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A Study on the Percentage of Pacing Strategies in Elite Asian Rowers: Analysis of Crew, Boat Type, and Gender

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ABSTRACT

Background: For optimal performance, rowers should maintain a consistent rowing cadence over the entire distances. However, the rowing cadence of each category can be influenced by several factors. Understanding the rowing strategy related to these factors may help improve rowing performance. **Objective:** This analytical research aimed to examine the pacing strategies used by elite Asian rowers in different categories: crew, boat type, and gender during competitions at the 2023 Asian Games. **Methods:** The official Final A competition results of 14 events, comprising 42 male and 37 female rowers, totaling 79 datasets, were used for statistical analysis. Pacing techniques for each category were analyzed in the 500 m intervals and expressed as a percentage. Pearson correlation coefficient was used to assess rowing interval correlation. **Results:** The 2- and 2X showed the most percentage change (9.56%), while the 8+ showed the lowest (6.83%). After 8.33% and 8.37% adjustments, sweeps and sculls were essentially identical. Male rowers changed 7.08%, while female rowers changed 9.49%. The 500 m and 1000 m interval had a moderate positive correlation ($r = 0.462$), while the 2000 m distance had a significant negative correlation ($r = -0.750$) and the 1000 m had a strong negative correlation ($r = -0.818$) ($p<0.05$). **Conclusion:** Rower's size and gender are the major factors influencing pacing percentage. Smaller boats are more affected than larger ones. Males are less different per interval than females. Crew, boat type, and gender may impact rowing performance during certain intervals. Coaches and athletes need specialized pacing strategies for competition success.

Key words: Water Sport, Rowing, Sports Performance, Sports Performance, Athletes

INTRODUCTION

The capacity of a rower to complete a 2000-meter race is influenced by various factors, such as the technical and complex physiological stress that occurs during the event (Volianitis et al., 2020). Consequently, the rower must possess a high level of physical fitness regarding energy systems. The keys to success for rowing athletes are speed, strength, and endurance, which are combined by energy systems that utilize high levels of aerobic (80-85%) and anaerobic energy (15-20%) (Matej et al., 2017; García-Pallarés & Izquierdo, 2011; Silva et al., 2020). In order to ascertain the optimal rowing performance, it is imperative to evaluate all pertinent variables (Held et al., 2020). Nevertheless, competition analysis can be challenging and intricate due to the significant variability of various factors (Smith & Hopkins, 2011). In addition to physical performance, the rowing pacing strategy is another critical factor that will assist athletes in accomplishing their competition objectives. Recently, it appears that elite athletes are progressively incorporating rowing strategies into their competitions to guarantee the effectiveness of their rowing (Martins et al., 2022; Mentzoni & Losnegard, 2021). They can enhance their performance by employing equations or calculations from a variety of statistics in competitions.

The majority of rowing strategy analyses in rowers uses splits to denote pacing strategies, such as 500 meter splits, to evaluate the power of each strategy employed in a competition or to analyze speed, which are depicted in the form of a parabola (Muehlbauer et al., 2010). Much evidence demonstrated that the majority of pacing strategies involve rowing in a reverse J-curve, with the highest speed in the first 500 meters, and thus maintaining the boat's pace until the finish line is reached in scull and sweep boats (Gee

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et al., 2013; Martins et al.,2022). Nevertheless, it has been common to use positive curve, even, reverse J-curve, and U-shape rowing strategies in competitions (Chu et al., 2023). The performance of rowers can be enhanced by fine-tuning the details of the rowing pacing strategy (Holt et al., 2021). This includes adapting training to the actual competition situation by utilizing data on average speed, stroke, and power stroke (Holt et al., 2020; Silva et al., 2020). Many successful rowers exhibit pacing that enhances their ability during the concluding split (Muehlbauer et al., 2010). The strategy is implemented by winners more frequently than by those who place last (Mentzoni & Losnegard, 2021). Furthermore, the investigation has indicated that paddlers, who were mature and had more experience showed superior performance when employing rowing strategies (Martins et al., 2022). Therefore, it is crucial to analyze the data from the competitions to interpret the rowing pacing strategies.

