The Effects of a Wetsuit on Biomechanical, Physiological, and Perceptual Variables in Experienced Triathletes

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ABSTRACT

Purpose: Wetsuit use has been shown to change swim biomechanics and thus increase performance, but not all athletes are comfortable with its use because of possible modifications in motor coordination. The aim of this study was to evaluate the effects of wetsuit on biomechanical, physiological and perceptual variables. **Methods:** Eleven national and international level triathletes, familiar with wetsuit use, performed 7x200 m in front-crawl at constant pre-set speed twice, with and without a full-wetsuit. The trunk incline (TI) and index of coordination (IdC) were measured stroke-by-stroke using video-analysis. Stroke, breathing and kick count and timing (as breathing/kick action per arm stroke cycle), stroke (SL) and underwater length were analysed using inertial measurement unit (IMU) sensors. Heart rate (HR), rate of perceived exertion (RPE), swimming comfort were monitored during the task. **Results:** A lower TI, IdC, number of strokes, kicks and breathing, HR and RPE for each 200m was found in wetsuit compared to swimsuit condition. Higher values of SL and underwater length were found in wetsuit, while no differences were found in swimming comfort and timing of kicks and breathings. An increase for swimsuit condition in number of strokes and breathings, HR and RPE were found during the task compared to the first 200m. **Conclusion:** Wetsuit use reduces TI, thus drag, increases propelling proficiency and shows lower fatigability, without modifying motor coordination, compared to a swimsuit use at the same speed. The use of a wetsuit during training sessions is recommended, to increase the comfort and the positive effects on performance.

Keywords: open water, swimming kinematics, drag, fatigability, comfort

INTRODUCTION

Swimming in open water leads athletes to face environmental challenges not typically present in pool environment such as swimming in packs, unpredictable waves and currents, salt water, absence of turns and cold water temperature exposure[1,2]. To prevent hypothermia, the use of a wetsuit is permitted in official competitions when water temperature is below 20°C in open water[3] and triathlon up to 1500 m, below 22°C in longer distances and below 24.6°C in age-group competitions[4]. A wetsuit is made of neoprene, a synthetic rubber that contains small bubbles of gas, that have the primary role of reducing convective heat loss[5]. The thickness of a wetsuit usually differs between the different parts of the athlete's body, but it cannot exceed 5 mm in triathlon[4] and it cannot be thinner than 3 mm in open water swimming competitions[3]. Other than protecting from cold water exposure, wetsuit use has shown effects on buoyancy, friction drag[6–8] and propelling proficiency (expressed as stroke length (SL) and stroke index (SI))[7,9–14], leading to a performance enhancement[6–22]. On the other hand, athletes have reported a lower comfort in the upper arms[12,17] at the end of a swimming task and an inhibition in kicking action[11,17,20] while swimming with a wetsuit[22]. The amplitude of these effects seems to be affected by how familiar the athlete is with a wetsuit, by his/her swimming ability[7,12] and by the model of wetsuit used[12,17,18,22]. Although wetsuit use has been reported to improve performance[6–22], its effects on motor coordination and comfort during a task simulating competition effort are lacking[22].

The majority of the studies investigating the effects of swimming with a wetsuit tested athletes only in short distance[7–9,12,16,17,19] or short time[13,15,18] tasks[22]. However, both open water swimmers and triathletes swim in open water from several minutes to hours (up to 25[23] and 3.8 km[4] in official competitions, respectively). In such long efforts the sensation of fatigue plays a fundamental role and a change in biomechanical, physiological and perceptual variables, defined as fatigability[24], could affect performance. During swimming locomotion the maintenance of a correct motor coordination has a critical role in the optimization of the ratio between propulsion and energy expenditure[25,26]. In this context, given the already reported effects on biomechanical[6–17], physiological[8,9,13,16,19,27] and perceptual[12,13,17,18,27] variables, a prolonged wetsuit use could have an additional role on fatigability and overall performance. Very few studies tested athletes while swimming with a wetsuit for longer time tasks[22] (20-75 minutes[10,27–29]) reporting a mitigation in the decrease of core/skin temperature in cold water[10,29] and a decrease[27] or no difference[10] in heart rate (HR). Moreover, only one study evaluated the effects of fatigability on upper limbs action comparing the first and the last length during a pre-set distance of 1500 m[14]. However, comparing wetsuit with swimsuit during a pre-set distance task could lead to artefactual results. Indeed, all the results found could be attributable to the higher swimming speed reported with a wetsuit[7–9,12,14,16,17,22] instead of as a direct effect of the wetsuit per se[22].

The aim of this study was to evaluate the effects of a full body wetsuit on biomechanical, physiological and perceptual variables during a 7x200 m front-crawl at constant speed (equal to Olympic distance race pace) training session in experienced triathletes. We hypothesized an effect of wetsuit use on biomechanical variables that would mitigate fatigability in front-crawl at pre-set speed, compared to swimsuit. Moreover, because of the tight-fitting, we hypothesized that wetsuit use could decrease the comfort and motor coordination of triathletes.

METHODS

Participants

Fifteen (five females) national and international level triathletes (Tier 3-4[30]) were recruited for the study. All triathletes were familiarized with the wetsuit use and with the rate of perceived exertion scale (CR-10 modified, Italian version[31]). The CR10 is routinely used during triathlon training camps[32] and commonly utilized to monitor training load, other than widely promoted by the Federation during training courses for coaches. Four triathletes (one female) were excluded (see methodology section), therefore only 11 triathletes were analysed. Detailed information about triathletes is provided in Table 1. Information regarding procedures was provided to each participant, written informed consent and personal information treatment were obtained. The study was approved by the Institutional Review Board (CAR 38/2020) and in accordance with the principles of the Declaration of Helsinki.

Table 1

Design

Each triathlete performed twice the same swimming protocol, once with the wetsuit and once with the swimsuit, in a random and counterbalanced order (seven triathletes performed the wetsuit condition first and eight the swimsuit) using a computer generated randomization order (https://www.graphpad.com/quickcalcs/randomize1/). The sessions were performed just before the competitive season, when athletes mostly utilize wetsuits, at the same time of the day with at least 48 h and no more than 7 days apart. The participants were instructed to maintain similar eating, sleeping and training habits and avoid intensive exercise 48 h prior to the tests.

Methodology

Before the first test session, subjects filled in an online survey (Google Form, Google, USA) to collect individual information such as age, height, training information and wetsuit use habits (see Table 1). The tests were performed in an indoor pool (length: 33.33 m, water temperature= 28.4±0.5°C, air temperature= 27.6±0.8°C) traditionally used by the triathletes. Prior to each test session body mass and fat were estimated by an impedance balance (Mi Body composition Scale 2, Xiaomi, China).

A standard warm-up, self-paced swimming up to 15 minutes[9,33], was performed before each swimming test. The swimming test consisted of a 7x200 m front-crawl constant speed protocol, with 1-minute rest between repetitions, performed at the individual average race speed of the Olympic distance triathlon (1500 m, see Table 1). A sound pacer (Tempo Trainer, Finis, Italy) was placed inside-the swimming cap and the swimmer followed the audio-signal to synchronise with his pre-set speed. The test in the wetsuit condition was performed using the full model wetsuit (covering the whole body except for the face, hands and feet) of each triathlete (details in Table 1). The subjects with a time difference between suit conditions in at least one repetition >3% (~1.9 s) were discarded and not analysed because of possible differences in biomechanical variables as previously reported[34]. The test was recorded by an underwater camera (Hero4 Black, GoPro, USA, 120Hz) placed in the sagittal plane of the swimmer. At least one to three complete stroke cycles were recorded each time the participant passed in front of the camera. Black pen (swimsuit) or red tape (wetsuit) markers were applied on the following anatomical landmarks in both sides of the body: acromion process, interior angle of the scapula, great trochanter, fibula head and lateral malleolus. Kinovea software version 0.8.15 (Joan Charmant & Contrib.) was used to manually analyse frame-by-frame the video sequences. Trunk incline (TI) was quantified using a video-based system[35]. The arm stroke phases events (entry, pull, push and recovery) were identified using video analysis to estimate the stroke phase percentages and the index of coordination (IdC)[36]. These variables were presented as mean value of the first and the seventh repetition of each test.

