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The Effect of Real-Time Feedback on Swimming Technique

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Running Head: Real-time feedback

ABSTRACT

We examine a new approach for accelerating the learning of efficient stroke mechanics: using a flume equipped to deliver multi-perspective live video footage and force analysis data simultaneously to the swimmer and the coach. A preliminary study of the effectiveness of this approach with a small group of age group swimmers shows gains in ability to generate force of around 20% and to improve swim velocity with only two hours of application.

***KEY WORDS**: Hand force, video, real-time, feedback*

INTRODUCTION

When learning the execution of a complex physical motion, the rate at which the skill is mastered typically depends on the evaluation of how well the motion was performed (the “feedback”), the time between the execution of the motion and the evaluation (the “feedback time”), and the number of repetitions performed. If the motion is highly repetitive (such as in swimming) and the evaluation is poor or the feedback infrequent, then the acquisition of the desired skill can be at best slow, and at worst never achieved. In extreme cases the use of poor technique over thousands of repetitions, with infrequent correction, can lead to debilitating injuries. The goal for successful coaching of stroke technique in swimming is therefore clear; provide high-quality feedback in the shortest possible feedback time on a frequent basis.

Swimming strokes are three-dimensional in nature and involve a complex interaction between the arms, legs, body and head. Indeed, there is still much debate about how we actually propel ourselves through water and therefore what constitutes optimal technique. Consequently, an objective evaluation of stroke technique is far from trivial. Technique evaluations are typically based on visual inspection of the stroke and extend from simple "on deck" viewing of the stroke (which provides very limited information), to the use of underwater mirrors, to multiple-angle, under and above water video footage. The quality of the visual evaluation depends on the expertise of the evaluator (the coach or athlete) and is always subjective. Recently the evaluation process has been expanded to include a force analysis of the stroke that is synchronized with video footage [1]. This represents an important step toward providing an objective evaluation. Moving forward with the assumption that the expertise of the evaluator is sufficient, then what is important for high-quality feedback is to provide the evaluator with as much objective information as possible in a timely manner.

Ideally, feedback is provided continuously to the athlete as they swim, in this way they can correct their technique in real time. Currently this can be done by locating mirrors at the bottom of, or above a swimming flume (visual feedback) and/or by electronic audio communication (from a coach who may be watching the athlete in the flume or via live video footage). All other feedback methods require the swimmer to stop swimming and are therefore slower (in many cases, much slower!).
In this paper we examine the advantages of providing multi-perspective live video footage and force analysis data to both the athlete while they are swimming and also to the coach. That is, we examine the benefits of providing high-quality feedback in real time.

METHODS

Approach to the Problem

The general approach is to deliver multi-perspective live video footage and force analysis data simultaneously to the athlete while they are swimming and the coach. To this end we use a flume (the Elite version of the Endless Pool) equipped with video cameras located below, above, to each side and forward of the swimmer, and a force sensor system attached to each of the athlete's hands (the

Aquanex system [1]). The force data and video streams are piped in real time to a coach's monitor by the side of the pool. The coach selects which data are simultaneously piped to the swimmer's monitors: one near the bottom of the pool, the other above the pool. Each monitor is located such that the swimmer can view the screen while swimming without compromising his or her head position. An additional monitor is located by the side of the pool for immediate playback of recorded video and force data.

Subjects

For this study we used four swimmers from a year-round age group team: two boys (ages 13 and 14) and two girls (ages 15 and 16). The study was focused on backstroke and lasted four days. The athletes represented a wide range in ability in backstroke, from USA-Swimming's "All-Times" to "AA" standard.

Procedures

The first step on day 1 was to record video and force data for each athlete before using the real-time feedback system. This allowed us to determine the swimmer's initial force profiles for each stroke (both shape and strength) and establish their current stroke mechanics. The second step was to educate each swimmer about the target profile for the stroke force curve – a linear increase in force with time. This target profile has both an empirical and theoretical basis [1,2]. The next step was for the coach and athlete to evaluate the force and video data just acquired. The final step was a 30-minute "in pool" session where the athlete focused on improving their stroke profile by monitoring their force profile in real time while swimming. During the first 20 minutes of this period the speed of the water in the flume was set so that the athlete could focus on their stroke without fatiguing too quickly. The athletes would then swim while watching their force profiles in real time and try to adjust their stroke to provide the target profile. Meanwhile the coach monitored both the multi-angle video streams and the force data. When a technique limitation was identified the coach would stream the video feed that best highlighted the limitation, with (or without) the force data, to the athlete and make suggestions on how to correct the limitation. The athlete would then strive to improve their force profile through the elimination of the identified technique limitation.