Official race results are the primary source of strategy analysis for timing strategies in analyzing of race data. In order to comprehend the pacing strategies of each rower, the duration of each pacing segment is evaluated (Martins et al., 2022; Muehlbauer et al., 2010; Silva et al., 2020). Astridge et al. (2023) demonstrated that a new pacing strategy for the rowing of each interval of pacing should be as similar as feasible to maintain a consistent (flat) rowing. The physiological response during paddling is directly influenced by avoiding a decrease or increase in paddling speed at each pace (Dimakopoulou et al., 2018). High-effort strokes or power rowing strategies during the initial 1500 meters of the race have a more detrimental effect on rowing performance due to elevated fatigue levels (Boillet et al., 2022), which may lead to diminished competitiveness. Alternatively, the primary factor may be the acceleration during the final 500 meters of the race, which is frequently observed in finals (Muehlbauer et al., 2010), may be the primary factor. Renfree et al. (2012) and Gee et al. (2013) have observed that the numerous strategies implemented in competition frequently exhibit variability. Nevertheless, the potential for complications to arise from physiological responses is likely to be mitigated by consistent boat control (Boillet et al., 2022). By comprehending the strategy of pedaling to reduce the physiological response level, athletes can achieve more consistent rowing performance by employing flat rowing strategies (Astridge et al., 2023). Another factor that influences the competition strategy is the distinction between individuals and team types, particularly the different physiological responses that are induced by each boat's rowing strategy (Muehlbauer & Melges, 2011). Furthermore, previous studies indicated that the retention of strategic ability in rowing is also influenced by gender (Warmenhoven, Cobley, Draper, Harrison, et al., 2018).

In order to improve their performance in the rowing competition, it is crucial for athletes, especially prominent Asian rowers, to have access to valuable information that can enhance their rowing strategy. This information, derived from analyzing competition data, such as numerics, parabolas, and percentages, can help them reflect on the significance of certain aspects and ultimately enhance their performance. In addition, there have been comparatively few research conducted on the elite Asian rowers. This study focuses on analyzing rowing pacing techniques, specifically assessing the differences in rowing speeds among different crews, boat types, and genders among elite rowers participating in the 2023 Asian Games.

METHOD

Study Design

This analytical research used the official data of the competitions from the 19th Asian Games Hangzhou (2023) official website (https://www.hangzhou2022.cn) to analyze the pacing strategies of rowers. The data of the competitions was selected only from the final round (Final A) based on competition categories that include number of crew: 1, 2, 4 and 8 crews, boat types: scull (two oars: X) and sweep (one oar: -), including 8+ that used one oar, and gender: male (M) and female (W). The competitions comprised M1X, W1X, M2X, W2X, M2-, W2-, LM2X, LW2X, M4X, W4X, M4-, W4-, M8+, and W8+. The data analysis for evaluating the rowing pacing strategy in this study was consistent with several previous studies (Chu et al., 2023; Martins et al., 2022; Muehlbauer et al., 2010). This research was approved by the Ethics in Human Research Committee of the Research and Development Institute, Nakhon Ratchasima Rajabhat University (HE-RDI-NRRU.011/2567), and was conducted in accordance with the ethical standards of the Helsinki Declaration.

Participants

In order to obtain the competitive data of elite rowers, a dataset that included only the official results data from all final competitions (Final A) was selected. Extracting data from the last stage would yield accurate high-performance data for the athletes. The dataset comprised 79 individual datasets sourced from 42 male and 37 female rowers, who participated in a total of 14 competitions. This data was categorized based on the number of crews, boat types, and genders. Before conducting data analysis, the data was thoroughly investigated and scrutinized by three seasoned rowing strategy analysts, who possessed over 3 years of expertise. The purpose of this process was to identify and rectify any potential errors present in the data. The data utilized for analysis would not disclose the athletes' identity, name, and nationality.

