

OLYMPIC ROWING: MODEL OF COMPETITIVE ACTIVITY OF INTERNATIONAL LEVEL ELITE FEMALE ATHLETES



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REMO OLÍMPICO: MODELO DE ACTIVIDAD COMPETITIVA DE LAS ATLETAS DE ELITE INTERNACIONAL

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ABSTRACT

Introduction: High-performance training should focus on motor capability determinants in competition to make physical preparation effective. **Objective:** To analyze and draw up an elite model based on competitive activity, to guide the theory and practice of female rowers, using data on the 42 finalists of the 2010-2018 world championships. **Methods:** Forty-two rowers from 2010-2018 world championships participated in the study, final A, women's single scull without weight restrictions. The statistical comparison was performed and differences between 500 meter splits analyzed for each variable were discussed. **Results:** Strong correlation was observed between time ($r=-0.99$, $p<0.01$), power ($r=0.99$, $p<0.01$), technical level ($r=0.99$, $p<0.01$) and speed. In the competitive model, the relationship between speed at 2000 meters and time ($r=-0.96$, $p<0.01$), speed ($r=0.94$, $p<0.01$) and power ($r=0.96$, $p<0.01$) showed a strong correlation with speed in the splits of the third 500 meters of the race. In terms of stroke rate ($r=-0.56$, $p<0.01$) and stroke length ($r=0.54$, $p<0.01$), the strongest correlation occurs at the start, in the first 100 meters of competition. **Conclusion:** Having performed these analyses, it is possible to confirm the need to investigate competitive activity in order to supplement the rower's fitness preparation system. **Level of evidence I; Diagnostic studies- Investigating a diagnostic test.**

Keywords: Rowing; Performance; Sporting activity.

RESUMO

Introdução: O treinamento no alto rendimento deve focar a capacidade motora determinante na competição, assim a preparação física se torna eficaz. **Objetivo:** Analisar e elaborar um modelo de elite, a partir da atividade competitiva, para orientar a teoria e a prática desportiva das remadoras, a partir dos dados das 42 finalistas dos mundiais de 2010 a 2018. **Métodos:** Participaram do estudo 42 remadoras de mundiais entre 2010 a 2018, final A, barco individual feminino sem restrição de peso. Realizou-se a comparação estatística e as diferenças entre as parciais de cada 500 metros analisadas para cada variável foram discutidas. **Resultados:** Observou-se o seguinte: forte correlação entre o tempo ($r=-0,99$; $p<0,01$), a potência ($r=0,99$; $p<0,01$), o índice técnico e a velocidade ($r=0,99$; $p<0,01$). No modelo competitivo, a relação entre a velocidade nos 2000 metros com o tempo ($r=-0,96$; $p<0,01$), a velocidade ($r=0,94$; $p<0,01$) e a potência ($r=0,96$; $p<0,01$) apresentou forte correlação com a velocidade na parcial dos terceiros 500 metros da prova. Já na quantidade ($r=-0,56$; $p<0,01$) e amplitude de remadas ($r=0,54$; $p<0,01$), a maior correlação apresenta-se na partida, nos primeiros 100 metros de competição. **Conclusão:** Feitas essas análises, pode-se assegurar a necessidade de investigar a atividade competitiva com o objetivo de complementar o sistema de preparação da condição física do remador. **Nível de evidência I; Estudos diagnósticos- Investigação de um exame para diagnóstico.**

Descritores: Remo; Desempenho; Atividades esportivas.

