Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 10, Issue, 04, pp. 35122-35128, April, 2020

RESEARCH ARTICLE OPEN ACCESS

# OLYMPIC ROWING: IDENTIFICATION OF THE MODEL OF COMPETITIVE ACTIVITY OF INTERNATIONAL ELITE MALE ROWERS

*[1]Fábio Barreto Maia da Silva, [2]João Paulo Reis Gonçalves Moreira de Brito e [3]Antonio Carlos Gomes

[1]Rowing Department, Vasco da Gama Rowing Club, 22470-001 RJ Rio de Janeiro, Brazil; [2]Polytechnic Institute of Santarém, Sport Sciences School of Rio Maior, 2040-413 RM Rio Maior, Portugal; [3]Institute Sport Training. Brazilian Academy of Trainers, 22631-000 RJ Rio de Janeiro, Brazil

**ARTICLE INFO**

***Article History:***
Received 09th January, 2020
Received in revised form
26th February, 2020
Accepted 06th March, 2020
Published online 29th April, 2020

***Key Words:***

*Rowing, Performance, Competitive model.*

***Corresponding author: Fábio Barreto Maia da Silva,***

**ABSTRACT**

This study analyzed and elaborated the competitive activity model. Data from the 40 rowers (29.52 ± 4.50 years) of the 2010-2018 world finalists were analyzed. Physical characteristics: age (years), body weight (kg), height (m) and body mass index (kg/m2). And motor activities during competition: time 2000m (s), average speed (m/s), stroke rate (spm), power (w), number (sn), length (m), cycle time (s) and technical level (%). After analysis of the results, the competitive and elite model was elaborated. Strong correlation between time ($r = -0.99$; $p < 0.01$), power ($r = 0.99$; $p < 0.01$) and technical level ($r = 0.99$; $p < 0.01$) with mean velocity in 2000 meters. test. In the competitive model, time ($r = -0.91$; $p < 0.01$) and power ($r = 0.92$; $p < 0.01$) showed a strong correlation with the average speed of 1500 meters. Already in the stroke number ($r = -0.52$; $p < 0.01$) and stroke length ($r = 0.51$; $p < 0.01$) higher correlation on arrival in the last 250 meters of competition. The beliefs of the applied training need to be revised, and still emphasize the partial of higher correlation. For with the competitive and elite model the training plan should approach the characteristics of the competition.



**Citation:** ***Fábio Barreto Maia da Silva, João Paulo Reis Gonçalves Moreira de Brito e Antonio Carlos Gomes.*** "Olympic rowing: identification of the model of competitive activity of international elite male rowers", *International Journal of Development Research*, 10, (04), 35122-35128.

## INTRODUCTION

The act of rowing is defined as a cyclic motion at Olympic level (Dawson et al, 1998). When force is applied to rowing, both upper and lower limbs work simultaneously in order to propel the boat (Warmenhoven *et al.,* 2018) and to reach competitive speed. In competitions, rowers increase their reaction time after a visual signal has been given to start the race. As a result, they accelerate over the first 100 meters, then maximum speed is reached over 500-600 meters and a reduction in speed takes place over 600-1000 meters. Then, they maintain their speed (speed endurance) from 1000-1500 meters of race and finally accelerate when reaching 1500-2000 meters. Considering all this, elite sports training should focus on the main motor skill required during competition, being the athlete's physical preparation crucial for achieving desired results (Korner, 1993). Therefore, it is of great benefit to learn about the features related to time and strength interaction (Smith and Loschner, 2002) in order to have a better understanding of this sport (Warmenhoven *et al.,* 2018) and to enhance boat speed. Some advances have been mentioned in the training theory and methodology of elite sports, and they are based on information and statistical data analyses from competitions and are of utmost importance to sports (Passfield and Hopker, 2017; Liedbermann *et al.,* 2002). So, it is really effective for training purposes to analyze the athlete's data from competitions in order to prepare a tailored training plan. Furthermore, it serves as a guide when building the model of competitive activity proposed by Platonov (2008). This model considers not only the structure and parts of the training process, but also the athlete's suitability for a certain sport, as a standard sample. Therefore, it is wise to learn about the elements involved in competitions to be able to tell the difference between an elite and a non-elite athlete, by analyzing the differences in performance and the percentages they achieved, as well as to be able to enhance each training phase. Despite the importance of monitoring elite athlete's performance in sports, there is still no precise tool available (either variable or permanent) that can predict that competence (Halson, 2014). Some strategies are put in place in the training program with the aim of improving performance, and consequently, reducing the mistakes made (Bourdon *et al.,* 2017). In order to accomplish these goals, the training plan is sometimes periodized so as to coincide with the competitions (Fox *et al.,* 2017). Therefore, the creation of the elite model may help the coach make adjustments to the rower's training system as a whole, or parts of it, to be able to correct mistakes in an effective way. This model also provides a comparative data base with the differences found in competitions, as per category, boat type and data collected from each world championship. Hence, the coaching staff should focus on the variables or parts of the race that really affect athlete's performance in elite sports. By doing so, the coaching staff will be able to learn more about the patterns, the athlete's characteristics and about individual comparisons (Nevill *et al.,* 2008). The bibliography in this field highlights the biological aspects and performance of Olympic and world champions (Mikulic and Bralic, 2018; Plews and Laursen, 2017). It also shows some models for performance prediction among categories and boat types (Akça, 2014; Silva *et al.,* 2017; Silva *et al.,* 2020). This paper aims at analyzing and creating the elite model of competitive activity in order to guide the theory and the practice of sports for male rowers, considering the data gathered from the top forty-two finishers from the 2010 to 2018 world championships, namely international elite rowers.

