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Enhancing Swimming Performance: Analyzing and Improving Breaststroke Mechanics in Rajasthan

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Abstract

Breaststroke is one of the most technically demanding swimming strokes, requiring precise coordination of body position, arm pull, kick mechanics, and breathing rhythm. Despite growing participation in competitive swimming across Rajasthan, limited research has focused on the biomechanical challenges faced by regional athletes who often train under resource-constrained conditions. This study investigates the breaststroke mechanics of competitive swimmers from Rajasthan, identifies common technical deficiencies, and proposes a structured intervention program to enhance overall performance. A group of thirty-two (n=32) competitive swimmers drawn from state-level competitions were assessed using video analysis, kinematic measurements, and standardized performance tests over a twelve-week training cycle. Results revealed significant weaknesses in knee alignment during the kick phase, suboptimal hand entry angle, and inefficient glide duration. Following a targeted corrective training program, participants demonstrated measurable improvements in stroke efficiency, race time, and overall stroke index. This paper contributes to the growing body of regional sports science literature and provides practical recommendations for coaches working with breaststroke swimmers in semi-arid and inland training environments such as those characteristics of Rajasthan.

Keywords: Breaststroke mechanics, swimming performance, biomechanics, Rajasthan, stroke efficiency, kick analysis, competitive swimming

1. Introduction

Swimming is widely recognized as one of the most complete forms of physical exercise, engaging virtually all major muscle groups while simultaneously developing cardiovascular endurance, muscular strength, and flexibility. Among the four competitive swimming strokes—freestyle, backstroke, butterfly, and breaststroke—breaststroke holds a distinctive position due to its complex, simultaneous limb movements and the high degree of technical precision it demands of the athlete (Colwin, 2002). Unlike other strokes where propulsion is relatively continuous, breaststroke relies on alternating phases of propulsion and passive glide, making the optimization of each phase critical for competitive success.

In the Indian context, swimming as a competitive sport has witnessed steady growth over the past two decades, with national federations investing increasingly in infrastructure and coaching. However, states such as Rajasthan, which lack a coastline and have historically focused on land-based sports, present a unique set of challenges for swimming development. The scarcity of Olympic-standard pools, limited access to certified coaches specializing in aquatic biomechanics, and the harsh semi-arid climate all contribute to a performance gap between Rajasthan-based athletes and their counterparts from more swim-intensive states such as Maharashtra, Delhi, and Karnataka (Singh & Sharma, 2011).

The breaststroke is particularly susceptible to technical errors when athletes are trained without systematic biomechanical feedback. Common errors include excessive knee spread during the kick, improper arm pull trajectory, mistimed breathing, and failure to exploit the hydrodynamic glide phase. These errors, if left uncorrected, become deeply ingrained habits that are difficult to remediate at advanced stages of athletic development (Maglischo, 2003).

The present study was conceived in response to the observable performance plateau among competitive breaststroke swimmers participating in the Rajasthan State Swimming Championships. Coaches and sport scientists working with these athletes identified recurring biomechanical deficiencies but lacked locally grounded, evidence-based intervention

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protocols tailored to the training conditions prevailing in the region. This paper aims to fill that gap by: (a) systematically documenting the breaststroke mechanics of regional competitive swimmers, (b) identifying the most prevalent technical errors and their likely causes, and (c) evaluating the effectiveness of a structured twelve-week corrective training program designed specifically for the Rajasthan context.

It is anticipated that the findings of this study will serve not only as a scientific contribution to the literature on aquatic sports performance but also as a practical resource for coaches, physical education professionals, and sports administrators working to advance swimming in inland and resource-limited regional settings.

2. Review of Literature

The scientific literature on breaststroke mechanics spans several decades and draws from disciplines including biomechanics, exercise physiology, motor learning, and sports coaching methodology. An understanding of the foundational research in this area is essential for contextualizing the present study within the broader field of aquatic sports science.

Maglischo (2003) provided one of the most comprehensive treatments of swimming biomechanics to date, documenting the distinct kinematic and kinetic characteristics of breaststroke. His work emphasized that the propulsive efficiency of breaststroke is uniquely tied to the coordination between the outsweep, insweep, and recovery phases of the arm pull, and that deviations from optimal hand path trajectory can significantly reduce thrust generation. This foundational insight continues to guide contemporary coaching practice.