Three IMU sensors (WaveTrack Inertial System waterproof, Cometa, Milan, Italy, 128 Hz, accelerometer full scale: 16g, gyroscope full scale: ± 2000°/s) were placed on the occipital bone, on the right wrist and 1 cm above the right lateral malleolus (Figure 1). The sensors were fixed with two swimming caps on the head and with biadhesive/co-band tape on the limbs. The wrist IMU automatically recognized the wrist entry instant in the water through the modulus of the signal output of the gyroscope (angular velocity). Due to the shock effect of the water drag on wrist water touch, an artefact in the smooth gyroscope signal was used for the wrist entry identification and detected using the local maxima of the jerk. Furthermore, an algorithm computed the lateral face entry and exit from the water surface recognizing with the peaks of the angular velocity of the occipital bone sensors in the mediolateral head roll. Finally, the downbeat end of the foot during the flutter kick was automatically detected applying the method described in Fulton et al. (2009)[37]. The following biomechanical variables were then calculated: breathing count (total, right and left side); percentage count of left/right breathing; timing of breathing (left and right) with respect to stroke cycle duration, starting with the right-hand entry; strokes count/lap; SL per lap; kicks count/lap; timing of kicks (first, second and third, when effectuated) with respect to stroke cycle duration, starting with the right-hand entry; underwater length from the push on the wall; index of synchronization (IdS)[38]; SI; stroke-breathing count ratio (ratio between stroke and breathing count). The start and the end of the underwater phase were automatically recognized using the angular velocity of the ankle IMU for the wall touch and of the wrist IMU for first-hand entry into the water, respectively. For more detailed information about the set-up and analysis of IMU sensors data, we recommend referring to the article published by Fantozzi et al. 2022[39].

The HR was continuously recorded by a bend sensor for swimming (HRM-Tri and Forerunner 935, Garmin, USA) during the test and the mean value was estimated for each repetition. After each 200m, the rate of perceived exertion (RPE) was collected (CR-10 modified scale, Italian version[31]). The subjects also provided their swimming comfort during the rest phase by a scale ranging between -5 "Very bad", 0 "Neutral" and +5 "Very good" (based on feeling scale[40]) answering the question "How do you feel your swimming comfort?".

Figure 1

Statistical Analysis

The sample size of 15 was estimated a priori using G*Power 3.1, with a power of 0.7, alpha of 0.05 and d of 0.6 for t-test difference between two dependent means. The statistical package SPSS version 25.0 (IBM, Chicago, USA) for Windows OS was used for statistical analysis. Non-parametric Friedman test, both with Kendall's W as effect size, was performed to assess differences between

conditions, to evaluate suit condition and between repetitions, to evaluate fatigability, in all variables. Wilcoxon test, both with biserial correlation (r) as effect size, was run as post-hoc to assess pairwise differences between the conditions for the same repetition and between each repetition with the first one within the condition. The value of r was considered as: small (.100-.299), moderate (.300-.499), large (.500-.699), very large (.700-.899) and extremely large (≥.900)[41].
The significance level was set at p≤0.05. Data are presented as median ± interquartile range.

RESULTS

Triathletes completed the tests with a mean time difference of 1.09±0.47% (~ 0.69 s) between suit conditions, with an average time of 158.02±11.12 s and 158.72±11.95 s for wetsuit and swimsuit condition, respectively. Four of the recruited triathletes achieved a time difference >3% (5.0±2.0%, corresponding to 7.73±3.07 s) between conditions, with the higher times performed in the swimsuit condition. These four subjects were discarded and not analysed as previously stated.

Suit condition
Lower TI (p<.001) (Figure 2) and a longer underwater phase (wetsuit 3.08±0.46 m, swimsuit 2.71±0.50 m; p .004) were found in wetsuit condition. Both number of strokes (p<.001) and kicks (p<.001) were lower in wetsuit, with an associated higher SL (p<.001), SI (p<.001) compared to swimsuit (Figure 3) and no difference in timing of kicking was found. Although a catch-up coordination was observed in both conditions, lower values of IdC were found in wetsuit compared to swimsuit (p<.001), both with a higher percentage in the no propulsive phases (p<.001): entry+catch (A: wetsuit 32.35±8.87%, swimsuit 32.10±7,64%) and recovery (D: wetsuit 28.63±8.72%, swimsuit 25.77±8.07%); and a lower percentage in the propulsive phases (p<.001): pull (B: wetsuit 16.98±2.25%, swimsuit 19.22±3%) and push (C: wetsuit 23.35±1.57%, swimsuit 24.65±4.17%) (Figure 3). No differences were found in IdS (wetsuit 0.06±0.22, swimsuit 0.01±0.12; p .911). The total (Figure 2) and right side number of breathings were lower in wetsuit (both p<.001), but not on the left side (p 726). The higher stroke-breathing count ratio found (wetsuit 1.38±0.43, swimsuit 1.28±0.32; p<.001) confirms the difference in number of breathings between conditions. However, no difference was found in the total percentage of right (wetsuit 62.9±24.09%, swimsuit 70.03±26.35%) and left side (wetsuit 37.85±23.63%, swimsuit 31.14±26.13%) breathings, nor in the timing of breathings (p .105). Higher HR and RPE were recorded in swimsuit, (both p<.001) with no differences in swimming comfort (wetsuit 0.1±1.9, swimsuit 0.7±2.0; p 206) (Figure 2).

Fatigability
A fatigability effect was found for HR in both swimsuit and wetsuit (both p<.001) and for count of strokes and breathings (both p<.001), SL (p<.001), stroke-breathing count ratio (p<.001) and RPE (p .001) in swimsuit condition only (Figure 2 and 3).

Detailed data and statistical analysis results are provided in Supplementary Material (available online).

Figure 2

Figure 3

DISCUSSION

Wetsuits are permitted in open water and triathlon events, depending on water temperature, age group and distance to be covered, with the main purpose to prevent hypothermia[22]. Previous research has shown an improvement in performance with wetsuit use by increasing buoyancy and gliding length and by decreasing energy cost[8,9,13,18,19]. However, athletes have reported a higher discomfort while swimming with a wetsuit and some technical changes have been reported such as an inhibition in kicking action[17,20,21]. Our results have further strengthened what is already known by highlighting that wetsuit use decreases trunk incline and drag leading to a delayed increase of effort. Contrary to our hypothesis, motor coordination (i.e. stroke coordination model, upper and lower limb coordination and breathings timing in a stroke cycle) was not affected by the wetsuit and neither was swimming comfort in experienced triathletes.

During a swimming activity the different density between legs and chest leads to an inclination of the body alignment on the sagittal plane of the swimmer, also known as "sinking legs", that increases resistance and reduces swimming speed[42]. The results of our study highlight the effect of wetsuit use on reducing TI (~28%, >3°) and thus the frontal area presented by the swimmer to the water that has an effect on the form component of active drag[6]. Toussaint et al, in their pioneer work in 1989[6], showed a 14% reduction in active drag (estimated with the Measurement Active Drag system) while swimming in wetsuit condition at 1.25 m/s. Other studies instead, showed no differences due to wetsuit use in active drag (measured by the perturbation method) when evaluated during a maximal sprint[8,19]. However, the speed in the wetsuit condition during a maximal sprint was higher (~5%[8]) compared to the swimsuit condition and this could justify the fact that no differences were found in active drag[13]. Moreover, we can hypothesize that also friction drag is decreased in wetsuit, as suggested by the longer underwater phase found in the current study (~13.7%), attributable to the water repellent properties of the wetsuit surface. Similarly, friction drag has been shown to decrease with wetsuit, inversely to the speed, when athletes were towed in a prone position[7]. As a consequence, there seems to be a direct effect of wetsuit in decreasing drag during swimming, at least in the form and friction components.

Due to the decreased drag in wetsuit condition, the propelling proficiency seems to increase by reducing stroke rate (SR) and increasing SL and SI, at the same swimming speed. Our results support previous findings where open water swimmers and triathletes swimming with a wetsuit showed technical adaptations that reduced SR and increased SL[9]. Although the IdC was classifiable as a catch-up model in both conditions, our results showed lower percentage values in wetsuit condition compared to swimsuit. The lower propulsive phases indicate a shorter period of propulsive force application, thus low power generation at the same swimming speed using a wetsuit[36]. However, other studies involving triathletes or open water swimmers showed different results[11,13,16] depending on speed, duration and if swimming in a flume or in a swimming pool. It has to be pointed out that most of the studies in the literature did not test subjects over a pre-set speed, leading to artefactual results attributable to the higher swimming speed reached in wetsuit condition[9,16,22].

Regarding the effects of wetsuit on number of kicks, our results confirm the perceived decrease in kicking frequency previously reported by the athletes using a wetsuit[20,21] and in accordance with what has already been reported during a 800 m[17], but not in shorter tasks[11]. Leg kicks have the main effect of reducing TI during crawl swimming[43]; the decrease of TI by wetsuit use brings to a consequent reduction in number of kicks needed to maintain the same position in the water. Moreover, the reduction of kicking frequency is profitable in both triathlon and open water races, which require cycling and running after the swimming fraction in triathlon and very intensive finishing strategies in long open water races[2,22].

