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Original article

OPTIMAL BODY MASSES FOR DIFFERENT OLYMPIC SPORTS

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Background. The weight of the best athletes at different distances and in different sports can be very different. It is known that rowers, as a rule, are very massive. In order to give a chance to athletes with a small mass, the rowing federation was introduced a special category with the weight restrictions. These facts are connected with the peculiarities of the aerobic and un-aerobic activities, drag and propulsion characteristics.
Objective. In this paper, we don't try to explain the body mass differences. We will only fix them for different sports: running, swimming (free style), skiing, skating, cycling, and rowing and for different Olympic distances.
Methods. A significant amount of data on the velocity and body mass of the best athletes professionals (both female and male) in Olympic sports (running, swimming, skiing, skating, cycling and rowing) was collected and analyzed. Since the weights of the best athletes only are taken into consideration, the expected results can be treated as the most suitable (optimal) body masses for different sports and distances. In order to check, how the values of body mass and average speed on the distance fit the linear dependence, the equation of the linear regression was used. The regression coefficient and two parameters of the straight line were calculated. In order to check that the velocity of skating doesn't depend on the athlete mass, the Fisher test was used.
Results. The optimal masses of athletes for different distances and sports were calculated. In general, for the short distances, the large masses of athletes are optimal and they decrease for long distances. Exception is the results for female swimming and running, where the largest masses of athletes correspond to the medium distances. For longer distances, results show that the most performing athletes are characterized by a lower body mass, except for skating. For a fixed distance, the optimal weights of female athletes are 79.5 ± 3.1% of the weight of male athletes, at the same time they develop 89.4 ± 1.8% of the speed of men.
Conclusions. The presented statistical analysis indicates that within one distance there is no significant dependence of speed on the mass (the exception is only rowing). For each distance there are their optimal masses of athletes, which are different for different sports. The revealed facts can be used in athlete selection and training. They need also further investigations with the use of the metabolic and propulsion peculiarities.

Keywords: Olympic sports; linear regression; Fisher test; athlete selection.

Introduction

The weight of the best athletes at different distances and in different sports can be very different. E.g., the body mass of 10 000 m runner champion – Kenenisa Bekele (55 kg), [1] – is only 58.5% of mass of 100 m one – Usain Bolt (94 kg) [2]. It is known that rowers, as a rule, are very massive. In order to give a chance to athletes with a small mass, the rowing federation was introduced a special category with the weight restrictions (72.5 kg for men) and (59 kg for women) [3, 4].

These facts are connected with the peculiarities of the aerobic and un-aerobic activities. The allometry and Kleiber's law [5] may be used to explain the drastic mass differences for sprinters and stayers. For rowing and swimming (where the movement is almost neutral buoyant), the substantial part of the energy released in the body is used to overcome the drag in water, while for human running the air drag can be neglected, but significant energy is used to support the weight [6].

In this paper, we don't try to explain the body mass differences. We will only fix them for different sports: running, swimming (free style), skiing, skating, cycling and rowing (individual category without athlete weight limitations [3, 4]), and for different Olympic distances. For this purpose, the statistical information about the best male and female athletes were collected and analyzed with the use of linear regression (for every distance) and the Fisher test (for skating). Since only the weights of the best athletes will be taken into consideration, the expected results can be treated as the most appropriate (optimal) body masses for different sports and distances. For example, many men compete on a distance of 100 m, but far not all run it for less than 10 seconds. One reason might be inappropriate weight. Therefore, we specifically use the data of athletes, who showed the best time to determine the most appropriate (optimal) body weights. The optimum weight of the body for each sport and distance is a result of natural selection. We just fix it.

Materials and Methods

Information collection. The information was collected on the official sites of sports (associations): International Association of Athletics Federations [7], International Swimming Federation [8], International Ski Federation [9], International Skating Union [10], International Cycling Union [11], International Rowing Federation [12], as well as on other sports sites in 2015–2016. The best sports achievements of athletes (male and female) over the past 3–4 years have been analyzed, as well as some of the best results achieved earlier. In total, information was collected and analyzed for 6 kinds of sports: running (8 male + 8 female distances, 692 results), swimming (free style) (5m + 5f distances, 609 results), skiing (6m + 6f distances, 553 results), skating (5m + 5f distances, 680 results), cycling (4m + 4f distances, 397 results), rowing (individual, no weight limit) (1m + 1f, 616 results (including intermediate ones)).

Linear regression. In order to check, how the values of body mass m and average speed U on the distance (collected for the fixed sport and the distance) fit the linear dependence, the equation of the linear regression m on U (the optimal straight line, minimizing the sum of squared distances between collected and theoretical points) was used [13]. The regression coefficient and two parameters of the straight line were calculated with the use of known formulas [13].

Fisher test for skating. In order to check that the velocity of skating doesn't depend on the athlete mass, two groups with smaller and larger mass were selected for every Olympic skating distance and for males and females separately. These two groups have an equal number of persons. For each group, the average velocities and body masses will be calculated. Then the Between group variability and Within group variability will be calculated according to the formulas:

$$B_{gv} = \sum_{i=1}^{m} n_i \frac{(\overline{Y_i} - \overline{Y})^2}{m-1} \tag{1}$$

where B_{gv} is Between group variability, $\overline{Y_i}$ denotes the sample mean in the i-th group, n_i is the number of observations in the i-th group, $\overline{Y}$ denotes the overall mean of the data, $m = 2$ denotes the number of groups;

$$W_{gv} = \sum_{i=1}^{m} \sum_{j=1}^{n_i} \frac{(Y_{ij} - \overline{Y_i})^2}{n-m} \tag{2}$$

where W_{gv} is the Within group variability, Y_{ij} is the j-th observation in the i-th out of m groups, n is the overall sample size [14].

We will use the F-test to check the null hypothesis that says that the average speeds do not differ for light and heavy athletes. The experimental value of the Fisher function can be calculated with the use of the formula:

$$F = \frac{B_{gv}}{W_{gv}}. \tag{3}$$

The corresponding values will be compared with the critical value $F_c(k_1, k_2)$, $k_1 = m - 1 = 1$, $k_2 = n - m$ of the Fisher function at a desired significance or confidence level α.

Results

Velocity versus weight dependences for fixed distances. The collected values of body mass and velocity for every athlete are shown by small rhombuses in Figs. 1–6 for running, swimming, skiing, skating, cycling, and rowing respectively. The boundaries of rhombuses are blue for males and red for females. The corresponding average values of the body mass and velocity are shown by greater rhombuses for every distance. The corresponding linear regression lines and regression coefficients are also shown in Figs 1–6. In the case of rowing, there is only one Olympic distance – 2000 meters. For this case, the intermediate results for 500 m and 1000 m are also represented in Fig. 6.

Figs. 1–5 demonstrate that within one distance there is no significant dependence of speed on the athlete weight. Corresponding correlation coefficients may be negative and positive but are close to zero. In the case of rowing, the speed increases with the increase of the body mass; especially for female athletes (the corresponding values of the correlation coefficient exceed 0.7).

