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Examining Stroke Efficiency: How an Olympian Outperformed a Masters Swimmer in Backstroke

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This study investigates whether eo SwimBetter can differentiate the efficiency and stroke pattern between elite and non-elite swimmer. The subjects are a three-time Olympian and USA Masters registered swimmers during a 50-meter backstroke while using the 3D accelerometer. We find the eo SwimBetter is able to differentiate between an elite swimmer and novice level Masters swimmer. In addition to a stopwatch, the eo SwimBetter provides swimmer sam coaches with an additional measurement tool to effectively measure swim performance.

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Introduction

The validity/reliability/accuracy of sensors used in sport is important to allow for confidence in the quantitative changes in values measured (Ide et al., 2017) and recorded (Katherine Douglass, 2024). The use of first principle physical techniques for evaluating the values recorded by sensors allows for both tracing measures back to known standards and easy replication by others.

Sensors were turned on and placed on their side, in a weighted bucket, to minimize the difference in the depth of the pair of sensors on a handset when they were lowered into the pool. The bucket had holes drilled in its side and bottom to allow free entry and egress of water. The bucket had holes drilled in its side and bottom to allow free entry and egress of water. The bucket was attached to a cord that had marks placed on it such that each mark, when aligned with the water's surface, would result in an initial depth of one meter and a change of depth of one meter (Mezêncio, 2020). The marks had been measured using a steel meter rule with the first mark aligned to the sensor location on the handsets.

Measures were made at one-meter depths from the surface (zero meters) to a depth of four meters (Morouço PG, 2018). The bucket was lowered over a period of 30 seconds and recordings made for a period of 30 seconds at each depth. Measures were also made at each meter depth on the way back up to allow for the determination of any hysteresis (Ganzevles, 2019).

Each swim was done with a pair of handsets (totaling four sensors) and two swims of a pair of handsets totaling two handsets and four sensors were undertaken. After the handsets returned to the surface, data collection was stopped and the data downloaded via a Bluetooth connection to a laptop computer. The swim trials resulted in seven hundred data points from the pressure sensors, corresponding to 14 sec while the sensors were stationary, were averaged for each depth. Depth in m was calculated for each averaged pressure measure using the formula

$$\text{depth} = \frac{pressure\ (hPa)}{10g}$$

where pressure was the difference between recorded pressure and the pressure above water, and g is acceleration due to gravity. This document outlines an initial series of pressure measure on two handsets (four sensors) conducted (Neil Baker, 2023) at Olympic size pool in Phoenix, Arizona, USA.

Methods

Participants

We had 3-time Olympian and USA Masters registered swimmer. The 3-time Olympian's personal best time was 1:00.55 in 100-meter backstroke in long course meter swim competition. The USA Masters registered swimmer's personal best time was 1:32.67 in 100-meter backstroke in long course meter swim competition. A stopwatch is clearly able to differentiate between the two swimmers, but this paper investigates if the eo SwimBetter also provides a valuable data to measure swim performance.

Experimental Design

The participants were welcomed in the Olympic size swimming pool and informed verbally about the measurement procedure. Both swimmers performed their own regular warm-up protocol both on land and in the water for approximately 10 minutes. After the warm-up, the participants left the pool, the back of the participant was dried, and the sensor was placed on the participant's hands. The participants went back into the pool holding a starting position with both feet on the wall and the arms extended in front of the body. The participant performed a 50-yard backstroke swim, after the researcher removed the sensor and the sensor's data downloaded to the computer.

Methodology

All measurements were performed in the Olympic size outdoor swimming pool with a constant water temperature of 79 Fahrenheit (26.1 Celsius). The same sensor and sensor position as described previously were used. This sensor consists of a tri-axial accelerometer with a range of -16 g to +16 g and a 12-bit resolution, with gathered and saved data in the binary format at a sample frequency of 100 Hz. The sensor had the following characteristics: 28 mm x 7 mm, weight 18 g, operating temperature between -30 through +60 Celsius. The gathered data were stored in system and transferred vis a wifi until to a computer after the measurement was completed (Morouço PG, 2018).

Prior to data collection, the eo SwimBetter handsets containing the IMUs (Inertial Measurement Unit) to be assessed were connected to a handset device which itself was affixed to a cordless electric drill (Mezêncio, 2020). The handsets were turned on and orientated as per a normal swim session (Ide, Johnson, Yoshimura, Schoeman, Kawamoto, Takise, S., … Noel, 2023). Handsets were then located and affixed to the handset device using rubber restraint. Prior to each trial, the handsets were then started, and the drill set at the slowest consistent rotational velocity (approx. 1 Hz). Drill rotation velocity was confirmed by manually timing 10 revolutions (Ide, 2010; Ide, Johnson, Takise, Konarzewski, Inada, Fujimori, … Plavin, 2021).