Motor coordination, in particular IdC model, IdS value, timing of kicking and breathing, appeared not to be affected by wetsuit use, indicating that aspects of motor control acting on technique are not related to the suit used. An unchanged effect in kick adjustment by wetsuit use is favourable to athletes during swimming in adverse environmental conditions, where waves might change the arm-leg coordination related to the effects of the moving body of water[26]. Moreover, a correct synchronization of breathing-stroke has shown to be crucial to apply a great impulse of force and its correctness is related to the relative swimming speed and performance level[25].

Enhancing buoyancy and decreasing drag seems to lead to a decrease of both physiological variables (lower HR and number of breathings) and rates of perceived exertion (lower RPE) at the same swimming speed while using a wetsuit compared to swimsuit. RPE increase throughout exercise is recognized as a major feature of sensation of fatigue as well as playing a pivotal role in regulating pacing during exercise[44]. Moreover, it has been reported that respiratory frequency is the best correlate of RPE during self-paced maximal effort exercise, irrespective of the intermittent or continuous nature of the protocol[45]. During a swimming activity, in particular during front-crawl, the breathing action disrupts the body alignment, increasing drag and reducing SL[25]. Interestingly, a lower breathing frequency was found in more skilled swimmers compared to less skilled[25]. The current study is the first investigating the effects of wetsuit on breathing, showing a lower number of breathings compared to swimsuit. The differences showed in RPE and HR are similar to what was previously shown at a speed of 1.31m/s, but not at lower speeds[13,18] or at pre-set distance[9,12,17] or time[10]. However, a pre-set distance or time test imply a difference in speed between swimsuit and wetsuit[9,10,12,17], therefore lower values of RPE or HR may be expected when normalizing by speed. Moreover, the pre-set speed tests were performed in a flume for 5 minutes for each trial[13,18], which may not be long enough to detect changes in RPE and HR. Indeed, we found no differences in HR or RPE during the first 200 m, but thereafter both increased in the swimsuit condition but not in the wetsuit.

The choice of our test was to evaluate not only differences between swimsuit and wetsuit on overall performance, but also how the use of wetsuit could mitigate the fatigability throughout a longer task. In detail, in the swimsuit condition more variables (i.e. RPE, HR, number of strokes and breathings) increased from the beginning to the end of the 7x200 m, while in the wetsuit condition only HR increased during the trial with no difference in RPE, number of strokes and breathings. We found no changes in stroke phases percentage during the task, while an increase in the propulsive phase was found between the first and the last length of a 1500 m in wetsuit, but not in swimsuit[14]. However, the task was conducted at maximal speed and it is unlikely that the swimming speed both between conditions and between the first and last length were the same. Recently, Rois et al.[27] reported a decreased HR in wetsuit condition compared to swimsuit while swimming in a 25°C flume for 75 minutes with no difference in RPE. However, the authors suggest that the increase in HR during the swimsuit condition was mainly due to compensate for heat generation rather than an index of intensity. Athletes were in fact swimming at an intensity of 70% of their critical velocity with a final RPE of 3 that corresponds to a sub-VT1 (ventilatory threshold 1) intensity[46]. Our triathletes instead reported an average RPE of 5 indicating a swimming intensity between the two thresholds[46]. The higher intensities reported in the current study might explain the variation in technical variables (i.e. number of stokes and SL), the increase of physiological (i.e. HR and number of breathings) and perceptual (i.e. RPE) variables in swimsuit, contrary to the steady-state shown in the wetsuit. The fatigability on biomechanical variables (i.e. decreasing SL, increasing SR, increasing kicking speed, increase of IdC value but not changing the model) has been reported during a classic 7x200 m incremental protocol between each repetition[34]. In particular, these variations were evident at speeds above the lactate inflection point explained by the technique reorganization to overcome increased hydrodynamic drag. This confirms the higher relative intensity sustained by our triathletes while swimming with a swimsuit compared to a wetsuit condition, at the same swimming speed (Figure 3).

The current study was the first evaluating swimming comfort in wetsuit and swimsuit during swimming activity[22]. Contrary to expectations, no difference in comfort was found. Based on our preliminary survey, triathletes reported to dislike wetsuit use mainly for upper arm discomfort during swimming (82%) and that they are forced in its use by rule restrictions (82%) and by the fact that opponents will use it (100%). However, there was no difference in swimming comfort with or without wetsuit, probably due to their familiarization with wetsuit use, as Table 1 shows. In fact, previous studies showed that pool swimmers reported a lower comfort because unfamiliar with the wetsuit use, compared to triathletes[12]. It is important to note that there is no clear indication in the literature on the definition of familiarity of an athlete with a wetsuit[22]. Our study is the first reporting the numbers of years each athlete has been training/competing with a wetsuit. In particular, the triathletes of the current study have been regularly using wetsuit (from 2 to 10 years) in a pool or open water, in addition to competitions. The current study was carried out just before the competitive season, when athletes mostly utilize wetsuits in training and competition.

PRACTICAL APPLICATIONS

Swimming with a full-body wetsuit during a 7x200 m front-crawl at pre-set speed, corresponding to the swimming race pace of an Olympic distance triathlon, leads to a reduction of TI and drag, at least in the form and friction components and thus to a delay in fatigability. Interestingly, no changes in motor coordination were found, which confirms that triathletes may utilize wetsuit also during training sessions. Indeed, triathletes with experience in wetsuit use did not perceive high discomfort and benefited in terms of performance and reduced fatigability by wetsuit use[7,12,22]. Therefore, the use of wetsuit is recommended also in training sessions to increase familiarization, without concerns about a possible negative effect on coordination. However, the amplitude of the effects might differ based on athletes (i.e. open water swimmers and triathletes, élite and recreational level, experience in wetsuit use) and more studies are necessary to highlight possible differences.

Our study has some limitations. The study was conducted in an indoor swimming pool with a water temperature of 28.4±0.5°C, due to the unfeasibility of cooling the water. In contrast, the athletes usually compete in an open water environment where a wetsuit use is physiological variables when comparing swimming in cold temperature[15,27] to a typical pool allowed only at temperatures (below 20-24.6°C[3,4]). Indeed, recent studies report differences in environment and also in biomechanical variables compared to open water[47]. However, it seems that different water temperatures (at least between 26° and 18° C) do not affect biomechanical parameters[15]. Our aim was to evaluate the presence of fatigability in biomechanical, physiological and perceptual variables during a protocol similar to a training situation. Studies conducted in an open water environment, simulating competition settings, are thus recommended[22]. We recruited only 15 young triathletes, but of International level and with experience in wetsuit use. However, four triathletes were excluded because not able to replicate the speed maintained during the wetsuit session and analysis was performed on only 11 subjects. The training session protocol of 7x200 m front-crawl constant speed interval with 1 minute rest was designed to allow triathletes to correctly perform the task and to be able to compare the variables. Secondly, it allows for in between measurements- (i.e. RPE and comfort). Our main intent was to compare at the same speed the selected variables but also to measure the effect of fatigue which we could obtain only by increasing the number of repetitions. Further studies performing a long-continuous task are recommended, as already recommended in a recent review on the topic[22], to confirm our results obtained during this simulated training session. Finally, the stroke and kick data were estimated by IMU sensors located on the right limbs only. In the following studies, we suggest locating IMU sensors on both sides for refining the estimation of technical variables.

CONCLUSIONS

Using a wetsuit during a swimming task simulating competition effort reduces the trunk incline, thus drag, compared to a swimsuit at the same speed. As a consequence, the triathletes show an increased SI and SL, both indexes of propelling proficiency and a lower fatigability, without modifying motor coordination. The use of a wetsuit also during training sessions is recommended, to increase the comfort and the positive effects on performance.

