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ABSTRACT

Purpose: Although wearing a wetsuit while swimming, when permitted, is primarily for safety reasons (*i.e.* to protect against hypothermia), changes in buoyancy, biomechanics and exercise performance have been reported. This narrative review covers the benefits of different wetsuit models on performance in swimming and triathlon. **Methods:** A computer search of online databases was conducted to locate relevant published research until March 2021. After the screening process, 17 studies were selected for analysis. **Results:** Most of the selected studies involved pool swimmers or triathletes completing short- or middle-distances in a pool whilst using a full or a long-sleeveless wetsuit. Swimming with wetsuit elicited significant improvements in performance (maximum 11%), mainly by decreasing drag, energy cost, buoyancy and by affecting technique. Different rates of change in each factor were found according to swimming ability and wetsuit model. Additionally, wearing a wetsuit was often rated as uncomfortable by athletes. **Conclusion:** Although improvement in swimming performance by wearing a wetsuit has been reported in the literature, the amplitude of the improvement remains questionable. The enhancement in swimming performance is attributable merely to improvements in propulsion proficiency and buoyancy, as well as a reduction in drag. The extent to which athletes are familiar with the use of a wetsuit, their swimming ability, and the wetsuit model may play important roles in this improvement. More studies simulating competition and comparing elite versus non elite athletes are needed.

Keywords: Triathletes, pool swimmers, performance, stroke technique, drag

INTRODUCTION

Depending on water temperature, swimming distance and age group[1], both triathletes and open water swimmers can compete with wetsuit. In general, triathletes are more familiar with wetsuits use than open water swimmers. The use of wetsuits has been introduced in triathlon races already in 1989[2], whereas wetsuit use by open water swimmers was only legalized by the International Swimming Federation in 2017[3] (Table 1). Regulations on wetsuit use, as thermal protection[4–6] in low water temperatures, were firstly provided for safety reasons[7–9]. Wetsuits are made of neoprene (*i.e.* synthetic rubber that contains small bubbles of gas) that reduces convective heat loss and provides varying degrees of thermal insulation[10]. Wearing a wetsuit has been shown to maintain core body temperature in water temperatures between 12 and 29.5°C[6,7,11,12].

Table 1

The use of wetsuit can change buoyancy and the biomechanics of swimming, with an associated enhancement of performance (Figure 1). But these effects are differentially related to the characteristics of the athlete, to individual swimming capacity, and to the wetsuit model that is utilised[8,13,14]. Therefore, there is still a need to determine the extent to which these factors influence the effects of wetsuit use in triathlon and open water swimming. This narrative review covers the scientific literature relating to the potential performance (*i.e.* physiological, biomechanical or technical) benefits to triathletes and open water swimmers of wearing a wetsuit, according to the model of wetsuit that is used.

METHODS

Literature search

Computer searches of the PubMed, SPORTDiscus, Web of Science and Scopus online databases were conducted to locate relevant research published until and including March 2021. To locate relevant studies, we searched for the following words in any part of the published papers (*i.e.* title, keywords, abstract): "swimming" AND "wetsuit" OR "wet-suit" OR "wet suit". The initial literature search identified 388 articles.

Screening process and Inclusion criteria

The article screening process was then conducted as follows: i) duplicates were deleted; ii) those with abstracts that were not pertinent were discarded; iii) integral reading of the remaining studies was conducted to exclude those not related to our research topic. All the reference sections of the selected articles were read to find other articles. The inclusion criteria for the studies that are included by this review were: (a) studies published in English; (b) studies with full texts available; (c) studies including only athletes. Table 2 summarizes the methodological approach of the 17 studies that were selected for this review.

Table 2

RESULTS

Figure 1

Drag

The smooth surface of the wetsuit leads to a reduction in friction drag, while the lower specific gravity of the neoprene increases the buoyancy of the swimmer, elicits a decrease in the frontal area and thus a decrease in pressure drag[15]. Moreover, the increase in swimming speed seems to be inversely related to the reduction in both active (estimated by the Measurement Active Drag system)[15] and passive (estimated by the towing method)[16] drags (-16.1% and -22% at 1.1 $m \cdot s^{-1}$ and by -12.1% and -10% at 1.5 $m \cdot s^{-1}$, respectively). However, during a maximal 30m test[17] neither drag coefficient nor active drag force (estimated by the velocity perturbation method) were shown to differ between the wetsuit and non-wetsuit condition. This may have been, as the authors themselves stated, because the study methodology was insufficiently sensitive to detect the flotation effect and the decrease in resistance that is provided by wearing a wetsuit. Although we are aware that the method utilized to measure drag may bring to different conclusions[18], it is beyond the scope of this review to discuss these methods. Drag decrease did not differ between males and females wearing a wetsuit[15].

