



The Relationship Between Aerobic Capacity and Stroke Efficiency In 50 Meter Breaststroke Swimmers

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Abstract

Study purpose. This study aimed to determine the relationship between aerobic capacity and stroke count as an indicator of stroke efficiency in 50-meter breaststroke swimming among club swimmers.

Materials and methods. This study employed a quantitative approach with a correlational research design. The participants consisted of 15 club swimmers selected using a purposive sampling technique. Aerobic capacity was assessed using the Beep Test (Multistage Fitness Test) to estimate maximal oxygen uptake (VO_{2max}). Stroke count data were obtained through a 50-meter breaststroke swimming test by calculating the total number of stroke cycles performed during the swim. Data were analyzed using descriptive statistics, the Shapiro–Wilk normality test, and the Pearson product-moment correlation test with a significance level of 0.05.

Results. The results showed that the swimmers had an average VO_{2max} of 46.18 ml/kg/min and an average stroke count of 29.93 strokes. The normality test indicated that both variables were normally distributed. Pearson correlation analysis revealed a significant negative relationship between aerobic capacity and stroke count ($r = -0.854$; $p < 0.05$). These findings indicate that swimmers with higher aerobic capacity tended to perform fewer stroke cycles during the 50-meter breaststroke event.

Conclusions. Aerobic capacity is significantly associated with stroke efficiency in 50-meter breaststroke swimmers. Higher aerobic capacity may contribute to more efficient movement patterns, allowing swimmers to maintain effective propulsion with fewer stroke cycles. Therefore, aerobic capacity and stroke count can be considered important indicators in swimming performance evaluation and training programs.

Keywords: Aerobic Capacity, Breaststroke Swimming, Stroke Count, Stroke Efficiency, VO_{2Max}

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Introduction

Swimming is a competitive sport in which performance is determined by the interaction of physiological, biomechanical, and technical characteristics. Effective performance requires swimmers to generate propulsion, manage hydrodynamic resistance, regulate energy expenditure, and coordinate body movements to maintain forward velocity. Recent reviews and empirical studies describe swimming performance as a multifactorial phenomenon involving energetics, biomechanics, anthropometrics, and technical efficiency (Born et al., 2020; Morais et al., 2021; Morais et al., 2022). In young swimmers, these factors develop together and contribute to differences in competitive performance, making the evaluation of physiological and technical characteristics important in swimming research (Morais et al., 2017; Maconyte et al., 2024). Recent evidence from 50-m breaststroke also indicates that performance is associated with multiple physical and technical determinants rather than a single characteristic (Kuberski et al., 2026). Therefore, examining physiological capacity together with technical movement variables can provide a more comprehensive understanding of swimming performance.

Within competitive swimming, each stroke has distinct movement patterns and energetic demands. Breaststroke is particularly distinctive because propulsion is produced through coordinated upper- and lower-limb actions, body alignment, breathing, and repeated transitions between propulsive and non-propulsive phases. Its cyclic movement pattern produces substantial intracyclic changes in velocity, and the timing and coordination of these phases influence propulsion and swimming efficiency (Nicol et al., 2022; Seifert & Carmigniani, 2021). Research on breaststroke has shown that limb coordination, body acceleration, stroke timing, and kinematic characteristics are associated with swimming velocity and performance (Kjendlie et al., 2016; Olstad et al., 2016). More recent biomechanical research demonstrates that intercycle kinematic variation differs according to competitive level, highlighting the importance of technical organization in breaststroke performance (Fernandes et al., 2024). A systematic review further indicates that breaststroke technique is associated with considerable variation in energy cost, reinforcing the importance of efficient propulsion and coordination (Alves et al., 2025).

