RATIO BETWEEN ROWING STROKE RATE AND DISTANCE PER STROKE WITH ITS EFFECT ON BOAT SPEED IN ELITE JUNIOR DOUBLE SCULL

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Abstract: Previous research that studied differences in rowing stroke rate and distance per stroke, and their influence on speed of the crew during race, monitored parameters were rarely recorded during the entire distance of 2000m and rarely compared between both genders. Female interest in rowing has grown over the years and the number of crews that can qualify for the Olympics has leveled with male. Development of technology and GPS devices contributed a more detailed analysis of listed parameters, given that we get the same variables measured fourty times at a defined race distance. Before, these variables were recorded only four times, at every 500m. The validity of the measured results was not called into question because of the fact that for all World Rowing Championships organized by FISA (World Rowing), officially timekeepers are „Swiss Timing", leader in this field. The biggest advantage is reflected on parameter the distance per stroke, because now it can be easily, indirectly estimated through the total number of strokes. Research has shown that the parameters stroke rate and distance per stroke are inversely proportional, which is a paradox, because in order to achieve a higher speed of the boat, it is necessary to maintain high values of both parameters. Hence the need to define the influence of the mentioned rowing stroke variables on the average speed of the boat. The research was carried out on the basis of race results from World Championships in rowing for juniors in Varese in 2022. The data from the competition are very significant in terms of results, as new World Best Times were set in four categories. The sample of respondents was represented by 44 crews in double scull for both genders (25 respondents in the JM2x category, 19 respondents in the JW2x category). The results showed that there are no significant differences between men and women when it comes to rowing stroke rate, and small differences when it comes to the distance traveled per stroke. Higher values of the distance per stroke are observed with men, than with women, which is logical due to the fact that they have physiologically greater strength and therefore move the boat more during one single stroke. Stroke rate had a very significant correlation with the speed of the boat for men, but for women it did not significantly affect the speed, while the distance per stroke had a high correlation and a very high degree of significance. The different tact and technique of rowing in women's double sculls, together with the new World Best Time (WBT) set in this discipline, is a potential indicator of the emergence of a new current in rowing, which creates a lot of room for more detailed research on this topic.
Keywords: rowing, race, speed, tempo, standard, time

1. INTRODUCTION

The analysis of the rowing stroke, along with the study of biomechanical variables in rowing, has been the subject of research by many sports experts (Ilić et al. 2009; Rajković 2015; Kleshnev 2016; Ilić 2018). The specific conditions in which rowing takes place provide the opportunity to test a large number of variables, with the aim of observing, quantifying and evaluating their effect on boat speed. Boat speed is the most important measure of rowing performance. It is common knowledge that the parameters that affect speed (rowing stroke rate and distance per stroke) are inversely correlated, so it was necessary to establish the linearity of the regression of the relationship between the two parameters mentioned. The values and influence of biomechanical variables on speed in rowing differ to a certain extent between disciplines and genders, so over time certain regularities in their relations could be observed. However, it very often happens that in some of the disciplines the trends of the results do not show the same regularities. Namely, the differences between the morpho-functional abilities within the sexes can lead to the emergence of different rowing techniques and tactics.

The subject of the research is the influence of the pace of the rowing stroke and the distance traveled per stroke on the realized speed of the boat at the World Junior Championships in Varese, 2022.

The aim of the research is to determine the differences between the parameters stroke pace and distance traveled per stroke and to examine their mutual influence on boat speed in double scull at the World Junior Championships in Varese, 2022.

RESEARCH HYPOTHESES

H1. Rowing stroke rate differentially affects boat speed in double sculls at the Varese 2022 World Junior Rowing Championships.

H2. Distance per stroke affects boat speed in double sculls in different ways at the Varese 2022 World Junior Rowing Championships.

H3. Total number of strokes differentially affects boat speed in double sculls at the Varese 2022 World Junior Rowing Championships.

