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ORIGINAL ARTICLE

The Relationship between the Kinematics Variables of University Male Students and Their Fitness in Butterfly Swimming

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ABSTRACT

Background. The butterfly stroke, renowned for its technical complexity, demands a unique interplay of strength, power, and coordination. While previous research has explored the biomechanics of elite butterfly swimmers, limited attention has been given to understanding the relationship between specific kinematic parameters and physical fitness in proficient but non-elite swimmers. This study addresses this gap by investigating the associations between swim velocity, stroke rate, and stroke length over a 25-meter distance with key physical fitness attributes in male college students. **Objectives.** This study aims to determine the relationship between select kinematic parameters of the butterfly stroke and physical fitness in male swimmers, focusing on the analysis of swim velocity, stroke rate, and stroke length over a 25-meter distance. **Methods.** The study group comprised seventeen male proficient butterfly swimmers enrolled in a physical education program. Baseline measurements of muscular strength, muscular endurance, speed, flexibility, and agility were collected during a pre-test to assess participants' physical fitness. Data were analyzed using means, standard deviations, and Pearson correlation coefficients to examine the relationships between these fitness parameters and the kinematic variables of swim velocity, stroke length, and stroke rate. **Results.** A significant positive correlation was observed between stroke length and muscular strength in butterfly swimming ($p<0.05$). Additionally, positive correlations were found between swim velocity, stroke rate, and speed $p<0.05$. **Conclusion.** These findings suggest that muscular strength is a crucial determinant of stroke length, highlighting its importance for efficient butterfly swimming. Furthermore, the positive correlations between swim velocity, stroke rate, and speed underscore the interconnected nature of these variables in overall performance. Swimming curricula should emphasize the development of muscular strength and speed-focused training to optimize the kinematic characteristics of the butterfly stroke in physical education students.

KEYWORDS: ***Swimming Performance, Kinematic Analysis, Physical Fitness Training.***

INTRODUCTION

Success in elite sports hinges on a multifaceted interplay of factors, with physical attributes playing a pivotal role (1). Athletes aiming for high-level competition rely on physical characteristics, including anthropometry and body composition, to gauge their readiness (2). As noted, the general physical characteristics of athletes significantly influence their success (3). Maintaining peak physical fitness is non-negotiable for athletes, as any decline can lead to a rapid decline in performance. Therefore, continuous monitoring of the physical condition of both athletes and coaches is paramount, as it directly impacts their ability to compete successfully and perform well (4, 5).

In swimming, numerous factors contribute to overall performance, but specific physical

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characteristics are crucial for success. The research underscores the significant relationship between anthropometric, biomechanical, and physical fitness characteristics and overall exercise performance. Specifically, swimming performance is greatly affected by body composition (6). For young athletes, development, maturation, and training experience further influence this complex interplay. Studies have established that anthropometric and physiological factors are directly related to swimming performance (7), with some of these characteristics demonstrating a close correlation with the performance of young swimmers. Furthermore, age, height, and swimming performance are closely related (8), while individual and physiological characteristics emerge as significant predictors of success in competitive swimming (9, 10).

A significant correlation exists between anthropometric and physiological factors and swimming performance in young swimmers (11). However, the limited research in this area has yielded inconsistent findings (12). Dokumaci et al. (2017) (13) discovered a strong correlation between anthropometric measurements, including height, upper arm length, and pelvic bone diameter, and the performance of male adolescent swimmers in 50, 100, and 400-meter races. Conversely, other studies have revealed an inverse relationship between anthropometric measurements and swimming performance, particularly in elite endurance swimmers. For example, one study found no correlation between anthropometric characteristics and race time, except for BMI in males. Similarly, research on early swimming performance indicated no significant correlation with anthropometric or physiological factors in either gender. Interestingly, one study highlighted body fat mass as the sole whole-body factor significantly impacting butterfly swimming speed.

Data collected from swimmers often include measurements such as arm length, forearm length, hand size, wingspan, foot size, palm width, forearm girth, grip strength, body fat percentage, swimming experience, forearm length to height ratio, and muscle mass to body weight ratio (14, 15). Knechtle et al. (2010) demonstrated a positive correlation between swimming performance and hand and foot size. The butterfly stroke, renowned for its difficulty, demands exceptional physical endurance and strength, particularly during the backward motion when the swimmer lifts their arms, shoulders, head, and torso out of the water to breathe. As stated, it demands considerable physical endurance and strength, especially in the backward motion when the arms, shoulders, head, and torso are lifted out of the water for breathing (16, 17). Successful execution of the butterfly stroke requires physical capabilities, refined technique, and smooth, precise movements.