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ID	Sex	Age (Yrs)	Height (cm)	Body mass (Kg)	Body fat (%)	Perf.	Sp. (m/s)	Tri. P. (Yrs)	Tri. T. (hrs/wk)	Swi. P. (Yrs)	Swi. T. (hrs/wk)	Swi. T. (Km/wk)	Swi. T. (n/wk)	Wetsuit Exp. (Yrs)	Wetsuit Details (thickness range)
2	M	27	183	74.90	18.5	G.P.	1.39	11	21	11	8	23	4	10	Zoot - WikiWiki (2:5)
3	F	23	165	59.97	28.9	E.Jr.	1.28	11	24	11	9	25	6	8	Huub – Astana (3:3)
5	M	19	187	73.78	15.9	E.c.Jr.	1.38	10	24	11	8	26	6	5	Zoot - WikiWiki (2:5)
6	M	16	180	64.08	12.3	N.Ch.	1.14	6	25	11	5	15	3	2	Zoot - Force 1.0 (2:5)
7	M	17	173	78.48	23.9	N.Ch.	1.25	11	25	11	6	15	4	4	Huub - Aerious II (3:5)
8	M	17	174	66.23	15.5	N.Ch.	1.25	7	21	11	9	20	5	2	Tyr – Hurricane C3 (3:5)
9	F	24	162	49.73	21.8	W.Jr.	1.29	11	27	11	6	25	6	9	Yonda – Ghost (1.5:5)
10	F	20	173	61.65	27.8	E.c.Jr.	1.23	11	16	11	6	13	3	6	Huub – Acara (3:5)
12	M	17	175	75.25	20.3	N.Ch.	1.25	5	20	8	7	20	5	3	Zoot - WikiWiki (2:5)
13	M	18	182	73.60	17.8	E.Y.	1.41	8	23	11	9	26	6	3	Zoot - WikiWiki (2:5)
14	F	17	169	59.00	24.3	E.Y.	1.21	10	20	11	8	23	6	2	Huub – Aegis (3:5)
	M	18.7±3.8	179.4±5.3	72.33±5.20	17.7±3.7		1.30±0.10	8.3±2.4	22.7±2.1	10.6±1.1	7.4±1.5	20.7±4.6	4.7±1.1	4.1±3.0	
	F	21.0±3.2	167.3±4.8	57.59±5.35	25.7±3.3		1.25±0.04	10.8±0.5	21.8±4.8	11.0±0.0	7.3±1.5	21.5±5.7	5.3±1.5	6.3±3.1	

	Total	19.6±3.6	174.8±7.7	67.0±9.0	20.6±5.3		1.28±0.08	9.2±2.3	22.4±3.1	10.7±0.9	7.4±1.4	21.0±4.8	4.9±1.2	4.9±2.9	(2.4:5) ±(0.6:0.6)

Table 1 – Subjects characteristics, training information and wetsuit details.
M = Male; F = Female; Perf. = Best Championship raced; G.P. = ITU Grand Prix Senior; E.Jr. = European Championships Junior; E.c.Jr. = European Cup Junior; N.Ch. = Individual National Championships Senior; E.Y. = European Championships Youth; Sp. = mean speed during Olympic distance swimming fraction; Tri. P. = Triathlon Practice; Tri. T. = Triathlon Training volume; Swi. P. = Swimming Practice; Swi. T. = Swimming Training volume; Wetsuit Exp. = Wetsuit Experience; Yrs = Years, hrs/wk = hours per week; Km/wk = Kilometers per week; n/wk = number of sessions per week; the thickness range represent the higher and lower thickness value in mm independently to the body position reported by the individual industry company.

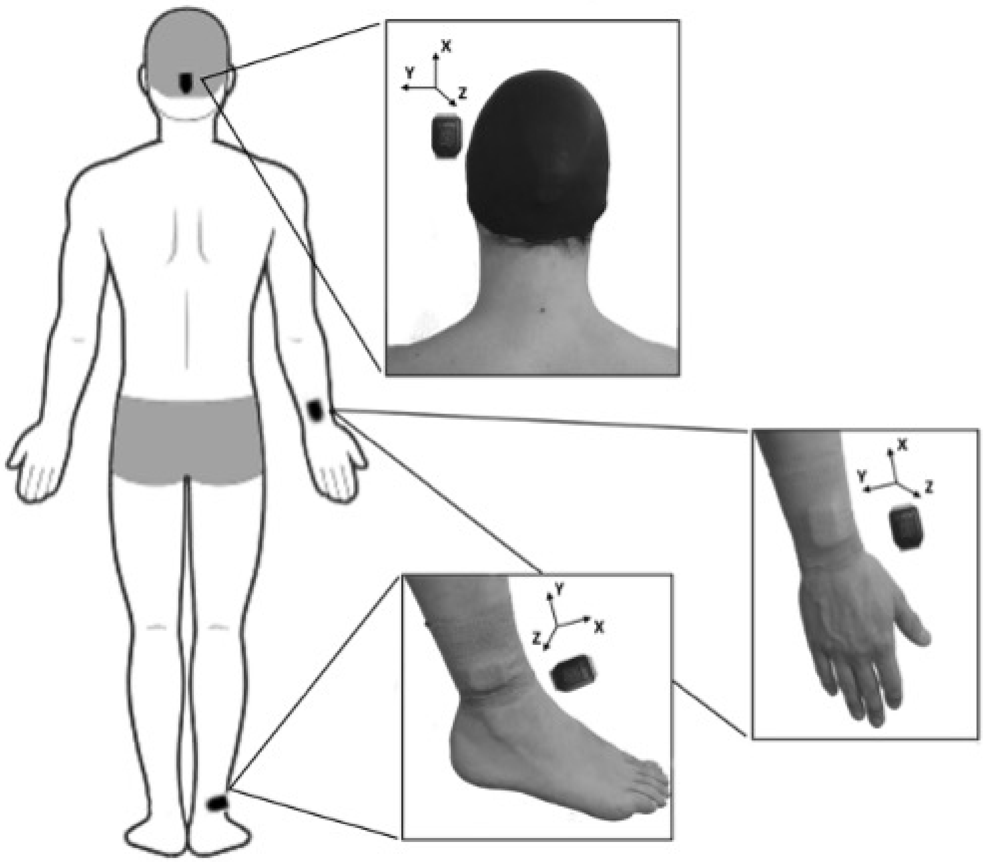

Figure 1 – Positioning of wearable inertial sensors located on the right ankle, right wrist and head with shown the alignment of axes (X, Y and Z) of the reference system.

132x118mm (96 x 96 DPI)

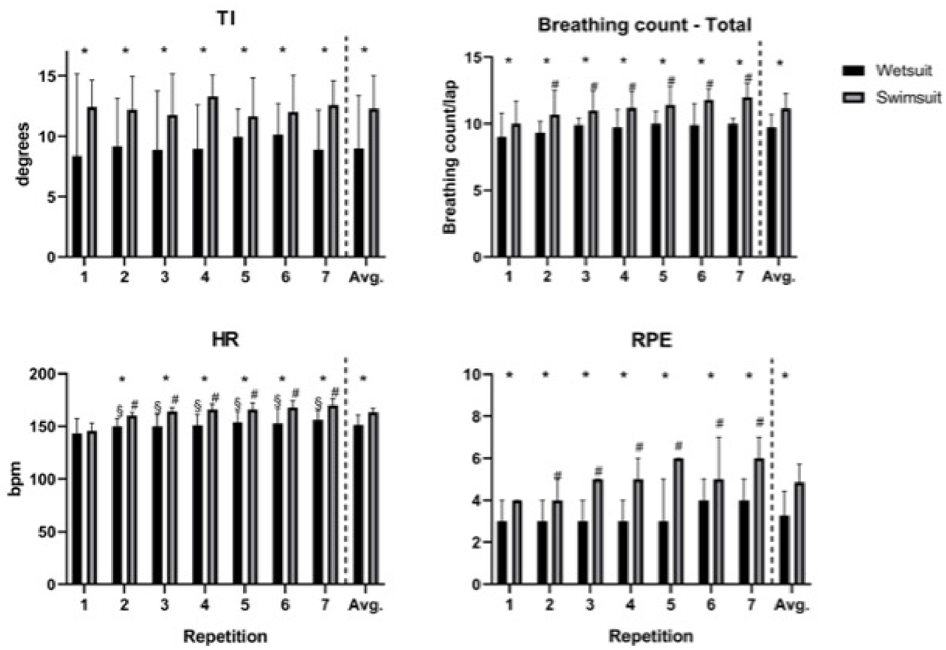

Figure 2 - Trunk incline (TI), Breathing count per lap, heart rate (HR) and rate of perceived exertion (RPE) for each repetition and average (Avg.) in wetsuit and swimsuit. Bpm = beats per minute* significantly different between conditions; § significantly different from repetition 1 in wetsuit; # significantly different from repetition 1 in swimsuit

170x119mm (96 x 96 DPI)

