Effect of Fastskin Suits on Performance, Drag, and Energy Cost of Swimming

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ABSTRACT

CHATARD, J.-C., and B. WILSON. Effect of Fastskin Suits on Performance, Drag, and Energy Cost of Swimming. *Med. Sci. Sports Exerc.*, Vol. 40, No. 6, pp. 1149–1154, 2008. **Purpose:** To investigate the effect of fastskin suits on 25- to 800-m performances, drag, and energy cost of swimming. **Methods:** The performances, stroke rate and distance per stroke, were measured for 14 competitive swimmers in a 25-m pool, when wearing a normal suit (N) and when wearing a full-body suit (FB) or a waist-to-ankle suit (L). Passive drag, oxygen uptake, blood lactate, and the perceived exertion were measured in a flume. **Results:** There was a 3.2% ± 2.4% performance benefit for all subjects over the six distances covered at maximal speed wearing FB and L when compared with N. When wearing L, the gain was significantly lower (1.8% ± 2.5%, $P < 0.01$) than when wearing FB compared with N. The exercise perception was significantly lower when wearing FB than N, whereas there was no statistical difference when wearing L. The distance per stroke was significantly higher when wearing FB and L, whereas the differences in stroke rate were not statistically significant. There was a significant reduction in drag when wearing FB and L of 6.2% ± 7.9% and 4.7% ± 4.4%, respectively ($P < 0.01$), whereas the energy cost of swimming was significantly reduced when wearing FB and L by 4.5% ± 5.4% and 5.5% ± 3.1%, respectively ($P < 0.01$). However, the differences between FB and L were not statistically significant for drag and oxygen uptake. **Conclusion:** FB and L significantly reduced passive drag, and this was associated with a decreased energy cost of submaximal swimming and an increased distance per stroke, at the same stroke rates, and reduced freestyle performance time. **Key Words:** BUOYANCY, DISTANCE PER STROKE, HYDRODYNAMIC, SWIMMING ECONOMY, STROKE RATE

APPLIED SCIENCES

Since the Sydney Olympics games, swimmers have been allowed to wear drag-reducing suits in competition. Two examples of this are the new fastskin suits of Lycra or elastane covering either a part or the whole body. Two different technologies are used, either woven fabric (Arena type) or knitted fabric (Speedo type). It has been indicated that they reduce friction and pressure drags. Mollendorf et al. (10) showed that fastskin suits decreased hydrodynamic resistances by 3% to 10%. This reduction was proportional to the covered surface of the skin. These data were confirmed by Benjanuvatra et al. (1).

The reduction in passive drag is assumed to be beneficial for swimmers, possibly resulting in higher swimming velocity for the same energy cost as well as reducing the energy cost for swimming at a given velocity (14). However, this hypothesis remains to be demonstrated. Indeed, Roberts et al. (12) showed that wearing an earlier version of a full-body suit (FB) at a given velocity did not decrease the oxygen uptake. These authors did not find any change in the hydrodynamic resistances either. These results were confirmed by Toussaint et al. (17) measuring active drag.

Until the present, no study has measured the maximal performance benefit when wearing the new-generation fastskin suit. The drag and the energy uptake have been measured during submaximal swimming, but the early results are controversial.

Thus, the aim of this study was to compare the effects of the two most used fastskin suits: one covering almost the full body, sleeveless, from shoulder to ankle, the other one covering the whole legs (L), from waist to ankle. The effects on 25- to 800-m performances were measured in real swimming situation, that is, in a pool, in 14 competitive swimmers, whereas drag and energy cost of swimming were measured in a flume at submaximal velocities to achieve comparisons at exactly the same velocity in the three conditions. The hypothesis was that fastskin suits should improve performance at competition speed (i.e., 1.5–2.3 $m \cdot s^{-1}$) and decrease drag and energy cost in proportion to the body skin coverage.

