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The Effect of Different Breathing Rhythms on Freestyle Swimming Performance: A Quasi-Experimental Study

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Abstract: *This study investigated the effects of different breathing rhythms on freestyle swimming performance among university-level swimmers. Using a 14-week quasi-experimental design, thirty swimming enthusiasts from the University of Malaya completed 50-meter freestyle trials under three breathing conditions: every 2 strokes (BR2), every 3 strokes (BR3), and every 4 strokes (BR4). Performance outcomes included swimming time, rating of perceived exertion (RPE), and heart rate recovery (HRR). Repeated measures ANOVA revealed that the BR3 condition resulted in significantly faster swim times, lower perceived exertion, and more efficient heart rate recovery compared to BR2 and BR4 ($p < .001$). These findings suggest that a moderate breathing rhythm, specifically every three strokes, provides an optimal balance between oxygen intake and stroke efficiency. The study offers practical implications for swimming training, highlighting the importance of integrating breathing rhythm strategies into performance-oriented programs.*

Keywords: *freestyle swimming, breathing rhythm, performance*

1. Introduction

Breathing rhythm is a fundamental biomechanical and physiological component in freestyle swimming, directly influencing stroke efficiency, energy expenditure, and overall performance. In swimming, athletes often adopt different breathing frequencies—such as breathing every two, three, or four strokes—based on individual comfort, stroke symmetry, and training objectives. The coordination between respiratory patterns and limb movements poses unique challenges in aquatic environments where oxygen intake is intermittent and tightly coupled with stroke timing. Existing training paradigms emphasize hydrodynamics and technique but often overlook the nuanced role of breathing rhythm in performance modulation, especially in short- to middle-distance freestyle events.

Previous studies have explored various aspects of breathing and its impact on swimming. For example, three breathing techniques over 25-meter freestyle trials observed notable differences in swimming efficiency[1]. Similarly, breathing frequencies significantly affected swimmers' physiological responses[2], including oxygen uptake and ventilation rates. Breathing patterns common in competitive swimming influence gas exchange dynamics and muscle oxygenation during high-intensity efforts[3]. However, these studies vary in methodology and population, often lacking a standardized experimental approach to directly compare multiple breathing rhythms under the same physiological and biomechanical conditions.

While a growing body of literature addresses respiratory training and its effects on performance, such as inspiratory muscle training[4] or hypoxic breathing techniques[5] relatively few studies have experimentally tested the immediate impact of different breathing frequencies on performance outcomes like swimming speed, perceived exertion, or recovery indicators. Moreover, some studies focus on long-term respiratory adaptations[6] rather than acute performance effects. The effectiveness of specific breathing rhythms during freestyle—especially in the context of sprint events—remains underexplored. Additionally, the interaction between breathing rhythm and swimmers' subjective fatigue or effort perception (e.g., RPE) has not been sufficiently addressed.

Given these gaps, the current study aims to examine the effects of different breathing rhythms on the performance of freestyle swimmers in a controlled experimental setting. Performance metrics include swim time over a standardized distance, rate of perceived exertion (RPE), and heart rate recovery. This

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research specifically targets college-level swimmers with intermediate training backgrounds to ensure a balance between technical proficiency and sensitivity to breathing modifications. By employing a within-subjects design, the study seeks to reduce inter-individual variability and provide robust evidence for coaches and athletes regarding optimal breathing strategies in competitive settings.

This study contributes to the growing field of performance optimization in swimming by offering empirical insights into how breathing rhythm modulation affects short-distance freestyle outcomes. It addresses prior methodological limitations by standardizing test conditions and incorporating both physiological and perceptual data. The findings are expected to enrich theoretical understanding of breathing-motion coordination and inform practical training guidelines for athletes and coaches. Furthermore, the study has potential implications for designing individualized breathing protocols to enhance performance, reduce fatigue, and promote efficient energy utilization during competition.