## METHODS

**Participants:** The data collected in this study was from 42 rowers (age: 29.52 ± 4.50 years, weight: 94.67 ± 7.07, height; 1.94 ± 4.93) adult male scullers with no restriction on the weight. All of them participated in the A final, the top six, from the 2010, 2011, 2013, 2014, 2015, 2017 and 2018 World Rowing Championships. Notice that, the 2012 and 2016 editions of the world rowing event did not include the single sculling races for adult men. Those specific races took place in the Olympic Games that occurred in the same years, but our study has focused only on world championships.

**Measures:** All data used in this research is publicly available from the website of the International Federation of Rowing (FISA) http://www.worldrowing.com. Data such as date of birth, weight, height, partial time for each 500 meters, total time to complete 2000 meters, speed and stroke rate has been collected.

**Design and Procedures:** Based on this data, the following variables have been calculated: age (date of the event – date of birth/365,25), body mass index (weight/height^2), time to complete the first 100 meters and the last 250 meters (distance/speed), number of strokes (stroke rate*total time in seconds/60 seconds), time for the stroke cycle (60 seconds/stroke rate), stroke length (speed*time for each stroke cycle), stroke power (2,8/pace^3) and technical level (100* (record in seconds/race time)^3). A model of competitive activity and an elite model were created after having analyzed the results, since they provided variables that served as a baseline for performance comparisons.

**Statistical analysis:** Statistical procedures have been used in order to characterize the value of different variables with reference to central tendency and dispersion. In the inferential statistical analysis, the distribution of variables has been tested by using the Kolmogorov-Smirnov normality test. Pearson's correlation coefficient has been applied to determine the relation between performance and all the parameters considered. The level of statistical significance established in the analysis was $p<0.05$. Data analysis was conducted by means of the SPSS 16 statistical software (Chicago, IL, USA). In order to create the Model of Competitive Activity and the Elite Model, line and radar graphs have been used respectively.

## RESULTS

Data regarding the physical characteristics of athletes, their competitive activity and how they correlate to speed in the 2000m race are displayed in table 1. The variables: time, (stroke) power, stroke length and technical level have in an isolated way influenced the boat speed significantly. Power and technical level were strongly correlated ($r=0.99$; $p<0.01$), height showed a weak correlation ($r=0.30$), the number of strokes displayed a weak negative correlation ($r=-0.30$) and stroke length a weak correlation ($r=0.31$; $p<0.05$). All other variables showed correlations below ($r=0.14$) and did not reveal any statistical value. The anthropometric variables that correlated to the average speed for each part of the race showed, in terms of height, a weak correlation with the second and third 500m ($r=0.33$; $p<0.05$, $r=0.31$; $p<0.05$), respectively. And body mass index with the first 500m ($r=-0.35$; $p<0.05$) (Table 2). When creating the model of competitive activity, variables were showed as different parts of the race: the start and finish (the first 100m and the last 250m) and the first, second, third and fourth 500m in the race. Time, speed and power had weak, medium and strong positive and negative correlation with statistical significance in all parts assessed. Also, the number of strokes and stroke length indicated a weak/medium positive and negative correlation with statistical significance in the third and fourth 500m and at finish line. All variables that were represented as parts were correlated with speed in the 2000m race. Moreover, time ($r=-0.91$; $p<0.01$), speed ($r=0.91$; $p<0.01$) and *watts* ($r=0.92$; $p<0.01$) indicated that in the third 500m there was a strong correlation with statistical significance with the boat speed in the 2000m. In terms of number ($r=-0.52$; $p<0.05$) and length of strokes ($r=0.51$; $p<0.05$) there was medium correlation with statistical significance in the last part of the race (finish), the last 250m. Furthermore, the first and the last 500m displayed the shortest time (99.63; 102.68 s), the fastest (5.01; 4.87 m/s), the highest stroke rate (38.04; 36.35 spm), the greatest power (354.31; 325.98 w), the highest number of strokes (63.16; 62.18 sn), and, consequently, shorter stroke length (7.93; 8.05 m) and the shortest time for stroke cycle (1.58; 1.65 s), respectively. In the second and third 500 m, time increased in this order (3.81; 4.44 s) in relation to the first 500m of race. There was a reduction in time (0.76 and 1.39 seconds) in the last 500m, as compared to the second and third 500m, respectively. Moreover, when comparing the first to the last 500m there was an increase in time (3.05 seconds), and these variations in time made the remaining variables change (Table 3). The graph in figure 1 shows the variables for each 500m. A database has been created after collecting information concerning the motor actions performed by rowers in world championships. This database can be used as an elite model, therefore allowing coaches to compare the data in the model to the performance of non-elite young and adult athletes.