METHODS

Subjects. Fourteen competitive swimmers signed informed consent and participated in the studies on a voluntary

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basis: 4 females (19 ± 3 yr, 169 ± 5 cm, 67 ± 6 kg) and 10 males, 11 young swimmers (18 ± 3 yr, 176 ± 8 cm, 72 ± 8 kg) and 3 master swimmers (52 ± 2 yr, 172 ± 6 cm, 78 ± 4 kg). Their best 100-m performances of the year were 62.8 ± 0.4, 57.6 ± 3.5, and 61.3 ± 5.3 s, respectively. They swam on average once or twice a day for a total distance of 20 to 40 $km \cdot wk^{-1}$. Approval for the project was obtained from the University of Otago Committee on Human Research.

Swim performance. Swimmers swam at maximal effort in a 25-m pool, over 2 wk, for six distances of 25, 50, 100, 200, 400, and 800 m freestyle when wearing FB, L, and a normal racing suit (N). The total number of swims was 252, corresponding to 6 distances × 3 swimming conditions × 14 swimmers. This number is relevant because it covers almost all short and long distances performed in competition. The order of all suit and performance conditions were randomly assigned. One day they swam, in the same session and after a standardized warm-up, 25, 50, and 100 m with rest between swims of 5 and 10 min. The swims were performed from a push-off in water rather than a start and were timed from when the feet broke contact with the starting wall to when the hand touched the finishing wall. The push-off start was used to avoid any diving effect on average velocity. After 2 or 4 d of recovery, they swam 200 and 400 m, rest between 15 and 25 min, and after another 2 or 4 d of recovery, they swam 800 m, average rest between 20 and 30 min. Each time, they swam in the three different suit conditions: FG, L, and N.

FB and L were purchased from local suppliers and were provided to swimmers according to their fit. Speedo Fastskin®, Arena Powerskin®, Tyr Aquashift®, ASCI, and Nike Lift® suits were used. They correspond to the first generation of fastskin suits that were used for the Sydney Olympics. The suits were also chosen because they are the most common fastskin used and easy to buy for all studied swimmers. The fastskin suits tested were made of microfiber polyester and Lycra or elastane material. All testing was done with the suits initially dry. It was determined that the swimmer's buoyancy was not modified by wearing FB or L. Buoyancy was evaluated by measuring the hydrostatic lift (HL) with and without wearing FB or L. The HL was the force that enables swimmers to float when they are immersed in forced inspiration. It was measured at the end of a maximal inspiration when the subjects were floating. The subjects were in the fetal position, facing downward. A lead mass (0.1–1 kg) was placed on the swimmer's back, between the shoulder blades. The load needed to keep the subject just under the water was taken as the HL. This method was demonstrated to be very reliable (r = 0.98 for eight swimmers) and easy to apply (3).

Immediately after each trial, subjects were asked to provide a RPE using the Borg (2) scale. Postexercise blood lactate concentration was determined in the blood sample taken at the finger extremity within the first minute after the maximal swims in the pool and within the first minute after the 4-min swims in the flume. Lactate concentrations were measured with a Lactate Pro meter (Arkay factor Inc., Shiga, Japan). All swims were recorded using a video camera. The stroke rate, hand entry to same hand entry, expressed as the number of strokes per minute, was measured 3 times per 25 m with a stopwatch while viewing the video of the complete trial. It was then averaged for the whole swim. The stroke length was calculated by dividing the mean swim velocity by the stroke rate.

Passive drag. The swimming flume of the University of Otago was used for passive drag measurement (6). The flume channel had a test section of length 10 m, width 2.5 m, and depth 1.5 m. The flow in that section could be set at speeds up to 3.0 $m \cdot s^{-1}$ with an accuracy of ± 0.02 $m \cdot s^{-1}$ and steady uniform flow to within 2% (20). Water temperature was 28 ± 0.2°C. The space over the test section of the flume was a temperature-controlled room (15 × 7 m) with a 2.5-m ceiling height. Before taking part in the study, all subjects were familiarized to flume swimming.