RESUMEN

Introducción: El entrenamiento en el alto rendimiento debe enfocar la capacidad motora determinante en la competición, así la preparación física se vuelve eficaz. **Objetivo:** Analizar y elaborar un modelo de elite, a partir de la actividad competitiva, para orientar la teoría y la práctica deportiva de las remadoras, a partir de los datos de las 42 finalistas de los mundiales de 2010 a 2018. **Métodos:** Participaron en el estudio 42 remadoras de mundiales entre 2010 a 2018, final A, barco individual femenino sin restricción de peso. Se realizó la comparación estadística y fueron discutidas las diferencias entre las parciales de cada 500 metros analizadas para cada variable. **Resultados:** Se observó lo siguiente: fuerte correlación entre el tiempo ($r=-0,99$, $p<0,01$), la potencia ($r=0,99$, $p<0,01$), el índice técnico y la velocidad ($r=0,99$, $p<0,01$). En el modelo competitivo, la relación entre la velocidad en los 2000 metros con el tiempo ($r=-0,96$, $p<0,01$), la velocidad ($r=0,94$, $p<0,01$) y la potencia ($r=0,96$, $p<0,01$) presentó fuerte correlación con la velocidad en la parcial de los terceros 500 metros de la prueba. Ya en la cantidad ($r=-0,56$, $p<0,01$) y amplitud de remadas ($r=0,54$, $p<0,01$) la mayor correlación se presenta en la partida, en los primeros 100 metros de competición. **Conclusión:** Hechos estos análisis, se puede asegurar la necesidad de investigar la actividad competitiva con el objetivo de complementar el sistema de preparación de la condición física del remador. **Nivel de evidencia I; Estudios de diagnósticos- Investigación de un examen para diagnóstico.**

Descriptorios: Remo; Rendimiento; Actividades deportivas.



INTRODUCTION

The stroke action in Olympic rowing is defined as a cyclic movement.¹ In the force application phase, the lower and upper limbs act simultaneously while rowing to propel the scull² and achieve competitive speed. In competitions, the rowers or scullers present reaction velocity after the visual signal at the start and consequent acceleration to 500 meters reaching maximum speed, while between 500 and 1000 meters there is a speed reduction and from 1000 meters velocity resistance up to 2000 meters. Accordingly, high-performance training should focus on the motor capability determinants in competition, with preparation being the determining factor in the athlete's result.³ Therefore, knowing the characteristics related to time and strength interaction⁴ is of considerable benefit in improving rowing comprehension² and scull speed.

In high performance sport, some advances are indicated in the training methodology and theory that are based on information from and statistical analyses of the competitions that add significant value to the sport.^{5,6} Thus, the act of analyzing the competitive data of athletes is an effective tool for developing the training plan that produces adequate and specific performance. Moreover, it directs the process of constructing the competitive activity model proposed by Platonov.⁷ This model not only reflects the structure and composition of the preparation process, but also the concrete set of athletes for a particular sport as a standard sample. Therefore, it is advisable not only to know the competitive properties to identify the difference between an average athlete and a world elite athlete, based on the dynamics and percentage of performance of both, but also to improve each stage of improvement and monitoring.

Despite the importance of high-level performance monitoring, there is still no definite tool or precise variable for predicting performance.⁸ Some training strategies are implemented to promote favorable performance by reducing poorly adapted training responses.⁹ To achieve these goals, training should be periodized from the training plan to coincide with competitions.¹⁰ Thus, the preparation of the elite model can minimize errors in the rower's fitness preparation, define a competitive split or variable as the most important, and also provide a comparative database with competitive differences, according to category, type of vessel and type of individual world championship. Thus, the variables or splits that influence high-level sport performance should attract more attention from the coaching staff, as this will enable them to know patterns, athlete characteristics and individual comparisons.¹¹

The specialized bibliography highlights the biological aspects and performance of Olympic and world champions.^{12,13} It also points out some performance prediction models between categories and types of vessel.^{14,15} This article aims to analyze and prepare the elite model of competitive activity to guide the theory and practice of female rowers, based on data from 42 world finalists between 2010 and 2018, the world rowing elite.

MATERIALS AND METHODS

We used the results of 42 female rowers, in the adult single scull category, without weight restrictions. Data refer to final A of the 2010, 2011, 2013, 2014, 2015, 2017 and 2018 world rowing championships. However, in Olympic Games such as those held in 2012 and 2016, the single scull category is not included in the world championship. Thus, the Olympic years were excluded, as they do not present the results in the International Rowing Federation (FISA). All the data used in this research project are available to the public, exhibited on the FISA website <http://www.worldrowing.com>.