Procedures and Data Analysis

Data of race times were converted to percentages and analyzed with some data presented as a parabola to make it easier to understand and apply. To analyze the rowing strategies of each type of rowers, races were divided into four 500-meter intervals: 500 m (P1), 1000 m (P2), 1500 m (P3), and 2000 m (P4).

Data analysis composed of percentage change of pacing strategies, percentage of speed loss, percentage range, and pacing strategy correlation. The percentage change of pacing strategies was calculated using the following formula:

[(Max pace – Min pace) ÷ Min pace] x 100

The percentage range was estimated to show the percentage range of change in each category. The analysis of pacing strategy correlation was conducted to show the correlation of pacing strategies in each 500 m split throughout the 2000 m distance.

Statistical Analysis

The SPSS V.26 computer program was used for statistical analyses. Pearson correlation coefficient was employed to evaluate the relationships between the pacing strategies in each rowing interval (500 m). A statistical significance was accepted at $p<0.05$. For easier understanding, the percentage change and the percentage range are based on the average percentage of rowing in each interval.

RESULTS

Upon evaluation of the crew category, it was found that the crew of 8+ rowers had the smallest percentage change, accounting for 6.83%. Moreover, this crew had a percentage range spanning from 98.02% to 103.38% (Figure 1). For the type of boat, the sweeps and the sculls exhibited similar percentage changes and percentage ranges. The percentage change for the sweeps was 8.33% and the range was 97.94% to 104.08%. For the sculls, the percentage change was 8.37% and the percentage range was 97.90% to 104.04%. When considering in gender, the study revealed that men experienced the percentage change of 7.08% and the percentage range of 98.29 to 103.57%, both of which were lower than those observed in women. On the other hand, female rowers had the percentage change of 9.49% and the percentage range of 97.58 to 104.49% (Figure 2). The percentage of pacing strategy in each interval for all categories is presented in Table 1, and the percentage change in pacing strategies across all categories is shown in Figure 3.

The Pearson correlation coefficient analysis of the percentage pacing strategy in each interval revealed a moderate positive relationship ($r = 0.462$) between the 500 m and 1000 m distances. The 500 m distance exhibited a moderate negative correlation with the 1500 m distance, with a correlation coefficient (r) of -0.403. Similarly, the 500 m and 1000 m distances showed a negative correlation with the 2000 m distance (500 m vs. 2000 m, $r = -0.750$; 1000 m vs. 2000 m, $r = -0.818$), and these correlations were statistically significant ($p<0.05$). The correlation data are presented in Table 2, and Figure 4.

DISCUSSION

The study revealed that rowers in the final rounds of the 2- and 2X events, as well as the 1X event, exhibited the most significant percentage changes in average speed in their rowing techniques. The percentage changes of both events exceeded the speed changes observed for the four and eight-rowers in both scull and sweep categories. The strategy by the crews consisting of one or two rowers involves maintaining a consistent pace towards upward-sloping curves, as the differences between each pace being greater than in other categories. In a smaller crew, it becomes more challenging to control pacing methods due to the dependence of the boat's speed on the rowing technique and the rower's performance (Buckeridge et al., 2015; Holt et al., 2020). According to Renfree et al. (2012), each athlete possesses distinct technical and performance qualities. It is uncommon for a single rower to have the capacity to apply force and influence the speed of the entire boat, as stated by Chu et al. (2023). On the other hand, it is evident that boats with four or eight rowers experience a less average percentage drop. This is due to the presence of more rowers, which leads to a more constant and balanced rowing strategy. Additionally, the strong bond between athletes enhances the effectiveness of rowing strategies (Jensen et al., 2023). Consequently, it is challenging to uphold pace tactics for rowing in boats with a reduced