2. MATERIALS AND METHODS

This research was done on the basis of the official results from the 2022 World Junior Rowing Championships in Varese. The competition lasted from July 27 to 31, and the results taken into account were measured on the last day of the competition. The air temperature was over 34°C, while the water temperature was around 28°C. Waves were not noticed on the surface of the water. The direction and intensity of the wind changed both during the entire competition and during one competition day.

The results of the races were measured by the "Swiss timing" company. Official race results are found on the website of the World Rowing Federation. All races are presented in a unit of time with the overall ranking, as well as the results of the passage of 500m from the start to the finish, which were measured using the technology of photo cells placed on the mentioned sections. In addition, a GPS device with a built-in accelerometer is placed on the back of the boat, which records the average stroke frequency and speed of the boat (m/s) every 50m from the start to the finish.

When the values of the average boat speeds are calculated based on the speeds recorded by the GPS device every 50m, certain small deviations are observed in relation to the values of the average boat speeds calculated based on the total time expressed in seconds and the defined race distance of 2000m. Other values, obtained by proportion will be taken as a more valid parameter, for the simple reason that between each measurement by the GPS device there is a difference between 6-9 strokes depending on the discipline, which creates the probability that during those strokes the speed will change to some extent, which makes them less reliable.

Sample Variables:

Independent:

Gender – Male and female; Race – Double sculls.

Dependent:

SR (1/min) – Speed of rowing; DPS (m) – distance traveled per stroke; TS – Total number of strokes; V (m/s) – Average speed.

A sample of respondents:

The sample of respondents consisted of 44 male and female rowers participating in all final races (Finals A-E) in double sculls at the World Junior Rowing Championships in Varese in 2022. For two-way Anova, additional 45 single scull male and female rowers are used as a sample of respondents.

Statistical analysis:

Descriptive statistics were initially performed for all variables (mean value, standard deviation, minimum and maximum value), in relation to gender.

Then, before applying more complex statistical techniques, the normality of the data distribution was confirmed by applying the Kolmogorov-Smirnov test, as well as by examining histograms and QQ plots. Equality of variance was confirmed by Levene's test.

The relationship between SR and DPS was tested through linear regression, while the relationships between speed (V) and stroke variables (SR, DPS and TS) were tested through Pearson's correlation coefficient (r), where correlation values of 0.10, 0.30 and over 0.50 were considered for small, medium and large, while values less than 0.10 are considered to have no correlation (Cohen, 1988).

Finally, to calculate differences in variables (SR, DPS, TS and V) between sexes, a two-way ANOVA for independent samples was applied. In case of statistically significant differences, the Bonferroni post-hoc test was applied, while the effect size was calculated using partial eta square, where effect size values of 0.01, 0.06 and over 0.14 were considered small, medium and large (Cohen, 1988).

The level of statistical significance was set at $p < 0.05$. All statistical operations were performed using SPSS 26.0 (IBM, Armonk, NY) and Microsoft Office Excel 2017 (Microsoft Corporation, Redmond, WA, USA).

3. RESULTS AND DISCUSSIONS

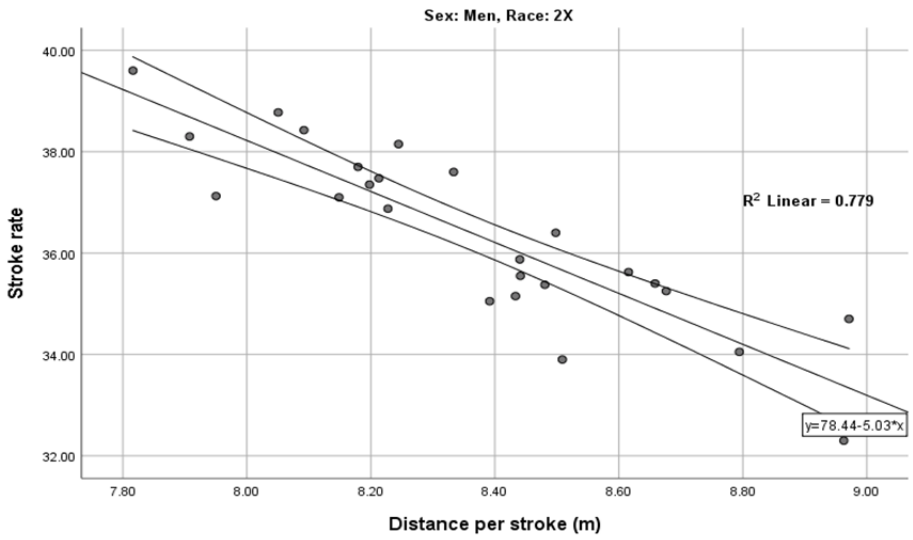
The results of descriptive statistics are shown in table 1. Based on the descriptive data, we can see that both women (36,22 ±1,03 spm) and men (36,36 ±1,74 spm) in double sculls have relatively the same average values of SR. The total number of strokes (TS) is expectedly higher in women compared to men.