Data collected from the worldrowing website: date of birth, weight, height, split, speed, 500 meter stroke rate and total race time for the 2000 meters. Calculated data: age (event date-date of birth/365.25),

body mass index (weight/height²), time of first 100 meters and last 250 meters (distance/speed), number of strokes (stroke rate*time in seconds/60 seconds), stroke cycle time (60 seconds/stroke rate), stroke length (speed*time of each stroke cycle), power of each stroke (2.8/pace³) and technical level (100*(record in seconds/race time)³).

Statistical analysis

Statistical procedures were used to characterize the values of the different variables in terms of central tendency and dispersion. In the inferential analysis, the normality of variables was tested using the Kolmogorov-Smirnov test. Pearson's correlation was used to determine the relationship between performance and all the parameters. The significance level was set at $p < 0.01$. Data were analyzed using SPSS 16 statistical software (Chicago, IL, USA). To construct the competitive and elite models, line and radar charts were used, respectively. The competitive model was the basis for the construction of the elite model, since the results of the world championships were established as a reference.

RESULTS

Data on physical characteristics and competitive activity and their correlation with speed in the 2000 meter race are presented in Table 1. The variables: time, power, stroke length and technical level alone had significant influence on scull speed. Power and technical level were ($r = 0.99$; $p < 0.01$), time ($r = -0.99$; $p < 0.01$), number of strokes ($r = -0.54$; $p < 0.01$) and stroke length ($r = 0.53$; $p < 0.01$). The other variables presented correlations below ($r = 0.14$), but still had no statistical significance.

In the formation of the competitive activity model, the variables were shown in splits: start initial 100 meters and finish line the last 250 meters; the first, second, third and fourth 500 meters. Time, speed, number of strokes, length of strokes and power presented medium and strong positive and negative correlation, and also statistical significance in all splits. Conversely, stroke rate and cycle presented weak positive and negative correlation, and still had no statistical significance in the splits. All variables displayed in splits were correlated with speed over the 2000 meters of the race. Moreover, in the third 500 meter split, time ($r = -0.96$; $p < 0.01$), speed ($r = 0.94$; $p < 0.01$) and power ($r = 0.96$; $p < 0.01$) indicated a strong correlation and statistical significance with scull speed over 2000 meters. However, in terms of the number ($r = -0.56$; $p < 0.01$) and length of strokes ($r = 0.54$; $p < 0.01$), there was a higher correlation and statistical significance at the start and initial 100 meters. In addition, the first and second 500 meters revealed the shortest time (110.91; 114.86s), respectively. Thus, the first 500 meters and the fastest (4.38 m/s) and most powerful (240.57W), consequently has the highest stroke rate in the race (40.85; 35.90 spm), while the highest number

Table 1. Physical characteristics and competitive activity of the 42 finalists of the 2010-2018 world 2000-meter rowing championships.

Variables	Mean	Standard deviation	Minimum	Maximum	r(2000m)	p-value
Age (year)	29.28	4.60	23.00	41.00	-0.03	0.83
Weight (kg)	74.26	5.01	69.00	86.00	-0.11	0.45
Height (cm)	181.00	5.40	171.00	193.00	-0.13	0.39
BMI (kg/m ²)	16.88	1.95	14.53	20.93	-0.07	0.65
Time 2000m (s)	456.24	11.65	434.95	484.60	-0.99	<0.01**
Average speed (m/s)	4.38	0.11	4.13	4.60	1.00	<0.01**
Stroke rate (spm)	34.03	1.75	31.20	40.50	-0.14	0.35
Power (W)	236.75	17.75	196.83	272.23	0.99	<0.01**
Number (nos)	258.86	16.06	230.87	322.27	-0.54	<0.01**
Length (m)	7.75	0.44	6.21	8.66	0.53	<0.01**
Cycle time (s)	1.76	0.08	1.48	1.92	0.13	0.40
Technical level (%)	82.69	6.20	68.75	95.09	0.99	<0.01**

** $p < 0.01$; BMI (body mass index), spm (strokes per minute), nos (number of strokes), m (meters).

of strokes was in the first and fourth 500 meters (66.37; 65.48 number of strokes), the greatest length of strokes in the second and third 500 meters (7.99; 7.95 m), and the shortest stroke time at the start and in the first 500 meters (1.47 s; 1.67 s), respectively (Table 2). Figure 1 show competitive activity in chart form with the dynamics of the variables in each 500 meter split of the race.