These characteristics are especially relevant to sprint breaststroke, including the 50-meter event. The 50-meter breaststroke requires swimmers to produce high propulsion and maintain velocity over a short distance while coordinating the arm pull, leg kick, breathing, and glide phases. Research specifically examining 50-m breaststroke has demonstrated relationships between performance and variables such as stroke frequency, stroke length, active drag, and maximal propulsive capacity (Olstad et al., 2024). Similarly, research on warm-up strategies has shown that physiological preparation can influence 50-m breaststroke performance, emphasizing the importance of the athlete's physiological state during this short, high-intensity event (Lee et al., 2025). The specific coordination demands of sprint breaststroke have also been demonstrated through studies of propulsive limb coordination and body acceleration during 50-m all-out swimming (Kjendlie et al., 2016). In addition, research published in the *Indonesian Journal of Physical Education and Sport Science* (IJPESS) has examined physical and physiological training factors associated with 100-m breaststroke performance in youth swimmers, providing recent evidence from a journal directly relevant to swimming and sport science (Kamil & Sheet, 2025). These findings support the need to examine physiological and technical variables within the specific context of breaststroke performance.

One physiological characteristic that is relevant to swimming performance is aerobic capacity. Aerobic capacity is commonly represented by maximal oxygen uptake ($\text{VO}_{2\text{max}}$), which reflects the integrated capacity of the body to transport and utilize oxygen during exercise. In competitive swimmers, $\text{VO}_{2\text{max}}$ can be assessed using several exercise modalities,

although the validity and reliability of the measurement may depend on the specificity of the testing mode (de Haan et al., 2024). Research involving swimmers aged 11–13 years has also demonstrated that aerobic capacity can be assessed through swimming and non-swimming exercise modalities, highlighting its relevance during the development of young swimmers (Maconyte et al., 2024). In addition, recent research published in IJPESS has reported changes in aerobic capacity following high-intensity interval training, further supporting aerobic capacity as an important physiological variable in sport performance research (Lesmana et al., 2026).

Although the 50-meter breaststroke is a sprint event, aerobic metabolism remains part of the overall energy contribution to swimming exercise, while aerobic capacity may also contribute to the ability to tolerate and recover from repeated high-intensity efforts. The metabolic response to competitive swimming varies according to exercise intensity and event demands, demonstrating that swimming performance cannot be interpreted solely through one energy system (Hellard et al., 2018). In young swimmers, physiological, energetic, biomechanical, and efficiency-related characteristics interact in determining performance (Morais et al., 2021). Thus, aerobic capacity should not be interpreted as the sole determinant of sprint performance; rather, it represents one physiological dimension that may be associated with how swimmers tolerate and perform high-intensity exercise.

While aerobic capacity represents a physiological dimension, technical efficiency represents an important biomechanical dimension of swimming performance. Swimming efficiency broadly concerns the ability to transform physiological and mechanical effort into effective forward movement while minimizing unnecessary energy expenditure and movement losses. Biomechanical and energetic studies have demonstrated that swimming performance is related to the interaction between propulsion, drag, energy cost, and technical execution (Morais et al., 2022). In front crawl, for example, research has shown that stroke efficiency is closely related to biomechanical and physiological predictors of swimming performance, supporting the broader importance of efficiency-related variables in swimming research (Peterson Silveira et al., 2019). Although these findings were obtained in front crawl, they provide a theoretical basis for considering stroke-related variables as practical indicators of technical execution.

One practical stroke-related variable is stroke count, which refers to the number of stroke cycles required to cover a standardized distance. Stroke count can be obtained directly during a swimming trial and can be considered together with stroke length, stroke rate, and stroke index when evaluating technical performance. Research using wearable technology has demonstrated that stroke count and other spatial-temporal variables can be measured during swimming, including breaststroke, and can provide useful information for coaches (Pla et al., 2021). Similarly, research on automated stroke identification has demonstrated the feasibility of counting swimming strokes using accelerometer-based methods (Pan et al., 2016). The relationship between stroke-related variables and performance is also supported by IJPESS research showing that biokinematic variables, including stroke-related characteristics, are associated with swimming achievement (Ibraheem et al., 2024). Therefore, stroke count provides a simple and practical technical measure that can be obtained during a standardized 50-m breaststroke test.