Propulsion proficiency

Stroke technique

During a fixed time or distance swimming, both stroke length (SL) and stroke rate (SR), and consequently stroke index (SI) (equal to speed•SL), have been shown to be increased[1,7,13,14,16,19,20] or unaffected[1,13,14,21] by wetsuit use, as compared to the control condition. Although no difference in the index of coordination (inter-arm coordination, IdC) was found in subjects wearing a wetsuit at different speeds[13,20], a significative increase (+21.88%) in the IdC was found at 1.36 $m \cdot s^{-1}$ (800m pace)[13]. Moreover, significant differences from the non-wetsuit condition in the stroke phases were found[13,20]. A significant decrease of pull phase percentage (-10.98%) was found at 1.36 $m \cdot s^{-1}$ (800m pace), while an increase of entry and catch phase (+9.81%) was reported at 1.61 $m \cdot s^{-1}$ (100m pace)[13]. During a maximal 1500m, an increase of catch phase percentage (+4.9%) and a decrease of propulsive phase time (-10.71% and -11.67%) and percentage (-6% and -5.17%) were found in the first and last 100m, while a decrease of catch phase time (-3.08%) was found only in the last 100m[20]. In addition, the deepest point of wrist trajectory was found to be deeper in underwater

phase during a 1500m swum with wetsuit as compared to a swimsuit (+12.5 and +9.84% in the first and last 100m, respectively)[20].

However, it has to be pointed out that the majority of the studies thus far have tested subjects over a fixed distance or time[1,7,22–24,9,11,14–17,20,21], when measuring the effects of wearing a wetsuit. consequently be artefactual *i.e.* attributable to the higher speeds that were reached by the subjects Therefore, all the reported changes in technical parameters that were reported by them may whilst wearing a wetsuit as compared to the non-wetsuit condition. It is easier to determine the changes in stroke related parameters that occur with wetsuit use if only the studies that have used pre-set speeds for both the wetsuit and non-wetsuit conditions are considered. At lower intensities (<80%$v\dot{V}O_{2max}$, between 0.67 and 0.94 $m \cdot s^{-1}$), only increases in SR have been reported[19] with wetsuit use. At higher intensities (*i.e.* 50m and 100m pace, corresponding to 1.72 and 1.61 $m \cdot s^{-1}$) increases in SL and consequently SI, but not in SR, were reported[13]. Moreover, no changes were reported at intermediate intensities (*i.e.* 800m pace, 1.36 $m \cdot s^{-1}$) in both SR and SL[13]. The changes in stroke are also supported by the higher deltoids muscle activity that has been found in a simulated swimming test while wearing a wetsuit[25]. Future studies on the current topic are needed to elucidate the stroke variable changes at different pre-set speed intensities.

Leg technique

Swimming with wetsuit showed no effects on leg technique[13], but a lower number of kicks per stroke cycle was found in active kickers subjects (*i.e.* with a 6 beat kick per cycle stroke)[21]. Whilst the change in leg technique has not been confirmed experimentally[13,21], some athletes have self-reported a perceived decrease in leg use whilst swimming with wetsuit over the control condition[11,24]. Remarkably, a decrease in leg use is crucial on overall performance in both triathlon, where athletes have to cycle and run after the swim, and in open-water swimmers, because despite swimming for 10km, the best athletes significantly increase their speed within the last few hundred meters of the race to sprint for a medal[26]. New overall indexes of coordination during swimming, such as the index of synchronization and the index of inter-limb coordination[27] were recently proposed. But, to the best of our knowledge, no study to date has investigated the effects of using a wetsuit on overall coordination by such indices.

