Coaching Applications

Kinematic Analysis of Peak Velocities in the Breaststroke as a Function of the Timing of the Kick

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ABSTRACT

The purpose of this study was to determine the effects of the timing of the Breaststroke kick on intra-cyclic velocity fluctuations. Researchers examined peak hip velocities of Breaststroke swimmers to determine any significant velocity drop-offs and magnitude of velocity regained between different kicking techniques. Subjects performed swimming trials with three different kick protocols: a conventional kick, a late kick, and a delayed late kick. Video analysis was used to analyze peak and minimum hip velocities within one Breaststroke cycle for each trial. Data was analyzed using ANOVA repeated measures analysis. Major findings of this study were that due to smaller percentages of hip velocity drop-off, greater swimming efficiency may be achieved when the kick is initiated during the insweep or early recovery arm phases and that video analysis and verbal cueing are viable tools to help swimmers improve their regular stroke technique.

Introduction

The Breaststroke can be broken down into three phases, the Kick, the Pull, and the Glide. When these three phases are completed in succession, a swimmer has completed one full cycle of the Breaststroke. The variations in the overall swimming velocity throughout one Breaststroke cycle are a good indicator of the swimmer’s stroke efficiency; the more efficient a swimmer’s stroke is, the better they will perform (17). A number of current studies have examined the coordination of the arms and the legs during the Breaststroke cycle (4, 8, 19). The earlier studies mainly focus on periods of propulsion provided by each phase and how they affect the acceleration and deceleration of the entire cycle. The most recent study by van Houwelingen et al. noted swimmers are capable of manipulating their arm-leg coordination resulting in intra-cyclic velocity variations. However, their results were inconclusive.
During the 2016 Olympics, British swimmer Adam Peaty won the men’s 100-meter Breaststroke race in world-record fashion using a kick technique that performs the kick phase of the Breaststroke later than it is conventionally taught. To our knowledge, there is currently no research that examines how the timing of the initiation of the kick, when occurring during different phases of arm pull can affect the propulsion, acceleration, and consequently intra-cyclic velocity of the Breaststroke.

The lack of research regarding analysis of the timing of the Breaststroke kick is likely due the relatively new nature of this technique. However, given the surprising effect this technique has had on Adam Peaty’s gold-medal, world-record performance at the 2016 Olympic games, it is clear that this technique should be investigated to determine if his performances were the result of training, or improved technique.

Kinematic analysis provides invaluable information for both swimmers and coaches; video playback allows them to immediately review a swimmer’s technique and obtain feedback for making corrections, and digital analysis allows a swimmer’s stroke efficiency to be formally evaluated and improved (3-5, 7, 16). The hip has been validated as the most reliable anatomical landmark to use for measuring intra-cyclic velocity and its changes within a stroke; the frame-by-frame analysis that can be utilized in accompaniment with the recorded intra-cyclic velocity fluctuations allows researchers to pinpoint which aspects of the technique are contributing to the fluctuations in order to make improvements (3-5, 7, 16, 19).

Currently there are no published studies that examine the effects of the timing of the Breaststroke kick during specific pull phases on intra-cyclic velocity fluctuations. The expectation is that this research can lead to improved stroke efficiency and consequently faster swimming times. The purpose of the study is to determine the effects of the timing of the Breaststroke kick on intra-cyclic velocity fluctuations. The expectation is that through this investigation it can be determined if the timing associated with a “late kick” can provide higher overall swimming speeds than the “conventional kick” technique.

**Methods**

**Participants**

Subjects were recruited from an NCAA Division I swimming team (4 males & 5 females). All participants swam Breaststroke as one of their primary competitive events and were current members of an NCAA Division I swimming team.

**Design**

This study examined the effects on peak velocity during the Breaststroke by having the participants swim three different trials of executing the kick during different arm phases of the stroke. The percentage of velocity drop-off and percentage of
velocity regained (per one stroke cycle) were the variables used to assess stroke efficiency for each trial.

Measures

Three high-speed digital cameras (Baumer Model HXG with CMOS sensors), installed in custom housings (The Sexton Company, Salem, Oregon) were used for filming swim trials. All 3 housings were attached to custom-designed mounting frames and positioned so as to provide the three required fields of view (Figure 1).

![Figure 1. Synchronized frames of the three camera angles used to film swimming trials.](image)

The subject performed a total of three trials of 3 specified swimming protocols. The three protocols consisted of the following:

**Protocol One (Conventional Stroke):** The subject, while swimming the Breaststroke, was required to use their regular technique, at an effort that corresponded to the pace they would complete a 100-yard race sprint. In all except a single case, the subject’s “conventional stroke” consisted of the initiation of the kick coinciding with the beginning stage of the insweep, called the “early insweep.”

**Protocol Two (Late Kick):** The subject, while swimming the Breaststroke, was required to time the initial draw-up of the kick to coincide with the period during which the hands were in the final stage of the second phase of the Breaststroke pull pattern (the insweep), called the “late insweep.”

**Protocol Three (Delayed Late Kick):** The subject, while swimming the Breaststroke, was required to time the initial draw-up of the kick to coincide with the period during which the hands were beginning the “recovery” phase, i.e. hands moving forwards.

