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Reliability of force and impulse measures in tethered swimming for expert swimmers

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1. Introduction

Tethered swimming is a widely used tool to measure propulsive force of swimmers. This method is currently one of the most relevant and robust for assessing the performance level of swimmers. Although tethered swimming is not exactly similar to real swimming (Samson et al, 2019), it is recognized as a specific method to evaluate propulsive force in water and thus more ecological than weight benches. Kjendlie and Thorsvald (2006) have shown that this method offers a test-retest reliability and pointed out that two trials could be enough in order to measure propulsive force. They also showed that there is a familiarization with tethered swimming for expert swimmers. However, the protocol was not very precise concerning temporality of measurements (in particular the number of days between each test). However, in the context of a longitudinal scientific swimmers follow-up, it is important to ensure that variations in measured force are not due to familiarization with the measurement method or device but to technical and/or physical progress (or on the contrary, a drop in force due to a state of fatigue).

Our study therefore aims to clarify familiarization effect of tethered swimming for expert swimmers. In order to answer those questions, measurements were performed in three days in a row sessions and gather elite french swimmers.

2. Methods

2.1 Test procedure

Experiments were conducted in three 50-meters swimming pools from three different clubs. Twenty-seven expert swimmers (13 women and 14 men, 17.2 ± 1.9 years old, height: 1.75 ± 0.08 m, mass: 65.7 ± 9.8 kg, level: 86.7 % ± 4.9 of World Record) volunteered to participate in this study. All participants (or their legal representatives for minors)

provided written consent prior to their participation. Test procedures were approved by Ethic Committee (IRB00012476-2020-17-07-64). Each swimmer performed two trials of 10' front crawl at maximum intensity with five minutes passive recovery between each trial. They reproduced this on 3 consecutive days, and therefore performed 6 trials total. The best of the two trials was chosen for each swimmer, each day. Before trials, swimmers performed a 20' warm-up followed by one-minute adaptation period to tethered swimming.

2.2 Device and data processing

Thanks to a custom device, swimmers were tethered with a non-stretch cable (stainless steel, 2.5 mm diameter) fixed on a belt around the pelvis, and connected to a mono-axial force transducer (Laumas[®], IP68; capacity: 2 kN; sensitivity: 2mV/V; combined error: +/- 0,02 %) fixed on the bar below the starting block (Figure 1). Sensor was connected to a Wi-Fi transmitter (SG-Link[®]-200, IP68), and data were transferred to a custom acquisition software (C#), located at the edge of the pool. Thanks to a pulley, the force produced by swimmer is applied along the sensor load axis (see Figure 1).

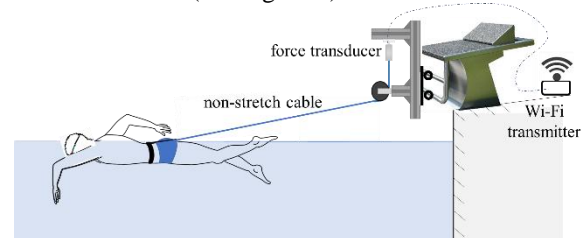


Figure 1 Representation of the tethered swimming device

2.3 Data analysis

Analysis were performed using a custom routine (Matlab[®] R2020b). To deal with electrical noise, force signals were filtered using a 3rd order Butterworth low-pass, zero-lag filter with 8Hz cut-off

frequency. Average force and impulse were computed over eight swimming cycles (from the 2nd to the 9th cycle) from the best of both trials carried out each day for each swimmer. Standard statistical methods were used for the computation of means. Systematic bias, which refers to a general trend for measurements to be different in a particular direction between repeated tests, was assessed with a repeated measures ANOVA. Pairwise comparisons were performed with the test of Tukey. The magnitude of the difference was assessed by the Hedges' g (g), which was considered small ($0.2 < |g| < 0.5$), moderate ($0.5 < |g| < 0.8$), or large ($|g| > 0.8$). Relative and absolute reliability, which represents the degree to which individuals maintain their position in a sample with repeated measures and the degree to which repeated measurements vary for individuals, were assessed with the intraclass correlation coefficient (ICC; model 2,1) and the standard error of measurement (SEM), respectively. We considered an ICC over 0.90 very high, between 0.70 and 0.89 high and between 0.50 and 0.69 moderate. Standard error of measurement was also used to determine the minimum difference to be considered real, which represents the limit under which the observed difference is within what we might expect to see in repeated testing just attributed to the noise in the measurement. Statistical significance was set at $p < 0.05$ for all analyses. All computations were made with Statistica 6.0 (Statsofts, Tulsa, OK, USA).

3. Results and discussion

	Mean Force (N)			Mean Impulse (N.s)		
Day 1	118.8			136.5		
Day 2	117.7			131.1		
Day 3	116.1			125.0		
p-value	0,497 <i>(D1-D2)</i>	0,01 <i>(D1-D3)</i>	0,419 <i>(D2-D3)</i>	0,01 <i>(D1-D2)</i>	0,0001 <i>(D1-D3)</i>	0,0006 <i>(D2-D3)</i>
Hedge's g	-	-0,12	-	-0,19	-0,43	-0,25
ICC (2,1)	0,97			0,90		
SEM	4,80 N	4.08%		5,91 N.s	4.51%	
MD	13,51 N	11.49%		16,39 N.s	12.52%	

Table 1 Mean for each day, p-values of RMA, Hedges's g values, ICC, SEM, MD for forces and impulses

For forces, difference was found between Day 1 and Day 3 ($p = 0.01$) but Hedges's value ($g = -0.12$) showed that difference was trivial. ICC value showed

excellent reliability between measures (ICC = 0.97). Standard error of measurement and minimum difference were 4.80 N and 13.31 N, respectively. For impulses, differences were found between each day ($p = 0.01$, $p = 0.006$, $p = 0.001$ for Day1/Day2, Day2/Day3 and Day1/Day3 respectively). Hedges's g values showed that differences were trivial for Day1/Day2 ($g = -0.19$) and small for Day2/Day3 and Day1/Day3 ($g = -0.25$ and $g = -0.43$ respectively). ICC value showed excellent reliability between measures (ICC = 0.9). Standard error of measurement and minimum difference were 5.91 N.s and 16.39 N.s respectively.

Differences between mean of each day were inferior to SEM, both for force and impulse (1.2 N and 2.45 N with 4.80 N for SEM; and 5.65 N.s and 5.25 N.s with 5.91 N.s for SEM) which means that differences between days were not statistically meaningful. ICC and SEM proved that there was no familiarization effect between days.

4. Conclusions

In conclusion of this study, tethered swimming is a useful tool to measure propulsive forces of swimmers, and doesn't require familiarization.

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