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The relationship between breathing frequency and mechanical efficiency of performance in freestyle swimming among students of the college of physical education and sports sciences

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Abstract
The regulation of breathing during freestyle swimming is a fundamental element that affects technical and mechanical performance, particularly for beginners who often struggle to integrate basic movements with systematic breathing. This research aims to study the relationship between breathing frequency and the mechanical efficiency of freestyle swimming performance among first-year students at the College of Physical Education and Sports Sciences for the academic year 2024-2025. The research sample consisted of (20) male students who were purposively selected after completing their learning of basic skills such as floating and preliminary movements. Four (4) students were excluded due to frequent absences, and another (8) students who were experienced swimmers were excluded to ensure sample homogeneity. The students were divided into two equivalent groups: an experimental group and a control group. The experimental group performed freestyle swimming with regulated breathing (one inhalation per 2-3 strokes) using a pull buoy to help stabilize leg movement, while the control group performed freestyle swimming without any specified breathing frequency. The results showed significant differences in favor of the experimental group at a significance level of ($\alpha \leq 0.05$) across all studied variables. The experimental group members recorded lower performance times and fewer strokes, along with a reduced breathing frequency compared to the control group, which resulted in higher mechanical efficiency. The results of Levene's test for equality of variances confirmed that the two groups were comparable in variance, which allowed for the use of the independent samples t-test. The research concluded that regulating breathing frequency is an influential factor in improving the temporal and mechanical performance of beginners in freestyle swimming, making it an important element to focus on in the early stages of learning to swim. The researcher recommends integrating regulated breathing drills into swimming instruction programs to enhance mechanical efficiency and completion time.

Keywords: Freestyle swimming, breathing frequency, mechanical efficiency, first-year students, temporal performance

Introduction
Swimming is one of the most important aquatic sports, combining both physiological and mechanical aspects. A good performance requires a high degree of integration between physical abilities, technical skills, and biomechanical characteristics. Freestyle, in particular, is distinguished as the most common and widely used stroke in both official competitions and instructional programs, owing to the freedom of movement and speed it provides (Maglischo, 2003) [20].

Performance in freestyle swimming depends on a set of interconnected variables, the most important of which are completion time, stroke count, stroke length, and the regulation of breathing frequency. Mechanical efficiency is considered a primary indicator of a swimmer's ability to utilize their kinetic energy most effectively, reflecting the relationship between the distance covered and the number of strokes used to achieve it (Barbosa *et al*., 2010) [21]. Therefore, any improvement in the breathing technique or its regulation can have a direct impact on other elements of technical performance.

Breathing regulation is a critical factor in freestyle performance. An irregularly high breathing frequency often leads to a disruption in movement rhythm and an increase in hydrodynamic resistance due to excessive head movements, which impairs the body's streamlining in the water.

In contrast, regulated breathing such as taking one inhalation every 2-3 strokes-contributes to improved coordination between the arms and body movement and reduces velocity loss during swimming (Toussaint & Truijens, 2005; Seifert, Chollet, & Bardy, 2004) [22, 23].

From a physiological perspective, reducing breathing frequency helps to utilize the lungs' vital capacity and increase the efficiency of gas exchange, allowing the swimmer to maintain a stable speed over a longer distance (Pyne & Sharp, 2014) [24]. This, in turn, reduces the number of strokes required to cover the distance and increases mechanical efficiency, reflecting the integration between the functional and mechanical aspects of freestyle swimming.

Given that first-year students in colleges of physical education and sports sciences are in the process of learning basic swimming skills, introducing elements of breathing regulation at this stage is of great importance. It can contribute to building a correct technical foundation and improve completion time and mechanical efficiency early in the learning phases. Consequently, studying the relationship between breathing frequency and mechanical efficiency in this population represents a significant scientific and practical step toward developing swimming instruction methods.

Importance of the research

The importance of this research stems from its focus on a fundamental aspect of learning freestyle swimming for first-year students at the College of Physical Education and Sports Sciences: the regulation of breathing frequency and its relationship with the mechanical efficiency of performance. Beginners often face difficulty in integrating basic swimming movements with the breathing process, which leads to a disruption of the movement rhythm and increased resistance in the water, consequently lowering performance levels. Hence, there is a need for a systematic scientific study to highlight the effect of regulated breathing on completion time, stroke count, and mechanical efficiency.

This research contributes to clarifying the vital role that regulated breathing plays in enhancing students' technical and mechanical performance, as it is expected to help reduce unproductive effort and increase motor effectiveness. The study also derives its importance from linking theoretical aspects based on biomechanical concepts with practical application in a real educational setting. This makes it a scientific addition that can benefit swimming instructors in developing their teaching methods, as well as students in improving their performance and overcoming the early difficulties associated with the breathing process during swimming.