Physiological data

Wearing a wetsuit indirectly affects the physiological (performance-related) variables of the athletes. Although $\dot{V}O_{2max}$ itself is unchanged[19], the speed at which both $\dot{V}O_{2max}$ ($v\dot{V}O_{2max}$) (+5-6%)[19,22] and lactate threshold (v_{LT}) (+3.4%)[17] are reached become higher with wetsuit. Indeed, the studies that have tested the effect of wetsuit use at pre-set swimming speeds noted a decrease in Csw[17,19,22] and $\dot{V}O_2$ at submaximal intensities[4,19]. These findings may be attributed to the enhanced buoyancy, especially at lower speeds, and the increase of propelling proficiency (previously reported) as a consequence of wetsuit use[19]. However, no difference in $\dot{V}O_2$ has been reported at higher intensities (≥80% of $v\dot{V}O_{2max}$), probably because this speed might be sufficient to generate a hydrostatic lift force to minimize the effects of the added buoyancy of a wetsuit[19]. Indeed, the lower limbs are already maintained in a horizontal position at a swim speed that is above 1.4 $m \cdot s^{-1}$[16,28]. Blood lactate concentrations ($[La^-]$)[1,7,19] and heart rate (HR)[1,7,14,21] responses to swimming with a wetsuit have been shown not to change, especially during pre-set speed tests.

Perceptual response

The perceptual responses of swimming whilst wearing a wetsuit are also of interest. Rating of perceived exertion (RPE) values have been shown to be unaffected by swimming with a wetsuit, both during pre-set speed[1,4], distance[14,21,22] and time[7] tests. Only at a pre-set speed of 1.31 $m \cdot s^{-1}$, a significant decrease in RPE was reported when wearing a wetsuit, but not at lower speeds[4]. Some studies evaluated the perceptual response or the comfort/discomfort of swimming whilst wearing a wetsuit by questionnaires[9,11,24] or scales[11,14,21]. Although athletes perceived themselves to be

swimming faster with a wetsuit[9,11,24], they also reported that swimming wearing a wetsuit is less comfortable than swimming without one[14,21].

Performance

As results of drag, buoyancy and propelling proficiency changes, swimming with wetsuit, whether over a pre-set distance or for a pre-set time, elicited a significant (-3.23 to -11%) decrease in time to complete the distance and an increase (between +2.34 and +9.2%) in mean swimming speed[1,7,23,24,9,11,14,16,17,20–22] over the control condition. However, the exact extent to which performance is improved by wetsuit use still requires investigation. It is important to highlight that the studies that are covered by this review were published over a large range of years (from 1986 to 2020). The discrepancies in the results of the various studies may, consequently, be partially due to technological improvements in wetsuit design. As reported by Millet and Vleck[29], the benefit of wetsuit use to swim times in ITU World Cup competitions appeared to progressively increase over the period 1997-2008, for both genders. The benefit of wearing a wetsuit in competition may (still) be increasing, probably due to technological improvement in wetsuit design. Also, the extent to which wearing a wetsuit may prove beneficial (*i.e.* propelling proficiency, physiological data and perceptual response) are affected by the individual characteristics of the athlete, including swimming capacity, and to the wetsuit model that is utilised[8,13,14]

Swimming ability

Higher performance improvements were found in triathletes, who are more familiar with wetsuit use, than have been reported for pool swimmers[14,16] (Table 3). Changes in SR[14,16], SL[14], passive drag[16] and Csw[16] were found in triathletes, but not in pool-swimmers, although the same increase in the hydrodynamic lift was reported when wearing a wetsuit[14,16]. The inconsistent results in the literature about the effect of wetsuit on leg technique that were referred to earlier may be explained by the ability to swim with a wetsuit. In fact, pool swimmers, unaccustomed to wearing a wetsuit, showed lower beat kick per stroke cycle [21], while no change in leg coordination was reported in triathletes[13]. In addition, the perceived comfort of swimming wearing a wetsuit was worse in pool-swimmers, compared to triathletes[14].

Although it has been suggested that leaner subjects and/or poorer swimmers (that correspond to the triathletes profile compared to pool swimmers) can benefit greatly from wearing a wetsuit[16], higher performance improvements have been observed in faster triathletes than in slower ones[24]. Unfortunately, it is not clear whether the difference in the reported effects of wetsuit use are more related to the ability of an athlete to swim with a wetsuit or individual characteristics, as swimming skill and body fat level. Indeed, when comparing triathletes and pool swimmers, the subjects differed both in anthropometrical characteristics (*i.e.* weight, body mass, both influencing hydrostatic lift) and familiarization with the wetsuit[14,16]. However, although in all the reported studies triathletes were described as being familiar with wetsuit use, no information about how this familiarization was evaluated has been reported[1,4,19,20,22,6,9,11,13–17]. Indeed, the use of a wetsuit has effects on muscle activation[25] and technique[1,7,13,14,16,19,20,22] during swimming. It is reasonable to hypothesize that an adequate level of familiarization is needed to adapt an athlete to this new motor skill. However, to date, there are no clear indications of when it may be appropriate to consider an athlete to be "familiar" with wetsuit use. We should be cautious in the interpretation of the results of studies that, in the attempt to evaluate the effects of wetsuit use, recruited athletes of different disciplines and/or swimming ability (as triathletes and pool swimmers)[1,7,15,17].

