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# PHYSIOLOGICAL INSIGHTS INTO ELITE SPRINT PADDLERS: UNRAVELLING PERFORMANCE DYNAMICS AND TRAINING IMPLICATIONS

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**Abstract**

**Study purpose.** This study aimed to investigate the relationship between physiological reactivity and sprint paddling performance among elite athletes, focusing on cardiorespiratory responses, metabolic efficiency, and energy utilization patterns.

**Materials and methods.** A group of N = 20 elite sprint paddlers from various regions in India was meticulously selected for this study. Detailed assessments of cardiorespiratory responses, metabolic efficiency, and energy utilization patterns were conducted using standardized protocols and cutting-edge measurement techniques. Individual differences among athletes were carefully documented.

**Results.** The study revealed a remarkable homogeneity among the athletes, reflecting stringent training standards. However, intriguing individual differences emerged, particularly in cardiorespiratory reactivity. Athletes with swift neural responses and adept metabolic acidosis adaptation showcased enhanced overall performance, indicating the critical role of the nervous system and efficient respiratory mechanisms in optimizing paddlers' capabilities. Analysis of $CO_2$ emissions and lactate concentrations indicated a balanced energy utilization pattern and optimal anaerobic metabolism and respiratory responses. Balancing anaerobic alactate and lactate capacities emerged as pivotal.

**Conclusions.** The findings underscore the need for targeted training programs that leverage individual differences, enhance neural adaptations, and metabolic acidosis tolerance, and optimize energy pathways. These transformative insights offer coaches, sports scientists, and athletes valuable tools to elevate performance outcomes. The study enriches our understanding of sprint paddling and serves as a paradigm for studying elite athletic performance, guiding the future of sports science and coaching. Future research avenues include exploring the long-term impact of tailored training interventions, investigating molecular mechanisms of cardiorespiratory reactivity, and studying psychological aspects of athletic performance. Comparative studies across diverse sports disciplines promise universal insights into elite athletic performance.

**Keywords:** sprint paddlers, physiological reactivity, athletic performance, cardiorespiratory responses, training interventions.

## Introduction

Research conducted recently highlights the indisputable association between great athletic accomplishments and a strong functional potential within the realm of canoe and kayak rowing (Kong et al., 2018; López-Plaza et al., 2019; Kong et al., 2020). These findings were published in Kong et al. (2018), López-Plaza et al. (2019), and Kong et al. (2020). A significant portion of this potential among paddlers may be ascribed to the accessibility of efficient high-capacity energy supply systems (Tesch, 1983; Sheykhlouvand et al., 2018; Pickett et al., 2018; Paquette et al., 2018). Several research (Garca-Pallarés et al., 2009; Guo et al., 2020; Diachenko et al., 2020, 2021) have already established techniques for assessing the power of these energy supply systems among highly trained paddlers at various distances. These studies may be found in the references section of this article. Researchers in the past have found that certain variables, such as the maximal aerobic power (MAP), lactate threshold (LT2), and the energy cost of kayaking per unit distance, can accurately predict the performance of kayak athletes over a wide range of distances, from 1000 metres all the way down to 200 metres (Fry & Morton, 1991; Bishop et al., 2002; van Someren & Howatson, 2008; Zamparo et al., 1999). Additionally, it has been shown that elite-level paddlers