The subjects were towed using a rope and a handle, at the water surface, no stroking or kicking or assisted flotation, in a streamlined prone position, face down, with the legs and the feet extended, the head between the extended arms, and the ears pressed between upper arms. Each swimmer was towed with a 1.5-m-long, 12-mm-diameter nylon rope via a pulley to a Celtron STC500 load cell (Celtron Technologies, Santa Clara, CA, USA). The load cell was mounted 10 cm above water level and was directly ahead of the swimmer. Before experimentation, the linearity of the load cell was tested between 0 and 98.1 N ($R^2 \approx 1$). The load cell zero was calibrated at the beginning and at the end of each test session. Subjects were towed at V1 = 1.20 $m \cdot s^{-1}$, V2 = 1.40 $m \cdot s^{-1}$, V3 = 1.60 $m \cdot s^{-1}$, V4 = 1.80 $m \cdot s^{-1}$, and V5 = 2.00 $m \cdot s^{-1}$. Passive drag was measured using the load cell connected to a MacLab analog to digital converter sampling at 200 Hz (AD Instruments, Dunedin, New Zealand). The digital signal was stored on a personal computer. The average drag was calculated over a minimum period of 10 s, three times per tested velocity. During the measurements, the subjects held their breath after a maximal inspiration. The variability coefficient percent was calculated using the SD and the mean of repeated measurements (M) made on the same subject using the equation (SD × 100) / M. It was 2.6% over 150 measurements on one subject. It was not statistically different between V1 and V5 (range between 2.3% and 3.3%).

Energy cost of swimming. Swimmers swam in the flume for 4 min at a velocity (mean ± SD = 1.23 ± 0.10 $m \cdot s^{-1}$) as close as possible to 90% of their best 1500-m performance in open water to avoid as much as possible the use of anaerobic energy and to avoid a blood lactate concentration over 4 mM. Then, they repeated the 4-min swimming test at the same pace wearing FB, L, and N in a randomized order with a 5- to 10-min rest period between trials.

Oxygen uptake ($\dot{V}O_2$, $L \cdot min^{-1}$) was measured from the expired air collected during the 4-min swims. Expired gases were analyzed using a modified Hans Rudolph three-way breathing valve (16) and a Sensormedics Metabolic Cart,

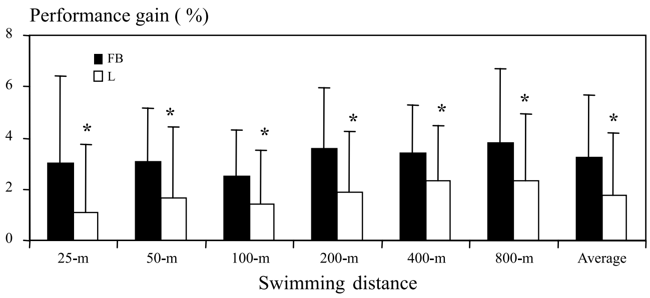

FIGURE 1—Performance gain (%) in the six swimming distances when wearing an FB and an L fastskin suit and when compared with the normal swim condition. Measurements were performed in a 25-m pool. *Significant difference between FB and L conditions.

model 2900Z BxB (Sensormedics Corp, Yorba Linda, CA, USA). Oxygen and carbon dioxide fractions were determined using zirconium and infrared absorption analyzers calibrated with gases of known concentrations. Volumes were measured with a flow meter by thermal conductivity. Oxygen uptake was averaged every 30 s. Within the last 90 s, swimmers were at steady state. Oxygen uptake values changed less than 150 mL during the last 90 s of the trials; the mean value was retained. RPE and lactate concentrations were measured immediately after each trial within the first minute after the 4-min swims in the flume and the maximal swims in the pool. Stroke rate and stroke length for flume swims were calculated using an underwater video camera. The stroke rate was measured over the 4 min, averaging eight 30-s measurements. The distance per stroke was calculated by dividing the mean swim velocity, as determined from the flow rate in the flume, by the stroke rate.