Table 3

Wetsuit models

In order to adapt the wetsuit to individual characteristics, its thickness usually differs between the sections that correspond to different parts of the athlete´s body. As ruled, the thickness of the neoprene cannot exceed 5mm, in any part of the wetsuit[2], in triathlon competitions, while it cannot be thinner than 3mm[3] in open-water swimming competitions. In general, a wetsuit has to cover the torso, back, shoulders and knees. Depending on the wetsuit model[2,3] it may also cover other parts of the body, except face, hands, and feet. In fact, three different wetsuit models are available and utilized: 1) full-sleeve: covering the whole body except for the face, hands and feet; 2) long-sleeveless: covering the whole body except for the face, upper arms and feet and; 3) short-sleeveless: covering the entire body apart from the face, upper arms and calves.

Better performance enhancements were reported when the athletes were wearing a long-sleeveless as compared to a full wetsuit[14,21] (Table 4). As a practical recommendation, it has been suggested that subjects with a weak hydrostatic lift (HL<10N) and/or a low swimming speed (<1.31 $m \cdot s^{-1}$) use a full wetsuit instead of a long-sleeveless model[14,16]. However, athletes reported higher rates of discomfort when they were wearing a full wetsuit than when they wore a long-sleeveless ones[14,21].

Anecdotally, a more important change in swim technique is attributed to the use of a full wetsuit. A full wetsuit could limit the movements during the swim but, at the same time, it may increase the positive effects of buoyancy and passive drag. Indeed, the HL increase was reported to be higher wearing a full wetsuit (+148%) as compared to a long sleeveless (+128%)[14]. Moreover, physiological values such as $\dot{V}O_2$ and V_E decreased more with a full-, as compared to a long- and short-sleeveless wetsuit at different pre-set speeds[4]. While the values of RER, HR and RPE did not change between wetsuit models[4,14,21]. No difference in SR and SL was found between wetsuit models[14,21], while a lower number of kick beats per stroke was shown in active kicker pool swimmers wearing a full wetsuit, as compared to the long-sleeveless wetsuit condition[21]. To our knowledge, no study comparing wetsuit models has investigated other stroke variables (*i.e.* IdC, phases, etc) or overall indexes of coordination. The information about the short-sleeveless wetsuits appears to be scarce. We are unaware of any study evaluating the change in performance time or mean swim speed when a short sleeveless wetsuit is worn. More studies are needed to define the effects on swimming when wearing a short-sleeveless wetsuit and to compare the results with those that are available regarding the other wetsuit models.

Table 4

Environmental test settings

In general, the reported improvement in performance appears to be dependent on several factors. However, the results of each study are not necessarily generalizable. Considering that the reported studies evaluated only limited distances (*i.e.* 25[22], 30[17], 400[1,14,16,22,23], 800[21], 1000[24] or 1500m[11,17,20,23]) and in a warm (>20°C [1,4,22,23,7,11,14–17,20,21]) pool[1,7,21–24,9,11,13–17,20] or flume[1,4,6,19,22] environment, it is unknown whether the reported performance benefits of wearing a wetsuit are related to the distance that athletes will have to swim (*i.e.* from 750m to 3800m in triathlon and from 5 to 25 km in open water races). Indeed, several additional factors, as the different buoyancy, the movement of waves and differences in the effective distance that has been covered[30], have to be taken into account when evaluating swimming within an open-water environment, as compared to the swimming flume and pool. In fact, the athlete's experience in a specific water environment plays a significant role in his/her performance[31]. The speeds (ranging between 0.67 and 1.72 $m \cdot s^{-1}$) which athletes were tested within the various wetsuit studies are comparable to the mean swimming speed of international-level triathletes (1.36-1.27 $m \cdot s^{-1}$ during 1500m[32], with single elite athletes who also reach 1.41 $m \cdot s^{-1}$, or 1.31-1.20 $m \cdot s^{-1}$ during a 3.8Km[33]) and open-water swimmers (>1.30 $m \cdot s^{-1}$ for all distances[26]). It has to be pointed out that all the athletes were tested only over a few meters (~25m)[13,15–17,22] or a short time (5min)[4,19] at the selected race-pace speeds. Moreover, most of the studies focused on triathletes[1,6,9,11,13,19,20,22], pool swimmers[4,21,23,24] or both[7,14–17], and only one study, up to date, included open water swimmers[1].