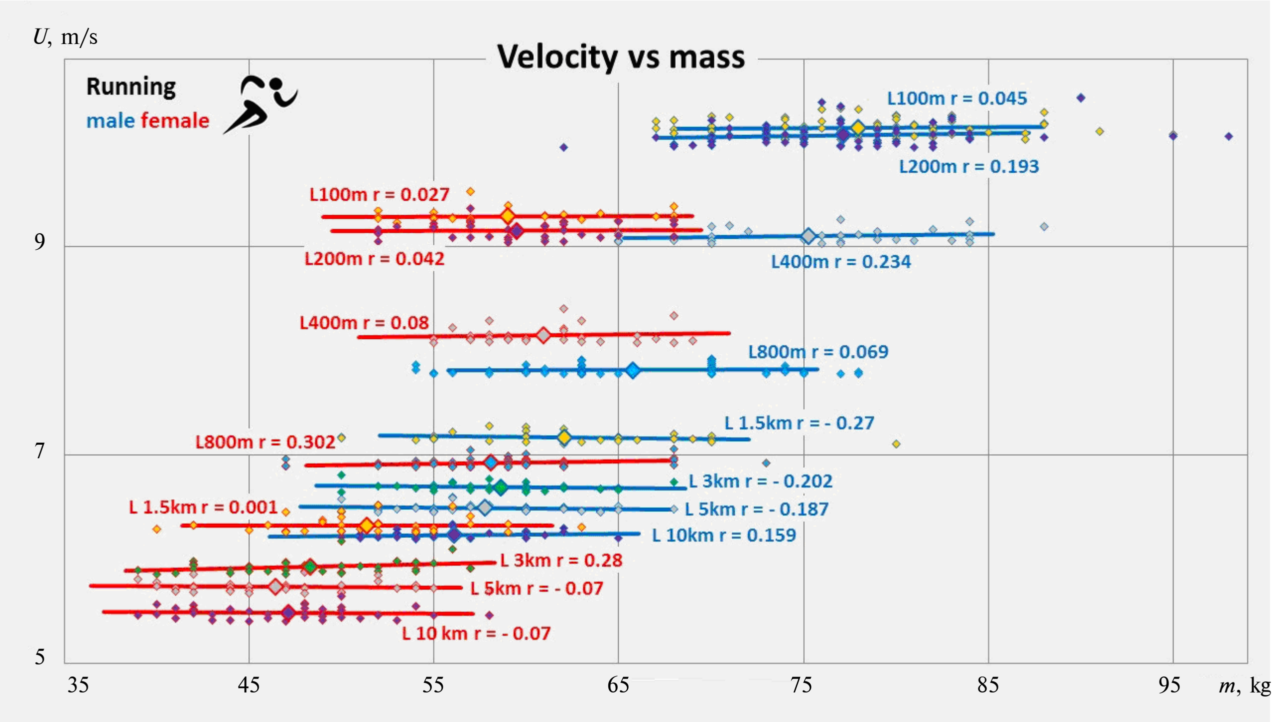

Figure 1: Running. The values of body mass and velocity. Small rhombuses are values for every athlete. Greater rhombuses are average values for every distance. The boundaries of rhombuses, corresponding linear regression lines and regression coefficients are blue for males and red for females

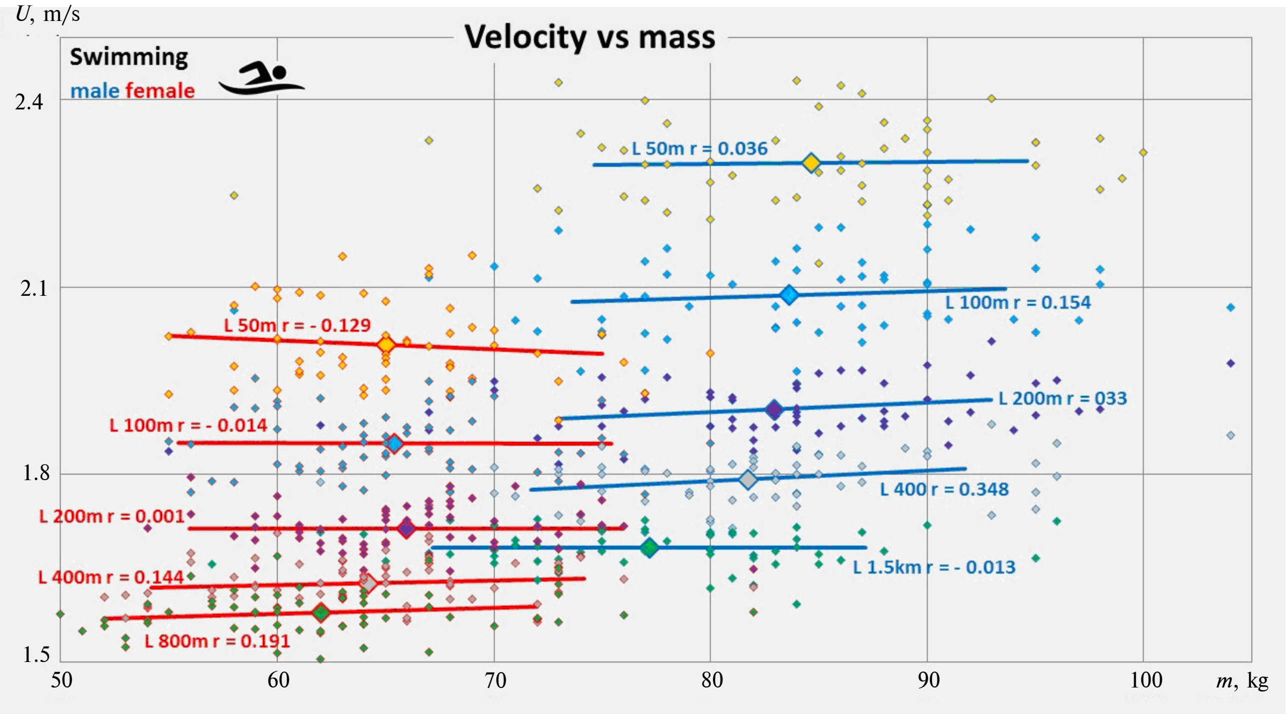

Figure 2: Swimming. The values of body mass and velocity. Small rhombuses are values for every athlete. Greater rhombuses are average values for every distance. The boundaries of rhombuses, corresponding linear regression lines and regression coefficients are blue for males and red for females

