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Influence of Different Strength Training Protocol on Breaststroke Performance in Competitive Swimmers

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ABSTRACT

The purpose of the study. This study aims to evaluate the effects of different strength training protocols on breaststroke performance in competitive swimmers, focusing on physiological adaptations, biomechanical efficiency, and performance outcomes.
Materials and methods. A 24-week randomized controlled trial was conducted with 48 competitive breaststroke swimmers (26 male, 22 female, aged 18–25 years). Participants were assigned to three groups: traditional endurance training, high-intensity interval training (HIIT), and an integrated approach combining HIIT with technical refinement. Training intensity, volume, and technical components were systematically varied and monitored. Performance metrics, physiological adaptations, and biomechanical parameters were analyzed using mixed-effects linear models and Cohen's d to determine effect sizes.
Results. The integrated training group demonstrated the most significant improvements across all metrics. Performance times decreased by 2.3% (50m), 2.7% (100m), and 3.1% (200m) compared to smaller gains in the traditional and HIIT-only groups. Biomechanical efficiency improvements included increased stroke length (10.2%) and reduced drag coefficient (12.4%). Physiological enhancements, such as a 12.3% increase in lactate threshold speed and 8.5% improvement in VO_2max, were also observed.
Conclusions. An integrated approach combining HIIT with technical skill development yields superior outcomes in breaststroke performance compared to traditional or HIIT-only protocols. This holistic training method optimizes both physiological and biomechanical adaptations, offering a robust framework for enhancing competitive breaststroke swimming.

Keywords: breaststroke swimming; strength training; high-intensity interval training; biomechanics; endurance training; performance optimization.

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INTRODUCTION

Endurance training is a crucial component of athletic development, particularly for swimmers specializing in the breaststroke event (Stewart & Hopkins, 2000). This discipline demands a unique blend of muscular strength, cardiovascular fitness, and technical efficiency, which can be enhanced through carefully designed training programs (Wirth et al., 2022). The physiological and biomechanical demands of breaststroke swimming require a multifaceted training in order to optimize performance (Fone & Tillaar, 2022). Breaststroke swimming represents one of the most technically demanding disciplines in competitive aquatics, characterized by its unique biomechanical properties and complex energy demands (Aspenes & Karlsen, 2012). Energy demands in competitive swimming are influenced by both distance and duration, with muscle stores of high-energy phosphates, such as creatine phosphate, serve as the primary fuel source for short, high-intensity bursts of activity. Unlike other swimming strokes, breaststroke requires precise coordination between upper and lower body movements, with distinct propulsive phases that must be perfectly timed to maximize efficiency and minimize drag forces (Leblanc et al., 2005). The stroke's distinctive rhythm and the requirement for perfect symmetry in movement patterns present particular challenges for both athletes and coaches in developing optimal training methodologies (Vasile, 2014). Enhancing technical proficiency is crucial for breaststroke swimmers, as small adjustments in stroke mechanics can have a significant impact on overall efficiency and energy expenditure (Lauer et al., 2015).

Recent advances in sports science have highlighted the critical importance of integrating physiological conditioning with

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technical mastery in breaststroke performance (Tiago et al., 2011; Seifert et al., 2013). However, traditional training approaches often emphasize either endurance development or technical refinement, potentially limiting overall performance gains (Wirth et al., 2022). Demonstrated significant correlations between technical efficiency and energy expenditure in breaststroke swimming, suggesting that these elements should not be trained in isolation (Girold et al., 2006). A holistic approach that combines targeted endurance training with a focus on technical optimization may be the most effective way to enhance breaststroke performance (Seifert & Chollet, 2005). A well-structured swimming training program, encompassing variations in training load, intensity (e.g., high-intensity interval training, long-distance steady state), and volume, alongside the incorporation of supplementary dryland training (e.g., strength training, plyometrics), typically elicits physiological adaptations that ultimately enhance swimming performance (González-Ravé et al., 2021).