**Table 1. Physical characteristics and competitive activity of the top 42 finishers of the 2000m race in the World Rowing Championships from 2010 to 2018**

| Variables | Mean | Standard Deviation | Minimum | Maximum | r(2000m) | p-value |
|---|---|---|---|---|---|---|
| Age (years) | 29.52 | 4.50 | 21.00 | 39.00 | 0.08 | 0.57** |
| Weight (kg) | 94.67 | 7.07 | 79.00 | 105.00 | 0.14 | 0.37** |
| Height (m) | 1.94 | 4.93 | 1.86 | 2.01 | 0.30 | 0.05** |
| BMI (kg/m2) | 23.75 | 2.67 | 18.04 | 28.70 | 0.05 | 0.74** |
| Time 2000m (s) | 409.63 | 7.42 | 397.12 | 424.82 | -0.99 | <0.01** |
| Average speed (m/s) | 4.88 | 0.08 | 4.71 | 5.04 | 1.00 | <0.01** |
| Stroke rate (spm) | 35.88 | 1.58 | 33.50 | 40.60 | 0.08 | 0.57** |
| Power (w) | 326.50 | 17.60 | 292.17 | 357.67 | 0.99 | <0.01** |
| Number (sn) | 244.99 | 11.25 | 222.13 | 274.80 | -0.30 | 0.05** |
| Length (m) | 8.17 | 0.36 | 7.28 | 9.00 | 0.31 | <0.05** |
| Cycle time (s) | 1.67 | 0.01 | 1.48 | 1.79 | -0.09 | 0.53** |
| Technical level (%) | 86.95 | 4.68 | 77.81 | 95.26 | 0.99 | <0.01** |

*$p \leq 0.05$ **$p \leq 0.01$; BMI (body mass index), spm (strokes per minute), sn (stroke number), m (meters).*

**Table 2. Correlation between the physical characteristics and the average speed reached at the start, at each 500m, and at the finish line, for the top 42 finishers in World Rowing Championships from 2010 to 2018**

| Variables | Age | Weight | Height | BMI |
|---|---|---|---|---|
| Avg. speed - start 100m (m/s) | -0.18 | -0.24 | -0.14* | -0.25* |
| Avg. speed 500m 1 (m/s) | -0.13 | -0.29 | -0.08* | -0.35* |
| Avg. speed 500m_2 (m/s) | 0.11 | 0.10 | 0.33* | -0.01* |
| Avg. speed 500m_3 (m/s) | 0.02 | 0.21 | 0.31* | 0.13* |
| Avg. speed 500m_4 (m/s) | 0.13 | 0.25 | 0.26* | 0.20* |
| Avg. speed - finish 250(m/s) | 0.16 | 0.18 | 0.20* | 0.14* |