The competitive activity of the rowers was used as a basis to create a model designed to compare athletes with international elite rowers. For this comparison the authors generated fictitious data on an imaginary rower for demonstrative purposes. The data created were: age 31 years, weight 61 kg, height 173 cm, splits of 183, 185, 186 and 188 seconds, and partial paces of 29, 26, 26 and 28 strokes per minute in every 500 meters, respectively. Soon after this, the radar chart served to visualize comparisons with the global mean. The black chart contains the model data and the gray graph the researchers' data (Figure 2).

DISCUSSION

The results showed a strong correlation between time and power over 2000 meters with the average speed over 2000 meters, confirming that the force applied in each stroke has an influence on performance in international rowing competitions. According to Warmenhoven et al.,² the greater the efficiency in the application of force in each stroke cycle phase, in which the oar is in the water, the greater the propulsion

of the scull, and consequently the shorter the race time. It is suggested, according to the data submitted, that an emphasis on special strength training in competitive exercise may help improve performance.

A classical experimental research project¹⁶ evaluated the stroke force of 71 athletes on 21 vessels in each phase of the stroke during a competition, and found that power is the main factor affecting boat speed. The authors continue by stating that power was significantly higher in the smaller boats, with the female single scull reaching 247 watts,¹⁶ close to the average presented by the world elite, 236.75 watts in the 2000 meter race. The number and length of strokes achieved a mean correlation and statistical significance with speed in the 2000-meter race, indicating that the greater the force applied in each stroke, the greater the boat displacement and stroke length, and the lower the number of strokes in the 2000-meter race in world championships. Verkhoshansky¹⁷ supports the idea that the main biomotor ability responsible for performance in sports is speed, which should be decisively recognized when focusing on the training of the various other abilities, depending on the sport to be trained. Gomes et al.¹⁸ claim that speed capacity development is essential for competitive success. The classic study by Steinacker¹⁹ maintains that power is greater in the initial phase in order to reach high speed in a shorter time. In view of the above, we recommend paying attention to the development of power, alactic and lactic capacity, as the stimuli reach up to 120 seconds^{7,18,20} through

Table 2. Competitive activity in the 2000 meter race in splits, average speed, stroke rate, power, number and length of strokes at the start, 500m split and finish line, of the 42 finalists of the 2010-2018 world rowing championships.