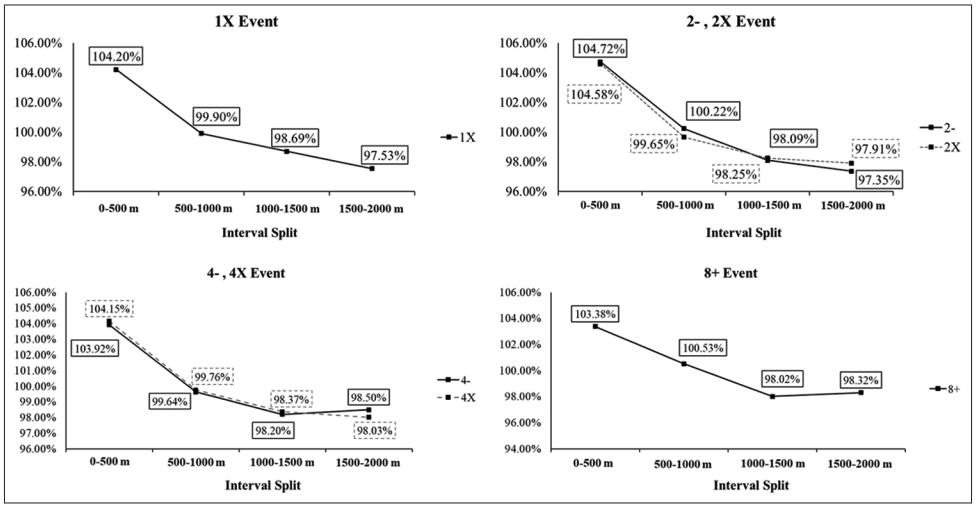

Figure 1. The parabolic classification of percentage pacing strategies for each number of crew category (1X, N=12; 2- and 2X, N=33; 4- and 4X, N=23; 8+, N=11)

Sculls: two oars, Sweeps: one oar, 1X, 2X, and 4X: Sculls, 1-, 2-, 4-, and 8+: Sweep, m: meter

Table 1. The percentage pacing strategies in each interval for all categories

Categories	N	Time Average (min: sec)	P1 (%)	P2 (%)	P3 (%)	P4 (%)	Range of percentage	% Change
Crew								
1X	12	01:53.0	104.20%	99.90%	98.69%	97.53%	97.53-104.20%	9.30%
2-,2X	33	01:46.0	104.65%	99.94%	98.17%	97.63%	97.63-104.65%	9.56%
4-,4X	23	01:38.9	104.04%	99.70%	98.29%	98.26%	98.26-104.04%	7.61%
8+	11	01:34.5	103.38%	100.53%	98.02%	98.32%	98.02-103.38%	6.83%
Boat Types								
Sweep (2-,4-8+)	32	01:41.3	104.08%	100.14%	98.08%	97.94%	97.94-104.08%	8.33%
Scull (1X,2X,4X)	47	01:44.4	104.04%	99.82%	98.47%	97.90%	97.90-104.04%	8.37%
Gender								
Men	42	01:37.4	103.57%	99.73%	98.59%	98.29%	98.29-103.57%	7.08%
Women	37	01:49.2	104.49%	100.11%	98.10%	97.58%	97.58-104.49%	9.49%

Sculls: two oars, Sweeps: one oar, 1X, 2X, and 4X: Sculls, 1-, 2-, 4-, and 8+: Sweep, min: sec : minute: seconds, N : number of rowers in each event, P1 : 500 meters, P2 : 1000 meters, P3 : 1500 meters, P4 : 2000 meters

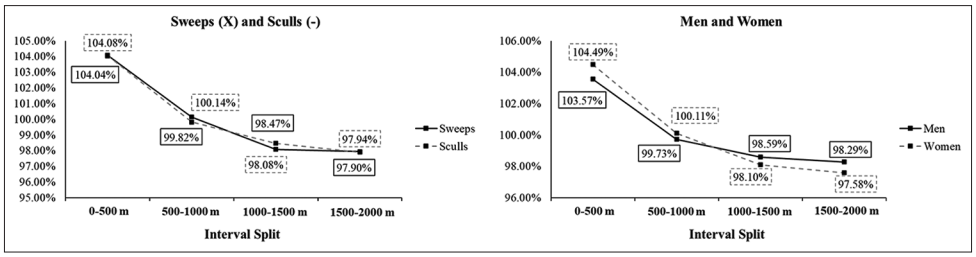

Figure 2. The parabolic classification of percentage pacing strategies for boat type and gender (Sweeps, N=32; Sculls, N=47)
Sculls: two oars, Sweeps: one oar, 1X, 2X, and 4X: Sculls, 1-, 2-, 4-, and 8+: Sweep, m: meter