Colwin (2002) explored the fluid dynamics underlying competitive swimming strokes and introduced the concept of stroke 'feel'—the proprioceptive awareness that elite swimmers develop over years of technical training. He argued that breaststroke, more than any other stroke, rewards athletes who develop a refined sensitivity to water resistance patterns during the pull and kick phases. His work highlighted the importance of coach-athlete communication in translating biomechanical principles into kinesthetically accessible cues.

Counsilman and Counsilman (1994) examined the role of wave drag in competitive breaststroke and were among the first to quantify the performance cost of excessive body undulation. Their research, drawing on underwater photography, demonstrated that swimmers who maintained a flatter body position during the glide phase experienced significantly lower drag coefficients, translating to measurable time improvements over race distances. Their findings remain relevant even as swimmer profiles and training technologies have evolved.

Persyn et al. (1992) conducted a landmark kinematic study of world-class breaststroke swimmers and identified distinct individual variation in stroke technique even among elite performers. They proposed a classification system based on arm pull width and kick angle, arguing against a one-size-fits-all approach to technical coaching. This work had significant implications for individualized coaching, particularly in talent development programs.

Thompson, Haljand, and MacLaren (2000) analyzed the stroke cycle parameters of Olympic-level breaststroke swimmers and found that stroke rate and stroke length interact in a complex, non-linear fashion. Their research showed that elite performers achieve superior performance not by maximizing stroke rate but by optimizing the balance between propulsive force and drag reduction during the glide phase. This finding has direct implications for how coaches should structure interval training and technical drills.

In the Indian sports science literature, research on swimming biomechanics has been relatively sparse compared to the global body of work. Singh and Sharma (2011) examined the physiological profiles of competitive swimmers from northern India and noted significant differences in aerobic capacity and body composition between swimmers from coastal regions and those from landlocked states. While their study focused primarily on physiological variables, they acknowledged the need for biomechanical investigation of regional athletes.

Vilas-Boas (1996) conducted a detailed analysis of the propulsive phases in breaststroke and identified three distinct kinematic sub-phases within the arm pull: the

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outsweep, the catch, and the insweep. He found that elite swimmers generated the majority of their propulsive force during the insweep phase and maintained it through a high-elbow position that maximized the effective surface area of the forearm and hand. These findings have become central to modern breaststroke coaching curricula worldwide.

Research by Arellano, Brown, Cappaert, and Nelson (1994) investigated the underwater dolphin kick used by elite swimmers during the breaststroke pullout phase following the start and turns. Their work demonstrated that an optimally timed and executed underwater dolphin kick could save between 0.2 and 0.4 seconds per turn, a margin that is decisive at the elite competitive level. Although this aspect of breaststroke mechanics falls outside the primary focus of the present study, it underscores the multifaceted nature of performance optimization in this stroke.

Hay (1993) offered a systematic framework for biomechanical analysis in sport, arguing that performance variables should be organized hierarchically from outcome measures (race time) through intermediate variables (stroke rate, stroke length) to the underlying mechanical factors (force, trajectory, timing). This hierarchical model has been widely adopted in swimming research and informs the analytical approach taken in the present study.

Taken together, the literature establishes that breaststroke performance is determined by a complex interplay of technical, physical, and psychological variables. The present study builds on this foundation by applying established biomechanical principles to the specific context of competitive swimmers in Rajasthan, thereby addressing a gap in regionally specific sports science research.

3. Objectives of the Study

The present study was guided by the following specific objectives:

1. To assess the baseline breaststroke mechanics of competitive swimmers representing Rajasthan state.
2. To identify and document the most prevalent technical deficiencies in the stroke technique of the sample group.
3. To design and implement a twelve-week corrective training intervention targeting the identified technical errors.
4. To evaluate the post-intervention changes in key kinematic parameters and competitive performance times.
5. To formulate evidence-based recommendations for breaststroke coaching in regional and resource-limited training environments.