Stroke count should nevertheless be interpreted carefully. A lower stroke count does not automatically indicate superior efficiency if it is accompanied by lower swimming velocity, reduced propulsion, or excessive glide duration. Technical efficiency depends on the interaction between stroke frequency, stroke length, propulsion, drag, and coordination rather than on stroke count alone (Nicol et al., 2022; Olstad et al., 2024). Nevertheless, when distance, stroke technique, and testing conditions are standardized, stroke count can provide useful information about how many cycles a swimmer uses to complete the same distance. This practical

characteristic makes stroke count particularly useful for club swimmers and coaches who may not have access to sophisticated biomechanical measurement systems.

The relationship between physiological capacity and technical execution may become especially relevant when swimmers are required to maintain performance under high-intensity demands. Repeated swimming efforts can alter kinematic characteristics, demonstrating that physiological stress may be accompanied by changes in movement execution (Borges dos Santos et al., 2020). Objective assessment of swimming velocity and stroke-related variables can also help identify changes in technical execution during swimming performance (Clément et al., 2021). Consequently, physiological capacity and technical efficiency can be viewed as complementary dimensions of swimming performance. A swimmer's aerobic capacity may be associated with the ability to tolerate physiological demands, whereas stroke count reflects an observable characteristic of technical execution. However, the direction and magnitude of their relationship may depend on stroke technique, competitive level, race distance, and individual characteristics.

Previous research has provided substantial evidence concerning the physiological, biomechanical, energetic, and technical determinants of swimming performance. Studies have examined aerobic capacity and VO_2max assessment in competitive and young swimmers (de Haan et al., 2024; Maconyte et al., 2024), breaststroke kinematics and coordination (Kjendlie et al., 2016; Olstad et al., 2016; Nicol et al., 2022; Fernandes et al., 2024), breaststroke energy cost (Alves et al., 2025), and 50-m breaststroke performance determinants (Olstad et al., 2024; Lee et al., 2025; Kuberski et al., 2026). Other studies have examined stroke efficiency and spatial-temporal variables (Peterson Silveira et al., 2019; Pla et al., 2021; Pan et al., 2016), while recent IJPESS studies have addressed biokinematic variables, aerobic capacity, and breaststroke-related physical and physiological performance (Ibraheem et al., 2024; Lesmana et al., 2026; Kamil & Sheet, 2025). Although these studies provide important evidence, they generally examine physiological capacity, technical characteristics, or performance determinants separately.

Based on the available literature, a more specific gap remains concerning the direct relationship between aerobic capacity and stroke count during a standardized 50-meter breaststroke performance test, particularly among club swimmers. Existing studies have extensively examined breaststroke kinematics, energetic demands, and performance determinants, but the relationship between a physiological indicator such as VO_2max and a practical stroke-related indicator such as stroke count has received less direct attention. This gap is relevant because coaches require practical measures that can connect physiological characteristics with observable technical performance. Examining VO_2max together with stroke count may therefore provide an integrated perspective on the association between physiological capacity and technical execution in sprint breaststroke.

The present study addresses this gap by examining the relationship between aerobic capacity, represented by VO_2max , and stroke efficiency, represented by stroke count, among 50-meter breaststroke club swimmers. The position of the study is at the intersection of physiological capacity and technical efficiency, with VO_2max representing the physiological dimension and stroke count representing a practical technical dimension. The novelty lies in examining these two variables simultaneously within the specific context of a standardized 50-meter breaststroke test among club swimmers. This approach differs from studies that have examined aerobic capacity, breaststroke kinematics, or performance determinants independently. Because the present study uses a correlational design, the relationship is interpreted as an association and not as evidence that aerobic capacity causes changes in stroke efficiency. Therefore, this study aimed to determine the relationship between aerobic capacity and stroke efficiency represented by stroke count in 50-meter breaststroke swimmers.

Materials and methods

Study participants

This study involved 15 club swimmers who actively participated in regular swimming training programs. Participants were selected using a purposive sampling technique based on specific inclusion criteria relevant to the objectives of the study. The inclusion criteria were: (1) active club swimmers with at least one year of training experience, (2) proficiency in breaststroke swimming technique, (3) aged between 12 and 18 years, and (4) free from injury during the data collection period. Athletes who did not complete all testing procedures were excluded from the study.