At the end of each trial, the drill and handsets were stopped, and the data downloaded (Neil Baker, 2024). One trial, of 40-50 seconds, at each of three distances from center of rotation, are conducted. Distances used were 69, 50, and 30 centimeters. Rotational vales presented in the graphs are 0.98 Hz (69 cm), 1.07 Hz (50 cm), and 0.96 Hz (30 cm). Adjustment of the drill controller on starting and stopping resulted in perturbations in the data that are seen at the beginning and end of recording (Ide, Johnson, Takise, Konarzewski, Inada, Fujimori, … Kawamoto, 2021).

Along with the time of data, sample output for Accel (*x*, *y*, *z*) and Quatermion values were extracted from the handsets. The accelerometer data are relative to IMU clip axis (*x*, *y*, *z*); vector rotation was applied to transform the accelerometer data into the pool frame of reference, annotated in the image below as *fwd*, *lot*, and *vent.* To ensure the data sampling rate of the handset is uniform, the data was resampled to ensure a uniform sampling rate prior to filtering away any high frequency noise above 50 Hz. Separating the acceleration into constituent components, *Accel_fwl*, *Accel_lat*, *Accel_vent*, the data are numerically integrated over time and spectrally filtered to remove the DC offsets, resulting in the relative velocities *vel_fwd*, *vel_lat*, *vel_vent*. Repeating the above process retunes the relative displacement *displ_fwd*, *displ_lat*, *displ_vent* (Figure 1). The relative displacement measured across all axis, along with the resultant magnitude of displacement. As the positioning of the handset on the rotating arm changes, it can be seen the relative displacement measured by the handset changes accordingly.

Figure 1. 3-time Olympian (above) and USA Masters swimmer (below), 3rd stroke right side (above) and left stroke (below) side on, overhead, and head on.

Results

There is a significant difference between 3-time Olympian to USA Swimming Masters swimmer; we find the eo SwimBetter 3rd stroke of right arm and 3rd stroke of left arm (Figure 2), the backstroke (Ide, Johnson, Takise, Konarzewski, Inada, Fujimori, … Watanabe, 2021) for shoulder to device right arm average 22.90479452 centimeter to 28.91190083 centimeter, Wilcoxon/Mann-Whitney.: -3.8178, $p < 0.05$, for shoulder to device left arm average 24.72175182 centimeter to 38.28976744 centimeter, Wilcoxon/Mann-Whitney.: -9.8551, $p < 0.05$.

The backstroke surface of water for right arm average -30.91554795 centimeter to -15.70115702 centimeter, Wilcoxon/Mann-Whitney.: -8.7261, $p < 0.05$, surface of left arm average -20.55029197 centimeter to -13.5472093 centimeter, Wilcoxon/Mann-Whitney.: -9.7335, $p < 0.05$.

The backstroke water force to device for right arm average 1.78726 m. s^{-1} to 1.76677 m. s^{-1}, Wilcoxon/Mann-Whitney.: 0.4902. The backstroke water force to device for left arm average 1.634745 m. s^{-1} to 1.732093 m. s^{-1}, Wilcoxon/Mann-Whitney.: -3.9797, $p < 0.05$. The backstroke centerline to device for right arm average -2.965 centimeter to 20.4161 centimeter, Wilcoxon/Mann-Whitney.: -10.0436, $p < 0.05$. The backstroke centerline to device for left arm average -3.9753956 centimeter to 24.365942 centimeter, Wilcoxon/Mann-Whitney.: -9.9309, $p < 0.05$. The backstroke one stroke total force for right arm average 0.877671233 N to 1.623287671 N, Wilcoxon/Mann-Whitney.: -6.1558. $p < 0.05$, W-value: 2,214.5, Mean Difference: 1.08. The backstroke one stroke total force for left arm average 1.1649407407 N to 1.442519685 N, Wilcoxon/Mann-Whitney.: -2.9814. $p < 0.05$, W-value: 2,776, Mean Difference: 1.07.

