (123,645–149,744). Finally, there was a statistically significant difference between the input groups with the standard deviation lesser than 0,001, while the power of the performed test with the alpha of 0.050 was 1.000.

T-test showed a statistically significant difference between the male and the female BMI ($P=0.024$), which count was lower in the females (10) than in the males (25). Normality test and the equal variance test were positive with $P=0.209$ and $P=0.077$. Estimated difference was 2.375 with 33 degrees of freedom. T-test showed that the female rowers had significantly lower average muscle power than the male rowers, which was 296.74 in comparison with 159,379. Normality test and the equal vari-

TABLE 1
CORRELATION BETWEEN THE AGE, THE BMI AND THE YEARS OF TRAINING WITH THE AVERAGE MUSCLE POWER IN THE MALE ROWERS

Male Rowers	Age	Male rowers BMI	Years of training	Average power during 1,41.5–1,51.5 s
	16	21.8	3	280
	16	22.15	3	280
	16	26.58	3	280
	16	21.8	3	311.111
	16	21.56	3	311.111
	16	21.21	3	311.111
	17	22.04	3	280
	17	22.11	3	350
	17	20.37	3	311.111
	17	24.93	4	315
	18	12.41	6	280
	18	24.44	6	280
	18	24.95	6	281.885
	18	27.40	6	290.370
	18	27.70	6	290.370
	18	24.63	6	298.914
	18	23.27	6	311.111
	19	21.43	7	300.741
	20	24.72	7	281.885
	20	28.75	7	300.741
	21	26.88	6	290.370
	21	23.48	7	290.370
	21	25.23	7	305.278
	23	26.88	10	274.815
	23	26.73	10	295.556
Average	18,3	23,7	5,4	296,074
Sd	2,2	3,4	2,2	17,161
Sem	0,4	0,7	0,4	3,4
Count	25,0	25,0	25,0	25,000
Median	18,0	24,4	6,0	290,4

TABLE 2
CORRELATION BETWEEN THE AGE, THE BMI AND THE YEARS OF TRAINING WITH THE AVERAGE MUSCLE POWER IN THE FEMALE ROWERS

Female Rowers	Age	Female rowers BMI	Years of training	Average power during 2,00,5-2,10,5 s
	15	18.39	2	132.191
	15	20.28	2	148.933
	16	22.05	3	145.232
	16	22.05	3	153.277
	17	22.32	3	145.232
	17	21.41	3	159.565
	19	20.96	7	175.458
	24	19.61	10	179.902
	21	23.13	8	172.411
	35	20.92	19	181.593
Average	19,5	21,1	6,0	159,379
Sd	6,2	1,4	5,4	17,091
Sem	1,9	0,4	1,7	5,4
Count	10,0	10,0	10,0	10,000
Median	17,0	21,2	3,0	156,421

ance test were again passed with P = 0.062 and P = 0.790. Estimated difference was 21.12 with 33 degrees of freedom, and it was statistically significant with P<0.001. There was no statistically significant difference between the age and the years of training between the male and the female rowers. Regarding the age median value was 18 years for the male rowers and 17 years for the female rowers, while the Mann-Whitney U Statistic test showed no significant difference between the two groups (P=0.617). Mann-Whitney U Statistic test failed to show the medians in the years of training between the males and the females, and there was no statistically significant difference between the two groups (P=0.596).

Pearson Product Moment Correlation has showed on one hand, that there was a significant positive correlation between the male age and the BMI, as well as a significant positive correlation between the male BMI and the years of training. Also, there was a significant positive correlation between the male age and the years of training. However, there was no correlation between the male age, the BMI and the years of training with the average muscle power. On the other hand, it showed that there was a significant positive correlation between the female age and the average muscle power, as well as the female years of training and the average muscle power. The female age was also positively correlated with the years of training. However, the female BMI did not correlate to any of the tested variables. While the average muscle power in the male rowers was not connected with neither of the tested variables, it was connected with the age and the years of training, but not the BMI in the female rowers.