have a lactate threshold at roughly 80% of their $VO_2$max and possess high aerobic capacities, both of which contribute considerably to the generation of energy, particularly across lengths of 200, 500, and 1000 metres (Borges et al., 2015). This finding was made possible by the fact that these paddlers have high aerobic capacities. Anaerobic capacities, including peak power, total work, and peak lactate concentration in a 30-second maximal effort on a kayak ergometer, have shown substantial correlations with on-water performance in distances of 200, 500, and 1000 metres (van Someren & Palmer, 2003; van Someren & Howatson, 2008; Borges et al. 2015). However, the relationship between other fitness variables, including the respiratory system reactance, and metabolic acidosis parameters concerning 200-meter. It should come as no surprise that current methods of training need to be subjected to a thorough analysis, in particular those used by experienced paddlers. This sense of urgency is brought on by the fact that a particular group may have to adapt the training methods they use in order for them to be compatible with a fresh competition format (Dyachenko, 2007; Kong et al., 2019). Accordingly, the fundamental purpose of this research is to expand our awareness of the inequalities in functional support for exceptional endurance across uniform groups of paddlers, who have been categorised based on sports qualification. To be more specific, the participants in this research include male kayak paddlers, male canoeists, and female kayak paddlers who specialise in paddling over a distance of 200 metres. The purpose of this investigation is to delve deeper into the nuanced intricacies of their physiological capacities and performance metrics within the specified competitive framework. In doing so, the investigators hope to shed light on the intricate interplay between various physiological variables and the specialised training requirements that are necessary in this area.

## Materials and Methods

### *Participants*

The study encompassed an extensive geographical spectrum within India, with data sourced from distinct regions across Indian states. The research was conducted during varying training periods, focusing on participants gathered from the esteemed National Aquatic Sports Training Centers. The study cohort comprised 20 meticulously selected qualified paddlers, representing a diverse pool of talents. This group included elite athletes, as well as members hailing from state teams spanning seven different regions of India.

The data acquisition process was methodically structured to ensure comprehensive insights into the functionality levels of the participants. Rigorous assessments were carried out on the selected paddlers, employing standardized protocols and tools. These assessments were meticulously conducted during specific training intervals, capturing the nuanced dynamics of their physiological responses and performance capabilities.

The inclusion criteria for the study participants were stringent, ensuring a high level of competence and uniformity within the sample group. Paddlers were chosen based on their proven qualifications and notable achievements, reflecting a rich blend of skills and expertise. The research specifically targeted individuals showcasing exceptional prowess in the domain of aquatic sports, adhering to the stringent standards set forth by national and state-level competitions. Ethical guidelines and protocols were strictly adhered to throughout the study. Informed consent was obtained from all participants, emphasizing their voluntary participation and understanding of the research objectives. Additionally, the study procedures were ethically reviewed and approved by the relevant institutional review boards, ensuring the well-being and rights of the participants were upheld at all times.

### *Research Protocol*

#### *Measurement of Physical Characteristics, Gas Exchange, HR, and Blood Lactate*

The study meticulously assessed the physiological parameters of the participants, employing advanced techniques to delve into their aerobic capacities and cardiorespiratory responses. Minute ventilation ($\dot{V}E$), oxygen consumption ($\dot{V}O_2$), and $CO_2$ production ($\dot{V}CO_2$) were precisely determined on a breath-by-breath basis, utilizing the state-of-the-art Oxycon mobile metabolimeter (Jaeger). The accuracy of the metabolic unit was assured through meticulous calibration with a precisely composed gas mixture (19.00% $O_2$, 5.00% $CO_2$). Heart rate (HR) was continuously monitored at 5-second intervals using a high-precision HR monitor (S610 Polar Electro, Kempele, Finland), ensuring real-time tracking of cardiovascular responses. Furthermore, the blood lactate concentration ([La]b) was determined post-exercise through a portable lactate analyzer (Biosen S. line lab +). Blood samples, critical for accurate lactate level assessments, were carefully collected from the earlobe at the conclusion of each test.

### *Ergometric Assessment*

A modified kayak-ergometer (Dansprint PRO) served as the primary apparatus for ergometric evaluations. Ergometric power (EP) of work was meticulously recorded during the exercise sessions, providing crucial data on the participants' energy expenditure and anaerobic capacities. All participants engaged in incremental exercise tests conducted on separate days, ensuring a robust study design. The intervals between these sessions were carefully controlled, with a minimum of 24 hours and a maximum of 84 hours between tests. This approach-maintained consistency while allowing participants adequate recovery periods to prevent fatigue-related confounding variables. The testing program was meticulously structured as a comprehensive test battery, strategically designed to assess specific components of aerobic abilities and cardiorespiratory responses among athletes. Each test within the battery was meticulously crafted to address distinct physiological aspects, ensuring a nuanced evaluation of the participants' capabilities.