PRACTICAL APPLICATIONS AND FUTURE PERSPECTIVES

Although the use of a wetsuit has been demonstrated to elicit an important improvement in swimming performance, more studies are needed to understand these reasons and eventually of any possible negative effects. Prior familiarization with wetsuits seems to be an important issue, but it may not be the only key influencing factor of the extent of performance enhancement that is obtained. Since muscle activity has been found to differ between the non-wetsuit and wetsuit-conditions[25], and athletes have generally reported higher levels of discomfort while wearing a wetsuit[14,21], it seems necessary to test the effect of wetsuit use over longer distances. Moreover, a clear definition of what constitutes an athlete who is "familiar" or "unfamiliar" with wetsuit use is lacking in the literature.

The swimming ability of the athlete and the wetsuit model may also play an important role[29]. The literature results[22,24] are not unanimous in indicating whether more or less skilled athletes benefit from wetsuit use, but it has to be pointed out that none of the tested athletes can be considered elite or accustomed to wetsuit use. We might hypothesize that elite athletes will benefit less percentage-wise than what has been reported by this review. However, to our knowledge, no comparative data for elite *vs.* non elite athletes, in wetsuit vs. non-wetsuit conditions, exist. As the introduction of wetsuit use in official open water races is only recent (2017) it is necessary to understand how the swimming technique of open water swimmers, who as a group are unaccustomed to racing with a wetsuit, might change with increasing distance and with increasing levels of fatigue throughout the race. Moreover, the majority of studies thus far have tested wetsuit use at water temperatures that are above the range that the International Triathlon or Swimming Federation consider wetsuit use to be mandatory. Therefore, more studies that simulate true competition settings (in terms of water temperature, open water, and longer distances) are needed, as studies that compare different levels of athletes.

CONCLUSIONS

Swimming wearing a wetsuit has been shown to elicit significant improvements in performance, but the amplitude of this improvement remains questionable. This enhancement in swimming performance is attributable merely to improvements in propulsion proficiency, buoyancy and reduction in drag. However, the extent to which athletes are familiar with the use of a wetsuit, their swimming ability, and the model of wetsuit that is involved may play important roles in this improvement.

Detailed data are provided in the Supplementary online material (*i.e.* summary of the different methodologies in the wetsuit studies, effects of wetsuit use in biomechanical and physiological factors).

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Swim Lenght	Forbidden	Mandatory	Event cancelled
Open Water (FINA)	20°C and higher	18°C and lower	Lower than 16.0°C
1501m and longer (WT)	22°C and higher	15.9°C and lower	Lower than 12.0°C
1501m and longer for age group (WT)	24.6°C and higher	15.9°C and lower	Lower than 12.0°C
Up to 1500m (WT)	20°C and higher	15.9°C and lower	Lower than 12.0°C
Up to 1500m for age group (WT)	22°C and higher	15.9°C and lower	Lower than 12.0°C

Table 1 – Temperature rules for wetsuit use regulated by International Triathlon Union (now World Triathlon; WT)[2] and Fédération Internationale de Natation (FINA)[3].