The participants were selected because they possessed relatively similar training backgrounds and technical experience, allowing for a more accurate examination of the relationship between aerobic capacity and stroke efficiency in 50-meter breaststroke swimming. Prior to participation, all athletes and their parents or guardians were informed about the purpose and procedures of the study and provided informed consent. The study was conducted in accordance with ethical principles for research involving human participants.

Study organization

This study employed a quantitative approach with a correlational research design to examine the relationship between aerobic capacity and stroke efficiency in 50-meter breaststroke swimmers. The research was conducted at a swimming club training facility during the regular training season.

Aerobic capacity was assessed using the Beep Test, also known as the Multistage Fitness Test, which is widely used to estimate maximal oxygen uptake (VO_{2max}) and evaluate aerobic fitness (Tomkinson et al., 2019). Participants performed repeated 20-meter shuttle runs following audio signals with progressively increasing speed until voluntary exhaustion. The final level achieved by each participant was used to estimate VO_{2max} .

Stroke efficiency was represented by stroke count obtained during a 50-meter breaststroke swimming test. Participants were instructed to perform the test at maximal effort while maintaining their normal competition technique. Stroke count was determined by calculating the total number of complete stroke cycles performed from the start to the finish of the swim. Lower stroke count values were interpreted as indicating greater stroke efficiency because swimmers were able to travel farther with each stroke cycle (Nicol et al., 2022).

Data collection was conducted in several stages. First, participants received explanations regarding the objectives and procedures of the study and completed a standardized warm-up lasting approximately 10–15 minutes. Second, participants performed the Beep Test to estimate aerobic capacity. To minimize the influence of fatigue, a recovery period of 24 hours was provided before the swimming performance assessment. On the following day, participants completed the 50-meter breaststroke swimming test. During the test, stroke count data were recorded independently by two trained observers to improve measurement accuracy and reduce observational bias.

Statistical analysis

Descriptive statistics were calculated to determine the mean, standard deviation, minimum value, and maximum value for each variable. Prior to hypothesis testing, the Shapiro–Wilk test was used to assess the normality of the data distribution because the sample size was fewer than 50 participants.

Since both variables met the assumption of normality, Pearson product-moment correlation analysis was conducted to determine the relationship between aerobic capacity and stroke efficiency represented by stroke count. The strength of the correlation was interpreted

according to commonly accepted correlation coefficient guidelines. Statistical analyses were performed using IBM SPSS Statistics software, and the significance level was set at $\alpha = 0.05$.

Results

This study aimed to examine the relationship between aerobic capacity and stroke efficiency represented by stroke count in 50-meter breaststroke swimmers. Descriptive statistics, normality testing, and Pearson product-moment correlation analysis were conducted to analyze the data.

Table 1. Descriptive Statistic Of VO₂Max and Stroke Count

Variables	N	Mean	SD	Min	Max
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹)	15	46.18	7.44	33.34	57.40
Stroke Count (cycles)	15	29.93	2.63	25	34

Table 1 presents the descriptive statistics of aerobic capacity and stroke count among the participants. Aerobic capacity showed a mean VO₂max of 46.18 ml·kg⁻¹·min⁻¹ (SD = 7.44), with values ranging from 33.34 to 57.40 ml·kg⁻¹·min⁻¹. Stroke count demonstrated a mean value of 29.93 cycles (SD = 2.63), with a range of 25–34 cycles. These findings indicate variability in aerobic capacity and stroke count among the swimmers.

Table 2. Shapiro-Wilk Normality Test Results

Variables	p-value	Interpretation
VO ₂ max	0.707	Normally Distributed
Stroke Count	0.605	Normally Distributed

As shown in Table 2, both variables obtained p-values greater than 0.05. Therefore, the data were normally distributed and met the assumptions required for Pearson product-moment correlation analysis.

Table 3. Pearson Correlation Analysis Between VO₂Max and Stroke Count

Variables	r	p-value	Interpretation
VO ₂ max and Stroke Count	-0.854	0.000	Very Strong Negative Correlation

Table 3 shows the results of the Pearson correlation analysis between aerobic capacity and stroke count. The analysis revealed a significant negative relationship between the two variables ($r = -0.854$, $p < 0.05$). The correlation coefficient indicates a very strong negative relationship between aerobic capacity and stroke count.