Variables	Mean	Standard Deviation	Minimum	Maximum	r(2000m)	p-value
Start time 100m (s)	22.96	1.90	19.61	27.78	-0.58	<0.01**
Time 500m_1 (s)	110.91	2.83	107.64	117.52	-0.73	<0.01**
Time 500m_2 (s)	114.86	3.06	108.15	119.74	-0.85	<0.01**
Time 500m_3 (s)	115.38	3.65	108.60	124.53	-0.96	<0.01**
Time 500m_4 (s)	115.08	3.90	108.76	123.89	-0.87	<0.01**
Finish time 250m (s)	58.01	2.11	54.35	62.50	-0.75	<0.01**
Average start speed 100m (m/s)	4.38	0.36	3.60	5.10	0.56	<0.01**
Average speed 500m_1 (m/s)	4.51	0.10	4.30	4.60	0.67	<0.01**
Average speed 500m_2 (m/s)	4.35	0.11	4.20	4.60	0.84	<0.01**
Average speed 500m_3 (m/s)	4.32	0.13	4.00	4.60	0.94	<0.01**
Average speed 500m_4 (m/s)	4.34	0.15	4.00	4.60	0.85	<0.01**
Average speed finish line 250m(m/s)	4.31	0.15	4.00	4.60	0.75	<0.01**
Stroke rate start_100m (spm)	40.85	2.72	35.70	48.80	0.12	0.44
Stroke rate 500m_1 (spm)	35.90	1.82	31.50	39.40	-0.20	0.18
Stroke rate 500m_2 (spm)	32.84	2.21	29.80	41.20	0.25	0.10
Stroke rate 500m_3 (spm)	32.83	2.18	29.30	41.00	-0.17	0.26
Stroke rate 500m_4 (spm)	34.15	1.87	30.90	40.50	0.26	0.08
Stroke rate finish line_250m (spm)	34.17	1.91	31.20	41.80	-0.06	0.69
Power 100m (W)	240.57	60.00	130.64	371.42	0.53	<0.01**
Power 500m_1 (W)	257.47	18.83	215.64	280.64	0.73	<0.01**
Power 500m_2 (W)	231.96	19.09	203.87	276.69	0.84	<0.01**
Power 500m_3 (W)	229.14	21.15	181.24	273.26	0.96	<0.01**
Power 500m_4 (W)	231.16	23.32	184.06	272.06	0.86	<0.01**
Power finish line_250m (W)	225.82	24.27	179.20	272.54	0.75	<0.01**
Number of strokes start 100m (nos)	15.59	1.15	13.22	19.17	-0.56	<0.01**
Number of strokes 500m_1 (nos)	66.37	4.03	57.07	76.56	-0.48	<0.01**
Number of strokes 500m_2 (nos)	62.87	4.71	54.08	81.05	-0.54	<0.01**
Number of strokes 500m_3 (nos)	63.16	5.07	55.96	82.84	-0.54	<0.01**
Number of strokes 500m_4 (nos)	65.48	3.79	57.74	82.07	-0.45	<0.01**
Number of strokes finish_250m (nos)	33.03	2.09	29.64	40.50	-0.49	<0.01**
Stroke length start 100m (m)	6.44	0.46	5.22	7.56	0.54	<0.01**
Stroke length 500m_1 (m)	7.55	0.45	6.53	8.76	0.47	<0.01**
Stroke length 500m_2 (m)	7.99	0.54	6.17	9.25	0.52	<0.01**
Stroke length 500m_3 (m)	7.95	0.56	6.04	8.93	0.52	<0.01**
Stroke length 500m_4 (m)	7.65	0.41	6.09	8.66	0.45	<0.01**
Stroke length finish line_250m (m)	7.59	0.45	6.17	8.43	0.48	<0.01**
Cycle time start 100m (s)	1.47	0.09	1.23	1.68	-0.09	0.54
Cycle time 500m_1 (s)	1.67	0.08	1.52	1.90	0.21	0.17
Cycle time 500m_2 (s)	1.83	0.11	1.46	2.01	0.22	0.15
Cycle time 500m_3 (s)	1.83	0.11	1.46	2.05	0.14	0.37
Cycle time 500m_4 (s)	1.76	0.09	1.48	1.94	-0.07	0.63
Cycle time finish line_250m (s)	1.75	0.09	1.44	1.92	0.03	0.84