The exercise protocols were designed with precision to elicit targeted physiological responses. Work intervals, characterized by maximum intensity, were interposed with rest intervals ranging from 40 seconds to 80 seconds. These carefully calibrated intervals facilitated the release of lactic acid into the bloodstream, augmenting the concentration of

**Table 1.** Physiological Indicators and Their Characteristics in Paddlers' Performance Evaluation

| Indicators | Test or Period of Measurement | Characteristics |
|---|---|---|
| Training Impulse, TI (c.u.) | Standard Work, 4 min | Degree of Intensity of Functional Support of Work |
| Watts Mean (13 s) | Test 13 s, Maximum Work | Paddlers' Work Release during Anaerobic Alactate Energy Supply |
| Watts Mean (37 s) | Test 38 s, Maximum Work | Paddlers' Work Release during Anaerobic Lactate (Glycolytic) Energy Supply |
| Watts Mean (30-39 s) | Work Release Peak, 30-39 s | Work Release during Peak Period of Anaerobic Lactate (Glycolytic) Energy Supply |
| Watts Mean (95 s) | Test 95 s, Maximum Work | Paddlers' Work Release during Anaerobic Energy Supply |
| Lactate, $mmol \cdot l^{-1}$ | After Test Task | Integral Physiological Characteristics of Power and Capacity of Anaerobic Energy Supply |
| $VE/PaCO_2$ | Test 13 s, Maximum Work | Respiratory System Reactance to Increase of Metabolic Acidosis |
| $VE/PaCO_2$ | Test 37 s, Maximum Work | Respiratory System Reactance to Increase of Metabolic Acidosis |
| $VO_2max$ ($ml \cdot min^{-1} \cdot kg^{-1}$) | Test 85 s, Maximum Work | Paddlers' Ability to Reach Maximal Aerobic Power under Conditions of Sprinting Type Training and Competition Loads |
| HR Restoration to 120 $bps^{-1}$ | During 2-4 minutes Restoration | Degree of Intensity of Functional Support of Work |

blood lactate in the muscles before the final maximum work phase. This approach allowed for the systematic exploration of anaerobic alactate and anaerobic lactate (glycolytic) pathways, providing valuable insights into the participants' metabolic responses. This rigorous and meticulously designed research protocol ensured the acquisition of high-quality data, allowing for a comprehensive analysis of the participants' physiological capacities and performance metrics in the context of their training and competition readiness.

Table 1 provides a comprehensive overview of key physiological indicators and their corresponding characteristics used in the evaluation of paddlers' performance. These indicators, measured during specific tests or periods, offer valuable insights into paddlers' aerobic and anaerobic capacities, energy supply systems, respiratory responses, and overall functional support during intense physical activities. Each indicator represents a distinct aspect of paddlers' physiological responses, aiding in the assessment of their athletic capabilities and training effectiveness.

The testing program was meticulously structured as a cohesive test battery, with each test methodically designed to address specific physiological tasks. These tests were meticulously executed in a predetermined sequence to ensure the systematic evaluation of paddlers' performance.

Preserving individual maximum parameters of ergometric power and carefully regulating rest intervals were paramount. Rest intervals were tailored, with intervals of 20 to 35 seconds allowing for a minute of recovery, while intervals of 40 to 80 seconds provided a more extensive five-minute recovery period. This precise structuring allowed for complete recovery, enabling in-depth diagnostics of the anaerobic energy supply system among sprint paddlers. Specifically, it facilitated the examination of anaerobic alactate and lactate (glycolytic) power, as well as anaerobic capacity. Furthermore, the testing program created an environment conducive to observing the reactive properties of the cardiorespiratory system and the power of aerobic energy supply during physical exertion. Noteworthy is the absence of parameters indicating the degree of stress on the cardiorespiratory system during work, such as training impulse and organism recovery rate, within the assessment system presented in the table. This omission stems from the inherent individuality of these evaluation criteria. Each athlete's unique physiological responses are considered dynamically, reflecting the evolving state of the athlete's body throughout the monitoring of their functional abilities. These personalized markers serve as vital indicators, providing nuanced insights into the athlete's physiological state during the rigorous training and evaluation process.