Author (year)	Environment (location, pool length, temperature)	Evaluation of performance	Subjects	Age (years)	Level	Wetsuit (model, thickness)
Parsons et al. (1986)[9]	Outdoor Pool 66y ~ 60.35m 18°C	30 min.	Tri	20-50+	From Novice to Elite	LS: No details
Toussaint et al. (1989)[15]	Pool - 26°C	10x23m at constant velocity between 1.0 and 1.8 $m \cdot s^{-1}$	Tri+Swi	Tri: 27-35 Swi: 22-29	-	LS: No details
Cordain and Kopriva (1991)[23]	Pool 25y ~ 22.86m 26-28°C	400m 1500m	Swi	19.09±0.9	-	LS: 3mm
Towsend and Murray (1991)[24]	Outdoor Pool 60m Unheated seawater	1000m maximal	Swi	Under 30-over 40	Moderately trained	No details
Lowdon et al. (1992)[11]	Outdoor/Indoor Pool 50/25m 17, 21.3, 29.5 °C	1500m maximal	Tri	28.6 ±6.37	From International to Club	LS: 2mm
Chatard et al. (1995)[16]	Pool 50m 26-26.5°C	Incremental test 13m towed 400m maximal	Tri+Swi	Tri: 18-22 Swi: 18-22	International	F: 5mm trunk, 3mm arms, 3mm legs
Trappe et al. (1995)[7]	Pool 25y ~ 22.86m 20.08, 22.73, 25.59 °C	30 min at triathlon race pace	Tri+Swi	22.8-58.2	-	LS: 3mm trunk, 4mm legs
Trappe et al. (1996)[4]	Flume - 26.5°C	0.90 $m \cdot s^{-1}$ (=28.9% $vV\dot{O}_{2peak}$), 1.05 $m \cdot s^{-1}$ (=36.7% $vV\dot{O}_{2peak}$), 1.18 $m \cdot s^{-1}$ (=45.4% $vV\dot{O}_{2peak}$), 1.31 $m \cdot s^{-1}$ (=64.5% $vV\dot{O}_{2peak}$) (5 min)	Swi	26.3±1.3	Moderately trained	F+LS+SS: 3-4mm
de Lucas et al. (2000)[17]	Pool 25m 25-26°C	Incremental test (3x200m) 30m maximal 1500m maximal	Tri+Swi	Male: 20.7±4.4 Female: 22.0±3.1	Tri: National Swi: Regional	F: 5mm trunk, 3mm arms, 3mm legs

Perrier and Monteil (2001)[14]	Pool 25m 26°C	400m maximal	Tri+Swi	Tri: 23±4 Swi: 23±6	Tri: National Swi: Regional	F: 5mm trunk, 3mm arms, 5mm legs LS: 5mm trunk, 5mm legs
Nicolaou et al. (2001)[21]	Pool 50m 27°C	800m	Swi	19.6±1.7	University team	F: 5mm chest/torso, 2-3mm back, 3mm arms, 3mm legs LS: 5mm chest/torso, 2-3mm back, 3mm legs
Hue et al. (2003)[13]	Pool 25m -	25m v_{50m} 25m v_{100m} 25m v_{800m}	Tri	23.7±3.1	International and National	F: 5mm trunk, 3mm arms, 3mm legs
Perrier and Monteil (2004)[20]	Pool 50m 26°C	1500m at triathlon race pace	Tri	24.8±3.7	International and National	F: 5mm trunk, 1.5mm arms, 5mm legs
Tomikawa et al. (2008)[19]	Flume - -	Incremental test for $\dot{V}O_{2max}$ 60%v$\dot{V}O_{2max}$ (5 min) 80%v$\dot{V}O_{2max}$ (5 min)	Tri	21.7±2.9	International, National and Inter-collegiate	F: 5mm trunk, 2-3mm arms, 2-3mm legs
Tomikawa and Nomura (2009)[22]	Flume (no info) and Pool - 25.7-27.7°C	Incremental test for $\dot{V}O_{2max}$ 2x25m 400m maximal	Tri	20±1	International and National	F: 5mm trunk, 2-3mm arms, 2-3mm legs
Saycell et al. (2018)[6]	Flume - 10, 12, 14, 16°C	20 min at triathlon Olympic distance race pace	Tri	16-61	Competing at ITU-events	F: No details
Gay et al. (2020)[1]	Flume and Pool 25m 27°C	400m maximal	Tri+OWS	Male: 26.3±12.8 Female: 26.69±10.34	-	F: 2.72mm trunk, 2.20mm arms, 2.58mm legs

Table 2 – Summary of wetsuit studies, in order of publication date, with details of the testing environment (*i.e.* location, pool length, water temperature), distance or speed that was tested, type, year and level of subjects that were recruited and thickness of wetsuits that were used. The studies were selected based on: English language full-text and athlete subject recruited. Swi= pool swimmers; Tri= triathletes; OWS= open water swimmers; v$\dot{V}O_{2peak}$= speed at $\dot{V}O_{2peak}$; v$\dot{V}O_{2max}$= speed at $\dot{V}O_{2max}$; $v_{50/100/800m}$= speed at 50/100/800m swimming pace; F=Full model; LS= Long sleeveless model; SS= Short sleeveless model.