The negative correlation suggests that swimmers with higher aerobic capacity tended to demonstrate lower stroke counts during the 50-meter breaststroke event. Conversely, swimmers with lower aerobic capacity tended to require more stroke cycles to complete the same distance. These findings indicate that greater aerobic capacity was associated with better stroke efficiency as reflected by a lower stroke count.

Discussion

The purpose of this study was to determine the relationship between aerobic capacity and stroke efficiency represented by stroke count in 50-meter breaststroke swimmers. The

results revealed a significant negative relationship between aerobic capacity and stroke count ($r = -0.854$, $p < 0.05$). This finding indicates that swimmers with higher aerobic capacity tended to perform fewer stroke cycles during the standardized 50-meter breaststroke test. The result suggests an association between physiological capacity and a practical indicator of technical execution. However, because the present study used a correlational design, the finding should not be interpreted as evidence that higher aerobic capacity directly causes a reduction in stroke count.

The finding is consistent with the multifactorial nature of swimming performance. Swimming performance is determined by the interaction of physiological, biomechanical, energetic, and technical characteristics rather than by a single factor (Born et al., 2020; Morais et al., 2021). In young swimmers, these characteristics develop concurrently and contribute to differences in performance and technical execution (Morais et al., 2017; Zacca et al., 2020). The present result extends this perspective by demonstrating a strong association between $\text{VO}_{2\text{max}}$ and a practical stroke-related variable in 50-meter breaststroke swimmers.

One possible explanation is that greater aerobic capacity may be associated with a greater ability to tolerate the physiological demands of swimming and maintain movement execution during performance. $\text{VO}_{2\text{max}}$ represents an important indicator of aerobic capacity, although its measurement in swimmers can vary according to the testing modality and exercise specificity (de Haan et al., 2024). Research in young swimmers has also demonstrated that aerobic capacity can be assessed through swimming and non-swimming modalities, supporting its relevance as a physiological characteristic during swimmer development (Maconyte et al., 2024). Although the 50-meter breaststroke is a short, high-intensity event, swimming performance involves contributions from multiple metabolic pathways, and physiological capacity should therefore be considered as one component of overall performance rather than as the sole determinant (Hellard et al., 2018; Morais et al., 2021).

The result may also be related to the specific biomechanical characteristics of breaststroke. Breaststroke involves coordinated arm and leg propulsion, recovery, breathing, and glide phases, with marked intracyclic variations in swimming velocity (Nicol et al., 2022; Seifert & Carmigniani, 2023). Previous research has shown that limb coordination, body acceleration, and kinematic organization are associated with breaststroke performance (Kjendlie et al., 2016; Olstad et al., 2016). More recent evidence indicates that intercycle kinematic characteristics differ according to competitive level, emphasizing the importance of maintaining an effective movement pattern during breaststroke performance (Fernandes et al., 2024). Thus, swimmers with greater physiological capacity may be better able to maintain coordinated movement throughout the standardized test, which may be reflected in fewer stroke cycles.

The finding is also relevant to the relationship between stroke mechanics and swimming efficiency. Breaststroke efficiency depends on the interaction between propulsion, drag, stroke timing, coordination, and energy cost (Alves et al., 2025). Research on 50-meter breaststroke has further shown that performance is related to variables such as stroke characteristics and maximal propulsive capacity (Olstad et al., 2024). Therefore, the lower stroke count observed among swimmers with higher aerobic capacity may reflect differences in technical organization under standardized conditions. Nevertheless, this interpretation must remain cautious because the present study did not directly measure energy cost, propulsion, drag, stroke length, or stroke rate.