### *Statistical Analysis*

The study employed rigorous methods of mathematical statistics to ensure a robust analysis of the collected data. Descriptive statistics were utilized, involving tabular presentations of individual variables, mean arithmetic value (M), and standard deviation (SD). These calculations provided a comprehensive overview of the dataset's central tendencies and variability. To assess the normality of the sample data, both the normal distribution formula and the Shapiro-Wilks test were applied. The Shapiro-Wilks test, a powerful tool for examining normality in relatively small sample sizes, was particularly instrumental in this analysis. The significance level ($\alpha$) was set at $\leq 0.05$, signifying the threshold for statistical significance. In cases where the p-value was less than or equal to 0.05, the results were deemed statistically significant, indicating departures from normal distribution. Additionally, the study utilized the non-parametric Mann-Whitney test, which is especially suited for comparing two independent groups when the assumptions of normality and

homogeneity of variance are not met. This method enabled a rigorous examination of differences between groups, providing valuable insights into the unique characteristics of each subgroup under consideration. By employing these advanced statistical techniques, the study ensured a meticulous analysis of the data, leading to scientifically valid conclusions regarding the studied parameters.

## Results

The indicators delineating the functional abilities of sprint paddlers, as presented in Table 2, underscore the remarkably high and distinctive demands placed on the development of specific aspects of functional support essential for achieving peak performance efficiency in the 200-meter distance category. This distinction becomes evident through the average values of these indices among paddlers belonging to a homogeneous group. Additionally, these metrics are reinforced by data characterizing the functional abilities of sprint paddlers who have demonstrated exceptional athletic prowess on the international stage. These insights have been meticulously gathered through extensive and long-term observations of elite athletes, particularly focusing on the leading athletes of China. The parameters defining the upper echelons of these indicators reveal a profound insight into the exceptional capabilities of sprint paddlers: "Aerobic Power ($VO_2$max): The observed range for aerobic power ($VO_2$max) spans between 65.3-73.5 ml·min$^{-1}$·kg$^{-1}$ for men and 62.0-65.4 ml·min$^{-1}$·kg$^{-1}$ for women. These values underscore the extraordinary cardiovascular capacities essential for sustained performance at the highest levels. Maximum Lactate Concentration in Blood (La max): The range for maximum lactate concentration in blood (La max) is found to be between 22.5-25.0 mmol·l$^{-1}$ for men and 15.5-17.1 mmol·l$^{-1}$ for women." These values illuminate the exceptional anaerobic thresholds and the body's ability to manage lactate production during intense exertion, a crucial factor in sustaining high-speed performances over short distances. These meticulously observed and quantified parameters serve as a testament to the extraordinary physiological capacities exhibited by elite sprint paddlers, shedding light on the specialized and demanding nature of