4. Hypotheses

Based on the objectives of the study and the insights drawn from the review of literature, the following hypotheses were formulated:

H1: Competitive breaststroke swimmers from Rajasthan will exhibit measurable technical deficiencies in kick mechanics, arm pull trajectory, and glide phase duration compared to biomechanically optimal standards documented in the literature.

H2: A structured twelve-week corrective training intervention will produce statistically significant improvements in the stroke index, stroke efficiency, and race time of the sample group.

H3: The degree of improvement will vary significantly between participants based on their years of training experience, reflecting the role of established motor patterns in the remediation of technical errors.

5. Methodology

5.1 Sample Selection

The study sample comprised thirty-two (n=32) competitive swimmers, all of whom had participated in at least one edition of the Rajasthan State Swimming Championship within the three years preceding the study. Participants ranged in age from fourteen to twenty-two years (mean age: 17.4 ± 2.1 years) and included both male (n=20) and female

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(n=12) athletes. All participants trained at one of five recognized swimming clubs affiliated with the Rajasthan Swimming Association, and each had a minimum of two years of structured breaststroke training experience. Written informed consent was obtained from all adult participants and from the parents or guardians of minor participants. Swimmers with any current musculoskeletal injury that would preclude full training participation were excluded from the study.

5.2 Data Collection Instruments

Biomechanical data were collected using dual-camera underwater video analysis. Cameras were positioned at the mid-pool lateral wall and at the end wall to capture both the sagittal and frontal plane kinematics of each swimmer. Video footage was recorded at sixty frames per second to allow precise frame-by-frame analysis of key kinematic events. Kinematic variables measured included: stroke rate (cycles per minute), stroke length (meters per cycle), body roll angle (degrees), knee angle at the catch position (degrees), hand entry angle (degrees), glide phase duration (seconds), and stroke index (calculated as stroke length multiplied by swimming velocity).

Competitive performance was assessed using timed 100-meter breaststroke trials conducted under standardized conditions in a twenty-five-meter pool. Electronic timing systems with touchpad sensors were used to ensure measurement precision. All trials were conducted at the same time of day (morning session, 7:00–9:00 AM) to minimize the influence of circadian variation on performance.

5.3 Intervention Program

Based on the pre-intervention assessment, a twelve-week corrective training program was developed in consultation with certified swimming coaches and sports scientists. The program comprised three training sessions per week of ninety minutes each. The intervention targeted the three most prevalent technical errors identified in the baseline assessment: (a) excessive knee spread and inadequate ankle dorsiflexion during the kick phase; (b) suboptimal hand trajectory during the insweep and outward sweep of the arm pull; and (c) premature initiation of arm recovery that reduced the effective glide duration.

Corrective exercises included targeted flexibility work for ankle dorsiflexion, resistance band exercises for hip external rotators, sculling drills to improve hand sensitivity and pull trajectory, and tethered swimming sets to develop awareness of glide position and timing. Video feedback sessions were conducted weekly to allow athletes to compare their technique against reference footage of biomechanically efficient breaststroke performers.

5.4 Statistical Analysis

Pre- and post-intervention data were analyzed using paired samples t-tests to assess the significance of changes in each kinematic variable and in race time. Effect sizes were calculated using Cohen's d to provide a standardized estimate of the magnitude of change. A significance threshold of $p < 0.05$ was adopted for all statistical tests. Data analysis was performed using SPSS version 20.0.

6. Results and Discussion

6.1 Baseline Technical Assessment

The pre-intervention video analysis revealed several consistent technical patterns that deviated from the biomechanical standards reported in the literature. The mean knee spread angle at the catch position was measured at 48.6 degrees, compared to the optimal range of 35–40 degrees suggested by Maglischo (2003), indicating a tendency toward excessive lateral knee displacement that increases form drag. Ankle dorsiflexion range was notably restricted in 68.75 percent of participants, a finding consistent with the limited access to systematic flexibility conditioning in regional training environments.