Table 1. Descriptive indicators of dependent variables of rowing stroke divided by gender

	Male					Female				
	N	Min.	Max.	SV	St. dev.	N	Min.	Max.	SV	St. dev.
SR	25	32.3	39.6	36.4	1.74	19	33.7	38.0	36.2	1.03
TS	25	222.9	255.9	239.2	8.70	19	251.6	279.5	263.2	8.04
DPS(m)	25	7.8	8.9	8.3	0.31	19	7.16	7.9	7.6	0.23
V(m/s)	25	4.8	5.2	5.1	0.12	19	4.3	4.8	4.6	0.13

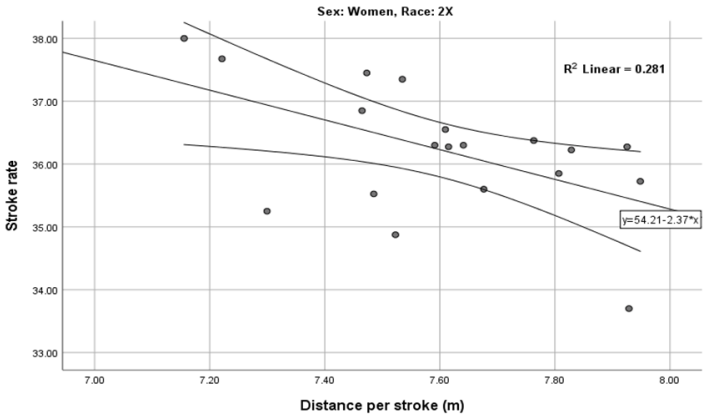
When we talk about the homogeneity of the group, the discipline in which there was the least variation in the values of the variables is women's double sculls. Based on the value of rowing pace, it can be concluded that women can absolutely match their abilities, with slightly higher values of the distance covered per stroke being noticeable in men. This phenomenon can be explained by physiological differences between men and women, i.e., with a greater force that the male musculature is capable of developing during one stroke and thus enables the system to travel a longer distance. Taking into account the difference in average speed, it falls within the limits prescribed by normative standards, as it is exactly 40 seconds. The average speed for the men's double event was 5.06 m/s, which would mean that the average race time was 6 minutes and 35 seconds. The average speed for the women's double sculls was 4.59 m/s, which would mean that the average race time was 7 minutes and 15 seconds.
The results of linear regression - the relationship between SR and DPS are shown in graphs 1-2. Graph 1 shows the results of the linear regression for men's doubles.

Graph 1. Regression lines with confidence intervals (95%) and the relationship between SR and DPS in men's doubles.



The first case of linear regression is characterized by a very high value of the coefficient of determination (R^2=0.779) and tells us that 78% of the variance of rowing pace can be explained by the distance traveled per stroke. The correlation coefficient is r=-0.88, which means that SR and DPS had a large negative correlation. For the JM2x category, the inverse proportionality of the parameters affecting the speed has been proven.
Graph 2 shows the results of the linear regression for women in doubles.

Graph 2. Regression lines with confidence intervals (95%) and the relationship between SR and DPS in women's doubles.