**Table 2.** Physiological indicators and performance metrics of sprint paddlers

| Indicators | Values of Indicators (M ± SD) | Highest Values of Indicators | Reduced Values of Indicators |
|---|---|---|---|
| **Values of Indicators for Men – Kayak** | | | |
| $VO_2$ max, ml·min$^{-1}$·kg$^{-1}$ | 64.7 ± 2.5 | 64.7 | 56.5 |
| VE/$PaCO_2$ 10 s | 2.1 ± 0.7 | 3.0 | 1.2 |
| VE/PaCO2 30 s | 3.7 ± 0.9 | 4.9 | 2.3 |
| La max, mmol·l$^{-1}$ | 17.5 ± 1.1 | 20.7 | 14.3 |
| W10 s, Watt | 550.0 ± 9.0 | 564.0 | 520.0 |
| W30 s, Watt | 485.0 ± 10.0 | 502.0 | 450.0 |
| W25-30 s – 30 s of test, Watt | 520.0 ± 8.5 | 536.0 | 465.0 |
| W90, Watt | 275.0 ± 12.0 | 290.0 | 250.0 |
| **Values of Indicators for Men – Canoe** | | | |
| $VO_2$ max, ml·min$^{-1}$·kg$^{-1}$ | 65.0 ± 2.3 | 65.0 | 55.0 |
| VE/$PaCO_2$ 10 s | 2.0 ± 0.6 | 3.0 | 1.2 |
| VE/$PaCO_2$ 30 s | 3.5 ± 1.0 | 4.7 | 2.6 |
| La max, mmol·l$^{-1}$ | 16.8 ± 1.0 | 20.3 | 15.7 |
| W10 s, Watt | 455.0 ± 6.5 | 475.0 | 448.0 |
| W30 s, Watt | 420.0 ± 13.0 | 438.0 | 400.0 |
| W25-30 s – 30 s of test, Watt | 435.0 ± 8.0 | 460.0 | 420.0 |
| W90, Watt | 265.0 ± 9.0 | 285.0 | 240.0 |
| **Values of Indicators for Women – Kayak** | | | |
| $VO_2$ max, ml·min$^{-1}$·kg$^{-1}$ | 59.8 ± 2.6 | 60.5 | 49.7 |
| VE/$PaCO_2$ 10 s | 2.1 ± 0.4 | 2.8 | 1.3 |
| VE/$PaCO_2$ 30 s | 3.4 ± 0.6 | 4.4 | 2.2 |
| La max, mmol·l$^{-1}$ | 16.5 ± 1.1 | 18.5 | 10.9 |
| W10 s, Watt | 320.0 ± 2.5 | 328.0 | 298.0 |
| W30 s, Watt | 295.0 ± 8.5 | 315.0 | 260.0 |
| W25-30 s – 30 s of test, Watt | 310.0 ± 7.5 | 320.0 | 285.0 |
| W90, Watt | 175.0 ± 5.5 | 188.0 | 152.0 |

competitive paddling at the international 200-meter distance level.

The data collection, which was collected from twenty different sprint paddlers, offers a treasure mine of information about their physiological capabilities. When compared across various categories of paddlers, the results of an analysis of aerobic power, as measured by $VO_2$max, indicate impressive levels.

Power aerobically (attained at $VO_2$max): Male Kayakers: The mean $VO_2$max for male kayakers is 64.7 2.5 ml $min^{-1}$ $kg^{-1}$, which demonstrates that they have remarkable cardiovascular endurance. Men (Canoe): Male canoe paddlers have a $VO_2$max of 65.0 2.3 ml·$min^{-1}$$kg^{-1}$, which demonstrates that they have powerful aerobic capacity. Women (Kayak): Women who participate in kayaking have a mean $VO_2$max of 59.8 2.6 ml·$min^{-1}$ $kg^{-1}$, which demonstrates that they have an admirable level of cardiovascular fitness. Parameters Relating to Respiration (VE/$PaCO_2$): Men (Kayak and Canoe): Both male kayak and canoe paddlers demonstrate efficient respiratory responses, with VE/$PaCO_2$ levels demonstrating their competent regulation of metabolic acidosis during extreme exercise. This is true regardless of the kind of paddling they engage in. Women (Kayak): Female kayakers have good respiratory control as well, as demonstrated by the values of their VE/$PaCO_2$ ratios. Anaerobic Threshold (La max): Men (Kayak & Canoe): 1 minute and 30 seconds. The anaerobic capacity of men kayak and canoe paddlers are significant, as shown by mean lactate concentrations (La max) that are within the competitive levels for their respective sports. Women (Kayak): Female kayakers have been shown to have outstanding anaerobic threshold values, which demonstrates their capacity to maintain high-intensity activities over time. Men's (Kayak & Canoe) Power Output (Watts): In the canoe and kayak divisions for male paddlers, powerful power outputs are shown at a variety of time intervals, highlighting their explosive strength and speed. Women (Kayak): Female kayakers demonstrate noteworthy power outputs, which indicate their capacity to create large force during sprints. This is especially true for female kayakers who compete in the Olympic Games. The amazing capabilities of sprint paddlers are shed light on by this in-depth examination of physiological signs and performance measurements. These athletes represent the pinnacle of physical capability because not only do they have outstanding aerobic endurance and efficient respiratory responses, but they also have strong anaerobic thresholds and fearsome power outputs. These results not only highlight the athletes' devotion and training, but they also offer coaches and sports scientists with significant information that may be used to improve training programmes and provide players a competitive advantage. This investigation provides a comprehensive look into the physiological underpinnings that push these athletes to triumph in the domain of sprint paddling, where every second and every stroke matters to determine the winner. The persistent devotion and physical prowess shown by these paddlers is evidenced by the synergy of their cardiovascular resiliency, respiratory efficiency, and muscular strength, which was displayed throughout the race. Such sophisticated studies pave the way for improving training approaches, nurturing a new generation of top athletes, and pushing the frontiers of human performance in the exciting seas of sprint paddling as the athletic world continues to progress.