Hand entry angle averaged 24.3 degrees below the horizontal plane in the baseline assessment, with significant variation across participants (SD = 6.8 degrees). This value exceeded the optimal entry angle of approximately 15–18 degrees, contributing to a deeper catch position that delays the transition to the propulsive insweep. Glide duration averaged

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0.31 seconds per stroke cycle, compared to the 0.45–0.55 seconds characteristic of efficient breaststroke performers at the competitive level, suggesting that athletes were rushing the recovery phase before maximizing the hydrodynamic benefit of the glide.

The mean stroke index at baseline was 1.82 meters squared per second, which is substantially below the values of 2.4–3.2 reported for national-level breaststroke swimmers in comparable studies (Thompson et al., 2000). Mean 100-meter race time at baseline was 84.7 seconds for male participants and 97.2 seconds for female participants.

6.2 Post-Intervention Changes

Following the twelve-week intervention, significant improvements were observed across all primary outcome measures. Mean knee spread angle decreased to 41.2 degrees ($p < 0.01$, $d = 0.84$), approaching the optimal range and reflecting improved hip external rotation strength and heightened technical awareness developed through drill-based practice. Glide duration increased to 0.44 seconds per cycle ($p < 0.01$, $d = 1.12$), indicating that athletes had successfully incorporated the coach's cues regarding delayed recovery initiation.

Stroke index improved to a mean of 2.19 meters squared per second ($p < 0.001$, $d = 1.34$), representing a 20.3 percent improvement from the baseline. This finding is particularly noteworthy as stroke index is widely regarded as a composite measure of both technical efficiency and swimming velocity. Hand entry angle normalized to a mean of 17.6 degrees ($p < 0.01$, $d = 0.72$), suggesting meaningful improvement in the initial positioning of the arm pull that would facilitate a more mechanically advantageous catch.

Mean 100-meter race time improved by 2.8 seconds for male participants (84.7 to 81.9 seconds) and 3.4 seconds for female participants (97.2 to 93.8 seconds). Both improvements were statistically significant at the $p < 0.01$ level. These time gains are practically meaningful at the regional competitive level and represent a substantial return on a twelve-week training investment.

6.3 Discussion

The results of this study offer several important insights for breaststroke coaching in Rajasthan and in comparable regional settings. The prevalence of excessive knee spread and restricted ankle mobility at baseline is consistent with the findings of Persyn et al. (1992), who noted that athletes trained without systematic flexibility monitoring tend to develop compensatory kick patterns that increase drag. The improvement in this parameter following the intervention underscores the value of targeted flexibility work and resistance training for the hip external rotators.

The improvement in glide duration following the intervention is particularly significant from a performance standpoint. Breaststroke is unique among competitive strokes in offering a hydrodynamically efficient glide position that, if properly exploited, allows the swimmer to maintain velocity with minimal muscular effort. The failure of baseline participants to utilize this phase adequately likely reflected a habitual reliance on stroke rate as a performance strategy—a pattern commonly observed in athletes whose training has emphasized volume over technical refinement. The video feedback sessions appeared to be especially effective in addressing this issue, as athletes reported increased awareness of their body position and timing during the glide phase.

The variation in improvement across participants, with more experienced swimmers showing smaller gains in technical variables but greater improvements in race time, suggests that technical changes in well-established motor patterns require extended practice to translate fully into competitive performance. This finding aligns with the motor learning literature's distinction between performance and learning, and suggests that a longer intervention period may be warranted for athletes with more established but inefficient technical habits.

7. Regional Context: Swimming Development in Rajasthan

Any serious discussion of swimming performance in Rajasthan must acknowledge the distinctive environmental, infrastructural, and cultural factors that shape athletic development

ISSN: 2393-8048

in the region. Rajasthan is India's largest state by area, characterized by an arid to semi-arid climate with extreme temperature variation between summer and winter months. The scarcity of natural water bodies and the historically low cultural salience of aquatic sports have historically limited both participation rates and the development of coaching infrastructure.

The number of Olympic-standard fifty-meter pools in Rajasthan remains critically low relative to the state's population. Most competitive swimmers in the region train in twenty-five-meter pools, and a substantial proportion train in pools that do not meet international standards for water temperature, lane width, or timing systems. This infrastructure gap has direct implications for the development of technical proficiency, as certain aspects of breaststroke training—most notably the optimization of the turn and the pullout—can only be fully practiced in regulation pools.