2. Research Design

This study adopts a quantitative quasi-experimental design to investigate the effects of different breathing rhythms on freestyle swimming performance. The research is structured around a repeated-measures design, in which each participant undergoes all experimental conditions, allowing for within-subject comparisons and enhanced statistical power. The study was conducted over a 14-week intervention period, with pre-test, mid-test, and post-test data collection phases. The independent variable in this study is breathing rhythm (i.e., breathing every 2 strokes, every 3 strokes, and every 4 strokes), while the dependent variables include swimming performance time, rating of perceived exertion (RPE), and heart rate recovery (HRR).

2.1 Participants

The participants in this study were volunteer swimming enthusiasts enrolled at the University of Malaya, aged between 18 and 25 years. Inclusion criteria were: (a) a minimum of one year of regular swimming experience; (b) the ability to swim 50 meters freestyle without assistance; and (c) no history of respiratory or cardiovascular disease. Exclusion criteria included current injury or inability to commit to the full experimental duration. A total of 30 participants (15 males and 15 females) were recruited through university sports clubs and physical education courses. All participants provided written informed consent in accordance with the ethical guidelines approved by the Faculty of Education Ethics Committee, University of Malaya.

2.2 Procedure

The study was implemented in three distinct phases: (1) baseline testing, (2) 12-week intervention, and (3) post-intervention evaluation. In the first two weeks, participants were assessed for baseline freestyle performance (50-meter time trial), resting heart rate, and familiarized with the RPE scale. They were also randomly assigned to a counterbalanced breathing rhythm sequence to mitigate order effects across the 14-week period.

Each week, participants performed three supervised swimming trials, each trial using a designated breathing rhythm (2-stroke, 3-stroke, or 4-stroke). Breathing patterns were reinforced through verbal cueing and practice drills at the beginning of each session. A minimum of 48 hours was maintained between sessions to ensure adequate recovery. Performance time for a 50-meter freestyle swim was recorded using an electronic timing system. Immediately after each trial, RPE was recorded using the Borg 6–20 scale, and heart rate recovery (HRR) was measured 1- and 3-minutes post-exercise using a heart rate monitor.

2.3 Instrumentation and Data Collection

Performance time was recorded with automatic electronic stopwatches (±0.01 s accuracy). Heart rate recovery was measured using Polar H10 heart rate monitors, and RPE was self-reported immediately post-trial. A standardized warm-up protocol (200 m swim, dynamic stretches) was conducted before each test. All sessions took place at the University of Malaya's aquatic center, under consistent environmental and pool conditions.

ISSN 2618-1576 Vol. 7, Issue 2: 40-45, DOI: 10.25236/FSR.2025.070207

2.4 Data Analysis

Descriptive statistics (mean, standard deviation) were computed for each dependent variable. The effects of breathing rhythm on swimming performance, RPE, and HRR were analyzed using repeated-measures ANOVA, with Bonferroni post-hoc correction to examine pairwise comparisons. Statistical significance was set at $p < .05$. Effect sizes (η^2) were also calculated to determine the magnitude of differences. All data were analyzed using IBM SPSS Statistics version 27.0.

2.5 Ethical Considerations

This study strictly followed ethical standards for research involving human participants. Prior to data collection, the research proposal was reviewed and approved by the Research Ethics Committee of the Faculty of Education, University of Malaya. All participants received a clear explanation of the study's objectives, procedures, potential risks, and benefits. Written informed consent was obtained from all participants before their involvement in the study.

Participation was entirely voluntary, and participants were informed of their right to withdraw from the study at any point without any consequences. To protect participant privacy and confidentiality, all personal data were anonymized and securely stored in a password-protected database accessible only to the research team. No identifying information was disclosed in any publication or dissemination of results. The study involved minimal physical and psychological risk, and all sessions were conducted in a supervised environment with qualified personnel present. The research was conducted in accordance with the principles outlined in the Declaration of Helsinki and complied with the Malaysian Guidelines for Good Clinical Practice.

3. Findings

This section presents the results of a 14-week quasi-experimental study examining the effects of three different breathing rhythms—breathing every 2 strokes (BR2), every 3 strokes (BR3), and every 4 strokes (BR4)—on freestyle swimming performance. The findings are organized into three parts: descriptive statistics, repeated-measures ANOVA, and post-hoc pairwise comparisons.