During the last 10 minutes the athletes worked on maintaining their stroke profiles for one-minute intervals with a one-minute rest period between efforts. That is, throughout the entire 30-minute sessions the athlete was able to work on improving their technique on a stroke-by-stroke basis. The four steps were repeated each day of the study period. During this period the athletes also continued to train with their team as normal but with the request that they practice their new stroke technique as much as possible.

Statistical Analysis

We assume that the variations we see in the force data over each trial are normally distributed around some mean value.

RESULTS

To evaluate the effectiveness of our proposed real-time feedback coaching approach we compare the average peak force per stroke cycle and the average force per stroke cycle over a 60 second swim as measured at the beginning and end of the study. We used these measures as it has been shown that there is a direct correspondence between hand-force and swimming velocity [3]. We also compare the "before" and "after" stroke profiles. We emphasize that during the evaluation measurements, the swimmers did not have access to any feedback. This was done to ensure that any measured changes reflected meaningful changes in stroke. That is, the swimmer had assimilated the necessary change and was not being guided in any way.

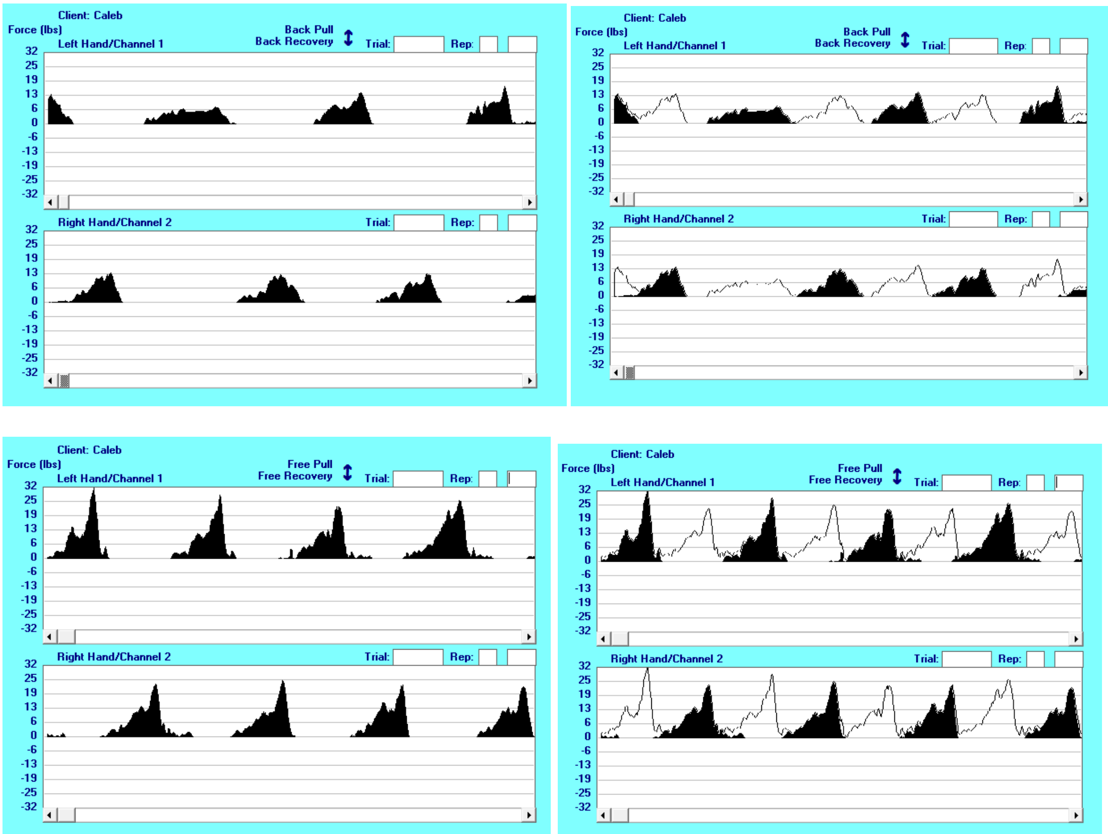

Figure 1. *This shows the hand force profiles for one of the male athletes swimming backstroke at the beginning (top row) and end (bottom row) of the study. The left column shows the individual hand force profiles, the right column shows the overlap of the force profiles.*