The butterfly stroke, which ranks second in speed after the crawl stroke, mimics the movement of a dolphin and requires high levels of muscle strength and joint flexibility. Athletes need a solid understanding of performance and the mechanical factors affecting it to enhance their swimming performance (18). Therefore, understanding the kinematic factors related to the butterfly stroke is crucial for both athletes and coaches. Mastering the butterfly stroke presents significant physical and psychological challenges, demanding dedication and effort to improve the kinematic variables associated with this complex stroke (19).

This study examines the correlation between several kinematic factors related to butterfly stroke and physical fitness among male Faculty of Physical Education at Vietnam National University Ho Chi Minh City students. This study is critical because it evaluates the physical condition of these students and its potential relationship with kinematic factors in the butterfly stroke.

The hypothesis posits that there is a statistically significant correlation between high levels of physical fitness and kinematic characteristics related to butterfly stroke among PE students.

MATERIALS AND METHODS

The research study aimed to assess the physical fitness levels of participants using a standardized testing protocol. A range of tools, including a measuring tape, a reference block, and a digital video camera, were utilized to collect data during the study (20). The researchers employed the Mohammed Allawi physical fitness status description test, a well-established and reliable measure of various aspects of physical fitness, such as muscle strength, endurance, speed, flexibility, and agility (21, 22).

The test items were categorized into five distinct components of fitness. Negatively phrased items (1, 11, and 21) focused on aspects like weakness, fatigue, or lack of power, while positively phrased items (6, 16, and 26) emphasized strength, vigor, or robustness (23, 24). The data analysis was conducted using Kinovea, a widely recognized dynamic analysis program known for its objectivity and consistency (25). The results can inform practitioners, test designers, and researchers about how fitness testing programs can be structured to ensure that all participants can benefit from the potential advantages of such assessments (26).

Regarding endurance, the positively phrased items (2, 12, and 22) could signify stamina, resilience, or prolonged effort, while the negatively phrased items (7, 17, and 27) may imply fatigue, depletion, or decreased capacity to sustain activity.

For speed, the positively phrased items (8, 18, and 28) might denote swiftness, velocity, or rapid movement, whereas the negatively phrased items (3, 13, and 23) could indicate sluggishness, slowness, or reduced pace.

Flexibility: positively phrased items 4, 14, and 24; negatively phrased items 9, 19, and 29.

Agility: positively phrased items 10, 20, and 30; negatively phrased items 5, 15, and 25.

A Likert pentagon scale was used as a feedback tool to assess the participant's fitness level. The levels were: "apply to a very high degree (5)," "apply to a large degree (4)," "apply to a moderate degree (3)," "apply to a small degree (2)," and "apply to a minimal degree (1)." In the assessment conducted by swimming sports professionals, each aspect, such as muscle strength, endurance, and speed, was evaluated independently on a scale ranging from 6 to 30 degrees. These scores were based on specific criteria and benchmarks related to each aspect. The total score, reflecting an individual's comprehensive fitness level, spanned from 30 to 150 degrees, with higher scores indicating better fitness. During the scoring process, phrases associated with each aspect were ranked ordinally, ensuring consistency and objectivity. Phrases that conveyed opposing meanings were appropriately reversed to maintain the integrity of the assessment. The study took place under the supervision and guidance of the swimming course instructor for students, utilizing the facilities at the swimming pool of the Physical Education Department. This ensured that the assessment was conducted in a controlled and conducive environment, allowing for accurate and reliable data collection. After instructing the participants how to perform the butterfly stroke, scores were recorded for phrases going in the spatial direction, while scores for phrases going in the reverse direction were reversed.

Test Validity. To validate the accuracy of the physical fitness evaluation tool, a committee consisting of three specialists in swimming instruction and pedagogy scrutinized the assessment questionnaire. Their expertise was leveraged to assess the suitability and practicality of implementing the questionnaire with the study participants to fulfill the research goals. This step aimed to ascertain that the assessment tool effectively captured relevant data and provided meaningful insights into the participants' physical condition, ensuring the study results' reliability.

Reliability Testing. The test-retest method was used in the study to measure the research variables, and the reliability of the measurements was evaluated using Pearson correlation coefficients.

A sample of research survey participants, including 17 students from similar environments, underwent a retest with a 5-day interval between tests. Table 1 displays stability coefficients for the tests used, indicating how closely scores from the two administrations correlate. Notably, the study did not include the findings of these 17 students.