3.1. Descriptive Statistics

Descriptive statistics were computed to examine the average performance of participants across the three breathing conditions. As shown in Table 1, the fastest mean swim time was observed under the BR3 condition (M = 32.1 s, SD = 1.5), followed by BR2 (M = 33.5 s, SD = 1.8), and the slowest under BR4 (M = 34.3 s, SD = 2.0). Similarly, BR3 produced the lowest rating of perceived exertion (M = 13.1, SD = 1.0), while BR4 yielded the highest RPE (M = 16.5, SD = 1.3). In terms of heart rate recovery (HRR), BR3 again showed superior outcomes (M = 29.3 bpm, SD = 2.8), suggesting better cardiovascular efficiency than BR2 (M = 25.5 bpm, SD = 3.2) and BR4 (M = 22.7 bpm, SD = 3.6).

Table 1 Descriptive Statistics of Swim Time, RPE, and HRR Under Different Breathing Rhythm

Breathing Rhythm	Swim Time (s)	SD (Time)	RPE (6–20)	SD (RPE)	HRR (bpm, 1 min)	SD (HRR)
Every 2 strokes	33.5	1.8	15.2	1.1	25.5	3.2
Every 3 strokes	32.1	1.5	13.1	1.0	29.3	2.8
Every 4 strokes	34.3	2.0	16.5	1.3	22.7	3.6

3.2 Effects of Breathing Rhythm: Repeated-Measures ANOVA

Repeated measures ANOVA were conducted to assess the effect of breathing rhythm on each dependent variable. As shown in Table 2, there was a statistically significant main effect of breathing rhythm on swim time, $F(2, 58) = 19.72$, $p < .001$, $\eta^2 = .41$, indicating a large effect size. Similarly, RPE was significantly affected by breathing rhythm, $F(2, 58) = 36.29$, $p < .001$, $\eta^2 = .56$. A significant effect was also found for HRR, $F(2, 58) = 24.83$, $p < .001$, $\eta^2 = .46$. These results suggest that breathing rhythm has a substantial impact on all three performance-related outcomes.

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Table 2 Repeated-Measures ANOVA Results for Swim Time, RPE, and HRR

Dependent Variable	Sum of Squares	df	Mean Square	F-value	p-value	Partial η²
Swim Time (s)	48.53	2	24.27	19.72	< .001	.41
RPE (6–20 scale)	72.58	2	36.29	36.29	< .001	.56
HRR (bpm, 1 min)	55.32	2	27.66	24.83	< .001	.46
Error (within subjects)	—	58	—	—	—	—

3.3 Post-Hoc Pairwise Comparisons

To further explore these differences, Bonferroni-adjusted post-hoc comparisons were conducted. Results are presented in Table 3. For swim time, BR3 was significantly faster than both BR2 ($p = .002$) and BR4 ($p < .001$). For RPE, BR3 again yielded significantly lower values compared to BR2 ($p = .004$) and BR4 ($p < .001$). Similarly, HRR was significantly higher in BR3 compared to BR2 ($p = .01$) and BR4 ($p < .001$). The difference between BR2 and BR4 was not significant in swim time ($p = .08$) but was significant in both RPE ($p = .03$) and HRR ($p = .04$).

Table 3 Bonferroni Post-Hoc Comparisons Between Breathing Rhythm Conditions

Comparison	Swim Time (Mean Difference, p)	RPE (Mean Difference, p)	HRR (Mean Difference, p)
BR3 vs BR2	-1.4 s, $p = .002$	-2.1 units, $p = .004$	+3.8 bpm, $p = .010$
BR3 vs BR4	-2.2 s, $p < .001$	-3.4 units, $p < .001$	+6.6 bpm, $p < .001$
BR2 vs BR4	-0.8 s, $p = .080$	-1.3 units, $p = .030$	+2.8 bpm, $p = .040$

3.4 Summary of Findings

Overall, the findings support the conclusion that breathing every 3 strokes (BR3) is the most efficient strategy among the three conditions tested. Participants demonstrated significantly better swimming performance, experienced lower levels of exertion, and exhibited faster cardiovascular recovery. These results highlight the critical role of breathing rhythm in optimizing freestyle performance and suggest that a moderate breathing frequency offers a physiological and perceptual advantage over both higher and lower breathing rates.