Stroke count should consequently be interpreted as a practical stroke-related indicator rather than as a complete measure of swimming efficiency. A lower stroke count does not automatically indicate superior efficiency if it is accompanied by reduced swimming velocity, inadequate propulsion, or excessive glide duration. Stroke-related performance depends on the interaction among stroke rate, stroke length, propulsion, and coordination (Nicol et al., 2022;

Olstad et al., 2024). In the present study, stroke count was measured during the same standardized 50-meter breaststroke distance for all participants, making it useful for describing differences in the number of cycles required to complete the task. This interpretation is also consistent with research demonstrating the practical use of spatial-temporal variables for monitoring swimming technique (Pla et al., 2021).

The present findings can further be considered in relation to the effects of physiological stress on technical execution. Borges dos Santos et al. (2020) reported changes in kinematic parameters following repeated swimming efforts, suggesting that demanding exercise can be accompanied by changes in movement characteristics. This is relevant to breaststroke because its alternating propulsive and non-propulsive phases require precise timing and coordination (Nicol et al., 2022). Therefore, differences in physiological capacity may be associated with differences in the ability to preserve a consistent stroke pattern during performance. However, the present study did not directly measure fatigue or changes in technique during the trial, so this explanation remains a possible interpretation rather than a demonstrated mechanism.

The practical implication of these findings is that coaches may consider aerobic capacity and stroke count together when evaluating 50-meter breaststroke swimmers. Aerobic capacity provides information about physiological fitness, whereas stroke count can be obtained relatively easily during a standardized swimming test. Recent studies have emphasized the value of combining physiological and technical information when evaluating swimmer development and performance (Zacca et al., 2020). Research published in IJPESS also supports the integration of physical, physiological, and biokinematic characteristics in swimming performance evaluation (Ibraheem et al., 2024; Kamil & Sheet, 2025; Lesmana et al., 2026). Thus, monitoring both variables may provide coaches with complementary information that is more informative than evaluating either physiological capacity or technical execution in isolation.

Several limitations should be considered when interpreting the present findings. First, the sample consisted of 15 club swimmers, which limits the generalizability of the findings to other competitive levels and swimming populations. Second, stroke efficiency was represented by stroke count only and did not include other biomechanical indicators such as stroke length, stroke rate, stroke index, swimming velocity, propulsion, or energy cost. Third, aerobic capacity was assessed using the Beep Test rather than direct swimming-specific gas analysis. Because $\text{VO}_{2\text{max}}$ values can vary according to the testing modality, this should be considered when interpreting the physiological variable (de Haan et al., 2024). Finally, the correlational design does not allow causal conclusions. Future studies should therefore involve larger and more diverse samples and examine stroke count together with stroke length, stroke rate, swimming velocity, propulsion, and other biomechanical variables using longitudinal or experimental designs.

Overall, the present study demonstrates a significant negative relationship between aerobic capacity and stroke count in 50-meter breaststroke swimmers. The finding contributes to the literature by linking a physiological indicator, $\text{VO}_{2\text{max}}$, with an observable stroke-related variable within a specific sprint breaststroke context. The result supports the importance of considering physiological and technical characteristics together when evaluating swimming performance, while recognizing that stroke count alone does not represent complete swimming efficiency and that the observed relationship should not be interpreted causally.

Conclusions

The findings of this study indicate that aerobic capacity is significantly related to stroke efficiency represented by stroke count in 50-meter breaststroke swimmers. A significant negative relationship was found between aerobic capacity and stroke count, suggesting that swimmers with higher aerobic capacity tended to perform fewer stroke cycles during swimming

performance. This finding indicates that aerobic capacity may contribute not only to physiological fitness but also to the ability to maintain efficient movement patterns and effective propulsion during breaststroke swimming. Swimmers with better aerobic fitness may be more capable of maintaining stroke coordination and movement efficiency, thereby reducing the number of stroke cycles required to complete a given distance. These results highlight the importance of considering both physiological and technical factors in swimming performance evaluation. From a practical perspective, coaches are encouraged to integrate aerobic conditioning programs with technical training and to monitor stroke count regularly as an indicator of swimming efficiency. Future studies should involve larger sample sizes and include additional biomechanical variables, such as stroke length, stroke index, swimming velocity, and propulsion measures, to provide a more comprehensive understanding of the factors influencing stroke efficiency in competitive swimmers.

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Conflict of interest

We declare no conflict of interest in this article

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