*$p \leq 0.05$ **$p \leq 0.01$; BMI (body mass index)*

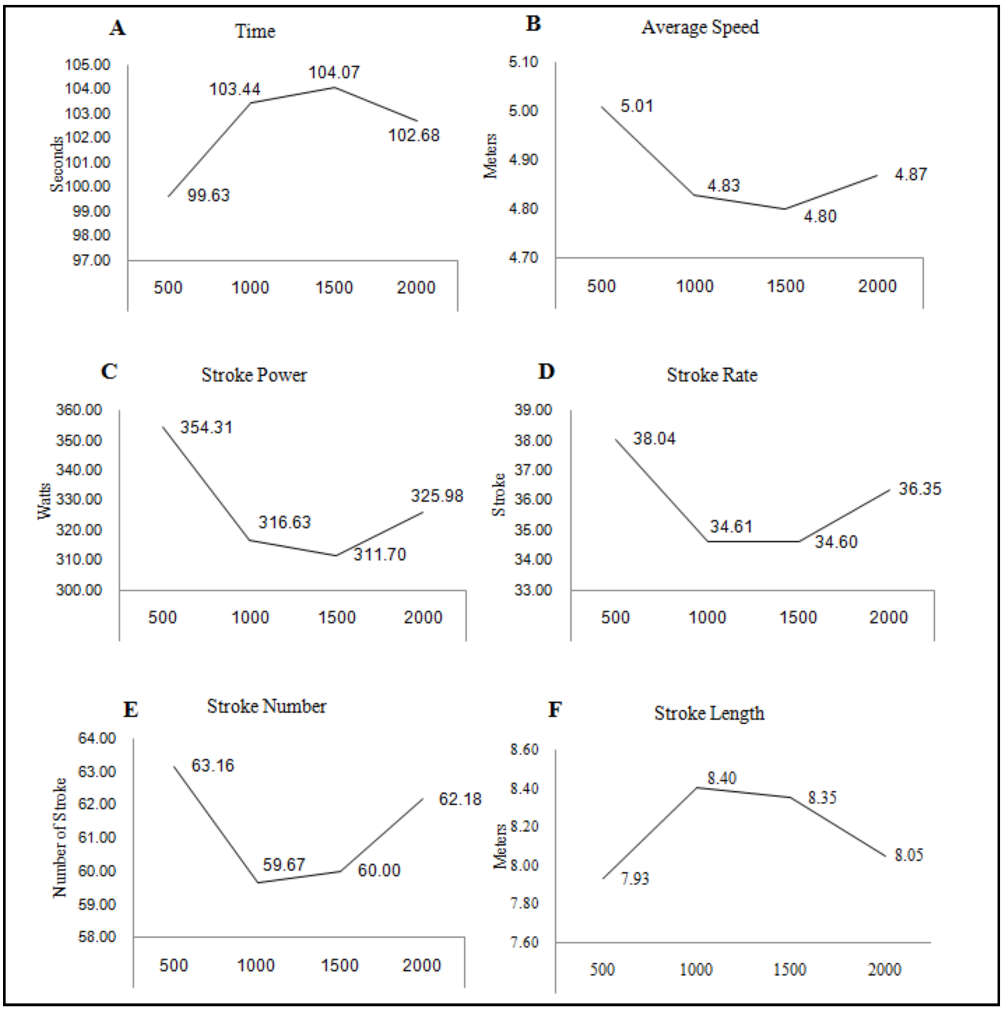


**Figure 1. Competitive Model of each 500 meters performed by rowers. Time in seconds (A), average speed m/sec (B), stroke power in watts (C), stroke rate (D), stroke number (E) and length of stroke in meters (F)**

**Table 3. Competitive activity for the 2000m in terms of time, average speed, stroke rate, power, number and length of stroke, at start, at each 500m and at finish line, for the top 42 finishers in World Rowing Championships from 2010 to 2018**