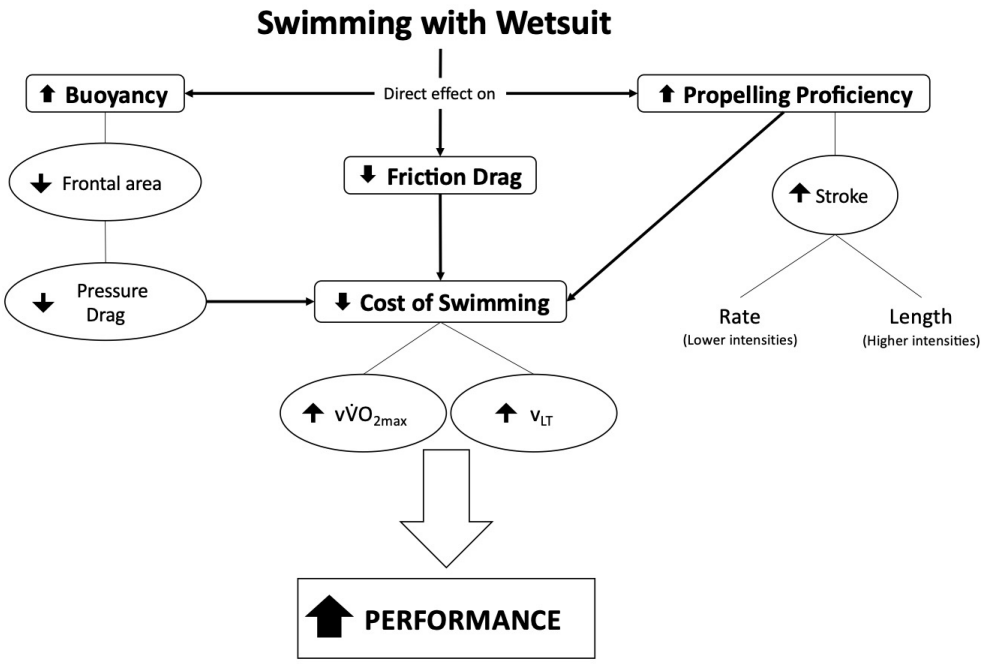

Figure 1 – Effects of wearing a wetsuit on swimming performance.↑ increase; ↓ decrease; vVO_{2max}= speed at VO2max; v_{LT}= speed at lactate threshold.

470x316mm (72 x 72 DPI)

Performance Level		Time	SL	SR	Drag	HL	RPE	HR	$\dot{V}_{O2}$	[La^-]	Csw
Same[14]	**Tri**	--	++	=		+	=	=			
	Swi	-	+	=		+	=	=			
Different[16]	**Tri (slower)**	-		+	-				=	+	-
	Swi (faster)	=		=	=				-	-	=

Table 3 – Summary of the effects of wearing a wetsuit on triathletes and pool swimmers. Performance level indicates the direct comparison between triathletes and pool swimmers with the same or a different time performance over a 400m swim.
SL=stroke length; SR=stroke rate; HL=hydrodynamic lift; RPE=rating of perceived exertion; $\dot{V}_{O2}$=oxygen uptake; [La^-]=blood lactate concentration; Csw=energy cost of swimming; + increase (number of + describes increase entity); - decrease (number of - describes decrease entity); = no change; Tri=triathletes; Swi=pool swimmers

Model	Time 14,21	SL 14,21	SR 14,21	KI 21	HL 14	RPE 4,14,21	HR 4,14,21	$\dot{V}_{O2}$ 4	$\dot{V}_{E}$ 4	RER 4	Comfort 14,21
Full	-	=	=	++	++	=*	=*	---	---	=	--
Long	--	=	=	+	+	=*	=*	--	--	=	-
Short						=*	=*	-	-	=	

Table 4 – Summary of the effects of full, long-sleeveless and short-sleeveless wetsuit use on swim performance related parameters. SL=stroke length; SR=stroke rate; KI= kick inhibition; HL=hydrodynamic lift; RPE=rating of perceived exertion; HR= heart rate; $\dot{V}_{O2}$=oxygen uptake; $\dot{V}_{E}$=minute ventilation; RER=respiratory exchange ratio; Comfort=perceived comfort; / no information; + increase (number of + describes increase entity); - decrease (number of - describes decrease entity); = no change; * RPE and HR were reported lower during constant speed swimming with a wetsuit only at 1.31 $m \cdot s^{-1}$.