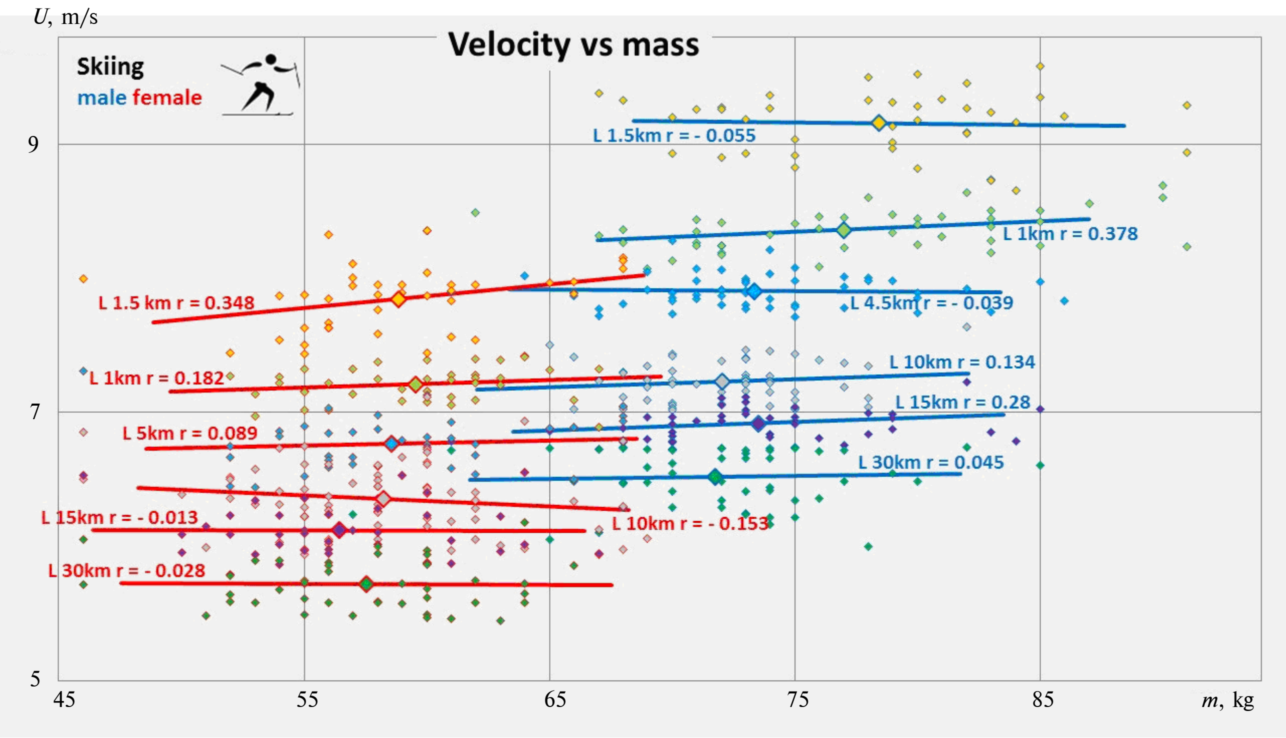

Figure 3: Skiing. The values of body mass and velocity. Small rhombuses are values for every athlete. Greater rhombuses are average values for every distance. The boundaries of rhombuses, corresponding linear regression lines and regression coefficients are blue for males and red for females

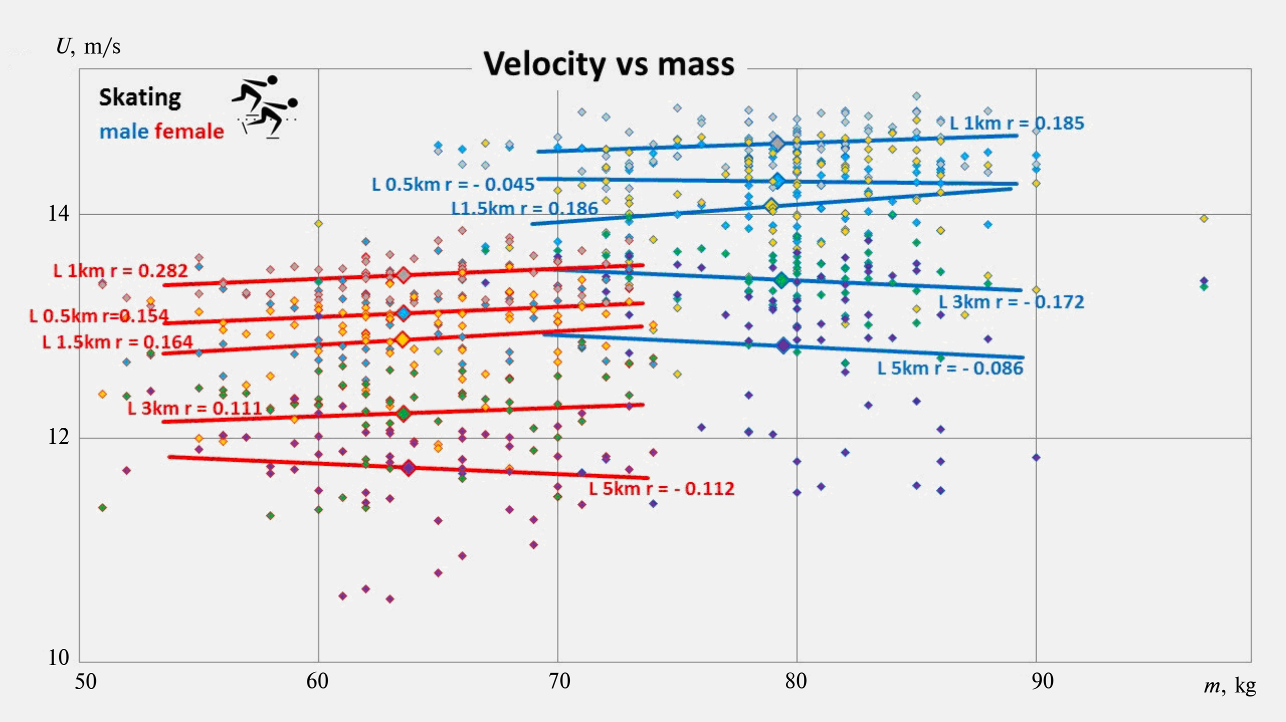

Figure 4: Skating. The values of body mass and velocity. Small rhombuses are values for every athlete. Greater rhombuses are average values for every distance. The boundaries of rhombuses, corresponding linear regression lines and regression coefficients are blue for males and red for females