| Variables | Mean | Standard Deviation | Minimum | Maximum | r(2000m) | p-value |
|---|---|---|---|---|---|---|
| Start time 100m (s) | 21.09 | 2.20 | 17.24 | 27.03 | -0.32 | <0.05** |
| Time 500m_1 (s) | 99.63 | 1.54 | 96.08 | 102.61 | -0.42 | <0.01** |
| Time 500m_2 (s) | 103.44 | 1.57 | 99.84 | 106.36 | -0.72 | <0.01** |
| Time 500m_3 (s) | 104.07 | 2.70 | 99.18 | 110.70 | -0.91 | <0.01** |
| Time 500m_4 (s) | 102.68 | 3.95 | 96.06 | 112.57 | -0.86 | <0.01** |
| Finish time 250m (s) | 51.56 | 2.26 | 46.30 | 56.82 | -0.81 | <0.01** |
| Avg. speed - start 100m (m/s) | 4.79 | 0.50 | 3.70 | 5.80 | 0.33 | <0.05** |
| Avg. speed 500m_1 (m/s) | 5.01 | 0.07 | 4.87 | 5.20 | 0.42 | <0.01** |
| Avg. speed 500m_2 (m/s) | 4.83 | 0.07 | 4.70 | 5.01 | 0.72 | <0.01** |
| Avg. speed 500m_3 (m/s) | 4.80 | 0.12 | 4.52 | 5.04 | 0.91 | <0.01** |
| Avg. speed 500m_4 (m/s) | 4.87 | 0.18 | 4.44 | 5.21 | 0.87 | <0.01** |
| Avg. speed - finish 250(m/s) | 4.85 | 0.21 | 4.40 | 5.40 | 0.81 | <0.01** |
| Stroke rate - start _100m (spm) | 41.67 | 3.46 | 33.60 | 49.30 | 0.04 | 0.45** |
| Stroke rate 500m_1 (spm) | 38.04 | 2.02 | 33.90 | 43.70 | 0.04 | 0.79** |
| Stroke rate 500m_2 (spm) | 34.61 | 1.86 | 31.50 | 40.30 | -0.05 | 0.71** |
| Stroke rate 500m_3 (spm) | 34.60 | 1.75 | 30.90 | 39.40 | 0.09 | 0.55** |
| Stroke rate 500m_4 (spm) | 36.35 | 1.63 | 33.60 | 40.60 | 0.26 | 0.08** |
| Stroke rate - finish_250m (spm) | 36.57 | 1.97 | 30.90 | 40.90 | 0.12 | 0.43** |
| Power 100m (w) | 317.74 | 100.88 | 141.78 | 546.31 | 0.33 | <0.01** |
| Power 500m_1 (w) | 354.31 | 16.66 | 323.97 | 394.61 | 0.43 | <0.01** |
| Power 500m_2 (w) | 316.63 | 14.50 | 290.89 | 351.69 | 0.72 | <0.01** |
| Power 500m_3 (w) | 311.70 | 23.52 | 258.00 | 358.75 | 0.92 | <0.01** |
| Power 500m_4 (w) | 325.98 | 36.07 | 245.36 | 394.86 | 0.87 | <0.01** |
| Power - finish_250m (w) | 322.64 | 42.28 | 238.49 | 440.79 | 0.80 | <0.01** |
| Number-start 100m (sn) | 14.58 | 1.33 | 12.41 | 17.84 | -0.26 | 0.08** |
| Number 500m_1 (sn) | 63.16 | 3.19 | 57.03 | 72.36 | -0.09 | 0.56** |
| Number 500m_2 (sn) | 59.67 | 3.29 | 54.34 | 68.07 | -0.26 | 0.09** |
| Number 500m_3 (sn) | 60.00 | 3.29 | 54.88 | 71.22 | -0.34 | <0.05** |
| Number 500m_4 (sn) | 62.18 | 3.07 | 55.30 | 68.29 | -0.42 | <0.01** |
| Number - finish_250m (sn) | 31.41 | 1.74 | 27.97 | 34.57 | -0.52 | <0.01** |
| Length-start 100m (m) | 6.90 | 0.61 | 5.61 | 8.06 | 0.27 | 0.07** |
| Length 500m_1 (m) | 7.93 | 0.38 | 6.91 | 8.77 | 0.09 | 0.56** |
| Length 500m_2 (m) | 8.40 | 0.43 | 7.35 | 9.20 | 0.26 | 0.09** |
| Length 500m_3 (m) | 8.35 | 0.43 | 7.02 | 9.11 | 0.34 | <0.05** |
| Length 500m_4 (m) | 8.05 | 0.40 | 7.32 | 9.04 | 0.42 | <0.01** |
| Length - finish_250m (m) | 7.98 | 0.44 | 7.23 | 8.94 | 0.51 | <0.01** |
| Cycle time- start 100m (s) | 1.44 | 0.12 | 1.22 | 1.79 | -0.11 | 0.46** |
| Cycle time 500m_1 (s) | 1.58 | 0.08 | 1.37 | 1.77 | -0.03 | 0.80** |
| Cycle time 500m_2 (s) | 1.73 | 0.08 | 1.49 | 1.90 | 0.05 | 0.74** |
| Cycle time 500m_3 (s) | 1.73 | 0.08 | 1.52 | 1.94 | -0.11 | 0.47** |
| Cycle time 500m_4 (s) | 1.65 | 0.07 | 1.48 | 1.79 | -0.26 | 0.08** |
| Cycle time - finish 250m (s) | 1.64 | 0.08 | 1.47 | 1.94 | -0.12 | 0.43** |

*p≤0,05 **p≤0,01. spm (strokes per minute), sn (stroke number), m (meters), r (2000m) correlation with average speed.

In order to illustrate this comparison with the elite model, the authors of this paper created some fictitious data of a so-called rower, only for demonstration purposes. The unreal data included was: age- 39 years old, weight- 100 kg, height- 175 cm, partial times of 110, 115, 117 and 113 seconds and partial paces of 39, 32, 32 and 37 strokes per minute for each 500 meters, respectively. Then, a spider graph was used to facilitate the comparisons to the average results of the international elite athletes. The black graph shows the data from the elite model whereas the gray one displays the fictitious data created by the authors (Figure 2).

## DISCUSSION

Results have demonstrated that there was strong correlation between time and power with the average speed in the 2000 meters, therefore proving that the force exerted on each stroke has influenced the athletes' performance in world championships. According to Warmenhoven *et al.,* (2018), exerting power efficiently in each phase of rowing stroke when the oar is in the water provides better boat propulsion and, as a result, better race time. The data presented suggests that performance can be improved when special strength training in competitive exercises is emphasized. A classic experimental research (Kleshnev, 1998) assessed the force exerted by 71 athletes in 21 boats in each phase of the rowing stroke during a competition. It has been verified that power was the main element affecting boat speed. The authors also confirm that power was significantly higher in the smaller boats, reaching 301 *watts* in single sculls(Kleshnev, 1998), which is close to the average results achieved by world elite athletes, 326.50 *watts* in the 2000 meters. This study shows that there is a weak negative correlation between body weight and height with speed at the start of the race and in the first 500m, thus suggesting that body weight and height may have some influence at the start of the race and on boat acceleration. In another review article (Soper and Hume, 2004), it has been shown that the greatest boat propulsion will depend upon the rower's physical and anthropometric capacities. Another study evaluated (Barret and Manning, 2004) 15 scullers with an average of 9.5 years of experience and found out that the tallest rowers reached higher boat speed in the 2000-meter test