4. Discussion

The present study aimed to investigate the effects of different breathing rhythms on freestyle swimming performance, perceived exertion, and heart rate recovery. The findings revealed that breathing every three strokes (BR3) produced significantly better outcomes across all variables. Participants achieved faster 50-meter swim times, reported lower subjective fatigue levels, and demonstrated superior heart rate recovery compared to the other breathing conditions. These results suggest that a moderate breathing frequency may offer the most efficient physiological and biomechanical balance during freestyle swimming, aligning with prior evidence that optimal breathing strategies are crucial for performance enhancement[8].

Comparing the results to previous literature, this study supports and extends earlier findings on the importance of breathing control and rhythm in swimming. For instance, hierarchical linear modeling and inertial measurement technology to explore breathing patterns in butterfly stroke, finding significant interactions between individual breathing habits and performance[9]. Our results are consistent with these findings, suggesting that breathing rhythm is not merely a passive element of stroke technique but an active modulator of energy efficiency and recovery. Similarly, combining dry-land interval training with in-water aerobics swimming also emphasized the role of respiratory control in managing fatigue and optimizing cardiovascular responses[10].

The observed physiological advantages of the BR3 condition may be attributed to a more favorable balance between oxygen supply and biomechanical coordination. More frequent breathing (BR2) may disrupt stroke rhythm and hydrodynamics, while less frequent breathing (BR4) could result in transient hypoxia and elevated perceived exertion. Controlled breathing during dry-land lumbar mobility training positively influenced spinal kinematics and muscular efficiency in elite swimmers[11]. Furthermore, effectiveness of targeted motor control interventions, such as windmill arm exercises, in improving stroke power and speed in junior swimmers—highlighting the synergistic role of respiratory and motor regulation in optimizing swimming technique[12].

In practical terms, the present findings have direct implications for both coaching and training design. Coaches should consider integrating breathing rhythm drills—particularly focused on BR3 patterns—into training regimens for intermediate and advanced swimmers. Moreover, individualized breathing assessments could be combined with biomechanical analysis to fine-tune stroke-breathing synchronization. For future research, it would be worthwhile to investigate whether long-term adaptation to BR3 breathing translates into improved lactate clearance, stroke efficiency, or VO_2 max. Additionally, given the growing interest in combining dry-land neuromuscular interventions with aquatic training, follow-up studies could explore how breathing rhythm interacts with land-based core or mobility exercises to influence overall performance.

5. Conclusion

This study examined the effects of three different breathing rhythms on freestyle swimming performance, perceived exertion, and heart rate recovery in university-level swimmers. The results demonstrated that breathing every three strokes (BR3) led to significantly better performance outcomes, including faster swim times, lower subjective fatigue (RPE), and more efficient cardiovascular recovery compared to both higher (BR2) and lower (BR4) breathing frequencies. These findings highlight the critical role of breathing rhythm as a modifiable factor in optimizing both physiological and perceptual aspects of swimming performance.

The superiority of the BR3 rhythm may be attributed to its balance between sufficient oxygen intake and minimal disruption to stroke mechanics. Unlike BR2, which may interfere with stroke symmetry, or BR4, which could lead to transient oxygen deficits, BR3 appears to offer a biomechanically and metabolically optimal pattern for short-distance freestyle efforts. This insight supports previous findings in both aquatic and dry-land training literature that emphasize the integration of breathing control with technical skill development.

In conclusion, breathing rhythm should be regarded as an integral component of swimming technique, rather than a secondary adjustment. Coaches and athletes are encouraged to incorporate breathing rhythm drills—particularly emphasizing three-stroke breathing—into structured training protocols. Future research may further explore long-term adaptations to breathing patterns, their impact on aerobic capacity and stroke economy, and how such adaptations vary across skill levels, distances, and stroke types.

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