Table 1. Stability coefficients for study variables

No.	Variants	Coefficient of stability
1	Endurance status	0.745
2	Fitness status	0.823
3	Overall physical condition	0.804
4	Speed status	0.864
5	State of elasticity	0.734
6	The state of muscular strength	0.714

Due to the high stability coefficients of the research variables in Table 1, the assessment sample describing physical conditions can be used in the study to achieve its objectives, though some confounding factors may be present. The intrinsic value of this investigation may be influenced by variables that can affect both dynamic and physical states. Some potentially confounding variables include:

Previous physical training: Participants' physical condition and dynamic performance may be influenced by varying levels of physical training or prior swimming experience.

Proficiency in swimming technique: Differences in swimming technique proficiency among individuals can affect dynamic variables in the butterfly stroke process and physical fitness levels. Skilled swimmers may exhibit different dynamic patterns compared to less-skilled swimmers.

Participants may demonstrate different dynamic responses and physical fitness levels depending on their health issues. Measures of dynamic variables and physical condition assessments may be affected by conditions such as musculoskeletal disorders or respiratory illnesses.

Motivation and effort: biases may be introduced by participants' fluctuations in these areas throughout the dynamic analysis and physical condition assessments. Those with high motivation may achieve higher scores on both tests.

Nutritional factors: Variations in individuals' dietary practices may affect their performance and physical condition. While it is difficult to fully control dietary parameters, collecting information on basic dietary practices can help mitigate the impact of any confounding variables.

Participants. The research subjects were exclusively male students enrolled in the Physical Education department at VNU-HCMC. This specific demographic was chosen due to the study's focus on understanding the relationship between physical fitness, kinematic characteristics, and butterfly stroke performance within a relatively homogenous population engaged in structured physical education (Table 2).

Inclusion Criteria. Age: Participants were required to be within the age range of 18 to 22 years old. This age bracket was selected to minimize potential variability in physical development and swimming experience that could arise from a more comprehensive age range.

Enrollment Status: All participants must be currently registered students in the PE department at VNU-HCMC.

Swimming Proficiency: Participants had to demonstrate proficient butterfly stroke abilities. This ensured that all subjects possessed a baseline competency in the stroke, allowing for a focused analysis of the relationship between physical attributes and performance within a specific skill level.

Exclusion Criteria. The students who participated in the pilot study and demonstrated exceptional performance in the pre-test examination were also excluded from the final sample. This exclusion aimed to prevent potential bias and ensure that the final sample comprised individuals with a representative range of butterfly stroke abilities within the proficient category.

Sampling Method and Sample Size. A purposive sampling method was employed to recruit participants. This non-probability sampling technique was deemed appropriate given the study's specific inclusion criteria and the desire to select participants who met the predefined characteristics.

The final study sample consisted of 17 male students aged 18 to 22 who met all the inclusion criteria and volunteered to participate. The sample size, while relatively small, was deemed sufficient for this exploratory study, particularly given the specific population and the use of descriptive statistics to analyze the data.

Pilot Study and Instrument Validation. Before the main study, a pilot survey was conducted with seventeen students. This pilot phase served two primary purposes:

Instrument Validation: The pilot study allowed for the testing and refinement of the research instruments, ensuring their reliability and validity in measuring the intended variables.

Methodological Refinement: The pilot phase provided an opportunity to identify and address any logistical or methodological challenges before implementing the main study.

Including six high-performing students from the pilot study in the final sample further strengthens the study's internal validity by mitigating potential bias and ensuring a representative sample.

Addressing Limitations. While the purposive sampling method was appropriate for this exploratory study, it limits the generalizability of the findings to a broader population. Future research should consider employing random sampling techniques and larger sample sizes to enhance the external validity and generalizability of the results.

Furthermore, the study's focus on a specific demographic - male PE students - restricts the applicability of the findings to other populations, such as female swimmers or athletes from different disciplines. Future studies should explore these variations to understand better the factors influencing butterfly stroke performance across diverse groups.

Table 2. Presents the descriptive statistical data regarding the research sample, including the maximum and minimum values for weight, height, and age, along with the mean values and standard deviations

The Variant	M	SD
Mass (kg)	67.65	3.84
Length (cm)	171.13	5.05
Age (year)	20.02	1.05

M: Mean; SD: Standard Deviation.

Statistical Analysis. The researchers used statistical variables, such as mean value, standard deviation, and Pearson correlation coefficient, to conduct the study's statistical analysis. A significance threshold of p=0.05 or higher was established. The software SPSS 20.0, a well-known tool often used for statistical analysis in research projects, was utilized to complete the data analysis.