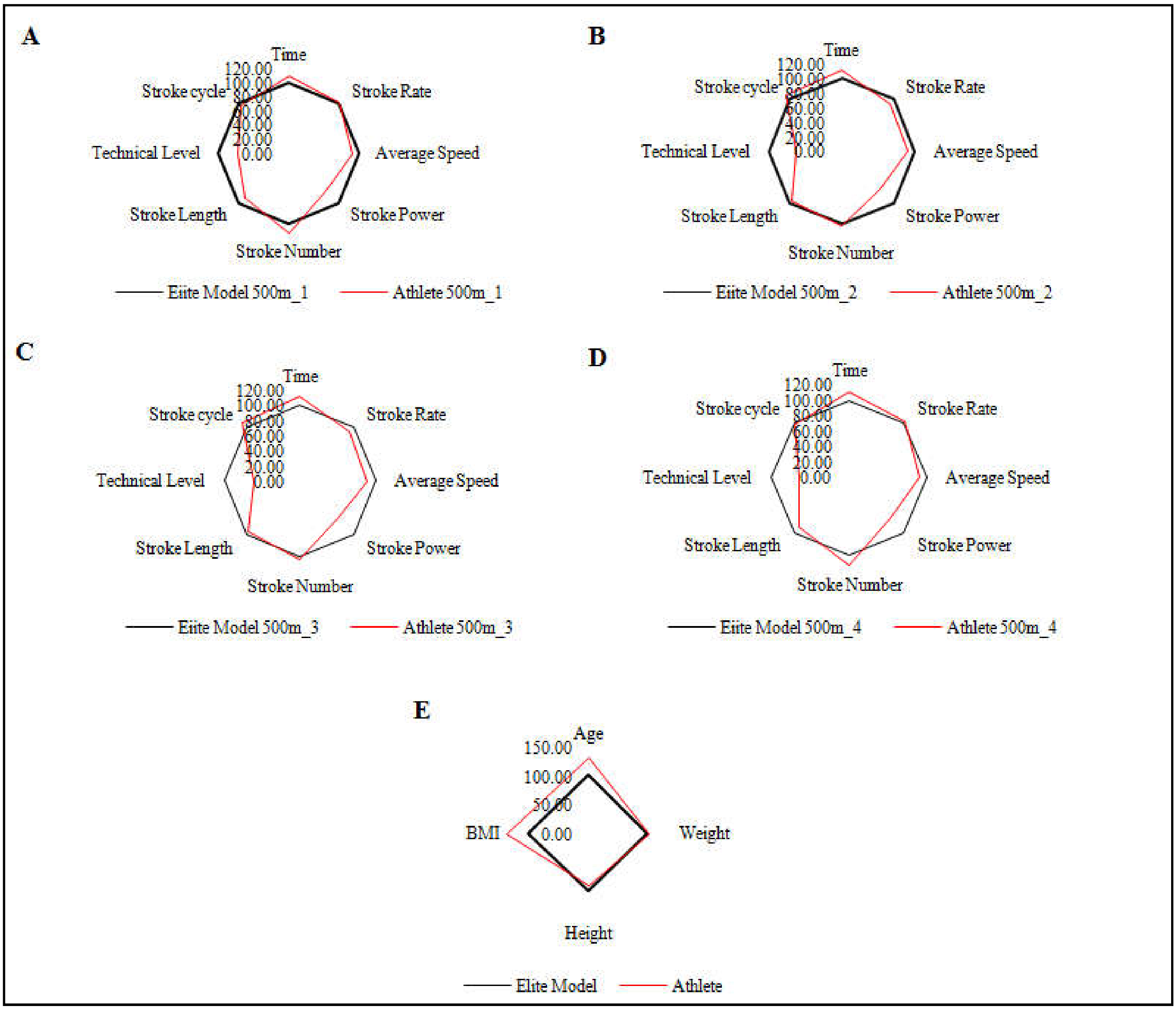


**Figure 2. Elite Model comparing the world average performance to that of a fictitious athlete, based on the competitive activity of rowers in world championships. First 500 meters of race (A), second 500 meters of race (B), third 500 meters of race (C), the last 500 meters of race and the physical characteristics (E)**