	25-30m	400m	800m	1000-1500m	30 min
Time		[–9.5 to –4.96]%[1,14,16,22,23]	–3.57%[21]	[–10 to –3.23]%[11,14,17,20,24]	
Speed	[+4.3 to +4.9]%[17,22]	[+5.98 to +6.9]%[1,22]	+2.34%[21]	+3.42%[17]	[+7 to +9.2]%[7,9]
SL		[+2.2 to +4.5]%[1,14,22]	=[21]	+3.21/+5.66%*[20]	+9.6%[7]
SR		[0 to +4.96]%[1,14,16,22]		+4.85%[20]	
SI		+10.53%[1]		+11.11/+14.13%*[20]	
IdC				=[20]	
Active Drag	=[17,22]				
RPE		=[1]	=[21]		=[4]
HR		=[1,14]	=[21]		=[4]
$\dot{V}O_2$		=[16,22]			=[4]
[La]		[0 to +15]%[1,16,22]			

Supplementary Table 1 – Summary of changes in technical and physiological parameters while wearing a wetsuit at pre-set distance or time. Pre-set variables in light orange and analysed variables in light blue. SL= stroke length; SR= stroke rate; SI= stroke index; IdC= index of coordination; RPE= rating of perceived exertion; $\dot{V}O_2$= oxygen uptake; [La]= blood lactate concentrations; Csw= energy cost of swimming; [ ] range of reported values; + increase; – decrease; = no difference.
*SL and SI were reported during the first and the last 100m of a maximal 1500m

Speed ($m \cdot s^{-1}$)	Intensity	Time Distance	SL	SR	SI	IdC	Active Drag	Passive Drag
0.67/0.7	60% $v\dot{V}O_{2max}$	5min	=[19]	+4.2%[19]				
0.90/0.94	80% $v\dot{V}O_{2max}$	5min	=[19]	+4.4%[19]				
1.1		13/23m					–16.1%[15]	–22%[16]
1.20		13m						–18%[16]
1.25		23m					–14.2%[15]	
1.30		13m						–14%[16]
1.36	v_{800m}	25m	=[13]	=[13]	+5.18%[13]	+21,88%[13]		
1.40		13m						–11%[16]
1.50		13/23m					–12.1%[15]	–10%[16]
1.60		13m						–9%[16]
1.61	v_{100m}	25m	+3.47%[13]	=[13]	+5.21%[13]	=[13]		
1.72	v_{50m}	25m	+3.11%[13]	=[13]	+5.92%[13]	=[13]		

Supplementary Table 2 – Summary of changes in technical parameters while wearing a wetsuit at pre-set speed.
Pre-set variables in light orange and analysed variables in light blue. SL= stroke length; SR= stroke rate; SI= Stroke index; IdC= Index of Coordination; vVO_{2max}= speed at VO_{2max}; $v_{50/100/800m}$= speed at 50/100/800m swimming pace; + increase; – decrease; = no difference.

Speed ($m \cdot s^{-1}$)	Intensity	Time Distance	RPE	HR	RER	VO_2	VE	vVO_{2max} vLT	[La]	Csw
0.67/0.7	60% vVO_{2max}	5min	=[19]			–9.4%[19]			=[19]	–14.4%[19]
0.9	29% vVO_{2peak}	5min	=[4]	=[4]	=[4]	–32.48%[4]	–23.73%[4]			
0.90/0.94	80% vVO_{2max}	5min	=[19]			NV[19]			=[19]	–7.5%[19]
1.05	37% vVO_{2peak}	5min	=[4]	=[4]	=[4]	–36%[4]	–24.07%[4]			
1.1		13m								–20%[16]
1.18	45% vVO_{2peak}	5min	=[4]	=[4]	=[4]	–32.97%[4]	–24.2%[4]			
1.20		13m								–14%[16]
1.30		13m								–7%[16]
1.31	65% vVO_{2peak}	5min	–11.59%[4]	–11.19%[4]	=[4]	–31.18%[4]	–23.48%[4]			
Incremental test						=[19]		[+5.2 +6] vV_{O2max}[19,22] +3.4v_{LT}[17]	=[19]	

Supplementary Table 3 – Summary of changes in physiological parameters whilst wearing a wetsuit at pre-set speed.
Pre-set variables in light orange and analysed variables in light blue. RPE= rating of perceived exertion; RER= respiratory exchange ratio; $\dot{V}O_2$= oxygen uptake; $\dot{V}_E$= minute ventilation; vVO_{2max}= speed at $\dot{V}O_{2max}$; v_{LT}= speed at lactate threshold; [La]= blood lactate concentrations; Csw= Energy cost of swimming; [ ] range of reported values; + increase; – decrease; = no difference.