The video data was then uploaded to the digitizing software, where it was digitized and the footage was synchronized to produce dynamic peak velocity-time graphs to analyze the fluctuations in peak velocities. The trials were compared to each other to record the resulting differences between the peak velocity, the minimum velocity recorded during the effort, and the velocity regained as the next stroke was initiated.
Each subject's stroke was digitized and analyzed using the Motus and Templo software. The percentage drop-off in peak velocity, percentage of the velocity regained, maximum hip velocity generated by the arms, and maximum hip velocity generated by the legs were seen through the use of time-velocity graphs (Figure 2).

**Figure 2.** Velocity - Time graph used to analyze velocities of the Breaststroke

Maximum knee flexion angle and time to complete kick were measured by using Templo's angle measure function on a time-stamped video (Figure 3).

**Figure 3.** Maximal knee flexion angle.

**Results and Discussion**

The purpose of this study was to describe the kinematics of the conventional versus the late Breaststroke kick technique using selected variables to determine
the efficiency of each technique. Currently, only one study exists that examines the effects of the timing of the Breaststroke kick on intra-cyclic velocity. However, this single study by van Houwelingen et al. used subjects that were of “average” competitive experience, and consequently not classified as competing at the elite levels.

Their conclusions were limited to stating that “average-level swimmers are capable of adjusting their leg-arm coordination with acoustic cueing and that different timing of the kick does affect intra-cyclic velocity variation” (19). Unfortunately, this study does not specifically address leg-arm coordination, how to replicate the study, nor were they able to explain how these findings could be applied by coaches when training swimmers.

Consequently, our study is the first to have defined parameters to classify leg-arm coordination and incorporate them into a specific variation of the Breaststroke swimming technique.

In order to be designated as a “Conventional Stroke”, “Late Kick” or a “Delayed Late Kick”, the time at which the kick reached 160 degrees of flexion was matched with the phase at which the pulling action of the hands coincided with this position of the knee.

During the protocol where the subjects were required to swim using their “Conventional Stroke”, the distinguishing feature was that the initiation of knee flexion took place during the early stages of the second phase of the Breaststroke arm pull. This phase is termed the “early insweep” which is the later stage and concluding portion of the propulsive phase of the Breaststroke pull (Figures 4a and 4b).

![Figure 4a. Protocol 1: Close up of hand position during the early insweep.](image-url)
The “Late Kick” was the time the hands were completing the “late insweep” (Figures 5a and 5b) and “Delayed Late Kick” coinciding with the position of the hands when they were starting to be thrust forwards into the recovery phase (Figures 6a and 6b).
Figure 5b. Protocol 2: Coincident knee kick.

Figure 6a. Protocol 3: Close up of hand position during the early recovery.
All nine subjects of this study were elite-level swimmers who were all able to perform each specified kick technique with only verbal cueing. The analysis of each subject’s trials revealed that the smallest percentages of velocity drop-off were seen during the “delayed late kick” technique.

That is, when the three protocols were compared, the third protocol, when the subjects waited until their hands started to be extended forwards, we observed the smallest drop-off in overall hip velocities. The second phase of “least drop-off” was the protocol designated “Late Kick”, when the hands were approaching the body, during the “insweep” phase of the arm pull.

The greatest amount of velocity regained was in the late kick technique and the delayed late kick technique. This indicates a smaller velocity variation within one stroke cycle, which indicates a more efficient Breaststroke technique than the subject’s normal technique. These findings are in agreement with the conclusions reached by two earlier published manuscripts (4, 19).

There were no significant differences in peak hip velocity generated by the arms or peak hip velocity generated by the legs between the subjects when using either of the three protocols. However, the fastest overall swimming velocities were achieved in the subjects’ regular Breaststroke technique trials before they were asked to make adjustments to their strokes. These results were expected because all subjects tested were currently in, or recently concluded, intense training, and were instinctively swimming at their current training velocities.
What was observed was that the subjects tended to increase the degree of knee flexion, the later they were asked to kick in their stroke.

In regards to the research questions posed for this experiment, it can be concluded that the initiation of knee flexion to perform the kick during different phases of the Breaststroke pull does yield significant differences in hip velocities. When the kick is initiated during later phases of the pull, there is less of a drop-off in hip velocities and higher values for regaining hip velocities – simply put, the swimmers lose less velocity, and are better able to regain velocity lost (increasing their overall efficiency) when they delay the initiation of the kick.

**Practical Applications**

The conclusions derived from this study are in agreement with the current trend in competitive sprint Breaststroke technique. Although the timing of the leg draw-up during the longest competitive distance, the 200 meters, still shows relatively early draw-up of the kick, the findings of this study shows clear differences when there is a delay before the initiation of the kick when swimming the shorter competitive distances.

This study revealed that by virtue of smaller decreases in the periods of velocity “drop-off”, higher swimming velocities may be achieved when the kick is initiated during the insweep or early recovery arm phases. This study also proves that video analysis and verbal cueing are both viable feedback tools that can be used to help swimmers learn to make adjustments to their regular techniques to become more efficient in the water.