**p<0.01. spm (strokes per minute), nos (number of strokes), m (meters), r(2000m) correlation with average speed.

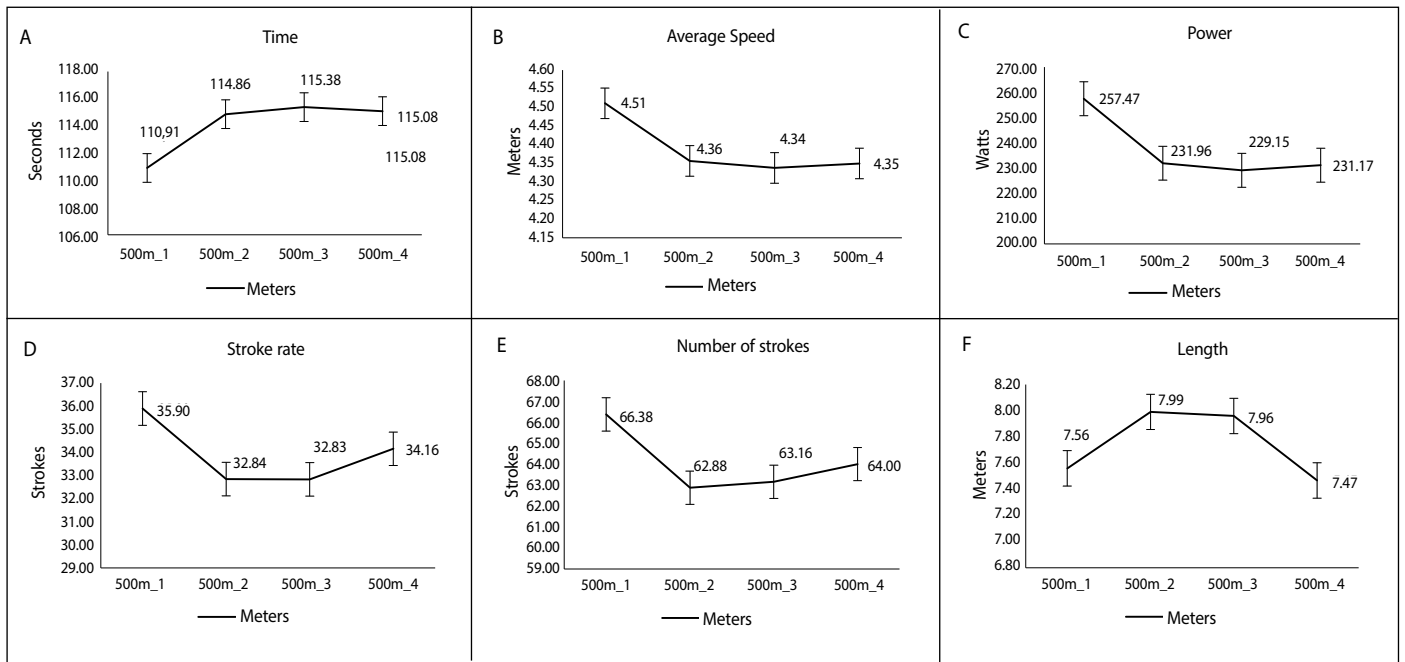


Figure 1. Competitive model of the 500 meter splits of female rowers. Time in seconds (A), average speed in meters per second (B), power of strokes in watts (C), stroke rate in strokes per minute (D), quantity of strokes in number of strokes (E) and length of strokes in meters (F).