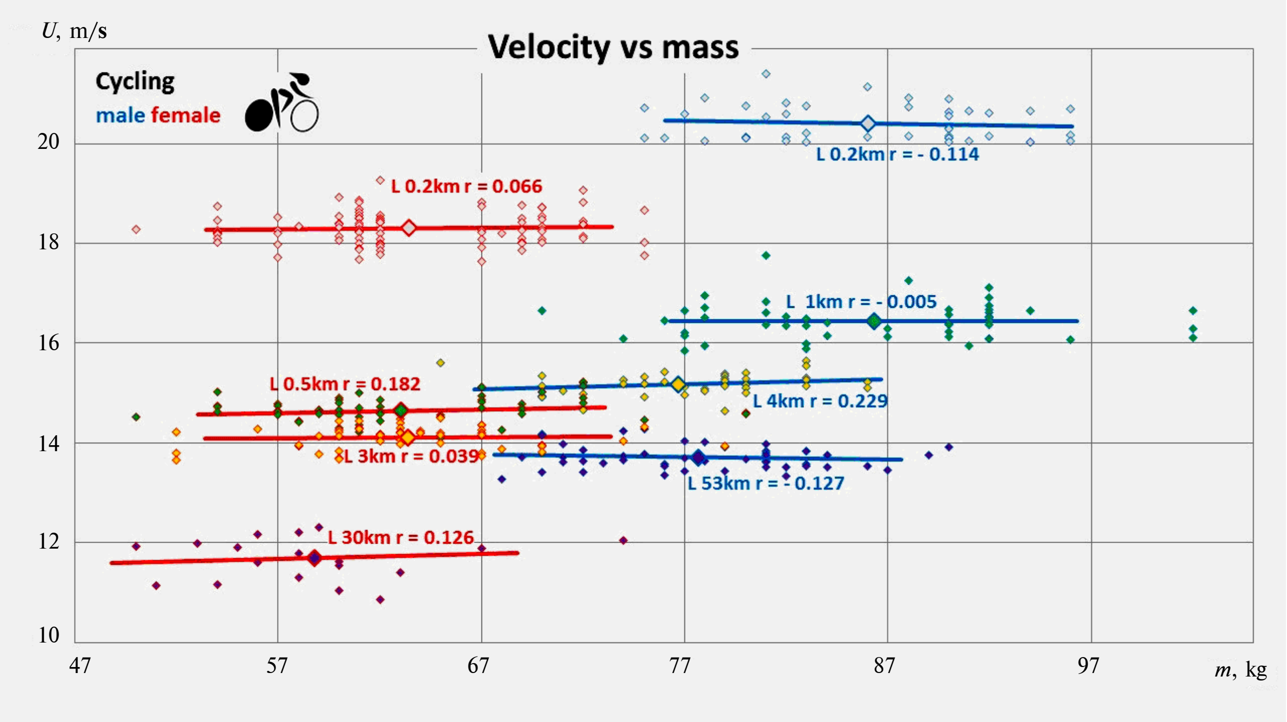

Figure 5: Cycling. The values of body mass and velocity. Small rhombuses are values for every athlete. Greater rhombuses are average values for every distance. The boundaries of rhombuses, corresponding linear regression lines and regression coefficients are blue for males and red for females

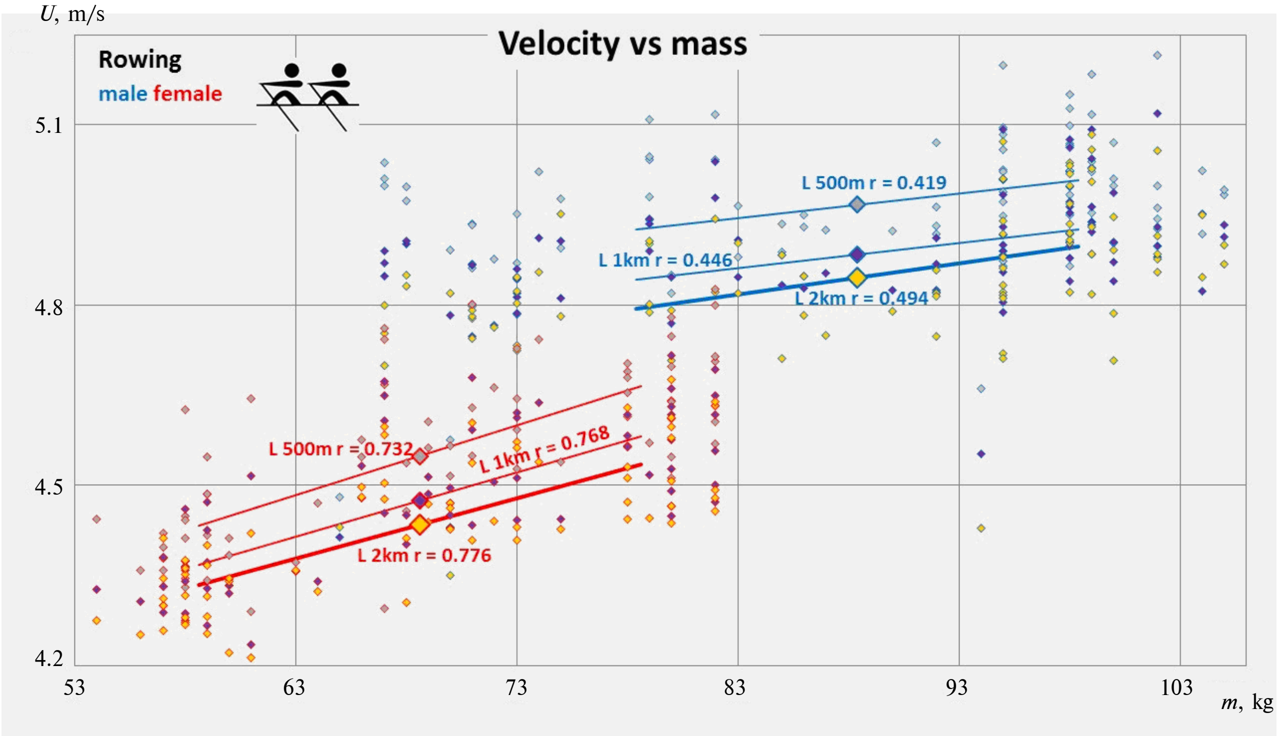

Figure 6: Rowing. The values of body mass and velocity. Small rhombuses are values for every athlete. Greater rhombuses are average values for every distance. The boundaries of rhombuses, corresponding linear regression lines and regression coefficients are blue for males and red for females

Average velocity versus average weight for different distances and sports. In spite of the weak dependence of speed on the mass at individual distances, in the case of running, swimming, cycling, and skiing, we can see an obvious reduction the average weight of the stayers in comparison with the sprinters in Figs. 1–3, 5 and in Table 1. E.g., for running the body mass of sprinters (100 m distance) is much larger than for stayers (10 km distance); the corresponding ratios are 1.25 and 1.39 for females and males respectively. For cycling the corresponding ratios are 1.08 (females) and 1.2 (males); 1.05(f) and 1.1(m) for swimming; 1.03(f) and 1.07(m) for skiing. For female athletes, the difference in body mass of sprinters and stayers is smaller in comparison with males.

For skating the difference in body mass of sprinters and stayers is practically invisible (see Figs. 4 and 7). Because the skaters are all-round (one athlete can develop high speed at different distances), this result is not surprising. To determine the dependence of velocity versus mass, a dispersion analysis for groups of light and heavy athletes for each of the Olympic skating distances will be presented in Section "Mass independence for skating".

Table 1: Average weights and speeds of athletes for different distances and sports

Sports	Distance, m	Mass, kg		Speed, m/s		% female/male at fixed distance		Duration, s	% female/male at fixed duration	
		male	**female**	**male**	**female**	mass	speed		mass	speed
Rowing	2000	88.39 ±12.07	68.64 ±9.04	4.85 ±0.13	4.43 ±0.12	77.7	91.5			
Cycling	200	86.05 ±6.11	63.43 ±5.84	20.40 ±0.36	18.30 ±0.32	73.7	89.7	10.93	73.8	90.1
	500		63.05 ±6.36		14.65 ±0.25			34.13	73.2	79.1
	1000	86.31 ±7.51		16.44 ±0.37						
	3000		63.38 ±5.41		14.11 ±0.23			212.66	80.1	91.1
	4000	76.66 ±4.98		15.17 ±0.22						
	29900		58.79 ±5.65		11.69 ±0.44			2557.50	76.1	82.0
	53500	77.65 ±5.60		13.71 ±0.24						
	Cycling average								**75.8**	**85.6**
Swimming	50	84.64 ±8.39	65.02 ±5.46	2.30 ±0.06	2.01 ±0.06	76.8	87.3	24.90	76.9	88.3
	100	83.63 ±8.67	65.43 ±5.43	2.09 ±0.06	1.85 ±0.05	78.2	88.6	54.05	78.3	89.5
	200	82.94 ±8.89	65.95 ±5.39	1.90 ±0.04	1.71 ±0.04	79.5	90.0	116.72	79.6	90.5
	400	81.73 ±7.80	64.19 ±6.32	1.79 ±0.04	1.63 ±0.03	78.5	90.7	245.97	78.7	90.9
	800		62.00 ±6.78		1.58 ±0.03			506.53	82.4	90.5
	1500	77.18 ±7.56		1.68 ±0.03						
	Swimming average					**78.3**	**89.2**		**79.2**	**89.9**
Skating	500	79.17 ±5.66	63.56 ±5.36	14.30 ±0.29	13.11 ±0.31	80.3	91.7	38.13	80.3	91.5
	1000	79.17 ±5.66	63.55 ±5.55	14.63 ±0.21	13.45 ±0.17	80.3	91.9	74.34	80.3	92.5
	1500	78.92 ±6.02	63.53 ±5.23	14.07 ±0.51	12.88 ±0.39	80.5	91.5	116.46	80.5	91.9
	3000	79.36 ±5.66	63.54 ±5.41	13.41 ±0.31	12.22 ±0.38	80.1	91.1	245.47	80.1	91.6
	5000	79.44 ±5.79	63.77 ±5.29	12.82 ±0.70	11.74 ±0.44	80.3	91.5	389.89	80.2	92.3
	Skating average					**80.3**	**91.6**		**80.3**	**92.0**