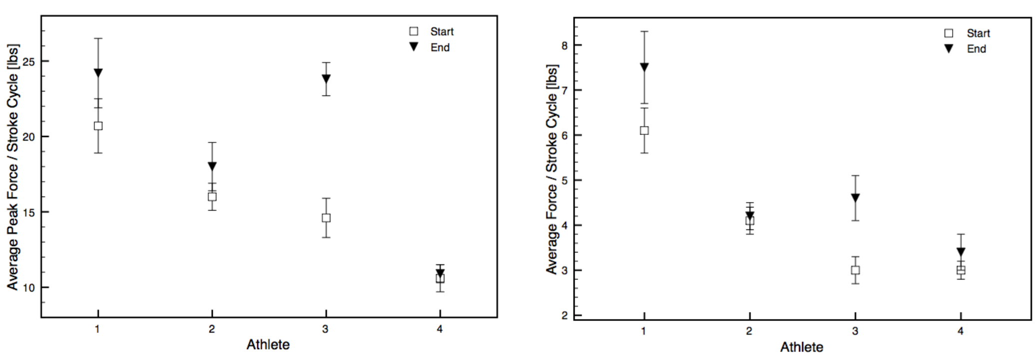

Figure 2. *This shows the average peak force/stroke cycle (left) and average force/stroke cycle (right) for each athlete at the start of the study (open squares) and the end (solid triangles). The ±1-sigma error bars are calculated assuming that the spread in the observed data is normally distributed. The improvements in average peak force/stroke cycle and average force/stroke cycle for the group as a whole were 24% and 22%, respectively.*

We found that after just two cummulative hours of real-time feedback, all four swimmers showed marked improvements both in the shape of their force profiles (e.g., Figure 1) and their ability to generate force during their stroke (Figure 2). Moreover, interestingly, the rate of improvement was seen to increase throughout the study suggesting that there is some acclimation time that the athlete goes through before the feedback process becomes efficient. This raises an interesting question, "How quickly does this rate of improvement level off?" In addition, we found that the flume water velocity had to be increased for each athlete over the course of the study. This is an indicator that their stroke efficiency had increased.

DISCUSSION

First and foremost, we note that the number of subjects in the study group was small and thus caution has to be exercised in the interpretation of the results. Having said that, it is extremely encouraging that with as little as two hours of real-time feedback we see a significant improvement in both the efficiency of the athletes to generate force in their stroke (of order 20%) and in the application of this force throughout the stroke. We also have some evidence that these improvements translated directly into increased swimming velocity. First, the flume water speed for each athlete had to be increased over the period of the study. Second, one of the athletes had posted a personal best time (by 0.68 seconds) in the 100m backstroke of 1:16.88 two days before the study. They raced the same event again at a meet the day after the study and posted a time of 1:12.82. The above results, along with the recognition that the force produced by a swimmer throughout the stroke provides an insight into the effectiveness of the technique [5], support our hypothesis that real-time feedback is beneficial for accelerating the learning of efficient stroke mechanics. Lastly, the real-time feedback goes to both the swimmer and the coach. For the swimmer, the power of the real-time feedback is two-fold. First it allows them, on a stroke-by-stroke basis, to detect exactly when in the stroke they are losing power and to then experiment with their stroke at this point and to see the results immediately. Second, the feedback then helps them to maintain the new stroke while the body learns what to do. For coaches, the combination of real-time force and multi-perspective video data not only enable them to see stroke limitations, such as subtle hand pitch changes, that would be otherwise be extremely difficult to detect, it also helps them guide the athlete toward a more efficient stroke in a shorter time interval. For example, the effects of suggested changes will be apparent in a very short time, consequently changes that are not beneficial can be quickly abandoned. We note that during the study we found that the main causes of loss of force were a shallow hand entry, late engagement of the water in the pull phase of the stroke, lack of capitalizing on the push phase and unnecessary (often subtle) hand pitch changes throughout the stroke.

PRACTICAL APPLICATIONS

This study suggests that the use of real-time feedback has significant potential as a teaching/training tool. Unfortunately, not every team is going to have access to a suitably equipped swimming flume. The question then is, how to achieve the benefits of real-time feedback in a typical swimming pool? One way would be to have the athletes swim on thethers with a mirror beneath (or above) them and a coach observing nearby underwater. The potential downside to this is that there is evidence that the mechanics of the swimmer's stroke may change when they are on a tether [4].

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