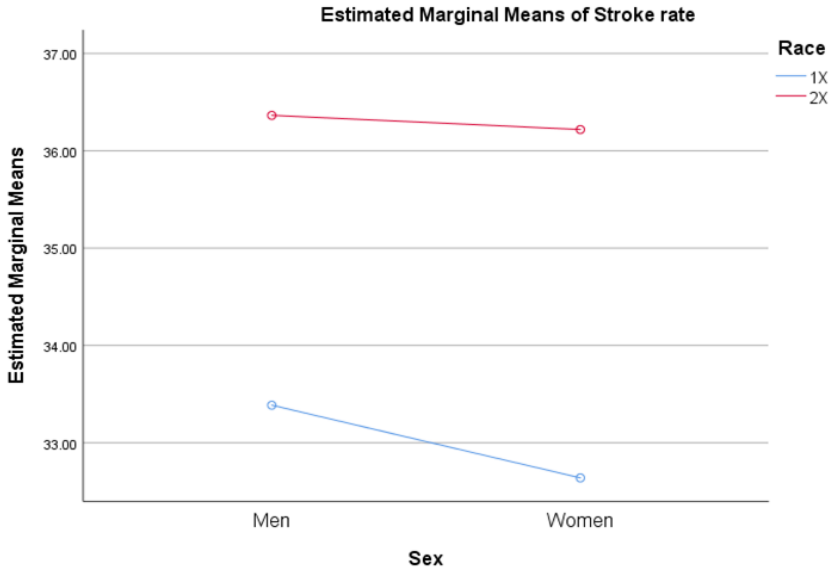
The second case of linear regression is characterized by a low value of the coefficient of determination (R^2=0.281) and tells us that 28% of the variance of rowing pace can be explained by the distance traveled per stroke. The correlation coefficient is r=-0.53, which means that SR and DPS had a large negative correlation.
The results of the linear regression for women in the doubles category showed that in this category the respondents differ in technique and style of rowing. The slope of the true linear regression for this group is much lower, in favor of the distance traveled per stroke.
Table 2 shows the results of the association between average boat speed (V) and stroke variables (SR, DPS and TS) divided by gender.

Table 2. Association between average boat speed and stroke variables divided by gender.

		Male			Female		
		SR	TS	DPS (m)	SR	TS	DPS (m)
V (m/s)	r	0.680**	0.256	-0.257	0.426	-0.539*	0.540*
	p	0.000	0.217	0.215	0.069	0.017	0.017
	N	25	25	25	19	19	19

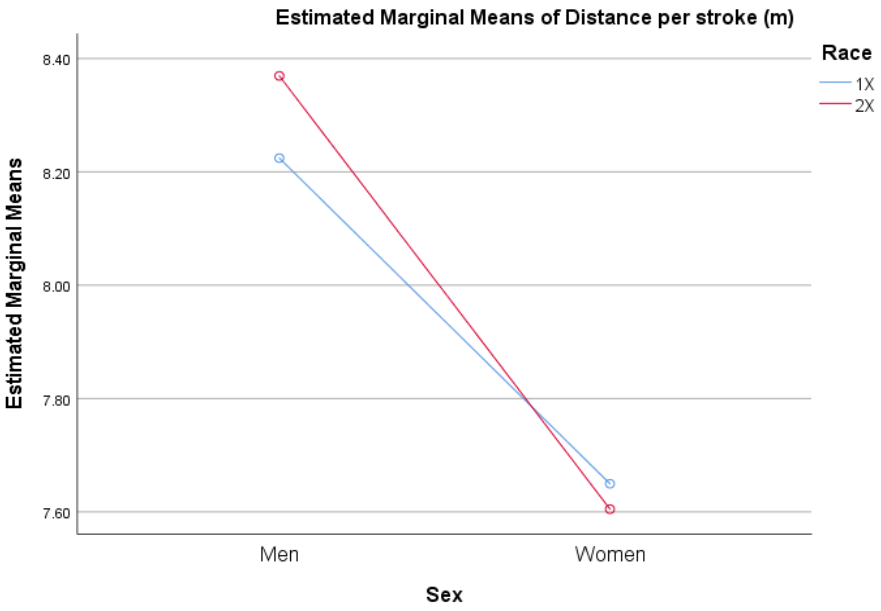
A trend of high positive correlation of rowing pace (SR) with boat speed occurs in the men's double sculls category (r=0.680**), with a very high degree of significance p<0.001. The total number of strokes (TS) and the distance traveled per stroke (DPS) did not have a statistically significant effect on speed.
The only category in which rowing pace did not significantly correlate with boat speed was the women's double sculls, but the distance traveled per stroke was highly correlated with boat speed (r=0.540*), with a high level of significance of p<0.05. The total number of strokes was negatively correlated with speed, with a high degree of significance p<0.05.
To test differences between variables (SR, DPS, TS and V) between sexes and races, two-way ANOVA for independent samples with Bonferroni post hoc test was applied. For comparison, race of single sculls has been aded as an example, where a sample of respondents consisted of 45 male and female rowers.
A two-way ANOVA applied to the SR variable showed a significant effect for the race factor ($F(1,85) = 59.01$, $p\eta 2 = 0.41$, $p < 0.01$), but not for the gender factor ($F(1,85) = 1.09$, $p\eta 2 = 0.01$, $p = 0.30$) and their interaction gender x race ($F(1,85) = 0.49$, $p\eta 2 = 0.01$, $p = 0.48$). Post hoc analysis of the race effect (Graph 10) showed that male and female double scull rowers have a significantly higher SR than male and female single scull rowers ($p < 0.01$).