## Discussion

The presented data and subsequent analysis offer a profound insight into the complex interconnections between physiological reactivity and performance metrics among sprinter paddlers. This discussion delves deeper into the implications of these findings, shedding light on the significance of the observed trends and their potential applications in the realm of competitive sports.

Homogeneity and Individual Differences: The homogeneity observed within the paddlers' group is a testament to the rigorous training regimens and selection processes prevalent in elite sports. However, despite this uniformity, the study uncovers intriguing individual differences, particularly in the reactive properties of the cardiorespiratory system. These differences are highlighted in the VE/$PaCO_2$ ratios during specific test tasks, indicating diverse responses among athletes. Understanding these variations is vital for tailoring training programs to accommodate individual physiological profiles, ensuring optimal performance enhancements. Cardiorespiratory Reactivity and Performance: One of the key findings of this study is the link between heightened cardiorespiratory reactivity and superior performance levels among sprinter paddlers. Notably, athletes demonstrating rapid and robust responses in the neural phase (as observed in the 10-second test) and efficient adaptation to metabolic acidosis during the 30-second task exhibited enhanced overall performance. This insight underscores the critical role of neural adaptations and efficient respiratory responses in sprint paddling, emphasizing the need for targeted training to enhance these specific attributes. $CO_2$ Emissions and Performance Consistency: The study's consistency in $CO_2$ emissions across the athletes, as indicated by the minimal range of individual differences, is a noteworthy finding. This uniformity suggests a standardized metabolic response within the group, indicating a balanced energy utilization pattern during high-intensity efforts. Maintaining consistent $CO_2$ emissions is crucial for sustaining energy levels and preventing premature fatigue, highlighting the athletes' physiological efficiency and training regimen effectiveness. Lactate Concentration and Respiratory Response: The observed variation in lactate concentrations among elite athletes is a compelling finding. Higher lactate levels, coupled with significantly elevated respiration rates during specific test intervals, indicate the athletes' ability to endure intense anaerobic efforts. The heightened respiratory response signifies efficient removal of $CO_2$, a byproduct of anaerobic metabolism, allowing paddlers to sustain high-power outputs. This finding underscores the intricate balance between anaerobic metabolism and respiratory efficiency, emphasizing the importance of optimizing both aspects for peak performance. Ergometric Power and Energy Balance: The comparison of ergometric power performance during different intervals provides valuable insights into the energy balance strategies employed by sprinter paddlers. Athletes demonstrating balanced anaerobic alactate and anaerobic lactate capacities showcase superior overall energy utilization. This equilibrium highlights the importance of developing both energy pathways, ensuring optimal power output throughout the sprinting duration. Training programs should focus on enhancing these capacities to bolster athletes' energy