Discussion and Conclusion

The results of our study have showed that on one hand the average muscle power in the male rowers was influenced with neither the age, neither the BMI nor the years of training. On the other hand, they have shown that the average muscle power in the female rowers was influenced by the age and the years of training, but not by the BMI. One can conclude that, although it is presumed that the appropriate body weight is crucial for the successful athletic performance, the results have showed that the BMI does not play a significant role in either male or female rowers regarding the average muscle power.

Already in the beginning of the study the rowers were divided into male and female subgroups, in order to avoid the influence of sex differences on one hand, and to create two independent comparable groups on the other hand. The mentioned division is in accordance with Yoshiga and Higuchi who have evaluated the rowing fitness of female and male rowers to their body size. They have observed that the rowing time was slower in the females than in the males with a similar body height (by approximately 10%) and body mass (by approximately 9%) and have concluded that individuals with large body size and aerobic capacity posses an advantage for a 2000-m row on ergometer, but that the variation in body size and aerobic capacity cannot explain the entire sex difference in ergo meter rowing performance[3].

Regarding our findings of the positive connection between the age and the average muscle power in female rowers, and the lack of the same in the male rowers, they are opposite to the findings of Seiler et al. They have looked at sex differences in rowing performance and power depending on age. Performance time to power output conversion revealed that men and women lose absolute power at a similar rate across the age span analyzed. However, their different starting positions on the exponential power-velocity curve create distinct differences in the pattern of performance decline and the maintenance of relative power. They have concluded that the differences in the effect of aging on performance across different endurance sports are caused more by physics than physiology[4]. The mentioned discordance between our and their results can be explained with the fact that the Ictus Rowing Club is a relatively small club, regarding the facilities, the funds and the number of the rowers, and which in order to keep its excellence is forced to train only the best potential rowers after the age of 18, which reveals why the older female rowers tend to be better than the younger female rowers, and why there is no difference between older and younger male rowers.

Our findings of the positive connection between the years of training and the average muscle power are in accordance with Battista et al who have examined the physical characteristics and performances of 90 female collegiate rowers depending on the level (novice, varsity) and the years of participation (0, 1, 2, and 3) in collegiate rowing. They have observed that varsity rowers had significantly more rowing experience (approximately 0.5 years) before college, higher vertical jump (approximately 3 cm), faster 2-km times (approximately 25 s), and lower endomorphic characteristics than novice rowers. They have concluded that collegiate rowers differ to some extant in physical and performance characteristics depending on level and experience[5]. They are also in accordance with Lasan and Katić who have tried to establish the influence of several years of programmed training on the structure of the body, oxygen carrying capacity and oxidation capacity of muscle cells, the chemical composition of blood and characteristics of pulse and lactate curves in rowers. They have measured 14 rowers and divided them in two groups according to age and the years of training. The two groups did not differ as to the structure of the body if equalized according to the body height, but differences existed in the determinants of oxygen carrying capacity and oxidation capacity of muscle cells. Older rowers had lower minute of the test on a bicycle ergometer and higher maximal oxygen pulse. While at rest, no significant differences between the groups were observed in most of the analyzed substances in the blood serum[6].

Finally our findings of the lack of any connection between the BMI and the average muscle power in both male and female rowers are in accordance with the other authors. Although the BMI is the most common measurement in sports medicine, there are numerous critiques of its usefulness. According to Jonnalagadda et al in the case of sportsmen, who have a high body weight due to higher lean body mass, the BMI may lead to misclassification of the athlete as overweight or obese. Thus, both the BMI and body composition assessment should be conducted before determining if an athlete is overweight or obese. Body weight goals of athletes should be determined for each athlete, based on the athlete's body size and shape, and the requirements of the sport, rowing in this case for example. The BMI is used as a surrogate for percent fat in classifying obesity. By default, the BMI is also used to classify athletes and young adults as obese[7].