Graph 3. Differences between SR in male and female single scull and double scull rowers



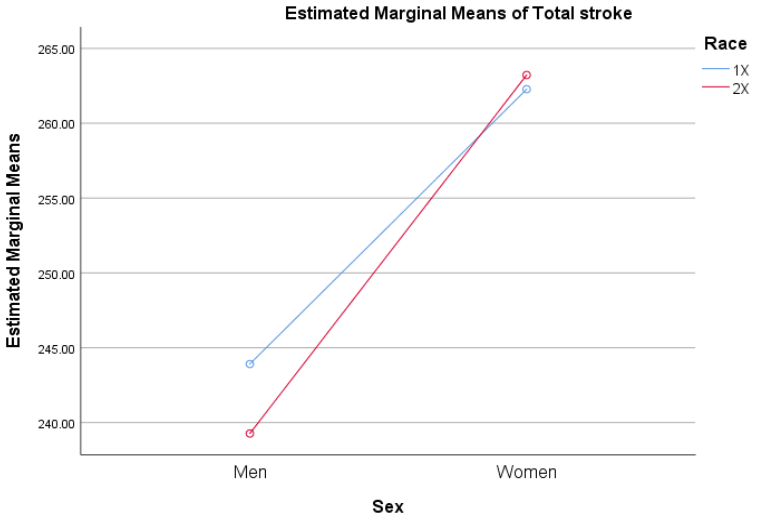
A two-way ANOVA applied to the DPS variable showed a significant effect for the gender factor ($F(1,85) = 68.69$, $p\eta2 = 0.45$, $p < 0.01$), but not for the race factor ($F(1,85) = 0.38$, $p\eta2 = 0.01$, $p = 0.54$) and their interaction gender x race ($F(1,85) = 1.38$, $p\eta2 = 0.02$, $p = 0.24$). Post hoc analysis of the gender effect (Graph 11) showed that men in both disciplines have a significantly higher DPS than women ($p < 0.01$).