RESULTS

Table 3 presents comprehensive statistics regarding the study participants' dynamic characteristics and physical conditions. The average temperature recorded during the assessment was 21.86 degrees Celsius, with a standard deviation of 4.46 degrees Celsius. While this information is relevant to the testing conditions, it does not indicate participant endurance levels directly. Slight variations in endurance levels, as evidenced by the standard deviation, were observed among individuals. Similarly, flexibility displayed significant individual variability, averaging 21.89 degrees and a standard deviation of 4.52 degrees. Regarding speed, the average speed coefficient was 20.50 out of 30, while muscle strength ranked third with an average score of 20.54 out of 30. These findings collectively suggest that the study participants exhibited high levels of physical fitness, with an overall physical fitness score of 102.87 out of 150.

Table 3. Lists the physical conditions and selected dynamic characteristics measured for each student enrolled in the physical education department during a butterfly swim

Variables (unit of measurement)	M	SD
Average arm stroke length in butterfly swimming (meters)	1.35	0.042
Average swimming speed of 25 M Butterfly (M/s)	0.98	0.031
Butterfly swimming arm stroke frequency (stroke/second)	0.56	0.024
Fitness status (degree)	19.82	4.140
Muscle strength status (degree)	20.54	1.313
Overall physical condition (degree)	102.87	12.078
Speed status (degree)	20.50	1.515
State of elasticity (degree)	21.89	4.516
State of endurance (degree)	21.86	4.455

M: Mean; SD: Standard Deviation.

Furthermore, analysis of dynamic variables revealed valuable insights into swimming performance. The average stroke length, determined by dividing the total distance covered by the total number of strokes, was 1.35 meters. The stroke frequency, calculated by dividing the total number of strokes by the total distance, was determined to be 0.56 strokes per second. Lastly, dividing the total distance traveled by the total time elapsed yielded an average swimming speed of 0.98 meters per second for the 25-meter butterfly event. These dynamic metrics offer valuable data for evaluating swimming performance and informing training strategies.

It was found that there is a statistically significant positive correlation ($\alpha<0.05$) between the average stroke length and muscle strength component. A positive statistically significant correlation ($\alpha<0.05$) was identified between the average swimming speed in the 25-meter butterfly event and the speed component. These findings suggest that swimming speed and muscle strength play crucial roles and positively correlate with the physical condition of the study sample during the butterfly stroke (Table 4).

Table 4. The study sample detailing the correlation coefficients between physical condition and the dynamic characteristics of the butterfly stroke

Variants ***(Pearson's r)***	**The average length of the arm stroke in butterfly stroke**	**Frequency of butterfly arm strokes**	**Average swimming speed in 25m butterfly**
Muscle Strength Status	0.82*	0.07	0.41
Endurance Status	0.04	0.39	0.39
Speed Status	0.18	0.88*	0.88*
Flexibility Status	0.05	0.38	0.43
Physical Fitness Status	0.52	0.06	0.28
Overall Physical Fitness Status	0.23	0.45	0.57

*: D at the level of $0.05\geq\alpha$; D: The test statistic value.

DISCUSSION

Our initial hypothesis proposed a strong correlation between physical conditioning, dynamic attributes, and successful butterfly stroke execution. Survey data revealed notable parameter variations among participants, with endurance and flexibility emerging as the most prominent factors. This aligns with established knowledge emphasizing the crucial role of endurance in swimming, particularly in structured training regimens (3-5). Flexibility, especially in the shoulder joint, is equally vital for executing the complex movements inherent to swimming, such as folding, stretching, and rotation (25).

While speed and muscle strength are significant, their lower ranking compared to endurance and flexibility suggests a potentially lesser impact on overall performance (3-5, 27). Interestingly, the dynamic factors observed in our study were less pronounced than those seen in competitive swimmers, indicating that enhanced muscle strength, as dictated by Newton's second law of motion, might be pivotal for achieving higher acceleration and speed in the water (28-31). This observation is corroborated by analyses of elite swimming competitions, where faster swimmers tend to execute fewer strokes, emphasizing the importance of stroke efficiency.

This study addresses a gap in the existing literature by investigating the correlation between physical fitness and kinematic characteristics of the butterfly stroke, specifically among students (32-41). While previous research has explored factors influencing swimming performance, this study provides unique insights into this population's specific needs and conditions. The findings confirm that physical fitness and kinematic factors significantly impact butterfly stroke performance, particularly highlighting the importance of endurance, flexibility, speed, and muscle strength.

A fundamental limitation of this study lies in the observed discrepancy between the dynamic factors of the participants and those of competitive swimmers. This difference highlights the need for future research to investigate training interventions designed to enhance muscle strength and stroke efficiency in swimmers of varying skill levels.

Recommendations for Enhancing Butterfly Stroke Performance.