in the water. Verkhoshansky(2001) sustains the idea that speed is the main biomotor ability responsible for sports performance and that, considering other capacities, it should be the primary focus of the training system. Gomes and Souza (2009) claim that the development of speed is crucial to succeed in competitions. Considering the results discussed in this study, it is noticeable that at the start of the race and in the first 500 meters, the heavier and taller the athlete, the slower the start and the lesser acceleration will take place until it reaches top speed. This means that the rower will have to exert a significant amount of force in the initial phase to counterbalance height and weight. By doing so, the inertia can be rapidly broken just as acceleration can briefly reach maximum speed between 500 and 600 meters of race, therefore corroborating with the findings of Steinacker (1993) classic study which states that the power exerted in the initial phase is greater than that throughout the race. Furthermore, the remaining parts of the race that were assessed had a positive correlation with body weight and height, suggesting that the heavier and taller the rower, the greater the boat speed. So, based on these results we suggest a focus on power training and the development of lactic and alactic capacities, since these capacities can be stimulated in the first 120 seconds (Platonov, 2008; Gomes and Souza, 2009; Graig *et al.,* 1989) by means of interval methods comprising general, specific and competition exercises. In regard to the model of competitive activity, this study has shown that time, speed and power had a strong and statistically significant correlation with speed for all parts of the race assessed. Some authors explain that an effective coordination of force during the stroke cycle is important for performance (Anderson *et al.,* 2005; Warmenhoven *et al.,* 2018). This study not only shows that the third 500 meters of race had the highest level of correlation, but it also suggests that the greater the power and the shorter the time in the 1500 meter of race, the higher the single scull speed will be in the 2000 meters. Speed endurance had the highest correlation in the third 500 meters of the race, and therefore should be emphasized when training, always taking into consideration the speed percentages from competitions. This analysis shows that for number of strokes and stroke length, the highest level of correlation ocurred at the end of the race, thus suggesting that the smaller the number of strokes and the higher the stroke length in the last 250 meters, the higher the boat speed in the 2000 meters. This supports the assumption that boat propulsion is improved when a continuous force is exerted (Warmenhoven *et al.,* 2018) during the phases of acceleration, speed endurance and at the end of the race, since the greater the power exerted, the faster the boat moves. In addition, the first and the last 500 meters are the fastest in the race, indicating that single male scullers accelerate within the first 500 meters. Then, they speed up to 1500 meters, and from this point of the race onwards they maintain their speed and force is exerted in a more efficient way. Finally, they accelerate towards the finish line. The technical level shows, by means of percentages, how far young athletes, beginners and professional athletes are from the world record. This study also indicates a strong and statistically significant correlation, which suggests that the average speed for world championships is 13.05% below the world record.

With the development of the competitive model of elite rowers and taking into consideration the competitive variables from world championships, it is possible to compare young athletes, beginners and professional athletes to international elite athletes. This model also provides a deeper understanding of the sport's theory and practice (Platonov, 2008). It is clear, by analyzing this model, that when a greater amount of power is exerted in each stroke phase, it could enhance boat speed in the 2000m. Zamotin et al. (2014) claim that competition activity is a culmination of a long training process and that it deserves an objective, systematic and in-depth analysis. The model of competitive activity of elite rowers makes us fully aware that training beliefs need to be revised. Also, the competition system is what guides the training system nowadays, since training should be as close as possible to the competition model. Now, training volume that accounted for a large portion of training programs has been reduced and speed/muscular power are emphasized instead, changing somehow training intensity. Parameters such as the average speed for competition, stroke number (frequency), power exerted on each action, and lactate concentration have all become the most valuable elements for a coach. Even though rowing is considered a sport that requires a high VO2 Max nowadays, when it comes to winning a competition, speed strength plays a major role in achieving that. This means that athletes should be trained at the same speed as or above that of competition. Special strength becomes the main element when physically preparing rowers nowadays, although it has not been acknowledged within the general theory yet, because coaches usually prefer to work with high-volume and low muscular power training programs.

This study is far from addressing all issues concerning a specific rowing training theory. More invasive studies are still needed in order to check the morpho-functional adaptations that would be brought about by low-volume training programs that focused on neuromuscular and functional aspects. Thus, this research has showed part of the reality faced at high-performance Olympic rowing competitions. The elite model of competitive activity proposed in this study shows that the key factors for rowers in world championships are power and the way variables act. Thus, the model put forward in this paper can not only be considered an important supplement for the physical preparation of female rowers but also guide training load percentages and characteristics. Further studies might be carried out in order to verify which variables or parts of raceassessed could predict performance, by means of the multiple linear regression analysis. Developing a model for each category might also be useful in order to verify whether a shell for more than 1 rower has the same dynamics compared to the model designed for a single athlete.

