Preliminary Results of a “Multi-2D”
Kinematic Analysis of “Straight- vs. Bent-arm”
Freestyle Swimming, Using High-Speed Videography.

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INTRODUCTION:
Synchronized high-speed digital cameras, coupled with “motion analysis” software, allows a more detailed kinematic analysis of the stroke mechanics of swimmers. One area of interest is the perceived outcomes in Freestyle (Front-Crawl) swimming between the underwater pull patterns with respect to the “bent-arm” vs. “straight-arm” pull.

The purpose of this paper is to describe the preliminary results of an analysis of the straight-arm vs. bent-arm underwater pull by examining selected kinematic variables.

METHODS:
Subjects: The six (6) swimmers included in the current reported data are all current or former members of the Men’s & Women’s University of Hawaii Intercollegiate swimming team (age= 19.4 +/- 0.8 yr; ht. 183 cms +/- 6.2 cms).

Trials: Each swimmer was filmed for a total of 6 trials, during 3 of which they were instructed to maintain their natural bent elbow position (B.A.), followed by 3 trials using a straight-arm (S.A.) underwater pull.

Cameras: Two high-speed digital cameras (Basler Model A602f), installed in custom housings, were mounted to rigid frames which themselves were bolted to the pool deck. The cameras were placed at a depth of 0.3 meters, at right angles to each other for frontal and lateral viewing. The cameras were controlled via dual cabling from a desktop computer. One cable was assigned for camera control via Firewire (IEEE 1394), the second cable was used for camera frame synchronization. Frame rate was set at 100 frames/second.

Digitizing: Rotational joint segments were identified using a series of light emitting diodes (LED’s) housed in waterproof housings. The LED’s were taped to the body and were powered by a battery pack attached to a belt worn by the swimmer at the waist. The system proved invaluable for automatic digitizing of the resulting footage.

Motion Analysis: Calibration was conducted using a 4-point frame (1m x 1m), located in the plane of motion. Motion analysis software (Vicon Motus, Denver, CO), was used for video capture, data analysis, and generating reports. The software includes a “Multi 2-D” (M2-D) feature, which enables multiple cameras to be synchronized. Each sequence was digitized using a combination of auto-tracking and manual modes. The “Multi 2-D” (M2-D) feature provides the most effective means of observing swimming stroke mechanics while monitoring selected kinematic parameters.

RESULTS:
A cursory application of statistical measure yielded no measurable differences in linear hip velocities, either within or between subjects, when swimming with either the “Bent-arm” or “Straight-arm” positions.

DISCUSSION:
This preliminary process of data collection focused on two areas of interest:
1) The advantages of using high-speed video technology to capture and analyze the underwater pull patterns of swimmers.

With respect to the ability to film at higher frame rates, the results were immediately apparent. Past experience using cameras that were limited to standard frame rates (30 fps or 60 fields/sec) consistently produced blurring of the hands, particularly during the last half of the underwater pull phase. As anticipated, these distortions are amplified with the caliber of swimmer being filmed. By increasing the frame-rate to 100 fps, there was a significant change in the image quality, which increased the accuracy of the digitizing process.

2) The examination of the linear changes in wrist and hip velocities in the primary plane of motion.

After the resulting data was filtered and processed, two primary observations emerged.

a) The linear hip velocity (LHV) changed over the duration of the underwater pull cycle. Below is a sample report that combines the lateral synchronized video frame with two graphs that plot LHV and linear wrist velocity (LWV), in the plane of motion as a function of “time.” The vertical line in the 2 graphs is a feature of the software, which allows the synchronization of each video frame with the respective time intervals on the selected graphs.

b) The degree of elbow-bend employed by the swimmers when asked to swim with a “normal bent-arm” (BA), as compared to consciously pulling with “straight-arms.” Tradition has dictated that we recommend maximum elbow-bend close to 90 degrees when the hands pass vertically below the line of the shoulders. However, all six of the subjects included in this data set held their arms at a more obtuse angle, ranging between 121 and 134 degrees.

CONCLUSION:
This paper should be treated as an introduction into the utilization of improved technology for studying swimming stroke mechanics. Although the small subject number produced no measurable differences in linear hip velocities, when swimming with a bent- or straight-arm pull, either within or between subjects, it may be surmised that this outcome may be the result of the absence of a distinct difference between the degrees of elbow flexion used by the subjects when asked to swim with the elbows flexed at the two designated limb positions.

What was intriguing was the consistent positions of the hand, during the underwater pull cycle, where maximum hip velocity was produced, and the tendency for these elite swimmers to use degrees of elbow flexion that are more obuse than have traditionally been recommended for optimal propulsion in the Freestyle.

Determining whether these elbow positions are coincidental, or a trend, and more importantly whether pulling with a straight-arm yields higher hip velocities in elite swimmers, will have to wait for a more in-depth analysis and an increase in subject number as the study is continued.

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