Furthermore, the research provides a database that can be built upon for future, more specialized studies addressing the relationship between physiological and mechanical factors in swimming, both at the learning and competitive performance levels. Therefore, the significance of this work is not limited to the academic framework but also extends to contributing to the improvement of practical practices in swimming education and training.

Research Objectives

- To determine the relationship between breathing frequency and mechanical efficiency in freestyle swimming among first-year students.
- To ascertain the effect of breathing frequency on the completion time of a 25m freestyle swim.
- To provide practical recommendations for swimming instructors regarding the best breathing patterns to enhance the mechanical efficiency of beginner students.

Research Hypotheses

- There is a statistically significant correlational relationship between breathing frequency and the mechanical efficiency of freestyle swimming performance.
- The completion time for a 25m freestyle swim differs according to the breathing frequency used (low frequency vs. high frequency).
- Students who use a regular breathing frequency will achieve higher mechanical efficiency compared to students with irregular breathing.

Research Domains

Domain	Description
Human	First-year students at the College of Physical Education and Sports Sciences, Al-Mustansiriyah University, for the academic year (2024-2025).
Spatial	The swimming pool of the Iraqi Army Sports Club in Baghdad.
Temporal	From April 11 to May 8, 2025, coinciding with the weekly swimming classes.

Research Methodology

The study adopted a quasi-experimental correlational approach, as it was deemed most appropriate for examining the nature, strength, and direction of the relationship between breathing frequency and mechanical efficiency within a relatively controlled field setting.

Tools Used

- A digital stopwatch to record time.
- Raw data recording forms.
- A camera (smartphone) to record and analyze performance.
- A calculator for computing mechanical efficiency (Distance covered / Stroke count).

Field Research Procedures

The study was conducted during the second semester of the academic year (2024-2025) on first-year students in the College of Physical Education and Sports Sciences, specifically Section (E), which consisted of (32) students. After an initial screening, (8) students who were experienced swimmers prior to enrolling in the curriculum were excluded to maintain sample homogeneity. Additionally, (4) other students were excluded due to repeated absences from practical lessons, making the final sample size (20) students, who constituted the core research sample.

The field procedures took place at the swimming pool of the Iraqi Army Sports Club in Baghdad. (25m length). The experimental variable was applied during the weekly swimming lessons after all students had learned the basic swimming movements and floating skills. Upon transitioning to the stage of learning full freestyle with breathing, they were divided into two equal groups of (10) students each. The research adopted a quasi-experimental design, as no specialized training program was used, and the only difference between the groups was the regulation of breathing frequency. The experimental group was instructed to follow a specific breathing pattern (one inhalation per 2-3 arm strokes) using a pull buoy as a tool to control breathing during performance. Meanwhile, the control group continued with their regular training without imposing a specific breathing pattern.

Pilot Study

A pilot study was conducted on (5) students from outside the main sample on May 22, 2025, with the following objectives:-

- To ensure the validity of the tools.
- To test the clarity of the recording forms.
- To test the clarity and angles of filming.
- To determine the appropriate time for data collection within the weekly lesson.

Main Experiment

The main experiment was conducted on May 29, 2025, with the participation of all sample members.

During the main experiment, each student performed one trial to cover a distance of (25 meters) freestyle at maximum possible speed. Performance time was recorded in seconds using a digital stopwatch, while stroke count and the number of breaths were counted manually with the help of observers. The mechanical efficiency of the performance was calculated by dividing the distance covered (25m) by the number of strokes completed. To enhance measurement accuracy, performance was recorded using a Korean-made smartphone camera with a 64-megapixel resolution and 4K/60fps video recording capability, which allowed for a high-precision review of the performance to verify the field data.

To standardize the measurement conditions, all students underwent a uniform warm-up period before starting. All tests were conducted in a similar aquatic environment and time frame within the same pool, with unified instructions and procedures for all sample members.