Table continuation

Sports	Distance, m	Mass, kg		Speed, m/s		% female/male at fixed distance		Duration, s	% female/male at fixed duration	
		male	female	male	female	mass	speed		mass	speed
Running	100	77.97 ±6.09	59.00 ±4.90	10.14 ±0.09	9.29 ±0.06	75.7	91.6	10.76	75.7	91.7
	200	77.1 ±7.90	59.49 ±4.44	10.07 ±0.10	9.15 ±0.07	77.1	90.9	21.85	77.2	91.6
	400	75.26 ±7.06	60.94 ±3.85	9.10 ±0.06	8.15 ±0.08	81.0	89.5	49.08	81.9	90.7
	800	65.75 ±6.27	58.09 ±4.70	7.82 ±0.04	6.93 ±0.04	88.4	88.6	115.50	89.0	89.5
	1500	62.06 ±6.64	51.39 ±5.07	7.17 ±0.04	6.33 ±0.07	82.8	88.2	237.12	83.3	88.9
	3000	58.61 ±4.54	48.31 ±4.86	6.69 ±0.04	5.93 ±0.06	82.4	88.6	505.98	82.6	89.0
	5000	57.77 ±4.58	46.44 ±4.88	6.49 ±0.04	5.74 ±0.05	80.4	88.4	871.45	80.7	88.8
	10000	56.10 ±3.77	47.12 ±4.64	6.24 ±0.04	5.49 ±0.05	84.0	88.0	1603.74	83.7	88.9
	Running average					**81.5**	**89.2**		**81.8**	**89.9**
Skiing	1000	76.98 ±7.27	59.54 ±4.06	8.36 ±0.15	7.21 ±0.12	77.3	86.2	138.67	76.7	82.8
	1500	78.43 ±5.88	58.84 ±4.67	9.16 ±0.23	7.85 ±0.24	75.0	85.7	191.15	75.4	86.5
	4500	73.37 ±5.07		7.91 ±0.12						
	5000		58.56 ±4.89		6.77 ±0.20			739.03	80.1	87.1
	10000	72.06 ±3.50	58.23 ±4.93	7.23 ±0.15	6.35 ±0.26	80.8	87.9	1573.92	80.4	88.8
	15000	73.53 ±5.10	56.41 ±4.44	6.92 ±0.11	6.12 ±0.21	76.7	88.5	2450.73	76.9	89.1
	30000	71.75 ±4.81	57.53 ±4.58	6.52 ±0.21	5.72 ±0.18	80.2	87.7	4601.59	79.8	89.1
	Skiing average					**78.0**	**87.2**		**78.2**	**87.2**
	Average					**79.5** ±3.13	**89.4** ±1.85		**79.4** ±3.31	**89.1** ±3.16

The average values of speed for different distances and sports are shown in Fig. 7 versus the average body mass of athletes. It can be seen that the optimal body mass is different for different sports. The heaviest athletes are successful in rowing. In sprint cycling, sprint swimming and skating, the mass of best athletes is rather smaller. The weight of skiers is usually even smaller. The somewhat chaotic nature of the dependences of the skier average speed versus average mass (see corresponding plots for male and female athletes in Fig. 7) can be explained by different profiles of distances and different weather conditions. The smallest are long distances runners. Their average weights are only 69% (f) and 63% (m) of the rower ones.

We analyzed also the ratio of the average masses of female and male athletes and ratio of average speeds for identical distances (female/male at fixed distance), see Table 1. The ratio of the average weight of female athletes to the average weight of male athletes (averaged as well for all sports and distances) is 79.5 ± 3.1%, at the same time the female athletes develop 89.4 ± 1.8% of the speed of male ones.

Average velocity versus average duration of sports activity. Fig. 8 and Table 1 illustrate the influence of the duration of a sports activity (the time spent on a distance) on the average velocity for different sports. Due to the fatigue, the speeds usually monotonously decrease with the duration increasing. Some exceptions occur only for 1 km and 1.5 km distances in skating and skiing respectively. Smaller speeds at shorter distances can be explained by the fact that athletes do not have enough time to reach the maximum speed.