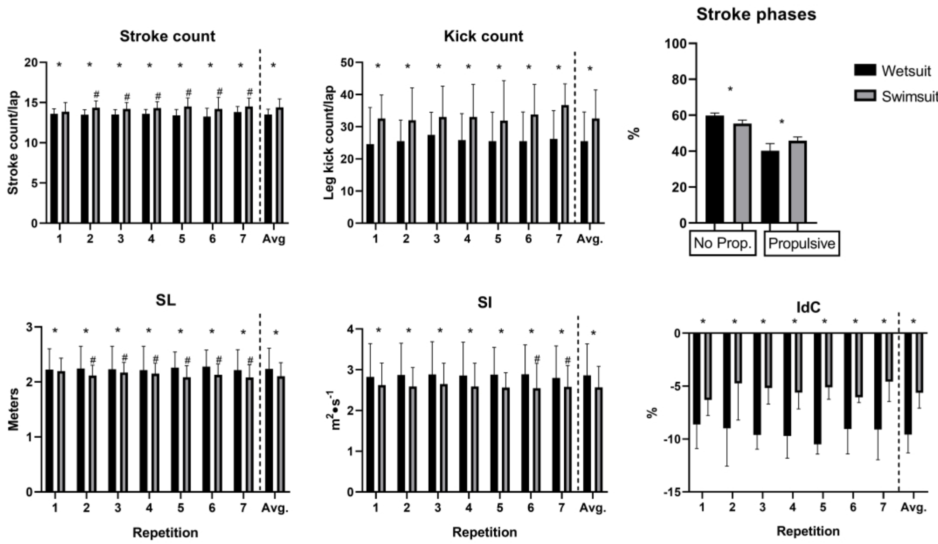

Figure 3 - Stroke (right side) count per lap, leg kick (right side) count per lap, stroke phases percentages (no propulsive= entry+catch and recovery, propulsive= pull and push), stroke length, stroke index (SI) and Index of coordination (IdC) for each repetition and average (Avg.) in wetsuit and swimsuit. * significantly different between conditions; § =significantly different from repetition 1 in wetsuit; # significantly different from repetition 1 in swimsuit

1517x896mm (96 x 96 DPI)

Detailed data

	1^ 200m	2^ 200m	3^ 200m	4^ 200m	5^ 200m	6^ 200m	7^ 200m	Avg.
Trunk incline (degrees)								
Wetsuit	8.18±9.27*	8.71±7.97*	8.35±8.82*	8.40±8.43*	9.38±7.58*	9.23±8.08*	8.48±7.52*	8.68±8.34*
Swimsuit	12.06±8.50*	11.75±7.86*	11.71±7.26*	12.91±9.10*	12.79±7.91*	11.76±8.58*	11.47±7.83*	12.07±8.20*
Underwater length (m)								
Wetsuit	3.19±0.36	3.11±0.52*	3.09±0.33*	2.95±0.48	3.14±0.21	3.23±0.42*	2.97±0.59*	3.08±0.46*
Swimsuit	2.95±0.80	2.89±0.63*	2.84±0.57*	2.80±0.48	2.79±0.68	2.76±0.59*	2.74±0.68*	2.71±0.50*
Strokes count per lap								
Wetsuit	13.7±3.2*	13.7±2.5*	13.7±2.5*	13.7±2.3*	13.5±2.0*	13.5±2.3*	13.8±2.0*	13.5±2.8*
Swimsuit	14.0±2.5*	14.7±2.4*#	14.8±2.2*#	14.8±2.2*#	14.8±2.9*#	14.8±3.0*#	14.8±2.6*#	14.4±2.6*
Stroke length (m)								
Wetsuit	2.21±0.59*	2.24±0.48*	2.21±0.48*	2.20±0.51*	2.22±0.35*	2.27±0.42*	2.22±0.34*	2.24±0.50*
Swimsuit	2.15±0.45*	2.06±0.33*#	2.04±0.37*#	2.04±0.40*#	2.04±0.39*#	2.04±0.42*#	2.04±0.39*#	2.10±0.39*
Stroke index ($m^2 \cdot s^{-1}$)								
Wetsuit	2.80±0.94*	2.85±0.90*	2.85±0.96*	2.83±1.06*	2.84±0.91*	2.87±0.92*	2.80±0.87*	2.86±1.00*
Swimsuit	2.59±0.61*	2.56±0.45*	2.54±0.50*	2.54±0.52*	2.52±0.54*	2.51±0.58*#	2.53±0.53*#	2.57±0.64*
Index of Coordination (%)								
Wetsuit	-8.63±3.74*	-8.99±6.74*	-9.61±6.26*	-9.72±5.14*	-10.50±4.69*	-9.05±4.65*	-9.11±4.82*	-9.59±4.66*
Swimsuit	-6.30±3.25*	-4.75±5.59*	-5.18±3.64*	-5.62±3.70*	-5.12±3.46*	-6.06±4.54*	-4.58±3.81*	-5.64±3.58*
Stroke Phase – No propulsive (%)								
Wetsuit	59.26±4.11*	60.13±7.91*	59.88±8.34*	60.15±10.84*	60.13±3.98*	59.10±4.99*	59.98±5.06*	59.75±5.45*
Swimsuit	55.74±4.00*	54.23±8.33*	53.30±4.76*	55.49±4.27*	56.01±6.96*	55.36±6.40*	54.24±6.81*	55.39±5.22*
Stroke Phase - Propulsive (%)								
Wetsuit	40.74±4.11*	39.52±7.91*	40.13±8.60*	39.85±10.84*	39.87±3.98*	40.90±4.99*	40.47±4.38*	40.25±5.49*
Swimsuit	44.26±4.00*	45.77±8.33*	46.70±4.76*	44.66±4.18*	44.49±7.02*	45.58±6.40*	45.76±6.81*	45.75±5.25*
Kick count per lap								
Wetsuit	24.5±20.5*	25.8±11.3*	29.2±17.0*	25.7±18.1*	25.8±17.4*	25.5±18.0*	26.17±16.5*	25.48±12.96*
Swimsuit	32.2±15.6*	32.5±18.3*	33.0±21.4*	33.0±24.2*	33.8±23.2*	33.8±24.6*	36.7±26.8*	32.5±13.97*
Kick timing – 1^ (stroke duration %)								

Wetsuit	4.22±8.31	3.70±6.10	4.13±7.37	4.76±9.50	4.40±18.15	3.77±15.15	4.40±7.62	4.72±24.63
Swimsuit	9.79±16.05	6.17±11.10	4.25±11.19	4.79±13.12	4.48±12.35	4.63±13.71	4.99±21.11	5.76±18.14
Kick timing – 2^ (stroke duration %)								
Wetsuit	43.33±14.80	41.10±16.81	41.24±16.08	41.90±17.04	45.16±16.92	43.67±16.43	42.05±11.90	43.84±15.19
Swimsuit	44.07±9.79	41.85±9.86	44.70±15.02	45.25±13.98	44.08±10.41	43.79±12.07	44.16±20.90	43.87±15.18
Kick timing – 3^ (stroke duration %)								
Wetsuit	73.96±18.75	73.16±18.27	74.43±18.64	74.72±19.03	75.72±18.51	75.97±18.48	74.24±13.70	75.08±18.45
Swimsuit	75.28±13.89	74.20±14.92	72.63±17.91	73.45±18.84	73.65±18.50	72.23±19.86	72.53±23.17	75.00±15.59
Index of synchronization								
Wetsuit	0.03±0.25	-0.01±0.30	-0.01±0.21	-0.02±0.16	0.01±0.19	0.06±0.27	0.06±0.24	0.06±0.22
Swimsuit	0.01±0.20	0.02±0.10	0.01±0.25	0.01±0.13	0.01±0.25	0.00±0.10	0.01±0.10	0.01±0.12
Breathings count per lap (tot)								
Wetsuit	8.8±1.2*	9.5±1.0*	9.8±1.4*	9.7±1.2*	10.0±1.4*	9.8±0.8*	10.0±1.7*	9.8±2.0*
Swimsuit	9.7±1.8*	10.7±1.5*#	11.0±1.2*#	11.2±0.8*#	11.3±0.5*#	11.8±0.7*#	12.0±1.1*#	11.2±1.6*
Breathings count per lap - right side								
Wetsuit	4.5±5.0*	4.8±6.0*	5.2±5.4*	4.8±5.8*	3.8±6.0*	4.7±4.8*	3.3±5.2*	5.5±4.6*
Swimsuit	6.3±6.6*	6.8±7.3*	6.2±7.42*	6.7±7.8*	7.7±8.8*	7.0±7.8*	6.8±8.6*	7.7±7.1*
Breathings count per lap - left side								
Wetsuit	3.2±3.4	3.5±4.1	3.0±3.9	3.3±3.3	2.8±4.5	3.2±2.9	3.7±4.8	3.2±3.2
Swimsuit	3.2±4.8	2.3±5.3	3.3±5.0	3.5±5.6	2.2±5.6	3.3±5.0	3.2±5.1	2.8±4.6
Stroke-breathing ratio								
Wetsuit	1.45±0.45	1.33±0.49*	1.33±0.32*	1.37±0.38*	1.35±0.38*	1.30±0.45*	1.29±0.42*	1.38±0.43*
Swimsuit	1.35±0.48	1.36±0.34*#	1.31±0.26*#	1.24±0.28*#	1.27±0.25*#	1.23±0.23*#	1.13±0.27*#	1.28±0.32*
Breathing timing - right side (stroke duration %)								
Wetsuit	84.40±9.13	86.60±8.34	85.25±9.28	84.30±6.96	83.90±8.75	83.30±8.58	83.60±8.88	86.41±9.05
Swimsuit	84.55±4.37	84.70±8.17	84.00±7.73	83.80±7.88	83.80±8.55	84.60±8.28	84.90±7.76	85.16±8.10
Breathing timing - left side (stroke duration %)								
Wetsuit	35.00±5.50	34.70±7.30	35.20±5.30	34.50±6.93	34.62±7.80	35.70±8.71	34.47±9.10	34.52±7.38
Swimsuit	33.08±9.60	31.75±11.30	31.48±10.60	32.76±11.80	33.98±12.30	32.88±12.30	31.14±13.50	33.27±9.85
Heart rate (bpm)								
Wetsuit	141.5±16.0	149.5±19.3*§	149.0±20.8*§	151.0±15.0*§	153.0±19.0*§	152.0±19.3*§	155.5±16.8*§	151.4±17.3*