The scientific literature offers valuable insights into the impact of various endurance training methodologies on breaststroke swimming performance (Strzała et al., 2017). Costill and colleagues have highlighted the potential limitations of traditional high-volume, low-intensity endurance training, noting that such approaches may not adequately prepare swimmers for the supramaximal efforts required in competition (Fone & Tillaar, 2022). Instead, the authors suggest the incorporation of interval-based training, which more closely mimics the intermittent nature of swimming races (Guo et al., 2022; Coates et al., 2023). This type of training has been shown to lead to greater improvements in both aerobic and anaerobic capacities, crucial for the physiological demands of breaststroke swimming (Nugent et al., 2019). By incorporating interval-based training that closely replicates the high-intensity bursts and recovery periods of competitive breaststroke events, swimmers can better develop the necessary physiological adaptations to perform at their optimal level (Thompson et al., 2004).

MATERIALS AND METHODS

Study Participants and Study Design

Our research employed a 24-week randomized controlled trial involving 48 competitive swimmers (26 male, 22 female) aged 18-25 years (mean age 20.3 ± 1.8 years), all specializing in breaststroke. Participant selection criteria included a minimum of five years of competitive swimming experience and qualification times meeting national championship standards. Prior to the study, all participants underwent comprehensive medical screening and provided written informed consent. The study protocol was approved by the Institutional Review Board of Universitas Negeri Medan, Indonesia and conducted in accordance with the Declaration of Helsinki.

Training Protocols

Participants were randomly assigned to three training groups using a computer-generated randomization sequence with stratification for gender and baseline performance levels. Each group followed a distinct training protocol as detailed in the following tables:

Table 1. General Training Parameters Across Groups

Parameter	Group A (Traditional)	Group B (HIIT-Focused)	Group C (Integrated)
Weekly Volume	45-50 km	35-40 km	40-45 km
Sessions per Week	11	10	11
Strength Training	2 sessions	3 sessions	3 sessions
Primary Focus	Aerobic Development	High-Intensity Intervals	Combined Approach
Heart Rate Zones	70-80% max	85-95% / 60-70% max	Variable

Table 2. Morning Session Details (6:00-8:00)

Component	Group A	Group B	Group C
Duration	120 min	90 min	100 min
Volume	6-8 km	4-5 km	5-6 km
Main Set Focus	Continuous Swimming	HIIT Sets	Alternating HIIT/Technical
Rest Intervals	Minimal	1:1 to 1:3 work:rest	Variable
Intensity Zones	Zone 2-3	Zone 4-5	Zones 2-5

Table 3. Afternoon Session Details (16:00-18:00)

Component	Group A	Group B	Group C
Duration	90 min	75 min	90 min
Volume	4-5 km	3-4 km	4-5 km
Main Set Focus	Technical/Race-Pace	Recovery/Technique	Complementary Work
Technical Analysis	Weekly	Bi-weekly	Twice Weekly
Video Review	Monthly	Monthly	Weekly

Table 4. Strength Training Specifications

Component	Group A	Group B	Group C
Sessions/Week	2	3	3

Component	Group A	Group B	Group C
Duration	45 min	60 min	60 min
Primary Focus	General Conditioning	Power Development	Combined Power/Technical
Exercise Type	Circuit Training	Olympic Lifts	Periodized Mix
Load Intensity	60-70% 1RM	80-90% 1RM	70-85% 1RM

Table 5. Technical Development Components

Component	Group A	Group B	Group C
Stroke Analysis	Monthly	Bi-weekly	Weekly
Biomechanical Assessment	Quarterly	Monthly	Bi-weekly
Technique Workshops	Monthly	Monthly	Twice Weekly
Race Analysis	Post-Competition	Post-Competition	Weekly
Individual Feedback	Weekly	Weekly	Daily

Table 6. Recovery and Monitoring Protocols

Component	Group A	Group B	Group C
Heart Rate Monitoring	Daily	Every Session	Every Session
Lactate Testing	Monthly	Bi-weekly	Weekly
RPE Recording	Post-Session	Every Set	Every Set
Recovery Sessions	Weekly	Bi-weekly	Bi-weekly
Physiological Assessment	Monthly	Bi-weekly	Weekly

These protocols were maintained throughout the 24-week study period, with minor adjustments made based on individual adaptation rates and competition schedules. All sessions were supervised by certified coaches and sport scientists to ensure adherence to prescribed intensities and technical standards.

Statistical Analysis

Data analysis employed mixed-effects linear models for repeated measurements and individual variations. Effect sizes were calculated using Cohen's d, and significance was set at $p < 0.05$. All statistical analyses were performed using R version 4.2.1 with the lme4 package.