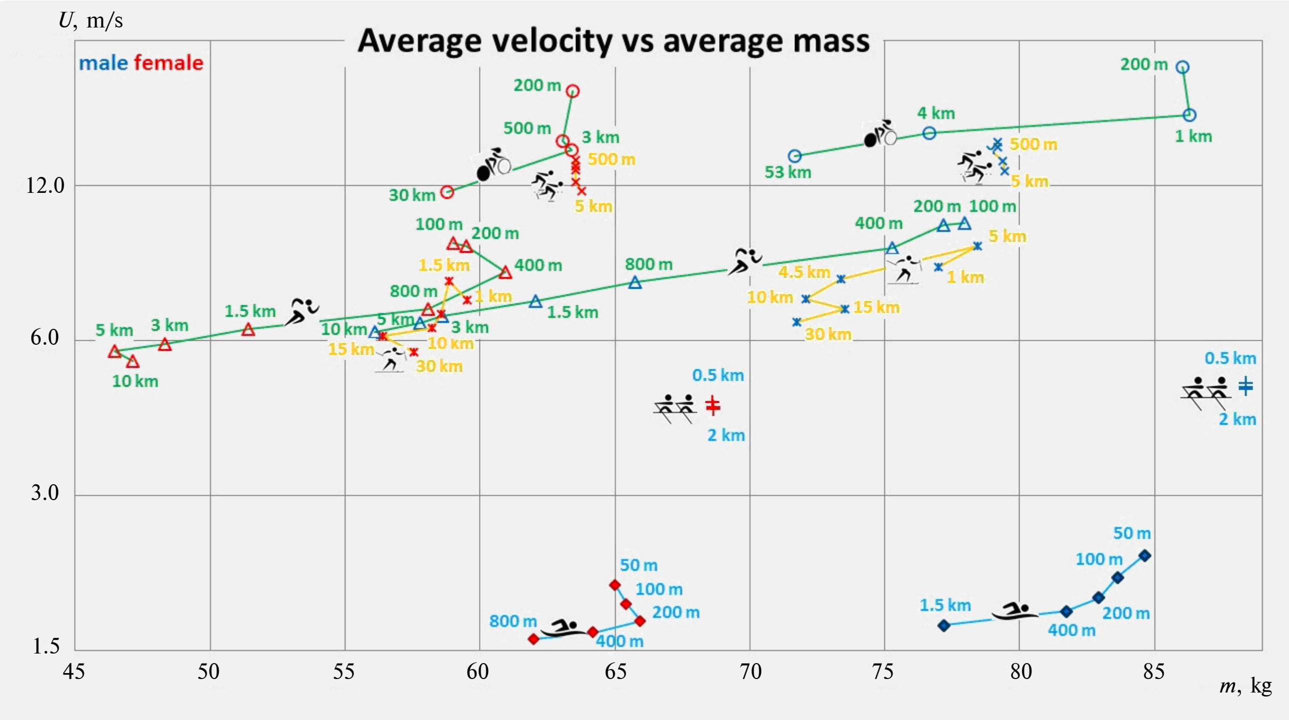

Figure 7: The average values of speed for different distances and sports versus the average body mass of athletes: triangles – running, rhombuses – swimming, snowflakes – skiing, tilted crosses – skating, circles – cycling, straight crosses – rowing. Signs are blue for males and red for females

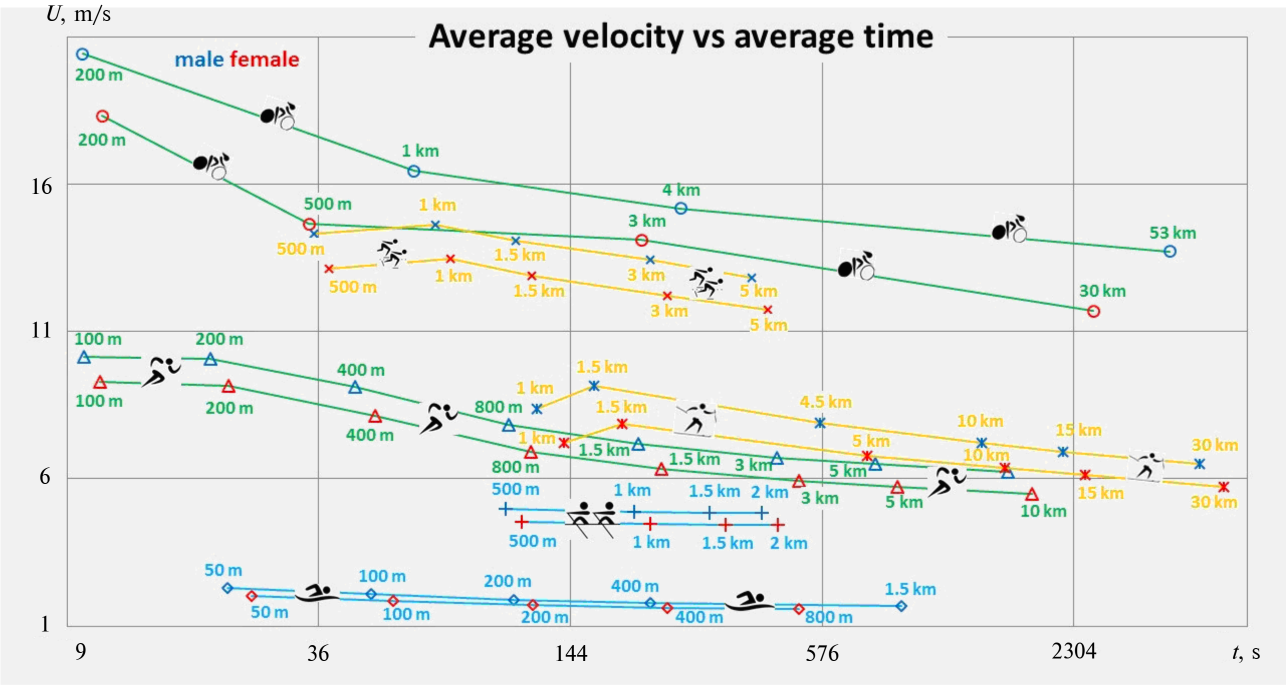

Figure 8: The influence of the duration of a sports activity (the time spent on a distance) on the average velocity for different sports: triangles – running, rhombuses – swimming, snowflakes – skiing, tilted crosses – skating, circles – cycling, straight crosses – rowing. Signs are blue for males and red for females

Table 1 also represents the ratio of the average speeds of female athletes to male ones at the fixed time of activity (female/male at fixed duration). If a value of speed at a fixed value of duration is unknown, we used linear interpolation of the results for nearest distances. It can be seen that female athletes on average develop 89.1 ± 3.2% of the speed of male ones.

Average body mass versus average time of activity. Fig. 9 and Table 1 show the average body mass versus the duration of a sports activity (the time spent on a distance) for different sports and distances. For rowers, the average mass is unchanged, since the Fig. 9 shows the intermediate results at only one distance of 2 km. As noted earlier, for skaters, the average mass varies very little. For skiers, the somewhat chaotic nature of the dependencies can be explained by different distance profiles and different weather conditions that affect the average duration of the activity. Nevertheless, for male skiers, it can be seen the tendency of weight decreasing for longer distances, in comparison with the female athletes.

Table 1 also represents the ratio of the average weight of female athletes to male ones at the fixed time of activity (female/male at fixed duration). The ratio of the average weight of female athletes to the average weight of male athletes (averaged as well for all sports and distances) is 79.4 ± 3.3%. The ratio of the average weight of women to men one among adult persons is about 83% [15, 16]), and is rather different for different countries (e.g., 73–77% for Croatia, Bangladesh, and Vietnam; 79–83% for Ethiopia, North Korea, Kuwait, England, Australia, South Korea, Germany, and Japan; 85–88% for Canada, USA, Brazil, Chile, and Ukraine; 94.5% for Russia).

Mass independence for skating. Table 2 shows the results of the F-test calculation. We ranked the results of the skating on the weight (n is the total number of results for each distance) and divided them into two groups equal in number (one group with heavier athletes and the second group with lighter athletes). Then we calculated the Between group variability (B_{gv}, see formula (1)), and Within group variability (W_{gv}, see eq. (2)) and the value of Fisher function (according to (3)). The critical values of Fisher function (Fc) are also shown in Table 2 for significance levels $\alpha = 0.05$ and $\alpha = 0.01$. The results indicate that the calculated values of the Fisher function are smaller than the critical ones (it is only one exception for male 1500 m distance