Swimsuit	149.5±11.5	161.5±10.5*#	164.5±7.8*#	166.5±7.5*#	166.0±11.3*#	168.5±10.0*#	170.0±11.3*#	164.2±8.6*
Rate of perceived exertion (CR-10)								
Wetsuit	3.0±2.0*	3.0±2.0*	3.0±1.5*	3.0±1.0*	3.0±2.5*	4.0±2.5*	4.0±2.0*	3.3±1.9*
Swimsuit	4.0±1.0*	4.0±2.0*#	5.0±1.0*#	5.0±2.0*#	6.0±2.0*#	5.0±3.0*	6.0±4.0*#	4.9±2.0*
Swimming comfort (from -5 to +5)								
Wetsuit	-1.0±5.0	0.0±3.0	0.0±2.0	1.0±2.0	0.0±2.0	0.0±2.0	0.0±2.0	0.1±1.9
Swimsuit	0.0±2.0	1.0±1.0	1.0±2.0	1.0±2.0	1.0±2.0	1.0±4.0	1.0±4.0	0.7±2.0

Measures of each repetition and average in wetsuit and swimsuit conditions. Median±interquartile range
* = significative different between conditions; § = significative different between repetition 1 in Wet; # = significative different between repetition 1 in Swi

Statistical analysis results: Between conditions

Friedman(13,11)

TI	IdC	Stroke Phase – No Propulsive	Stroke Phase - Propulsive	HR	RPE	Swimming Comfort
X^2=85.565, p=.000*, W=.658	X^2=97.443, p=.000*, W=.681	X^2=70.984, p=.000*, W=.496	X^2=67.301, p=.000*, W=.471	X^2=72.507, p=.000*, W=.797	X^2=82.779, p=.000*, W=.579	X^2=16.853, p=.206, W=.118

Friedman(13,10)

Underwater length	Stroke count	SL	SI	Kick count	Kick Timing – 1^	Kick Timing – 2^	Kick Timing – 3^	IdS
X^2=30.397, p=.004*, W=.334	X^2=65.752, p=.000*, W=.723	X^2=70.008, p=.000*, W=.769	X^2=66.843, p=.00, W=.735	X^2=71.819, p=.000*, W=.789	X^2=8.400, p=.817, W=.162	X^2=4.192, p=.989, W=.046	X^2=3.400, p=.996, W=.033	X^2=6.820, p=.911, W=.087
Breathing count - Total	**Breathing count – right side**	**Breathing count – left side**	**Stroke-Breathing count ratio**	**Breathing Timing - right side**	**Breathing Timing - left side**			
X^2=74.622, p=.000*, W=.820	X^2=50.882, p=.000*, W=.435	X^2=9.600, p=.726, W=.082	X^2=57.031, p=.000*, W=.627	X^2=19.635, p=.105, W=.189	X^2=25.440, p=.020*, W=.280			

Wilcoxon (11)

Mean difference, coefficient intervals 95% and delta %

Pearson's r thresholds: .1 small (S), .3 moderate (M), .5 large (L), .7 very large (VL), .9 extremely large (EL)[19]

1^ 200m	2^ 200m	3^ 200m	4^ 200m	5^ 200m	6^ 200m	7^ 200m	Avg.
Trunk incline							

Z=-1.956, p=.050*, r=.852^VL	Z=-2.667, p=.008*, r=.929^EL	Z=-2.224, p=.026*, r=.882^VL	Z=-2.803, p=.005*, r=.933^EL	Z=-2.803, p=.005*, r=.963^EL	Z=-2.803, p=.005*, r=.976^EL	Z=-2.803, p=.005*, r=.962^EL	Z=-2.223, p=.005*, r=.913^EL
1.5, [0.5 2.4], 32.4%	1.0, [0.3 1.7], 12,3%	2.1, [0.7 3.6], 20.5%	2.1, [0.7 3.5], 21.6%	3.3, [1.1 5.5], 29.7%	3.2, [1.1 5.4], 30,3%	3.2, [1.0 5.3], 27.6%	3.5, [1.2 5.9], 30.8%
Index of Coordination							
Z=-2.934, p=.003*, r=.857^VL	Z=-2.936, p=.003*, r=.887^VL	Z=-2.934, p=.003*, r=.886 ^VL	Z=-2.934, p=.003*, r=.874 ^VL	Z=-2.936, p=.003*, r=.867 ^VL	Z=-2.936, p=.003*, r=.929 ^EL	Z=-2.934, p=.003*, r=.857 ^VL	Z=-2.934, p=.003*, r=.949 ^EL
3.1, [1.0 5.1], -7.1%	4.4, [1.4 7.3], -143.3%	3.5, [1.2 5.9], -98.4%	4.0, [1.3 6.7], -84.5%	4.5, [1.5 7.5], -77.5%	4.0, [1.3 6.7], -131.5%	4.8, [1.6 8.0], -65.0%	4.0, [1.3 6.7], -124.6%
Stroke phase – No propulsive							
Z=-2.223, p=.026*, r=.542^L	Z=-2.934, p=.003*, r=.829^VL	Z=-2.756, p=.006*, r=.796^VL	Z=-2.667, p=.008*, r=.754^VL	Z=-2.845, p=.004*, r=.490^M	Z=-2.134, p=.010*, r=.629^L	Z=-2.134, p=.033*, r=.714^VL	Z=-2.934, p=.003*, r=.889^VL
2.9, [1.0 4.9], 6.4%	5.9, [1.9 9.9], 13.0%	3.8, [1.2 6.3], 8.3%	4.4, [1.4 7.3], 9.7%	5.5, [1.8 9.2], 11.5%	3.1, [1.0 5.2], 6.8%	4.6, [1.5 7.7], 9.6%	4.3, [1.4 7.2], 9.6%
Stroke Phase – Propulsive							
Z=-2.223, p=.026*, r=.516 ^L	Z=-2.934, p=.003*, r=.838 ^VL	Z=-2.401, p=.016*, r=.700 ^VL	Z=-2.667, p=.003*, r=.646 ^L	Z=-2.845, p=.004*, r=.522 ^L	Z=-2.134, p=.033*, r=.623 ^L	Z=-2.667, p=.008*, r=.725 ^VL	Z=-2.934, p=.003*, r=.857 ^VL
-2.9, [-1.0 -4.8], -5.4%	-.57, [-1.9 -9.5], -10.6%	-4.0, [-1.3 -6.7], -7.4%	-4.1, [-1.3 -6.8], -7.4%	-5.7, [-1.9 -9.5], -11.0%	-3.0, [-1.0 -5.0], -5.5%	-4.5, [-1.5 -7.6], -8.8%	-4.3, [-1.4 -7.1], -7.8%
HR							
Z=-1.051, p=.293, r=.383^M	Z=-2.403, p=.016*, r=.672 ^L	Z=-2.805, p=.005*, r=.631 ^L	Z=-2.550, p=.011*, r=.537 ^L	Z=-2.578, p=.010*, r=.560 ^L	Z=-2.763, p=.006*, r=.556 ^L	Z=-2.758, p=.006*, r=.578 ^L	Z=-2.312, p=.021*, r=.582 ^L
3.0,	9.5,	12.0,	12.4,	11.6,	12.5,	12.9,	10.3,

[1.0 5.0], 1.6%	[3.1 15.8], 5.9%	[3.9 20.1] 7.2%	[4.1 20.7] 7.3%	[3.8 19.5] 6.9%	[4.1 21.0] 7.3%	[4.2 21.6] 7.5%	[3.4 17.2] 6.2%
RPE							
Z=-2.456, p=.014*, r=.910 EL	Z=-2.699, p=.007*, r=.841 VL	Z=-2.701, p=.007*, r=.805 VL	Z=-3.035, p=.002*, r=.928 EL	Z=-2.831, p=.005*, r=.807 VL	Z=-2.965, p=.003*, r=.860 VL	Z=-2.836, p=.005*, r=.863 VL	Z=-2.934, p=.003*, r=.912 EL
0.8, [0.3 1.3], 21.1%	1.2, [0.4 2.0], 28.5%	1.3, [0.4 2.2], 29.8%	1.6, [0.5 2.7], 36.5%	1.8, [0.6 3.0], 35.8%	1.7, [0.6 2.8], 34.3%	1.8, [0.6 3.0], 32.2%	1.5, [0.5 2.4], 32.4%