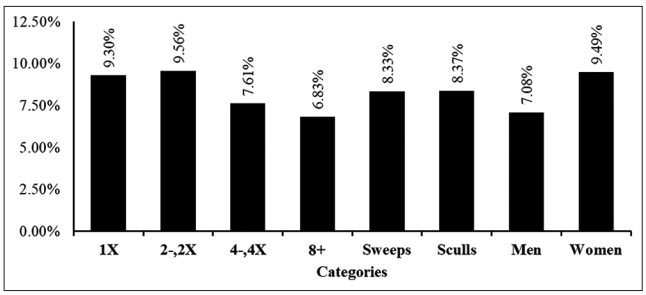

Figure 3. The percentage change in pacing strategies across all categories
Sculls: two oars, Sweeps: one oar, 1X, 2X, and 4X: Sculls, 1-, 2-, 4-, and 8+: Sweep, m: meter

number of individuals. However, in a boat with a larger size, there may be associated psychological elements at play, as the act of rowing together as a team fosters greater teamwork among athletes.

The results did not vary based on the type of boat used, whether it was a sweep or scull. This can be attributed to the similarity in training programs or methods for both types of boats, or the athlete's familiarity with rowing these boats. As a result, there was no difference in terms of pacing strategies, including similar speed percentages. Male rowers exhibited a smaller reduction in rowing speed compared to female rowers, indicating a consistent approach to pacing. This finding aligns with previous research suggesting that there are fewer established strategies among women (Chu et al., 2023). Additionally, it suggests that women may not have consistent control over technique and exertion in rowing, which could limit their ability to employ strategic approaches during competition (Warmenhoven, Cobley, Draper, Harrison, et al., 2018). This finding indicates that the rowing tactics employed in each event generally vary, and this variation may be influenced by the size of rowers involved.

Maintaining consistent performance throughout the tournament is crucial for athletes to maximize their chances of winning (Astridge et al., 2023; Li et al., 2023). While athletes generally maintain their speed effectively over distances ranging from 500 to 1000 meters, paddle performance declines as the race distance increases. This decline may be attributed to athletes trying to accelerate by increasing their strokes and power too much in the initial phase, leading to a decrease in performance during the final 500 meters before reaching the finish line (Boillet et al., 2022). The decreased performance of rowing, leading to a notable negative correlation between the 500 m, 1500 m, and 2000 m rowing distances, as well as the 1000 m and 2000 m. This outcome suggests that the rower's pacing tactics result in a constant average reduction, aligning with the existing rowing techniques characterized by a positive curve (Chu et al., 2023) and a reverse J-curve, albeit with minor variations. Each boat category prioritizes starting with a substantial amount of power in order to establish and maintain a lead throughout the race. This strategy aims to reduce energy consumption in

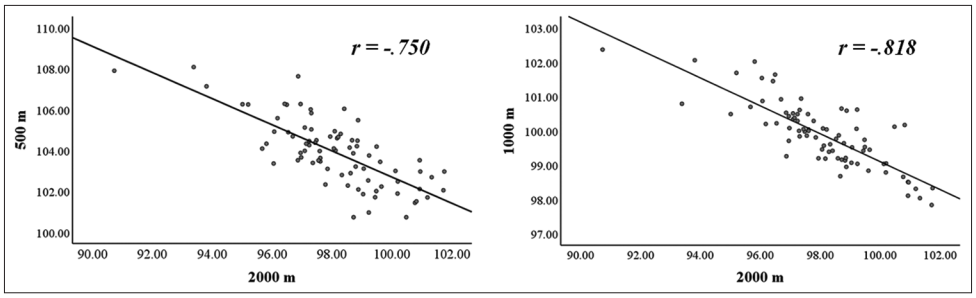

Figure 4. The negative correlation between interval splits
m: meter

Table 2. The correlation between the percentage pacing strategies in each interval