RESULTS

The results of the study will be described as follows:

Race Performance Improvements

Table 7. Race Performance Improvements

Distance	Metric	Group A (Traditional)	Group B (HIIT)	Group C (Integrated)
50m	Time Improvement (%)	1.2*	1.8**	2.3***
	Effect Size (d)	0.68	0.89	1.24
	Mean Time Change (s)	-0.31	-0.44	-0.57
100m	Time Improvement (%)	1.5*	2.1**	2.7***
	Effect Size (d)	0.72	0.95	1.38
	Mean Time Change (s)	-0.89	-1.22	-1.56
200m	Time Improvement (%)	2.1*	2.4**	3.1***
	Effect Size (d)	0.84	1.02	1.45
	Mean Time Change (s)	-2.34	-2.67	-3.45

*p < 0.05, **p < 0.01, ***p < 0.001

The results demonstrate a clear hierarchy in the effectiveness of the three training approaches, with the integrated program (Group C) consistently producing superior outcomes across all race distances. Several key patterns emerge:

Sprint Performance (50m): Group C's superior improvement (2.3%) suggests that the integrated approach effectively develops both power and technique. The larger effect size (d = 1.24) indicates a robust and practically significant improvement. HIIT-focused training (Group B) showed intermediate benefits, highlighting the importance of high-intensity work for sprint events.

Middle Distance (100m): The greatest absolute time improvements were observed in this distance. Group C's 2.7% improvement represents a significant competitive advantage. The effect size (d = 1.38) suggests these improvements are highly meaningful in competitive contexts.

Distance Performance (200m): All groups showed their most significant percentage improvements at this distance. Group C's 3.1% improvement demonstrates the effectiveness of combined technical and physiological development. The progressive improvement pattern (A < B < C) was most pronounced at this distance.

Physiological Adaptations

Table 8. Physiological Adaptations

Parameter	Group A (Traditional)	Group B (HIIT)	Group C (Integrated)
Lactate Threshold Speed (% increase)	6.5*	8.7**	12.3***
Lactate at Race Pace (mmol/L decrease)	-1.2*	-1.8**	-2.4***
VO2max (% increase)	4.8*	6.2**	8.5***
Oxygen Economy (% improvement)	5.2*	7.1**	9.4***
Heart Rate Recovery (% improvement)	6.8*	8.9**	11.2***
Anaerobic Power (% increase)	5.4*	8.8**	10.5***

*p < 0.05, **p < 0.01, ***p < 0.001

The physiological data reveals several important insights: 1) Metabolic Efficiency: Group C's superior lactate threshold improvement (12.3%) indicates enhanced metabolic efficiency; The larger decrease in race-pace lactate levels suggests better buffering capacity; VO2max improvements correlate well with performance gains. 2) Energy Systems Development: The integrated approach produced balanced improvements across both aerobic and anaerobic parameters; Heart rate recovery improvements suggest enhanced cardiovascular adaptation; Anaerobic power increases were notably higher in Groups B and C.

Biomechanical Parameters

Table 9. Biomechanical Parameters

Parameter	Group A (Traditional)	Group B (HIIT)	Group C (Integrated)
Glide Phase Duration (% increase)	8.4*	11.2**	15.2***
Propulsive Efficiency (% improvement)	10.5*	14.3**	18.7***
Drag Coefficient (% reduction)	-7.2*	-9.8**	-12.4***
Peak Propulsive Force (% increase)	8.7*	11.5**	14.3***
Stroke Length (% improvement)	5.3*	7.8**	10.2***
Stroke Rate Consistency (CV%)	8.2*	6.4**	4.1***

*p < 0.05, **p < 0.01, ***p < 0.001

The technical analysis reveals significant adaptations: 1) Stroke Mechanics: Group C's superior improvements in glide phase duration (15.2%) and propulsive efficiency (18.7%) demonstrate the effectiveness of integrated technical training; Reduced drag coefficients suggest better streamlining and body position; Improved stroke length with maintained stroke rate indicates enhanced efficiency. 2) Force Application: The 14.3% increase in peak propulsive force in Group C, combined with improved efficiency, suggests optimal force application; More consistent stroke rates (lower CV%) indicate better technique retention under fatigue; The relationship between force production and drag reduction suggests improved technique under load.