Wilcoxon (10)
Mean difference, coefficient intervals 95% and delta %
Pearson's r thresholds: .1 small (S), .3 moderate (M), .5 large (L), .7 very large (VL), .9 extremely large (EL)[19]

1^ 200m	2^ 200m	3^ 200m	4^ 200m	5^ 200m	6^ 200m	7^ 200m	Avg.
Underwater length							
Z=-1.836, p=.066, r=.248 S	Z=-2.497, p=.013*, r=.552 L	Z=-2.073, p=.038*, r=.550 L	Z=-1.125, p=.260, r=.382 S	Z=-1.820, p=.069, r=.738 VL	Z=-2.547, p=.011*, r=.750 VL	Z=-2.521, p=.012*, r=.619 L	Z=-2.395, p=.017*, r=.672 L
-0.3, [-.1 -.5], -13.1%	-0.4, [-.1 -.7], -15.8%	-0.4, [-.1 -.7], -16.0%	-0.3, [-.1 -.5], -13.1%	-0.3, [-.1 -.6], -13.8%	-0.4, [-.1 -.7], -15.6%	-0.4, [-.1 -.7], -14.2%	-0.4, [-.1 -.6], -14.7%
Strokes count per lap							
Z=-2.552, p=.011*, r=.935 EL	Z=-2.666, p=.008*, r=.932 EL	Z=-2.521, p=.012*, r=.895 VL	Z=-2.429, p=.015*, r=.807 VL	Z=-2.366, p=.018*, r=.775 VL	Z=-2.668, p=.008*, r=.863 VL	Z=-2.521, p=.012*, r=.875 VL	Z=-2.803, p=.005*, r=.926 EL
0.9, [0.3 1.6], 6.8%	1.3, [0.4 2.2], 9.3%	1.4, [0.4 2.3], 9.8%	1.4, [0.4 2.3], 9.7%	1.3, [0.4 2.2], 8.8%	1.6, [0.4 2.7], 10.9%	1.6, [0.4 2.7], 9.8%	1.3, [0.4 2.3], 9.4%
Stroke lenght							
Z=-2.497, p=.013*, r=.943 EL	Z=-2.803, p=.005*, r=.944 EL	Z=-2.666, p=.008*, r=.917 EL	Z=-2.666, p=.008*, r=.906 EL	Z=-2.524, p=.012*, r=.793 VL	Z=-2.666, p=.008*, r=.872 VL	Z=-2.521, p=.012*, r=.889 VL	Z=-2.803, p=.005*, r=.940 EL

-0.1, [.0 -.2], -6.4%	-0.2, [-.1 -.3], -9.2%	-0.2, [-.1 -.4], -9.9%	-0.2, [-.1 -.4], -10.1%	-0.2, [-.1 -.3], -8.8%	-0.2, [-.1 -.4¡], -11.1%	-0.2, [-.1 -.4], -10.0	-0.2, [-.1 -.3], -9.3%
Stroke index							
Z=-2.803, p=.005*, r=.975 EL	Z=-2.701, p=.007*, r=.968 EL	Z=-2.666, p=.008*, r=.950 EL	Z=-2.666, p=.008*, r=.967 EL	Z=-2.521, p=.012*, r=.904 EL	Z=-2.670, p=.008*, r=.942 EL	Z=-2.521, p=.012*, r=.946 EL	Z=-2.803, p=.005*, r=.970 EL
-0.3, [-.1 -.5], -9.6%	-0.3, [-.1 -.5], -10.6%	-0.3, [-.1 -.5], -10.9%	-0.3, [-.1 -.5], -10.9%	-0.3, [-.1 -.4], -9.8%	-0.3, [-.1 -.6], -11.7%	-0.4, [-.1 -.6], -11.4%	-0.3, [-.1 -.5], -10.6%
Leg kicks count per lap							
Z=-2.803, p=.005*, r=.911 EL	Z=-2.805, p=.005*, r=.895 VL	Z=-2.666, p=.008*, r=.952 EL	Z=-2.666, p=.008*, r=.843 VL	Z=-2.521, p=.012*, r=.920 EL	Z=-2.666, p=.008*, r=.904 EL	Z=-2.366, p=.018*, r=.855 VL	Z=-2.803, p=.005*, r=.915 EL
6.3, [1.8 10.7], 21.6%	7.6, [2.2 13.1], 25.1%	6.6, [1.9 11.4], 22.2%	8.1, [2.3 13.9], 25.3%	7.6, [2.2 13.0], 24.0%	8.3, [2.4 14.3], 26.9%	8.2, [2.3 14.0], 22.0%	6.8, [1.9 11.7], 17.4%
Breathings count per lap (tot)							
Z=-2.805, p=.005*, r=.965 EL	Z=-2.803, p=.005*, r=.901 EL	Z=-2.524, p=.012*, r=.907 EL	Z=-2.666, p=.008*, r=.984 EL	Z=-2.521, p=.012*, r=.766 VL	Z=-2.668, p=.008*, r=.909 EL	Z=-2.521, p=.012*, r=.919 EL	Z=-2.803, p=.005*, r=.963 EL
1.0, [0.3 1.7], 9.7%	1.7, [0.5 2.9], 15.1%	1.6, [0.5 2.7], 14.3%	1.8, [0.5 3.0], 15.9%	1.9, [0.5 3.2], 15.5%	2.0, [0.6 3.5], 17.4%	2.3, [0.6 3.9], 17.3%	1.7, [0.5 2.9], 15.1%
Breathings count per lap – right side							
Z=-2.499, p=.012*, r=.971 EL	Z=-2.670, p=.008*, r=.959 EL	Z=-2.521, p=.012*, r=.966 EL	Z=-2.255, p=.024*, r=.938 EL	Z=-2.075, p=.038*, r=.923 EL	Z=-2.552, p=.011*, r=.955 EL	Z=-2.192, p=.028*, r=.524 L	Z=-2.599, p=.009*, r=.947 EL
1.1, [0.3 1.9], 13,8%	2.0, [0.6 3.4], 24.8%	1.6, [0.5 2.8], 21.1%	1.5, [0.4 2.6], 11.2%	1.9, [0.5 3.2], 16.2%	2.2, [0.6 3.8], 21.9%	3.6, [1.0 6.1], 4.6%	1.9, [0.5 3.3], 20.6%
Stroke-breathing ratio							

Z=-1.376, p=.169, r=.938 EL	Z=-2.191, p=.028*, r=.905 EL	Z=-2.100, p=.036*, r=.934 EL	Z=-2.249, p=.015*, r=.970 EL	Z=-2.521, p=.012*, r=.915 EL	Z=-2.666, p=.008*, r=.928 EL	Z=-2.521, p=.012*, r=.925 EL	Z=-2.701, p=.007*, r=.971 EL
0.0, [0.0 -.1], -3.4%	-0.1, [0.0 -.2], -7.2%	-0.2, [-.1 -.4], -5.7%	-0.2, [-.1 -.4], -7.3%	-0.4, [-.1 -.7], -8.3%	-0.2, [-.1 -.4], -8.3%	-0.2, [0.0 -.3], 1.4%	-0.1, [0.0 -.2], -6.8%
Timing Breathing - left side							
Z=-0.560, p=.575, r=.832 VL	Z=-1.820, p=.069, r=.927 EL	Z=-1.040, p=.310, r=.858 VL	Z=-1.521, p=.128, r=.908 EL	Z=-1.014, p=.310, r=.893 VL	Z=-1.521, p=.128, r=.885 VL	Z=-1.183, p=.237, r=.874 VL	Z=-1.400, p=.161, r=.882 VL
-3.4, [-1.0 -5.9], -2.4%	-1.5, [-.4 -2.5], -4.8%	-1.0, [-.3 -1.8], -4.2%	-1.9, [-.5 -3.3], -6.2%	-4.0, [-1.1 -6.9], -3.2%	-5.7, [-1.6 -9.8], -7.1%	-1.7, [-.5 -2.8], -6.9%	-4.3, [-1.2 -7.4], -4.7%

Statistical analysis results: Within condition

Friedman (6,11)

	TI	IdC	Stroke phase – No propulsive	Stroke phase – Propulsive	HR	RPE	Swimming Comfort
Wetsuit	X^2=4.671, p=.587, W=.078	X^2=2.104, p=.910, W=.032	X^2=6.000, p=.423, W=.091	X^2=5.961, p=.428, W=.090	X^2=38.278, p=.000*, W=.709	X^2=9.996, p=.125, W=.151	X^2=2.086, p=.912, W=.032
Swisuit	X^2=1.364, p=.968, W=.021	X^2=7.776, p=.255, W=.118	X^2=7.013, p=.320, W=.106	X^2=9.000, p=.174, W=.136	X^2=52.069, p=.000*, W=.868	X^2=17.687, p=.007*, W=.268	X^2=1.789, p=.938, W=.027