Odde et al. have proved that the BMI should be used cautiously when classifying fatness in college athletes and non-athletes and that a different BMI classification for the overweight people should be used in these populations[8]. Nevill et al have proved that the skin folds increase at a much greater rate relative to a body mass than that assumed by the geometric similarity, but the taller subjects had less rather than more adiposity, which has called into question the use of the traditional skin fold-stature adjustment, of 170.18/stature. According to them the best body-size index reflective of skin fold measurement was a stature-adjusted body mass index similar to the BMI. However, sporting differences in the skin fold thickness persisted, having controlled for differences in the body size (the approximate BMI) and the age, with the male strength- and speed-trained athletes having 32% and 23% lower skin folds and female strength athletes had 29% lower skin fold measurements compared to controls, having controlled for body size and age. These results cast serious doubts on the validity of the BMI to represent adiposity accurately and its ability to differentiate between populations. These findings suggested that a more valid assessment of fatness will be obtained using surface anthropometry such as the skin folds taken by experienced practitioners following established procedures[9]. Fuji et al have proved that the delayed menarche in athletes is influenced by the stress of regular sports training. The change in the BMI with the age was examined by applying the wavelet interpolation method (WIM), and a critical period for body fat in terms of the coming of menarche was estimated from the growth velocity. Health examination records showing these subjects' heights and weights from the first grade of elementary school to the final year of high school (1984–1995) were collected and the BMI was calculated for each grade[10].

Prentice et al have proved that although the BMI is the cornerstone of the current classification system for obesity and its advantages are widely exploited across disciplines ranging from international surveillance to individual patient assessment, like all anthropometric measurements, it is only a surrogate measure of body fatness, especially during infancy and childhood, ageing, racial differences, athletes, military and civil forces personnel, weight loss with and without exercise, physical training, and special clinical circumstances, so they have proposed that actual measurements of the body fat mass should be introduced[11]. Neville et al have suggested that the lean body mass index (LBMI), which is the index height^2/weight, is empirically and theoretically, superior to the traditional BMI. Its distributional properties were both symmetric and normally distributed. When height and weight are recorded in centimetres and kilograms, the suggested working normal range for the LBMI is 300–500 with the median at 400[12]. Norgan et al have examined the relationships between BMI and body composition in different population groups. The relationship between the BMI and fat as a percentage of body weight is approximately linear although theoretically a curvilinear relationship is to be expected. Low BMI approximates to low weight, fat mass and fat-free mass. There are differences in the relationships of the BMI to body composition but over the range 20–25 kg/m^2 these may not be important in the epidemiological studies. To interpret the BMI in terms of body composition in more detail it is necessary to take into account the sex, the age, the shape and the ethnicity[13].

Jackson et al have studied the effects of the sex, the age and the race on the relation between the BMI and the measured percent body fat (%fat) by the cross-sectional validation study of sedentary individuals using the Heritage Family Study cohort of 665 black and white men and women who ranged in age from 17 to 65 years. For the same BMI, the percentage fat of females was 10.4% higher than that of males. General linear models analysis of the women's data showed that age, race and race-by-BMI interaction were independently related to %fat. The same analysis applied to the men's data showed that %fat was not just a function of the BMI, but also age and age-by-BMI interaction. These data and results published in the literature showed that the BMI and %fat relationship are not independent of age and sex. They have also showed a race effect for women, but not men[14]. Welborn et al have compared weight/height, weight/height^2 which is the BMI, and weight/height^3. They have analysed the cross-sectional data from the surveys of 6948 adults (3334 men (the mean age 43 years, the mean BMI 24.8 kg/m^2), and 3614 women (the mean age 42 years, the mean BMI 24.3 kg/m^2)) in Busselton, Australia whose weight, height, triceps skin fold, and cardiovascular risk factors were measured from 1966 through to 1978. In men, weight/height^2 met the criteria for a satisfactory index in that there was a very strong correlation with the triceps skin fold, and a negligible correlation with the height. For women, weight/height was as good a measure as weight/height^2, with both having strong correlations with the triceps skin fold, and minimal correlations with the height. They have concluded that weight/height^2 is an appropriate index of leanness and obesity in males at all ages, whereas weight/height is at least as good an index for females[15]. Goh et al tried to explain how good the BMI and the other anthropometric measures are as indices of obesity. None of the other anthropometric indices was better than the locally established BMIs. They have shown that the BMIs for obesity for the local men and women are different. These BMIs were most precise among all indices studied. However, they still have lead to high false-positive rates[16].