The backstroke one stroke propulsive for right arm 0.670486111 N to 1.028682171 N, Wilcoxon/Mann-Whitney.: -1.2481, W-value: 3,318.5, Mean Difference: 0.67. The backstroke one stroke propulsive for left arm average 0.848507463 N to 0.8296875 N, Wilcoxon/Mann-Whitney.: -2.167, W-value: 3,058, Mean Difference: 1.01. The backstroke one stroke lateral for right arm average -0.00145 centimeter to 0.40585 centimeter, Wilcoxon/Mann-Whitney.: -3.3241. $p < 0.05$, W-value: 2,682.5, Mean Difference: 0.25. The backstroke one stroke lateral for left arm average -0.01871 centimeter to 1.44251985 centimeter, Wilcoxon/Mann-Whitney.: -1.5468, W-value: 3,092.5, Mean Difference: -0.03. The backstroke one stroke vertical for right arm average -0.0283642384 centimeter to -0.979 centimeter, Wilcoxon/Mann-Whitney.: -6.7419. $p < 0.05$, W-value: 2,682.5, Mean Difference: -0.18. The backstroke one stroke lateral for right arm average -0.00145 centimeter to 0.40585 centimeter, Wilcoxon/Mann-Whitney.: -6.7419. $p < 0.05$, W-value: 1,453.5, Mean Difference: -0.18. The backstroke one stroke lateral for left arm average -0.365555556 centimeter to -0.732824427 centimeter, Wilcoxon/Mann-Whitney.: -6.6907. $p < 0.05$, W-value: 1,410.5, Mean Difference: -0.42 (Figure 3).

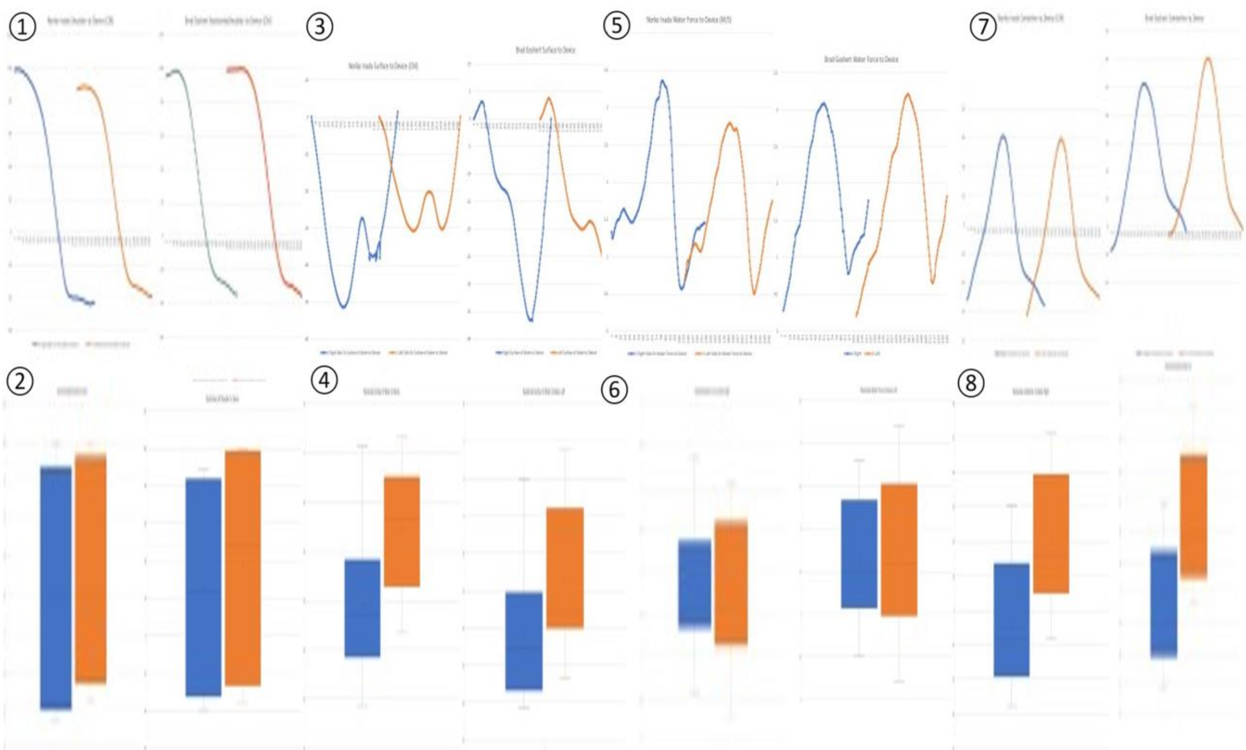

Figure 2. 3-time Olympian (blue) vs. USA Masters swimmer (orange) stroke path & hand velocity. ① & ② shoulder to device, ③ & ④ surface of water to device, ⑤ & ⑥ water force to device, ⑦ & ⑧ centerline to device.