Friedman (6,10)

	Underwater length	Stroke count	SL	SI	Kick count	Kick Timing – 1^	Kick Timing – 2^	Kick Timing – 3^	IdS
Wetsuit	X^2=2.238, p=.897, W=.041	X^2=5.165, p=.523, W=.096	X^2=5.676, p=.460, W=.105	X^2=4.665, p=.587, W=.086	X^2=3.675, p=.721, W=.068	X^2=4.393, p=.624, W=.183	X^2=4.821, p=.567, W=.100	X^2=7.238, p=.299, W=.134	X^2=5.171, p=.522, W=.108
Swisuit	X^2=7.766, p=.256, W=.162	X^2=32.547, p=.000*, W=.678	X^2=28.828, p=.000*, W=.601	X^2=15.215, p=.019*, W=.317	X^2=19.005, p=.004*, W=.396	X^2=11.265, p=.081, W=.268	X^2=5.839, p=.441, W=.122	X^2=1.071, p=.893, W=.022	X^2=4.598, p=.596, W=.096
	Breathing count - total	**Breathing count – right side**	**Breathing count – left side**	**Stroke – Breathing count ratio**	**Breathing Timing - right side**	**Breathing Timing - left side**			
Wetsuit	X^2=7.936, p=.243, W=.147	X^2=4.348, p=.630, W=.072	X^2=2.573, p=.860, W=.043	X^2=8.609, p=.197, W=.159	X^2=12.192, p=.058, W=.226	X^2=4.489, p=.611, W=.094			

Swisuit	X^2=35.739, p=.000*, W=.745	X^2=7.852, p=.249, W=.145	X^2=3.869, p=.694, W=.072	X^2=31.255, p=.000*, W=.651	X^2=3.767, p=.708, W=.070	X^2=8.000, p=.238, W=.190

Wilcoxon (11)
Mean difference, coefficient intervals 95% and delta %
Pearson's r thresholds: .1 small (S), .3 moderate (M), .5 large (L), .7 very large (VL), .9 extremely large (EL)[19]

	1-2	**1-3**	**1-4**	**1-5**	**1-6**	**1-7**
			HR			
Wetsuit	Z=-2.552, p=.011*, r=.973 ^{EL}	Z=-2.673, p=.008*, r=.986 ^{EL}	Z=-2.677, p=.007*, r=.968 ^{EL}	Z=-2.668, p=.008*, r=.967 ^{EL}	Z=-2.668, p=.008*, r=.914 ^{EL}	Z=-2.668, p=.008*, r=.952 ^{EL}
	5.3, [1.7 8.9], 3.8%	6.7, [2.2 11.1], 4.6%	8.2, [2.7 13.7], 5.7%	9.6, [3.1 16.0], 6.6%	10.7, [3.5 17.8], 7.6%	11.4, [3.8 19.1], 8.2%
Swimsuit	Z=-2.805, p=.005*, r=.761 ^{VL}	Z=-2.807, p=.005*, r=.853 ^{VL}	Z=-2.803, p=.005*, r=.823 ^{VL}	Z=-2.805, p=.005*, r=.749 ^{VL}	Z=-2.805, p=.005*, r=.781 ^{VL}	Z=-2.807, p=.005*, r=794 ^{VL}
	12.9, [4.2 21.6], 10.2%	17.1, [5.8 29.6], 13.6%	19.8, [6.5 33.1], 15,2%	20.3, [6.7 33.9], 15.8%	22.5, [7.4 37.6], 17.2%	23.6,[7.7 39.5], 18.0%
			RPE			
Swimsuit	Z=-2.236, p=.025*, r=.935 ^{EL}	Z=-2.268, p=.023*, r=.713 ^{VL}	Z=-2.460, p=.014*, r=.532 ^{L}	Z=-2.441, p=.015*, r=.449 ^{M}	Z=-1.904, p=.057, r=.058 ^{S}	Z=-2.328, p=.020*, r=.152 ^{S}
	0.5, [.1 .8], 20.8%	0.8, [0.3 1.3], 42.2%	1.0, [0.3 1.7], 58.1%	1.4, [0.5 2.4], 76.5%	1.4, [0.4 2.3], 84.5%	1.8, [0.6 3.0], 99.6%

Wilcoxon (10)
Mean difference, coefficient intervals 95% and delta %

Pearson's r thresholds: .1 small (S), .3 moderate (M), .5 large (L), .7 very large (VL), .9 extremely large (EL)[19]

	1-2	1-3	1-4	1-5	1-6	1-7
Strokes count per lap						
Swimsuit	Z=-2.527, p=.012*, r=.990 EL	Z=-2.384, p=.017*, r=.959 EL	Z=-2.527, p=.012*, r=.958 EL	Z=-2.243, p=.025*, r=.952 EL	Z=-2.692, p=.007*, r=.978 EL	Z=-2.670, p=.008*, r=.962 EL
	0.3, [0.1 0.6], 2,5%	0.4, [0.1 0.7], 3.0%	0.5, [0.1 0.9], 3.7%	0.6, [0.2 1.0], 4.0%	0.7, [0.2 1.2], 4.9%	0.8, [0.2 1.3], 5.7%
Stroke lenght						
Swimsuit	Z=-2.142, p=.032*, r=.982 EL	Z=-2.196, p=.028*, r=.947 EL	Z=-2.524, p=.012*, r=.962 EL	Z=-2.103, p=.035*, r=.942 EL	Z=-2.668, p=.008*, r=.973 EL	Z=-2.677, p=.007*, r=.973 EL
	-0.1, [0.0 -.1], -2.2%	-0.1, [0.0 -.1], -2.6	-0.1, [0.0 -.1], -3.5	-0.1, [0.0 -.1], -3.5	-0.1, [0.0 -.2], -4.5	-0.1, [0.0 -.2], -5.1
Stroke index						
Swimsuit	Z=-0.766, p=.443, r=.980 EL	Z=-0.534, p=.594, r=.969 EL	Z=-1.719, p=.086, r=.983 EL	Z=-1.192, p=.233, r=.966 EL	Z=-2.103, p=.035*, r=.987 EL	Z=-2.429, p=.015*, r=.983 EL
	0.0 [0.0 0.0], -0.7%	0.0 [0.0 0.0], -0.6%	0.0 [0.0 -.1], -1.7%	0.0 [0.0 -.1], -1.9%	0.0 [0.0 -.1], -2.4%	0.0 [0.0 -.1], -3.1%
Leg kicks count per lap						
Swimsuit	Z=-1.785, p=.074, r=.941 EL	Z=-1.836, p=.066, r=.984 EL	Z=-1.838, p=.066, r=.961 EL	Z=-1.544, p=.123, r=.977 EL	Z=-1.719, p=.086, r=.958 EL	Z=-1.836, p=.066, r=.911 EL
	0.6, [0.2 1.1], 1.9%	1.2, [0.3 2.1], 3.9%	1.6, [0.5 2.7], 4.6%	1.5, [0.4 2.5], 4.0%	1.8, [0.5 3.0], 5.0%	2.1, [0.6 3.6], 6.0%
Breathing count per lap						

Swimsuit	Z=-2.810, p=.005*, r=.978 EL	Z=-2.668, p=.008*, r=.974 EL	Z=-2.677, p=.007*, r=.968 EL	Z=-2.371, p=.018*, r=.881 VL	Z=-2.670, p=.008*, r=.938 EL	Z=-2.666, p=.008*, r=.924 EL
	0.7, [0.2 1.3], 7.6%	1.0, [0.3 1.8], 10.8%	1.1, [0.3 1.9], 11.5%	1.3, [0.3 1.9], 11.5%	1.5, [0.4 2.5], 15.4%	1.7, [0.5 2.9], 17.1%
Stroke-breathing ratio						
Swimsuit	Z=-2.395, p=.017*, r=.968 EL	Z=-2.666, p=.008*, r=.966 EL	Z=-2.666, p=.008*, r=.970 EL	Z=-2.521, p=.012*, r=.921 EL	Z=-2.666, p=.008*, r=.944 EL	Z=-2.666, p=.008*, r=.943 EL
	-0.1, {0.0 -.1], -4.6	-0.1, [0.0 -.2], -6.8%	-0.1, [0.0 -.2], -6.8%	-0.1, [0.0 -.2], -7.8%	-0.1, [0.0 -.2], -8.6%	-0.1, [0.0 -.2], -9.3%