Distance	500 m	1000 m	1500 m	2000 m
500 m	1			
1000 m	0.462**	1		
1500 m	-0.403**	0.038	1	
2000 m	-0.750**	-0.818**	-0.150	1

*indicates significant correlation between the distance intervals ($p<0.05$); m : meter

the final 500 meters, increasing the likelihood of winning the race (Ofoghi et al., 2011). However, the implementation of the flat-pace approach remains uncommon in this competition. Pacing strategy profiles can enhance the comprehension of rowing methods for coaches and athletes (Chu et al., 2023; Silva Alonso et al., 2018; Warmenhoven, Cobley, Draper, & Smith, 2018).

Furthermore, the utilization of biomechanical and physiological knowledge in training is crucial for enhancing rowing performance, as it aids in achieving the objectives established by the coach (Yusof et al., 2020). Rowers employ techniques, as described by Li et al. (2023), to sustain energy levels throughout competitions and prevent physical exhaustion. This involves implementation of pacing tactics and prioritization of anaerobic energy systems to enhance the effectiveness of rowing strategies in elite athletes, as highlighted by Sandford et al. (2021). In future competitions, the utilization of physiological principles pertaining to energy systems may have a more significant impact (Akça, 2014; Astridge et al., 2023). Thus, it is imperative for coaches to train in connecting the competitive objectives and physical abilities of athletes in order to enhance their peak performance levels (Connolly & Janelle, 2003). According to the current analysis, rowers still use positive curves, even curves, or reverse J-curves as their rowing methods. The presence of either positive or negative circumstances throughout the race may result in a divergence in the approach to rowing. Boats with tiny crews consisting of one or two rowers may encounter more difficulty in maintaining their speed during pacing compared to other types of boats. This is because these smaller crews have a stronger influence on managing the stroke and speed of the boat. In upcoming years, mastering rowing strategies in rowing competitions may gain significance, particularly at the 2028 Summer Olympics in Los Angeles. The distances in the races will be shortened, potentially intensifying the sport's physical demands and strategic aspects (Volianitis et al., 2022; Astridge et al., 2023). This study offers valuable insights into the determinants of pacing tactics and their correlation with race distances, using authentic data from legitimate races. These findings can be utilized to enhance coaching preparation. Nevertheless, while this study classifies pacing strategies, its scope is restricted by the lack of detailed data on each specific race. Therefore, it is imperative to seek additional pertinent data from diverse races in order to obtain more precise information.

CONCLUSION

Variations in rower's size, number, or gender pose challenges in managing the boat velocity. These findings suggest that elite Asian rowers may experience a decline in performance as they approach the end of the race. Elite Asian rowers continue to face the issue of maintaining an effective rowing strategy throughout their rowing sessions. Interpreting the results of this study can help using the right rowing strategies and being provided with a thorough understanding, leading rowers to enhance their chances of success in competition. Analyses of the rowing pacing strategies may be required in order to assist coaches and athletes in comprehending rowing strategies to enhance their performance.

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DATA AVAILABILITY

This study information is based on the official website of the 19th Asian Games 2023 (https://www.hangzhou2022.cn).

AUTHORS CONTRIBUTION

W. K.: Conceptualization, Methodology, Writing - Review & Editing, W. R.: Writing - Original Draft, P.P.: Conceptualization, Formal analysis, N. S.: Software, Writing - Review & Editing, K.P.: Writing - Original Draft, W. M.: Validation, Writing - Review & Editing, B. P.: Software, Resources, P.

J.: Resources, Data Curation, N. S.: Resources, Data Curation, and T. S.: Validation, Investigation, Writing - Review & Editing, All authors collectively approved the final versions.

ETHICAL APPROVAL

This research was approved by the Ethics in Human Research Committee of the Research and Development Institute, Nakhon Ratchasima Rajabhat University (HE-RDI-NRRU.011/2567), and was conducted in accordance with the ethical standards of the Helsinki Declaration.

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