Despite these challenges, Rajasthan has produced a number of competitive swimmers who have represented the state at national championships. The Rajasthan Swimming Association has made concerted efforts in recent years to expand coaching certification programs and to introduce systematic talent identification processes at the district level. The present study was undertaken in the spirit of supporting these developmental efforts by providing a scientific basis for coaching interventions that are both technically rigorous and practically adapted to the regional context.

The climatic factor also deserves consideration. Training in outdoor pools during Rajasthan's summer months—when temperatures can exceed 45 degrees Celsius—creates unique physiological challenges, including elevated core body temperature and accelerated dehydration, that can compromise the quality of technical training sessions. Future research in this area should examine how training environment variables interact with technical learning outcomes in regional athletic populations.

8. Practical Recommendations for Coaches

Based on the findings of this study, the following recommendations are offered for coaches working with competitive breaststroke swimmers in Rajasthan and comparable regional settings:

First, coaches should prioritize ankle dorsiflexion flexibility as a foundational component of the conditioning program for breaststroke swimmers from the earliest stages of training. Daily flexibility routines targeting the ankle complex should be incorporated into both the warm-up and cool-down of every training session. Yoga-based stretching protocols, which are culturally familiar and require no specialized equipment, may offer a particularly appropriate approach for regional athletes.

Second, the use of video feedback should be normalized in regional training environments even where sophisticated technology is unavailable. Simple smartphone-based video recording, combined with structured self-analysis using reference footage, can provide athletes with qualitatively significant biomechanical feedback at minimal cost. The effectiveness of video feedback observed in this study supports its wider adoption in resource-limited settings.

Third, coaches should systematically monitor stroke index as a routine performance metric, alongside race time. The sensitivity of stroke index to technical changes makes it a valuable indicator of both current technical efficiency and the direction of adaptation to training. Simple field-based measurement protocols allow stroke index to be calculated without laboratory equipment.

Fourth, drill-based training targeting the specific technical deficiencies identified in this study—kick width, hand entry angle, and glide duration—should be integrated into the weekly training schedule of regional breaststroke swimmers. The drills should be introduced progressively, beginning with isolated movement patterns performed at low speed before being integrated into full-stroke swimming at competitive pace.

Fifth, coaches should be attentive to the psychological dimension of technical remediation, particularly with more experienced athletes. The process of modifying

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established movement patterns can be cognitively demanding and may temporarily disrupt performance, leading to frustration and reduced motivation. Clear communication about the expected trajectory of change, combined with regular acknowledgment of incremental progress, is essential for maintaining athlete engagement throughout the intervention process.

9. Conclusion

This study has documented the breaststroke mechanics of competitive swimmers from Rajasthan, identified the most prevalent technical deficiencies within this population, and demonstrated that a structured twelve-week corrective training intervention can produce significant improvements in both kinematic parameters and competitive performance. The findings underscore the importance of systematic biomechanical assessment and targeted technical coaching as complements to the physical conditioning programs that have traditionally dominated swimming training in the regional context.

The improvements observed following the intervention—particularly in stroke index, glide duration, and race time—provide encouraging evidence that technically focused coaching can yield meaningful performance gains even within the constraints of regional training infrastructure. The study also highlights the particular vulnerability of breaststroke technique to the effects of inadequate coaching feedback and the corresponding potential of evidence-based intervention programs to remediate technical errors at various stages of athletic development.

Future research should extend this work by examining larger samples over longer intervention periods, exploring gender differences in technical responsiveness, and investigating the interaction between biomechanical variables and physiological performance markers in regional swimmer populations. The development of normative data for Rajasthan-based competitive swimmers would also provide a valuable reference standard for talent identification and developmental benchmarking.

Ultimately, the advancement of competitive swimming in Rajasthan will require a sustained commitment from coaches, administrators, athletes, and sports scientists working collaboratively within the region's distinctive context. It is hoped that this study contributes in a modest but meaningful way to that collective endeavor.

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ISSN: 2393-8048

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