Statistical Methods

Statistical data were processed using SPSS (Version 27) to analyze the research results in accordance with the established objectives and hypotheses. The following statistical methods were used:

- Mean
- Standard Deviation
- Range (Minimum-Maximum)
- Independent Samples t-test
- Levene's Test for Equality of Variances
- Effect Size (using Cohen's d, Hedges' g, and Glass's delta)

Presentation of Results

Descriptive Statistics

Group		N	Minimum	Maximum	Mean	Std. Deviation
Control	Performance. Time	10	24.9	25.7	25.310	.2685
	Stroke. Count	10	20	22	21.20	.789
	Breathing. Frequency	10	8	10	9.00	.667
	Mechanical. Efficiency	10	1.14	1.25	1.1820	.04290
	Valid N (listwise)	10				
Experimental	Performance. Time	10	24.1	24.8	24.430	.2312
	Stroke. Count	10	18	20	18.70	.675
	Breathing. Frequency	10	7	8	7.20	.422
	Mechanical. Efficiency	10	1.25	1.39	1.3410	.04725
	Valid N (List Wise)	10				

he results for the control group (N=10) showed that the performance time for the 25-meter freestyle ranged from 24.9 to 25.7 seconds, with a mean of 25.31 seconds and a standard deviation of 0.26. The arm stroke count ranged from 20 to 22 strokes, with a mean of 21.20 strokes and a standard deviation of 0.78. Regarding breathing frequency, it ranged from 8 to 10 breaths/25m, with a mean of 9.0 breaths and a standard deviation of 0.66. Mechanical efficiency values ranged from 1.14 to 1.25 m/stroke, with a mean of 1.18 m/stroke and a standard deviation of 0.04.

Independent Samples Test

		Levene's test for equality of variances		t-test for Equality of Means						
		F	Sig.	T	DF	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Performance. Time	Equal variances assumed	.136	.716	7.854	18	.000	.8800	.1121	.6446	1.1154
	Equal variances not assumed			7.854	17.611	.000	.8800	.1121	.6442	1.1158
Stroke. Count	Equal variances assumed	.233	.635	7.615	18	.000	2.500	.328	1.810	3.190
	Equal variances not assumed			7.615	17.580	.000	2.500	.328	1.809	3.191
Breathing. Frequency	Equal variances assumed	.194	.665	7.216	18	.000	1.800	.249	1.276	2.324
	Equal variances not assumed			7.216	15.207	.000	1.800	.249	1.269	2.331
Mechanical. Efficiency	Equal variances assumed	.282	.602	-7.879	18	.000	-.15900	.02018	-.20140	-.11660
	Equal variances not assumed			-7.879	17.835	.000	-.15900	.02018	-.20142	-.11658

The results of the Independent Samples T-test indicated the presence of significant differences at the (α≤0.05) level between the control and experimental groups across all studied variables. Furthermore, the results of Levene's test showed that the variance between the two groups was similar, with no significant difference found (p>0.05). Therefore, the assumption of homogeneity of variances was met, and the standard t-test results were relied upon.

The mean performance time was significantly lower for the experimental group, indicating a faster completion speed. A significant difference was also observed in stroke count, with the experimental group using fewer strokes compared to the control group. Regarding breathing frequency, the experimental group exhibited a lower number of breaths, reflecting better regulation of the respiratory rhythm during swimming. Finally, the experimental group recorded statistically significant higher values in mechanical efficiency, demonstrating greater efficiency in utilizing kinetic energy to produce effective propulsion in the water.

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Performance. Time	Cohen's d	.2506	3.512	2.057	4.930
	Hedges' correction	.2616	3.363	1.970	4.721
	Glass's delta	.2312	3.807	1.850	5.725
Stroke. Count	Cohen's d	.734	3.406	1.978	4.796
	Hedges' correction	.767	3.261	1.894	4.593
	Glass's delta	.675	3.704	1.789	5.580
Breathing. Frequency	Cohen's d	.558	3.227	1.844	4.573
	Hedges' correction	.582	3.090	1.766	4.379
	Glass's delta	.422	4.269	2.126	6.378
Mechanical. Efficiency	Cohen's d	.04512	-3.524	-4.945	-2.066
	Hedges' correction	.04712	-3.374	-4.735	-1.978
	Glass's delta	.04725	-3.365	-5.106	-1.583

A) The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Analysis of the practical significance of the differences, using effect size coefficients (Cohen’s d, Hedges’ g, and Glass’s delta), revealed that the statistical differences between the two groups also held practical importance to varying degrees. The effect size for performance time was relatively small (D=0.25), but it indicated a consistent improvement in completion speed for the experimental group. Meanwhile, the effect size for stroke count was moderate to large (D=0.73), which shows that the reduction in strokes was directly associated with increased efficiency. Breathing frequency demonstrated a moderate effect size (D=0.56), suggesting that breath regulation had a distinct impact on performance. Finally, mechanical efficiency showed a moderate effect size (D=0.45), reflecting a tangible practical superiority of the experimental group. This reinforces the role of breathing frequency control in enhancing motor efficiency in the water.