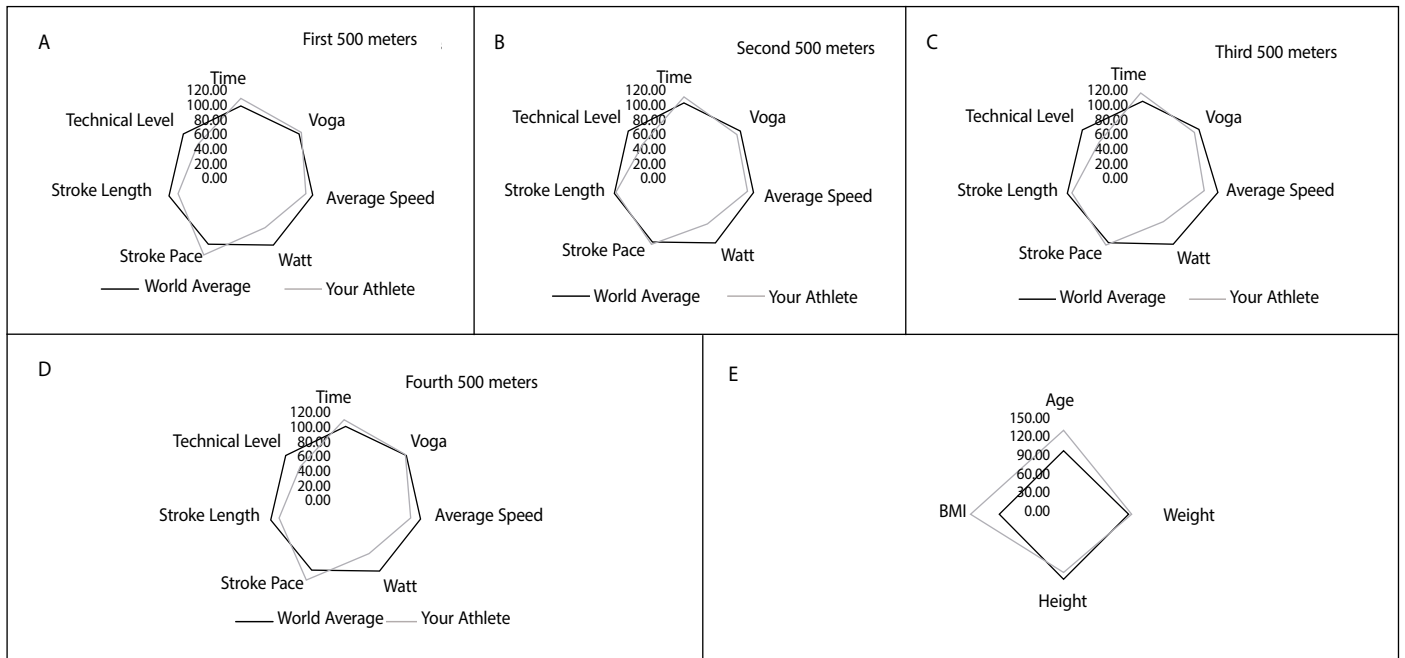


Figure 2. Elite model, comparing the world average with a fictitious athlete, based on the competitive activity of female rowers in international rowing competitions. First 500 meters of race (A), second 500 meters of race (B), third 500 meters of race (C), last 500 meters of race and physical characteristics (E).

the interval workout method, with special and competitive exercises distributed in the training plan.

The technical level indicates how far the athlete is from the world record, and in this particular research project has strong correlation and statistical significance, indicating that the average speed of world championships is 17.31% away from the world record.

Regarding the competitive model, the study showed that time, speed and power had strong correlation and statistical significance with speed in all splits. Some authors explain that effective strength coordination throughout the stroke cycle is a significant aspect of performance.²¹⁻²³ Not only does the current study demonstrate that the highest correlation is found in the third 500 meter split, but also proposes that the greater the power over the 1500 meters of the race, the better the result. Also, particular attention should be focused on speed resistance stimuli,

always within the percentage calculations of competitive speed, since the highest correlation occurs in the third split.

In terms of the number and length of strokes, average correlation and significance is shown in all splits. There is also the higher correlation at the start, suggesting that the lower the number and the greater the length of strokes, the higher the speed of the scull. Corroborating the assumption that continuously applying force improves scull propulsion² in the acceleration, speed, velocity resistance, and finish line phases, as the greater the power the greater the scull's displacement.

The model allows the comparison of any athlete with the world elite, due to the analysis of competitive variables. It also drills deeply into the theory and practice of the sport.⁷ Based on the analysis of this model, it is evident that higher power in each stroke phase could improve performance in the 2000-meter single women's scull race. Zamotin et al.²³

claim that competitive activity is the culmination of a long training process and deserves an objective, systematic and thorough analysis. Thus, knowing the competitive activity model of high performance scullers gives us the exact notion that applied training beliefs need to be reviewed. In other words, the current main guiding principle of the training system is undoubtedly the competition system. We need to train as close as possible to the competitive model. Training volumes, which used to take up significant time in preparation programs, have decreased in this new stage while speed/muscle power is taking on greater importance, thus presenting new dynamics in terms of training intensity. Parameters such as average competition speed, number of strokes (stroke rate) and stroke execution power, as well as lactate concentration, made the elements most valuable to the coach.

It is now understood that despite being a sport that requires high maximal oxygen uptake (VO₂max), the winner is the athlete who has the ability to produce fast strength most of the time, and this is acquired by training at and above competitive speeds. Special strength becomes the key element of the preparation of today's rowers, which general theory still resists, because the high volume and consequently low muscle power of training has always been the coach's strategy of choice.

As a limitation, this study is still far from clarifying all the details that might help in a rowing-specific training theory. We still need to carry out more invasive studies to verify the morphofunctional adaptations that can produce workouts with less volume and more neuromuscular and functional qualities. In any event, this study provided us with an oversight of the competitive reality of high performance Olympic rowing.

CONCLUSIONS

The elite model of competitive activity in this study demonstrates the behavior of variables and power as a key factor in female rowers in world championships. Therefore, the model presented in this study can be seen as an important complement in female rowers' fitness preparation, and may also serve as a guide for the percentages and characteristics of training loads.

Future studies should both verify which of these variables or splits are predictors of performance, and analyze the competitive activity of each category and gender, as the dynamics may differ from the model presented.

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