These results provide strong evidence that the integrated approach (Group C) produces superior adaptations across all measured parameters. The synergistic effects of combining HIIT with systematic technical training appear to enhance both the magnitude and sustainability of performance improvements.

DISCUSSION

The results of this study provide compelling evidence for the superiority of an integrated approach to breaststroke training. The significant performance improvements observed in Group C, which combined high-intensity interval training with systematic technical training, suggest a synergistic relationship between physiological adaptation and technical refinement. This integrated approach appears to optimize both the magnitude and sustainability of performance gains, underscoring the importance of balancing physical conditioning and skill development in elite-level breaststroke swimming (Post et al., 2023; Correia et al., 2023; Monteiro et al., 2023). By targeting both the physiological and biomechanical aspects of performance, the integrated training protocol demonstrated the ability to enhance metabolic efficiency (Yu et al., 2014; Viana et al., 2019), energy system development, and technical proficiency in a complementary manner (Fernandes & Vilas-Boas, 2012; Aspenes & Karlsen, 2012). These findings highlight the value of a holistic training methodology that leverages the synergies between physical and technical adaptations to maximize competitive outcomes in breaststroke swimming.

Physiological Mechanisms

The enhanced performance in Group C can be attributed to several key physiological adaptations demonstrating the synergistic effects of integrating high-intensity interval training with systematic technical training. The combination of these complementary approaches appears to optimize the development of both the aerobic and anaerobic energy systems, while maintaining a high level of mechanical efficiency (Schöenfeld & Dawes, 2009; Earnest et al., 2012). The higher lactate threshold observed in Group C suggests improved buffering capacity and greater tolerance to high-intensity work, which is crucial for success in the 200m breaststroke event. This enhanced metabolic efficiency, combined with the technical improvements in stroke mechanics (Hellard et al., 2007), likely contributed to the superior performance gains seen in this group. The integrated training protocol seems to have facilitated a more holistic adaptation, where physical conditioning and skill development reinforce each other to elevate the athletes' overall competitive capabilities (McGown et al., 1990; Kjørmo & Halvari, 2002).

Biomechanical Considerations

The superior technical improvements observed in Group C suggest that high-intensity training, when properly integrated with systematic technical work, can actually enhance rather than compromise stroke mechanics. The superior technical improvements observed in Group C suggest that when systematically integrated with high-intensity training, focused technical work can enhance, rather than compromise, stroke mechanics. The periodized approach employed in this integrated training protocol appears to have effectively facilitated the athletes' ability to maintain efficient technique even under conditions of fatigue (Tobin, 2014; Yu et al., 2014). The documented increases in peak propulsive force production, coupled with reductions in measured drag coefficients, indicate that the technical adaptations were successfully incorporated into the athletes' automated motor patterns. This synergistic effect, where physical conditioning and skill development reinforce one another, highlights the value of a holistic training methodology that targets both the physiological and biomechanical aspects of performance enhancement in breaststroke swimming (Wirth et al., 2022; Nicol et al., 2022; Muñiz-Pardos et al., 2020).

CONCLUSION

This comprehensive study offers compelling evidence that an integrated approach to breaststroke training, blending high-intensity interval training with systematic technical development, produces optimal results across a range of performance metrics. The significant improvements observed in both physiological and biomechanical parameters suggest that this multifaceted approach effectively addresses the complex and multidimensional demands of competitive breaststroke swimming. The synergistic effects of combining physical conditioning with skill refinement appear to unlock heightened adaptations, elevating the athletes' overall competitive capabilities. By targeting both the physiological and technical aspects of performance in an integrated manner, this training methodology facilitates a more holistic development, where physical adaptations and skill acquisition reinforce and enhance one another.

These findings have important implications for coaching practice and athlete development, particularly at the elite level of breaststroke swimming. The insights gleaned from this study underscore the value of a holistic, integrated training approach that leverages the synergies between physical and technical domains to maximize competitive outcomes. Implementing such an approach can help coaches and athletes optimize performance, equipping them to navigate the complex demands of high-level breaststroke competition more effectively.

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CONFLICT OF INTEREST

The authors wish to formally affirm and unequivocally state that, after careful consideration and thorough review of all relevant circumstances, there exists no discernible conflict of interest that could potentially compromise the integrity of their research or influence the outcomes of their findings in any manner.

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