Discussion of Results

The results of the Independent Samples T-test showed significant differences at the ($\alpha \leq 0.05$) level between the experimental and control groups for all studied variables. Furthermore, Levene's test results indicated that the variance between the two groups was similar, with no significant difference found ($p>0.05$). Therefore, the t-test results from the "equal variances assumed" row were relied upon for interpretation.

First, the results showed that the mean performance time was lower in the experimental group compared to the control group. This indicates that regulating breathing frequency (one inhalation per 2-3 strokes) helped improve movement rhythm and optimize the use of body energy during swimming. This finding is consistent with Maglischo (2003) [20], who stated that coordination between strokes and breathing reduces hydrodynamic turbulence and increases gliding efficiency in the water. Similarly, Toussaint & Truijens (2005) [22] noted that breath control reduces resistance caused by irregular head movements, which explains the time difference between the two groups.

Second, the results revealed that the stroke count was lower in the experimental group, which is a direct indicator of higher mechanical efficiency. Reducing strokes while maintaining speed implies a greater Stroke Length. This idea is supported by the study of Seifert, Chollet, & Bardy (2004) [23], which confirmed that regulated breathing is positively associated with an increase in stroke length due to the stabilization of the movement rhythm.

Regarding breathing frequency, the experimental group recorded fewer breaths compared to the control group. This suggests that the experimental intervention helped students utilize their lungs' vital capacity for longer periods, thereby reducing the disruption of movement rhythm caused by frequent breathing. This result aligns with the findings of Pyne & Sharp (2014) [24], who mentioned that reducing breathing frequency in freestyle contributes to improving movement economy and increases the swimmer's ability to maintain a constant speed over a longer distance.

Finally, the higher mechanical efficiency in the experimental group was a direct outcome of the integration of the preceding variables (faster performance time, fewer strokes, and regulated breathing frequency). This is consistent with what was proposed by Barbosa *et al*. (2010) [21], who argued that mechanical efficiency is a reflection of the relationship between physical performance and motor regulation, and that improving breathing is one of the most influential factors.

Based on this, it can be concluded that the hypotheses set forth in the research have been validated. The results have proven that regulating breathing frequency using a pull buoy had a positive and effective impact on the mechanical and temporal performance of beginner students in freestyle swimming.

Conclusions

- The results showed that controlling breathing frequency in beginner swimmers led to a reduction in the total time to complete a 25 meter freestyle swim. This indicates that controlling the respiratory rhythm contributes to improving streamlining and reducing hydrodynamic resistance, thereby achieving a faster and more stable performance.

- It was found that swimmers who adhered to a regular breathing pattern used fewer strokes compared to the control group. This reflects an increase in the length of a single stroke and an enhancement of motor efficiency, indicating that breath regulation is linked to improved movement economy and reduced unnecessary mechanical effort.
- The findings demonstrated that reducing the number of breaths did not negatively affect performance; rather, it helped stabilize the motor and physiological rhythm of beginner swimmers. This reflects the swimmers' ability to utilize their lung's vital capacity and endure longer periods without the need for frequent breathing.
- An increase in the level of mechanical efficiency was observed among the members of the experimental group compared to the control group. This confirms that regulating breathing not only improves the physiological aspect but also enhances the biomechanical aspect of performance, as reflected in the increased distance covered per stroke and reduced wasted motion.
- The results showed that all research objectives were achieved, as the four hypotheses related to performance time, stroke count, breathing frequency, and mechanical efficiency were validated. This reinforces the main premise that controlling breathing frequency is a decisive variable in improving the mechanical and physiological performance of beginner swimmers.
- The findings reveal the importance of integrating specific breathing regulation drills into swimming lessons for beginners. This type of intervention contributes to accelerating the learning process, improving physiological responses, and enhancing mechanical performance in a comprehensive manner.

Recommendations

- It is necessary to integrate specific exercises for regulating breathing frequency into the educational curricula for first-year students in colleges of physical education and sports sciences, due to their direct role in improving completion time, reducing stroke count, and increasing mechanical efficiency.
- Breathing frequency and stroke efficiency can be adopted as key indicators for assessing students' progress in learning freestyle, alongside performance time and stroke count.
- It is advisable to adopt the principle of progressive overload in training on breathing patterns, starting with frequent breathing and advancing to breath control over longer intervals to develop aerobic capacity and improve movement economy.
- Coaches and researchers should view breathing not only as a physiological process but also as a mechanical factor that directly affects movement streamlining, stroke length, and mechanical efficiency.
- It is recommended to conduct future studies on larger samples and different age groups, with a focus on comparing multiple breathing patterns and studying their impact on performance over various swimming distances.

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