Based on the study findings and identified research gaps, the following recommendations are proposed:

1) Training Programs: Integrate specialized endurance and flexibility training tailored to the biomechanics of the butterfly stroke. This could involve incorporating exercises that mimic the stroke's movements, improving cardiovascular fitness, and enhancing range of motion in the shoulders, hips, and spine.

2) Strength Development: Prioritize strength training programs that target the arms and legs, aiming to increase stroke length and overall swimming speed. Exercises such as pull-ups, dips, squats, and lunges can be modified and integrated into training routines to target muscle groups essential for butterfly stroke propulsion specifically.

3) Further Research: Conduct in-depth studies to elucidate further the complex relationship between propulsion force and swimming speed in

the butterfly stroke. This research should focus on quantifying the forces generated during different phases of the stroke, analyzing the impact of varying stroke rates and amplitudes, and exploring the influence of hydrodynamic drag on overall performance.

4) Coaching Techniques: Educate coaches and students on the potential drawbacks of excessive undulating strokes on swimming hydrodynamics. Emphasize the importance of maintaining a streamlined body position, optimizing stroke efficiency, and minimizing unnecessary movements contributing to drag and reducing overall speed.

By integrating these findings and recommendations, sports education programs can refine training methodologies, enhancing swimming performance, particularly in the technically demanding butterfly stroke.

CONCLUSION

This study investigated the factors influencing butterfly stroke performance in university students specializing in endurance training. The study revealed that high levels of endurance and flexibility are crucial for optimal butterfly performance. This underscores the need for training programs that prioritize these fitness components, tailored to different swimmer groups' specific skill levels and individual needs.

A strong positive correlation was observed between arm stroke frequency and butterfly swimming speed. Put, a faster stroke rate translates to a faster swim. This highlights the importance of developing stroke rate as a key performance indicator in butterfly training.

The research confirmed a direct link between muscle strength and arm stroke length. Greater muscle strength allows swimmers to generate more power with each stroke, leading to a longer pull and increased distance covered per stroke. This finding emphasizes the importance of strength training in optimizing butterfly technique.

While endurance and flexibility were identified as primary physical factors in this study group, their dynamic variables (likely referring to overall power output and efficiency) were lower compared to elite swimmers. This suggests that while endurance and flexibility are essential foundations, developing explosive power and refining techniques are crucial for reaching higher levels of butterfly performance.

The study acknowledges limitations related to its specific study group and calls for further research to confirm these findings in a broader population. Future studies should incorporate objective performance measures to explore the influence of technique, psychological factors, and coaching styles on butterfly performance. Longitudinal studies are also needed to establish transparent cause-and-effect relationships between training interventions and performance outcomes.

In conclusion, this research provides valuable insights into the critical physical and technical factors underpinning butterfly stroke performance. By focusing on developing endurance, flexibility, stroke rate, and muscle strength, coaches can create tailored training programs that optimize performance in butterfly swimmers of all levels. Further research is warranted to explore the complex interplay of these factors and refine training methodologies for this technically demanding stroke.

APPLICABLE REMARKS

- The study emphasizes the importance of tailored physical training programs for improving the fitness levels of students, especially those involved in competitive sports such as swimming.
- The findings highlight the relationship between kinetic parameters and overall fitness, suggesting that specific training regimens can significantly enhance performance in butterfly swimming.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Dao Chanh Thuc. Acquisition of data: Ha Minh Diu. Analysis and interpretation of data: Dao Chanh Thuc. Drafting the manuscript: Dao Chanh Thuc. Critical revision of the manuscript for important intellectual content: Ha Minh Diu. Statistical analysis: Dao Chanh Thuc. Administrative, technical, and material support: Ha Minh Diu. Study supervision: Ha Minh Diu.

CONFLICT OF INTEREST

The authors declare that no conflicts of interest could be perceived as interfering with the publication of this study.

FINANCIAL DISCLOSURE

The authors declare no financial relationships with any entities that could have influenced the work reported in this manuscript.

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ETHICAL CONSIDERATION

This study adhered to the ethical standards set by the Declaration of Helsinki. Approval was obtained from the Institutional Ethics Committee at An Giang University, Vietnam National University, Ho Chi Minh City. All participants provided informed consent prior to the commencement of the study.

ROLE OF THE SPONSOR

The sponsor provided funding for equipment and material support but was not involved in the study design, data collection, data interpretation, or manuscript preparation.

ARTIFICIAL INTELLIGENCE (AI) USE

Artificial intelligence tools were not used to collect, analyze, or interpret the data for this study. However, AI-assisted tools were employed to refine language and grammar during manuscript preparation. The authors reviewed all content to ensure its accuracy and originality.

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