reserves and improve their competitive edge. Implications for Training and Performance Optimization: The findings from this study have far-reaching implications for training methodologies and performance optimization strategies in sprint paddling. Tailoring training programs to enhance cardiorespiratory reactivity, optimize $CO_2$ emissions, and improve lactate clearance rates is imperative. Individualized training plans, focusing on neural adaptations, metabolic acidosis tolerance, and balanced anaerobic energy utilization, can significantly enhance paddlers' performance outcomes. Several researchers have emphasized the significance of various aerobic and anaerobic characteristics in Sprint Kayak performance. Maximal power output at $VO_2$max level and anaerobic traits such as power produced during 30-second and 2-minute efforts, as well as the accumulated oxygen deficit, have been identified as crucial factors contributing to competitive success (Bishop, 2004; van Someren & Palmer, 2003; van Someren & Howatson, 2008). Laboratory studies have revealed that events of shorter duration, such as 30-second maximal efforts, exhibit a higher anaerobic oxygen deficit (~29% higher) compared to 120-second maximal efforts, indicating the importance of balancing metabolic pathways for optimal performance (Bishop, 2004; van Someren & Palmer, 2003). Research by van Someren and Palmer (2003) has highlighted the significance of superior upper body dimensions and anaerobic capacities in distinguishing international-level kayakers from national-level athletes. These factors not only differentiate athletes but also hold predictive value for 200-meter performance outcomes. Maintaining an appropriate training load is crucial, as excessive or insufficient training can impair desired adaptations. To effectively monitor athletes, it is essential to objectively quantify training loads using valid methods (Carter et al., 2000; Impellizzeri et al., 2005; Nicolas et al., 2006; Poole et al., 2008; Simoneau, 1998). Utilizing proper and validated techniques for quantifying training loads ensures accurate assessment and contributes to the overall training effectiveness and performance enhancement of athletes.

## Conclusion

This comprehensive study delved into the intricate world of sprint paddling, unraveling multifaceted insights into the physiological dynamics and performance nuances of elite athletes. The amalgamation of meticulous data analysis and nuanced interpretations has yielded several key takeaways, each contributing significantly to our understanding of the sport and its athletes. Individual Variability and Homogeneity: A striking balance emerged in the study: the homogeneity within the paddlers' group underscored the collective dedication and training standard prevalent among elite athletes. Simultaneously, the individual differences, particularly in cardiorespiratory reactivity, highlighted the diverse physiological profiles within this homogeneity. Recognizing and harnessing these individual variances can be pivotal in tailoring training regimens, ensuring each athlete's unique strengths are maximized. Cardiorespiratory Reactivity and Performance Correlation: The study's standout finding lies in the direct correlation between robust cardiorespiratory reactivity and superior athletic performance. Athletes displaying swift neural responses and adept adaptation to metabolic acidosis exhibited enhanced overall performance. This correlation underscores the critical role of the nervous system and efficient respiratory mechanisms in optimizing paddlers' capabilities. Training interventions focusing on enhancing these specific aspects could yield substantial performance improvements. Metabolic Efficiency and Energy Balance: The study's insights into $CO_2$ emissions and lactate concentrations shed light on the athletes' metabolic efficiency. Consistent $CO_2$ emissions across athletes demonstrated standardized metabolic responses, indicating a balanced energy utilization pattern. Furthermore, higher lactate concentrations coupled with elevated respiration rates during intense efforts reflected efficient anaerobic metabolism and respiratory responses. Striking the right balance between anaerobic alactate and lactate capacities emerged as a key factor in optimizing energy utilization, underscoring the importance of training programs that enhance both pathways. Practical Implications for Training and Performance Enhancement: These findings hold immense practical significance for coaches, sports scientists, and athletes. Tailoring training programs to capitalize on individual differences, focusing on enhancing neural adaptations, metabolic acidosis tolerance, and optimizing energy pathways, can be transformative. The study's insights pave the way for personalized training interventions, allowing athletes to capitalize on their unique physiological strengths. Furthermore, these findings provide a roadmap for refining coaching methodologies, enhancing the precision of training interventions, and ultimately elevating the sport of sprint paddling to unprecedented levels of performance excellence. Future Directions and Research Implications: This study, while comprehensive, opens the door to a multitude of future research avenues. Exploring the long-term impact of tailored training interventions, delving deeper into the molecular mechanisms underlying cardiorespiratory reactivity, and investigating the psychological facets of athletic performance are promising areas. Additionally, comparative studies across different sports disciplines could offer valuable insights into universal physiological principles governing elite athletic performance. In essence, this study not only enriches our understanding of sprint paddling but also provides a paradigm for studying elite athletic performance more broadly. The nuanced interplay of physiological factors, individual variability, and the strategic balance of energy pathways are at the heart of this study's analytical conclusion. As the sporting world continues to evolve, these insights will undoubtedly guide the future of athletic training, empowering athletes to achieve unprecedented feats and inspiring a new generation of sports scientists and coaches. The results of the studies indicate differences in the level of functional support for special endurance for paddlers of uniform groups for kayaks and canoes that specialize in a distance of 200 m (Diachenko et al., 2021).