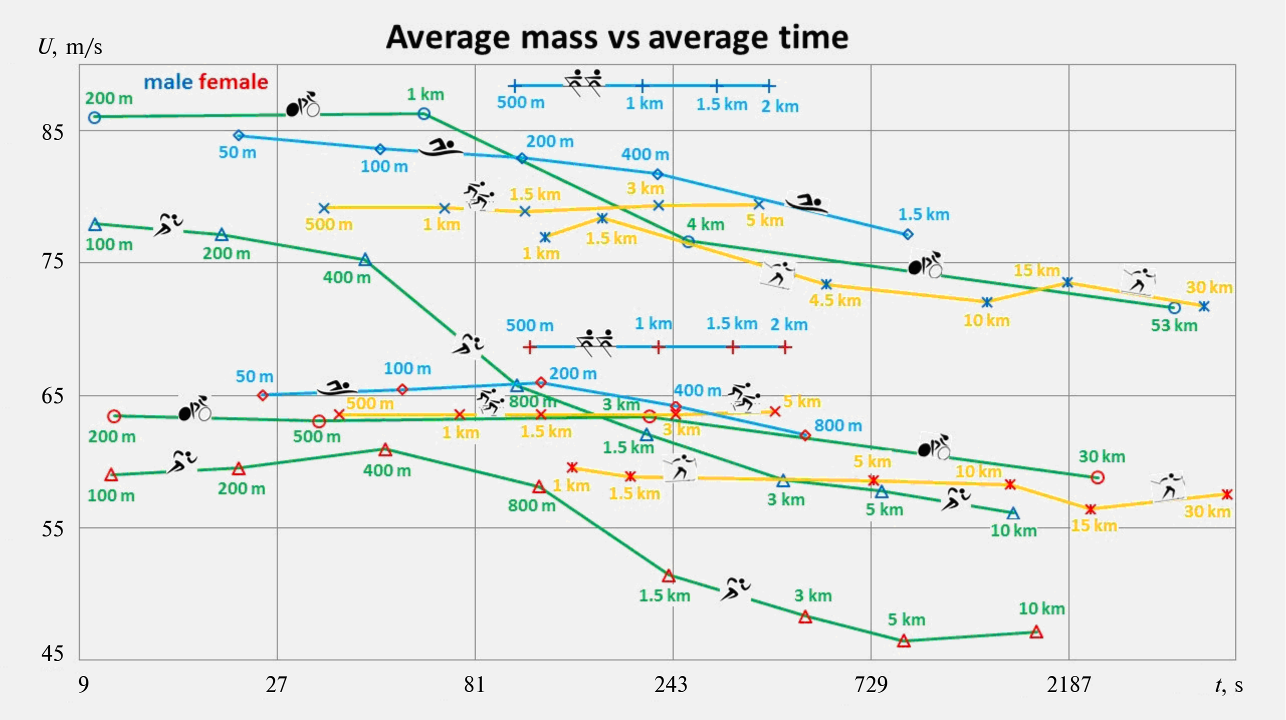

Figure 9: The average body mass versus the duration of a sports activity (the time spent on a distance) for different sports and distances: triangles – running, rhombuses – swimming, snowflakes – skiing, tilted crosses – skating, circles – cycling, straight crosses – rowing. Signs are blue for males and red for females

at the significance level α = 0.05). Thus, we can conclude that the skaters' speed does not depend on their weight.

Discussion

Fig. 8 and Table 1 show the speed differences for different sports. The fasters athletes are cyclists. Skaters and skiers are slower. These speed differences can be explained by different friction coefficients. The runners are the slowest athletes among moving in air. Their movement is a series of jumps which is connected with rather high energy loss [6, 17]. Water sports are the lowest, since the drag in water is very high [18]. Due to the special shaped elongated shape of the boat [19], the rowers are more than twice faster.

The human running champions are approximately 3 times slower than cheetah – the fastest terrestrial animal. To estimate the efficiency of motion, a special characteristic – capacity-efficiency, C_e – was proposed in [6, 20], which indicates how much metabolic capacity (energy released in the body per unit of weight and per unit of time) is used to move the center of mass. The estimations of C_e presented in [21] yield the values 0.286 m/s (Male record, 100 m, Usain Bolt), 0.268 m/s (Female record, 100m, Florence Griffith-Joyner) and 0.319 m/s (Male record 10 km, Kenenisa Bekele). In comparison for cheetah C_e = 0.277 m/s [21]. Thus, the running effectiveness of our champions is comparable with one of the fastest terrestrial animal. Nevertheless, the running effectiveness of the fastest horses (C_e = 0.467 m/s) and kangaroos (C_e = 0.567 m/s) is higher [21]).

It must be noted that real maximum metabolic rate of human athletes is approximately 2.9 m/s (28 W/kg), [22]. It means that only 1/10 part of the capacity released in body is used to move the center of running body. In the case of swimming this part is much smaller. E.g., C_e = 0.0097 m/s [20] for fastest underwater human swimming style (dolphin kick, speed 2.7 m/s). The best fish swimmers are more than 10 times faster. E.g. the Atlantic sailfish, *Istiophorus albicans* is able to achieve the speed 30.6 m/s [20]. The highest value of C_e = 8.4 m/s was calculated for the juvenile Blue shark, *Prionace glauca* in [20]. Thus

Table 2: The results of F-test for male and female skating

Gender	Distance, m	Mass, kg			Velocity, m/s (average)	Average		*F*	B_{gv}	W_{gv}	*n*	*Fc* α = 0.05	*Fc* α = 0.01
		min	max	average		mass, kg	speed, m/s						
Male	500	65	80	74.97	14.35	79.17	14.30	1.58	0.12	0.08	74	4.0	7.1
		80	90	83.62	14.27								
Male	1000	65	80	74.44	14.61	79.17	14.63	3.07	0.13	0.04	72	4.0	7.1
		80	90	83.42	14.69								
Male	1500	60	80	74.20	13.96	78.92	14.07	4.19	1.09	0.26	92	4.0	7.1
		80	97	83.37	14.18								
Male	3000	60	80	75.25	13.44	79.36	13.41	0.27	0.02	0.09	56	4.1	7.3
		80	97	83.32	13.40								
Male	5000	60	80	75.18	12.98	79.44	12.82	1.86	0.82	0.44	68	4.0	7.1
		80	97	83.56	12.76								
Female	500	51	63	59.19	13.09	63.56	13.11	0.93	0.08	0.09	64	4.0	7.1
		63	73	67.66	13.16								
Female	1000	51	63	59.04	13.41	63.55	13.45	2.64	0.08	0.03	52	4.1	7.3
		63	73	67.81	13.49								
Female	1500	51	63	59.29	12.86	63.53	12.88	0.11	0.02	0.15	76	4.0	7.1
		63	74	67.61	12.89								
Female	3000	51	63	59.13	12.17	63.54	12.22	1.71	0.24	0.14	60	4.0	7.1
		63	74	67.73	12.30								
Female	5000	52	63	59.42	11.82	63.77	11.74	1.08	0.19	0.17	52	4.1	7.3
		63	74	68.15	11.70								

compared with the fast aquatic animals, both the speed and effectiveness of human swimming is much lower. The low drag elongated shape of the rowing boat (and may be higher propulsion coefficient) allows more than 5 times increase the efficiency of movement in water. E.g., $C_e \approx 0.051$ m/s for rowing Lightweight Men Single, best time [6].

The sprinter running speed does not substantially depend on the body mass, but increases with the increasing of the stride length [21]. The statistical analysis of fit male and female sprint runners [23] demonstrate the linear increasing of the speed versus stride length. Since the taller and heavier athletes have larger stride length, we can expect that they have the highest speed. The optimal weight of 100m male runners (approx. 78 kg, see Table 1) is larger than the average weight of adult men (74 kg). Nevertheless, the optimal weight of 100m female runners (approx. 59 kg, see Table 1) is smaller than the average weight of adult women (61 kg).