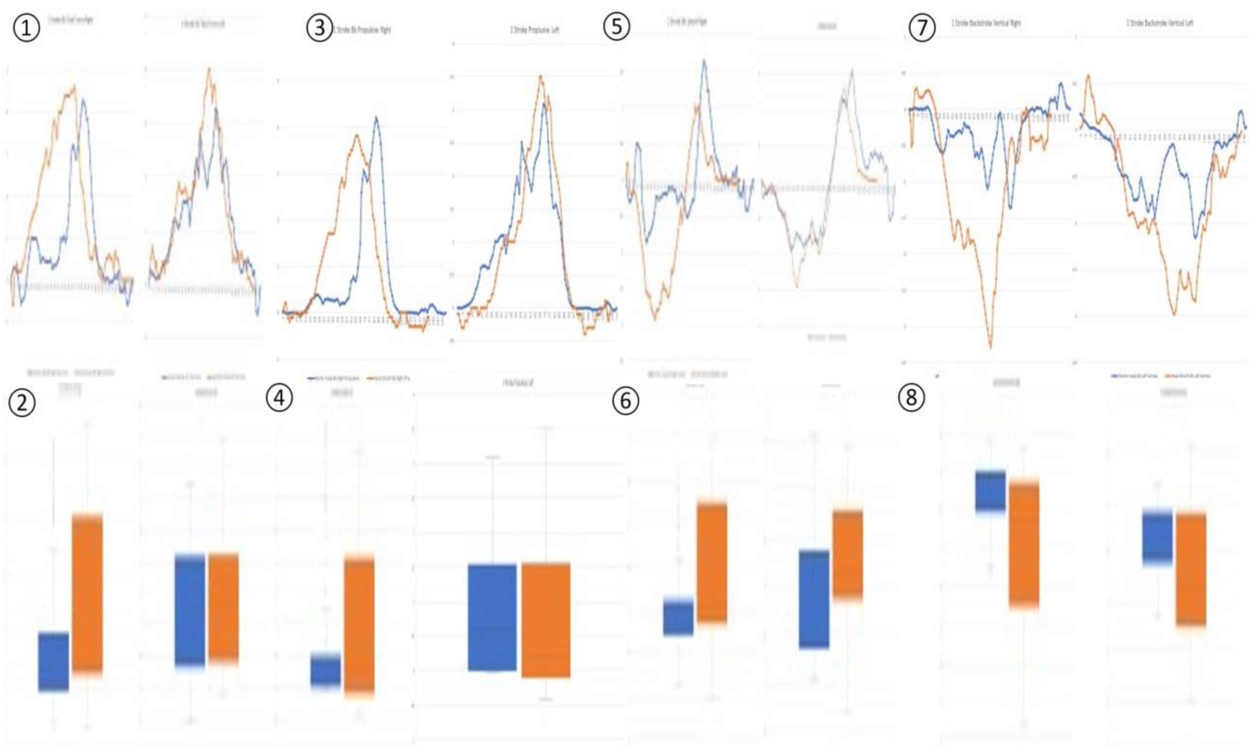

Figure 3. 3-time Olympian (blue) vs. USA Masters swimmer (orange) backstroke one stroke of force. ① & ② total force, ③ & ④ propulsive, ⑤ & ⑥ lateral, ⑦ & ⑧ vertical.

Discussion

Backstroke performance appears to be influenced by stroke (Ide, Johnson, Takise, Yoshimura, Kawamoto, & Schoeman, 2016), path velocity (Ide et al., 2012), and the force applied to the device. Backstroke performance improved through possible reason is backstroke one stroke vertical (Ide, Takise, Yoshimura, Johnson, & Kawamoto, 2016). We found water force and one stroke of total force results were equal to 3-time Olympian to USA Masters swimmer. The backstroke water force to device for right arm average 1.78726 m. s^{-1} to 1.76677 m. s^{-1}, Wilcoxon/Mann-Whitney.: 0.4902. The backstroke water force to device for left arm average 1.634745 m. s^{-1} to 1.732093 m. s^{-1}, Wilcoxon/Mann-Whitney.: -3.9797, $p < 0.05$. The backstroke one stroke total force for right arm average 0.877671233 N to 1.623287671 N, Wilcoxon/Mann-Whitney.: -6.1558. $p < 0.05$, W-value: 2,214.5, Mean Difference: 1.08. The backstroke one stroke total force for left arm average 1.1649407407 N to 1.442519685 N, Wilcoxon/Mann-Whitney.: -2.9814. $p < 0.05$, W-value: 2,776, Mean Difference: 1.07. The results of this paper reveal that with proper training (Ide et al., 2024) and technique (Ide, 2007), the 3-time Olympian can result in much faster 100-meter backstroke (Ide, Johnson, Takise, Hicks, Fujimori, Fujimori, … Mikish, 2023) long course meter time.

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