## REFERENCES


Akça F. 2014. Prediction of rowing ergometer performance from functional anaerobic power, strength and anthropometric components. *Journal Human Kinet*. 41, pp. 133-142

Anderson R., Harrison A., Lyons G.M. 2005. Accelerometry-basedfeedback--can itimprovemovementconsistency and performance in rowing?. *Sports Biomech*. 04, pp. 179-195

Barrett R.S., Manning J.M. 2004. Relationships between rigging set-up, anthropometry, physical capacity, rowing kinematics and rowing performance. *SportsBiomech*. 03, pp. 221-235

Bourdon P.C., Cardinale M., Murray A., Gastin P., Kellmann M., Varley M.C., Gabett T.J., Coutts A.J., Burgess D.J., Gregson W., Cable N.T. 2017. Monitoring Athlete Training Loads: Consensus Statement. *Int J Sports Physiol Perform*. 12, pp. 2161-2170

Craig N.P., Pyke F.S., Norton K.I. 1989. Specificity of test durationwhenassessingtheanaerobiclactacidcapacity of high-performance trackcyclists. *Int J Sports Med.* 10, pp. 237-242

Dawson R.G., Lockwood R.J., Wilson J.D., Freeman G. 1998. The Rowing Cycle: Sources of Variance and Invariance in Ergometer and On-the-Water Performance. *J Mot Behav.* 30, pp. 33-43

Fox J.L., Scanlan A.T., Stanton R. 2017. A Review of Player MonitoringApproaches in Basketball: CurrentTrends and FutureDirections. J Strength Cond Res. 31, pp. 2021-2029

Gomes AC, Souza J de 2009. Futebol: Treinamento desportivo de alto rendimento, Artmed Editora, São Paulo, Brazil.

Halson S.L. 2014. Monitoring training load to understand fatigue in athletes. Sports Med. 44, pp. 139-147

Kleshnev V. 1998. Estimation of Biomechanical Parameters and Propulsive Efficiency of Rowing. Australian Institute of Sport, Biomech Department. 01, pp. 1-17

Korner T. 1993. Background and Experience With Long-Term Build-up Programmes for High Performance Rowers. FISA-Coach-Level III. 49, pp. 1-6

Liebermann DG., Katz L., Hughes M.D., Bartlett R.M., McClements J., Franks I.M. 2002. Advances in theapplication of informationtechnologyto sport performance. J Sports Sci. 20, pp. 755-769

Mikulic P., Bralic N. 2018. Elite status maintained: a 12-year physiological and performance follow-up of twoOlympicchampionrowers. *J SportsSci. 36*, pp. 660-665

Nevill A., Atkinson G., Hughes M. 2008. Twenty-fiveyears of sport performance research in theJournal of Sports Sciences. *J SportsSci.* 26, pp. 413-426

Passfield L., Hopker J.G. 2017. A Mine of Information: Can Sports Analytics Provide Wisdom From Your Data?. *Int J Sports Physiol Perform.* 12, pp. 851-855

Platonov VN 2008. Tratado Geral de Treinamento Desportivo, Phorte Editora, São Paulo, Brazil.

Plews D.J., Laursen P.B. 2017. Training Intensity Distribution Over a Four-YearCycle in Olympic Champion Rowers: DifferentRoads Lead to Rio. Int J Sports Physiol Perform. 27, pp. 1-24

Silva F.B.M da, Brito J.P. de, Gomes A.C. 2020. Remo olímpico: modelo da atividade competitiva das atletas de elite feminina. Rev Bras de Med do Esporte. 26, pp. 162-166

Silva F.B.M da., Brito J.P. de., Reis V.M. 2017 Predição do desempenho a partir das características antropométricas, fisiológicas e de força no remo. Rev Bras de Med do Esporte. 23, pp. 446-449

Smith R.M., Loschner C. 2002. Biomechanics feedback for rowing. *J Sports Sci.* 20, pp. 783-791

Soper C., Hume P. A. 2004. Towards an ideal rowing technique for performance : the contributions from biomechanics. Sports Med. 34, pp. 825-848

Steinacker J.M. Physiological aspects of training in rowing. *Int J Sports Med.* 14, pp. 3-10

Verkhoshansky Y 2001. Teoría y metodología del entrenamiento deportivo, Editorial Paidotribo, Barcelona, Espanha. Warmenhoven J., Smith R., Draper C., Harrison A.J., Bargary N., Cobley S. 2018. Force coordination strategies in on-water single sculling: Are asymmetries related to better rowing performance?. *Scand J Med Sci Sports.* 28, pp. 1379-1388

Warmenhoven J., Cobley S., Draper C., Smith R. 2018. Over 50 Years of Researching Force Profiles in Rowing: What Do We Know?.*Sports Med*. 48, pp. 2703-2714

Zamotin M., Issurin V.B. 2014. Egorenko LA. Examination of the competitive activity of the rowers os russian national rowingteam. Uchenyezapiski universitetaimeni P.F. Lesgafta. 07, pp. 69-73

********