Regarding the measured physical traits other then the BMI it should be mentioned that Slater et al have looked at physique traits and their relationship to competitive success amongst 107 lightweight rowers competing at the 2003 Australian Rowing Championships. Lower body fat, greater total body mass, and muscle mass were associated with faster 2000 m heat times. They have concluded that more successful lightweight rowers were those who had lower body fat and greater total muscle mass[17]. Mikulić has examined the anthropometric and metabolic determinants of performance of 25 internationally successful male heavyweight rowers during 6000-m of rowing on an ergometer. The strongest correlates ($r>0.5$, $p<0.05$) with performance were lean body mass index ($r=-0.767$), power output at ventilator threshold ($r=-0.743$), power output at maximal oxygen uptake ($r=-0.732$), body mass ($r=-0.693$), chest girth ($r=-0.598$), relaxed arm girth ($r=-0.574$), forced vital capacity ($r=-0.519$), and arm span ($r=-0.505$). They have concluded that rowers competing over a 6000 m distance on a rowing ergometer should devote their training time to the improvement of the lean body mass and to the improvement of the power output corresponding to the ventilator threshold[18].

As mentioned above our results have showed that there was no influence of the BMI on the average muscle power in both the male and female rowers. Bearing on mind the formula for the calculation of the BMI, which is body mass (kg) / body height (m)^2, one can conclude that neither the weight nor the height have any influence on the rowing fitness. This questions the above mentioned conclusion of Yoshiga and Higushi that the individuals with the large body size posses an advantage for a 2000-m row ergometer[3]. Based on this one can conclude that there is no hereditary predisposition for the rowing fitness, but that it is dependant solely on the training efforts. This is conformed by the statistically significant correlation between the age and the years of training with the average muscle power in the female rowers. However, we were not able to determine the statistically significant connection between the average muscle power and any of the observed parables among the male rowers. In conclusion, it could be said that while we can advice the female rowers to improve their rowing fitness through training efforts, there should be conducted future studies regarding the male rowing fitness.

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Bruno Atalić

»Josip Juraj Strossmayer« University, Medical School Osijek, Chair for Physiology and Immunology, Josip Huttler 4, 31000 Osijek, Croatia
e-mail: brunoatalic@yahoo.co.uk

UTJECAJ DOBI, GODINA TRENIRANJA I INDEKSA TJELESNE MASE NA PROSJEČNU MIŠIĆNU MASU KOD VESLAČA I VESLAČICA

SAŽETAK

Cilj rada bio je procijeniti utjecaj dobi, godina treniranja i indeksa tjelesne mase (BMI) na prosječnu mišićnu snagu. U radu su analizirani postignuti rezultati testiranja članova veslačkoga kluba Iktus iz Osijeka u Hrvatskoj. Rezultati su dobiveni redovitim godišnjim testiranjem na veslačkome ergometru za veslačku sezonu tijekom 2009. godine. Članovi veslačkog kluba IKTUS podijeljeni su u dvije podgrupe prema spolu. Dobiveni rezultati analizirani su zasebno za svaku podgrupu, prema dobi, godinama treniranja i indeksu tjelesne mase. Rezultati su pokazali da je prosječna mišićna snaga neovisna o sva tri promatrana parametara kod veslača, dok je kod veslačica prosječna mišićna snaga ovisna o dobi i godinama treniranja. Rezultati ukazuju da indeks tjelesne mase uopće ne utječe na prosječnu mišićnu snagu. Može se zaključiti da dok se s jedne strane veslačicama može savjetovati produživanje treniranja s ciljem poboljšanja njihovih veslačkih sposobnosti, s druge strane je potrebno napraviti daljnja istraživanja kako bi se formulirao odgovarajući savjet i za veslače.