Graph 4. Differences between DPS in single scull and double scull rowes



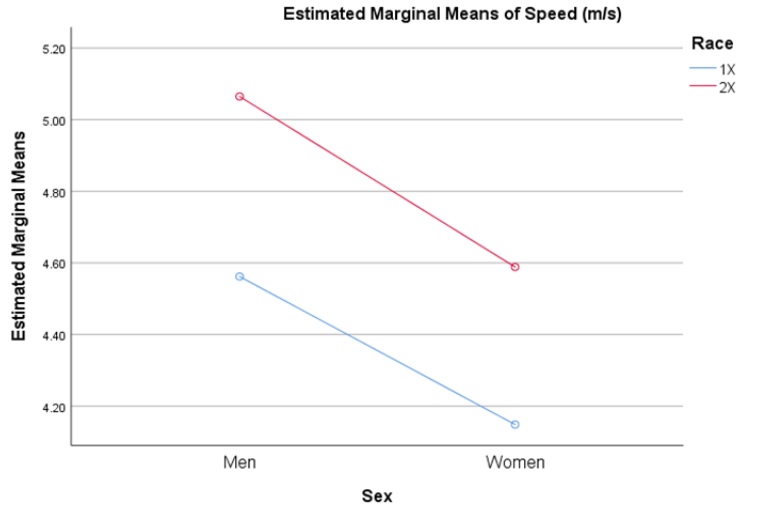
A two-way ANOVA applied to the TS variable showed a significant effect for the gender factor ($F (1,85) = 67.18$, $p\eta2 = 0.44$, $p < 0.01$), but not for the race factor ($F (1,85) = 0.51$, $p\eta2 = 0.01$, $p = 0.48$) and their interaction gender x race ($F (1,85) = 1.17$, $p\eta2 = 0.01$, $p = 0.28$). Post hoc analysis of the gender effect (Graph 12) showed that men in both disciplines have a significantly lower TS than women ($p < 0.01$).

Graph 5. Differences between TS in single scull and double scull rowers



Two-way Anova applied to variable V showed significant effects for the factor gender (F (1,85) = 183.20, pŋ2 = 0.68, p < 0.01), and race (F (1,85) = 205.84, pŋ2 = 0.71, p < 0.01) but not for their sex x race interaction (F (1,85) = 0.91, pŋ2 = 0.01, p = 0.34). Post hoc analysis of the effects of gender and race (Graph 13) showed that in both disciplines men have a higher V than women (p < 0.01), as well as single scull rowers have a lower V than double scull rowers.

Graph 6. Differences between V in single scull and double scull rowers



For most variables (DPS, TS and V) there are significant differences in results between the sexes. The only variable where gender did not prove to be a significant factor was SR. On the other hand, SR and V values differ significantly in different disciplines, while this is not the case with DPS and TS. The interaction of gender and discipline did not have significant effects in any case.
These results tell us that, due to the significant influence of the gender and discipline factors, it was correct to divide all competitors into 4 groups, on which a separate regression analysis was performed.

4. CONCLUSIONS

The hypothesis in this paper is based on a theoretical consideration of the relationship between various biomechanical variables that are measured during the competition and have an impact on the achieved speed of the boat. In accordance with the obtained research results, it can be concluded that:

- The first hypothesis in the paper H1 – Rowing stroke rate differentially affects boat speed in double sculls at the Varese 2022 World Junior Rowing Championships – was partially confirmed.
- The second hypothesis in the paper H2 – Distance per stroke affects boat speed in double sculls in different ways at the Varese 2022 World Junior Rowing Championships – was partially confirmed.
- The third hypothesis in the paper H3 - Total number of strokes differentially affects boat speed in double sculls at the Varese 2022 World Junior Rowing Championships - was partially confirmed.

Although in senior rowers the distance traveled per stroke has the same influence on speed as rowing pace (Kleshnev, 2001), in junior rowers these laws are still not present. The only discipline in which distance covered per stroke had a significant effect on boat speed was JW2x, which is also evident from the top results achieved in that race.

The inverse proportionality of the variables total number of strokes and boat speed is not observed in junior rowers, except in the JW2x category.

It is important to say that all the tested kinematic variables of the stroke depend to the greatest extent on the dynamic variables. The morphological and functional abilities of athletes often differ, and they determine the relationship between the value of rowing pace and the value of the distance traveled per stroke, which is why their ideal relationship cannot be defined with certainty. In this regard, in order to achieve top results, it is most important that the quotient of the values of these two parameters be as high as possible, because therefore the speed of the boat's movement will be higher.

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