For male cycling, running and swimming the optimal body mass decreases with the increasing the duration of activity (the only exception is the cycling distance of 1km). In comparison, for female cycling, running and swimming dependence of the optimal body mass versus the duration of activity is not monotonous. This peculiarity of female sports needs further investigations.

Conclusions

A significant amount of data on the velocity and body mass of both female and male athletes professionals in Olympic sports (running, swimming, skiing, skating, cycling, and rowing) was collected.

The average values for different distances were calculated and the linear regression analysis was applied to find the relationships between the body mass and the velocity for every distance.

Within one distance there is no significant dependence of speed on the mass (except for rowing). For each distance, there are their optimal masses of athletes, which are different for different sports. This result needs further investigations and analysis.

The large masses of athletes are optimal for the short distances. For longer distances they usually decrease, but not for the female swimming and running (where the largest masses of athletes correspond to the medium distances) and not for the male and female skating (where speed is practically independent from the body mass). These facts need to be studied and explained.

For a fixed distance, the optimal masses of female athletes are 79.5 ± 3.1% of the weight of male athletes, at the same time they develop 89.4 ± 1.8% of the speed of men.

The obtained results can be also useful for selection of athletes for different sports and distances. The differences in optimal weights for different sport and distances need further investigations. They can be very complicated, since the metabolic and propulsion peculiarities, drag in water or/and air, energy waste to support the body on the ground, wheels friction drag etc. must be taken into account.

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ОПТИМАЛЬНІ МАСИ ТІЛА ДЛЯ РІЗНИХ ОЛІМПІЙСЬКИХ ВИДІВ СПОРТУ

Проблематика. Вага кращих спортсменів на різних відстанях і в різних видах спорту може бути дуже різною. Відомо, що веслярі, як правило, дуже масивні. Для того щоб дати шанс атлетам з меншою масою тіла, федерація з веслування ввела спеціальну категорію з ваговими обмеженнями. Ці факти пов'язані з особливостями аеробної та неаеробної активності, характеристиками опору та руху.

Мета. У цій статті ми не намагаємося пояснити різницю між масами тіла спортсменів. Ми лише зафіксуємо їх для різних видів спорту (біг, плавання, лижні перегони, ковзанярський спорт, велоспорт, веслування) і для різних олімпійських дистанцій.

Методика реалізації. Ми зібрали та проаналізували значну кількість даних про швидкість та масу тіла кращих спортсменів-професіоналів (жінок та чоловіків) у олімпійських видах спорту (біг, плавання, лижні перегони, ковзанярський спорт, велоспорт, веслування). Оскільки ми беремо до уваги маси тіла тільки найкращих спортсменів, то отримані результати можуть розглядатись як найбільш сприятливі (оптимальні) маси тіла для різних видів спорту і відстаней. Для того щоб перевірити, наскільки значення маси тіла і середньої швидкості в межах однієї дистанції відповідають лінійній залежності, ми використали рівняння лінійної регресії. Розраховано коефіцієнт кореляції та параметри прямої регресії. Для того щоб перевірити припущення, що швидкість ковзанярів не залежить від маси спортсмена, ми використали тест Фішера.

Результати. Розраховано оптимальні маси спортсменів для різних відстаней у різних видах спорту. Загалом на коротких відстанях великі маси спортсменів є оптимальними, і вони зменшуються для великих відстаней. Винятком є результати для плавання та бігу серед жінок, де найбільші маси спортсменів відповідають середнім дистанціям. Для більш довгих відстаней результати показують, що найбільш успішні спортсмени характеризуються меншою масою тіла, за винятком ковзанярського спорту. Для фіксованих відстаней оптимальні маси тіла атлетів-жінок становлять 79,5 ± 3,1 % від маси тіла атлетів-чоловіків, у той же час жінки-спортсмени розвивають швидкість, яка становить 89,4 ± 1,8 % від швидкості чоловіків-спортсменів.

Висновки. Проведений статистичний аналіз свідчить, що в межах однієї дистанції немає значної залежності між швидкістю та масою тіла спортсмена (за винятком веслування). Для кожної відстані існують оптимальні маси тіла спортсменів, які є різними для різних видів спорту. Встановлені факти можуть бути використані у підборі спортсменів та їх підготовці. Вони потребують також подальших досліджень з урахуванням особливостей метаболізму та руху.

Ключові слова: олімпійський спорт; лінійна регресія; тест Фішера; підбір спортсменів.

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ОПТИМАЛЬНЫЕ МАССЫ ТЕЛА ДЛЯ РАЗНЫХ ОЛИМПИЙСКИХ ВИДОВ СПОРТА

Проблематика. Вес лучших спортсменов на разных дистанциях и в разных видах спорта может сильно отличатся. Известно, что гребцы, например, довольно массивные. Для того чтобы дать шанс атлетам с меньшей массой тела, федерация гребцов ввела специальную категорию с весовыми ограничениями. Эти факты связаны з особенностями аэробной и неаэробной активности, характеристиками сопротивления и движения.

Цель. В этой статье мы не пытаемся объяснить разницу между массами тела спортсменов. Мы только определим их для разных видов спорта (бег, плавание, лыжные гонки, конькобежный спорт, велоспорт, гребля) и для разных олимпийских дистанций.

Методика реализации. Мы собрали и проанализировали большое количество данных о скорости и массе тела лучших профессиональных спортсменов (женщин и мужчин) в олимпийских видах спорта (бег, плавание, лыжные гонки, конькобежный спорт, велоспорт, гребля). Так как мы принимаем во внимание массы тела только лучших спортсменов, то полученные результаты могут рассматриваться как наиболее подходящие (оптимальные) массы тела для разных видов спорта и дистанций. Для того чтобы проверить, насколько значения массы тела и средней скорости в рамках одной дистанции соответствуют линейной зависимости, мы использовали уравнения линейной регрессии. Рассчитаны коэффициент корреляции и два параметра прямой регрессии. Для того чтобы проверить предположение, что скорость конькобежцев не зависит от массы тела спортсмена, мы использовали тест Фишера.

Результаты. Рассчитаны оптимальные массы спортсменов для разных дистанций в разных видах спорта. В общем, на коротких дистанциях оптимальными являются большие массы тела спортсменов, и они уменьшаются для более длинных дистанций. Исключение составляют результаты для плавания и бега среди женщин, где самые большие массы спортсменов соответствуют средним дистанциям. Для более длинных дистанций результаты показывают, что наиболее успешные спортсмены обладают меньшей массой тела, за исключением конькобежного спорта. Для фиксированных дистанций оптимальные массы тела атлетов-женщин составляют 79,5 ± 3,1 % от массы тела атлетов-мужчин, в то же время женщины-спортсмены развивают скорость, которая составляет 89,4 ± 1,8 % от скорости мужчин-спортсменов.

Выводы. Проведенный статистический анализ показал, что в рамках одной дистанции нет значительной зависимости между скоростью и массой тела спортсмена (за исключением гребли). Для каждой дистанции существуют оптимальные массы тела спортсменов, которые оказались разными для разных видов спорта. Полученные результаты могут быть использованы в подборе спортсменов и их подготовке. Они нуждаются также в дополнительных исследованиях с учетом особенностей метаболизма и движения.

Ключевые слова: олимпийский спорт; линейная регрессия; тест Фишера; подбор спортсменов.