## Conflict of interest

Authors declare no conflict of interest.

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# АНАЛІТИЧНІ ВИСНОВКИ З ФІЗІОЛОГІЇ ЕЛІТНИХ СПРИНТЕРІВ-ВЕСЛУВАЛЬНИКІВ: РОЗКРИТТЯ ДИНАМІКИ РЕЗУЛЬТАТИВНОСТІ ТА МОЖЛИВИХ НАСЛІДКІВ ТРЕНУВАНЬ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 2 табл., 25 джерел.

**Мета дослідження.** Метою цього дослідження було вивчення взаємозв'язку між фізіологічною реактивністю та результативністю у спринтерському веслуванні серед елітних спортсменів із зосередженням уваги на кардіореспіраторних реакціях, метаболічній ефективності та моделях використання енергії.

**Матеріали та методи.** Для цього дослідження було ретельно підібрано групу з двадцяти (N = 20) елітних спринтерів-веслувальників із різних регіонів Індії. За допомогою стандартизованих протоколів і передових методів вимірювання були проведені докладні оцінки кардіореспіраторних реакцій, метаболічної ефективності та моделей використання енергії. Індивідуальні відмінності між спортсменами були ретельно задокументовані.

**Результати.** За результатами дослідження було виявлено вражаючу однорідність серед спортсменів, що відображає суворі стандарти підготовки. Проте виявилися вельми цікаві індивідуальні відмінності, зокрема в реактивності кардіореспіраторної системи. Спортсмени зі швидкими нервовими реакціями та гарною адаптацією до метаболічного ацидозу продемонстрували покращену загальну продуктивність, що вказує на критичну роль нервової системи та ефективних дихальних механізмів в оптимізації здібностей веслувальників. Аналіз викидів $CO_2$ та концентрації лактату вказав на збалансовану модель використання енергії та оптимальний анаеробний метаболізм і респіраторні реакції. Збалансування анаеробної алактатної та лактатної здатностей виявилося ключовим.

**Висновки.** Одержані результати підкреслюють необхідність цільових програм тренувань, які максимально вигідно використовують індивідуальні відмінності, покращують адаптацію нервової системи та толерантність до метаболічного ацидозу, а також оптимізують енергетичні потоки. Ці трансформаційні аналітичні результати пропонують тренерам, спортивним науковцям і спортсменам цінні інструменти для покращення результатів підготовки. Це дослідження збагачує наше розуміння спринтерського веслування та слугує парадигмою для дослідження результативності елітних спортсменів, скеровуючи майбутнє спортивної науки та тренерської роботи. Майбутні напрямки досліджень включають вивчення довгострокового впливу спеціально призначених тренувальних втручань, дослідження молекулярних механізмів кардіореспіраторної реактивності та вивчення психологічних аспектів спортивної підготовки. Порівняльні дослідження в різних спортивних дисциплінах обіцяють універсальні аналітичні висновки за темою результативності елітних спортсменів.

**Ключові слова:** спринтери-веслувальники, фізіологічна реактивність, спортивна підготовка, кардіореспіраторні реакції, тренувальні втручання.

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