Statistical methods. Means and SDs were calculated for all variables. A repeated-measures ANOVA (Statview program) was used to compare results in suits conditions (i.e., FB, L, and N) and in the five drag velocity conditions. Performances were compared among the groups. ANOVA was used to calculate differences in swimming velocities and performance benefit. A P value of 0.05 was chosen as the level of statistical significance.

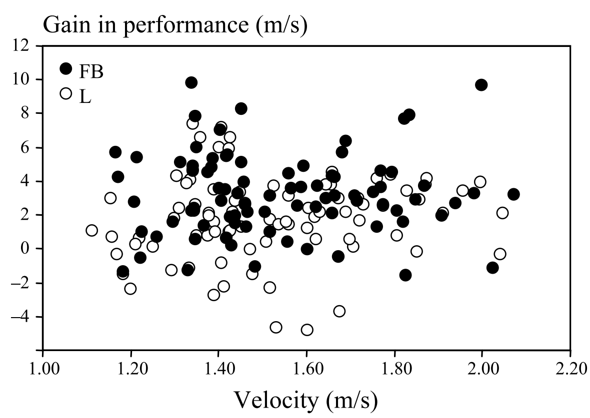

FIGURE 2—Individual performance gain (%) and swimming velocity in the six swimming distances when wearing an FB and an L fastskin suit and when compared with the normal swim condition. Measurements were performed in a 25-m pool.

RESULTS

The average buoyancy when wearing their N suits was 2.8 ± 1.1 kg for the male and 3.2 ± 1.1 kg for the female and was not modified by wearing FB and L.

Performance benefit. On average, there was a 3.2% ± 2.4% performance benefit, i.e., decreased swim time, wearing FB for the six studied distances when compared with the normal swim condition (Fig. 1). When wearing L, the gain was significantly lower (1.8% ± 2.5%, $P < 0.01$) than when wearing FB. Individual data are presented in Figure 2. When comparing the three swimming conditions and the six distances, on 63 occasions, swimmers swam faster when wearing FB than when wearing L. In the L condition, the average performance gain decreased when the average swimming velocity increased from 800 to 25 m ($r = 0.93$, $P < 0.01$; Fig. 3). In the FB condition, the decrease was not statistically significant ($r = 0.42$, $P = 0.16$; Fig. 3). For 21 swims out of 84 swims (6 swims × 14 swimmers), the gain of wearing an L suit was higher than the gain with FB (2.9% ± 2.2% vs 2.3% ± 2.4%; $P < 0.01$). In these 21 swims, the swimming velocities were also higher with L than with FB (1.60 ± 0.26 vs 1.59 ± 0.25 $m{\cdot}s^{-1}$, $P < 0.01$). For the 63 remaining swims, the gain of wearing FB was higher than the gain with L (3.5% ± 2.4% vs 1.4% ± 2.3%; $P < 0.01$), and the swimming velocity was also higher for FB than for L (1.53 ± 0.21 $m{\cdot}s^{-1}$ vs 1.49 ± 0.21 $m{\cdot}s^{-1}$, $P < 0.01$).

For subjects as a whole, over the six distances, the average perception of the exercise was significantly lower when wearing FB than that in normal condition (Table 1), whereas there was no statistical difference when wearing L. Postexercise blood lactate concentrations were not statistically different among conditions, indicating that the FB, the L, and the N swim efforts were performed on average with the same intensity. The distance per stroke was significantly higher when wearing FB and L, whereas the differences in stroke rate were not statistically significant.

Drag benefit. On average, for the whole measurements, there was a significant reduction in drag when wearing FB and L of 6.2% ± 7.9% and 4.7% ± 4.4%, respectively ($P < 0.01$). However, the difference between FB and L was not

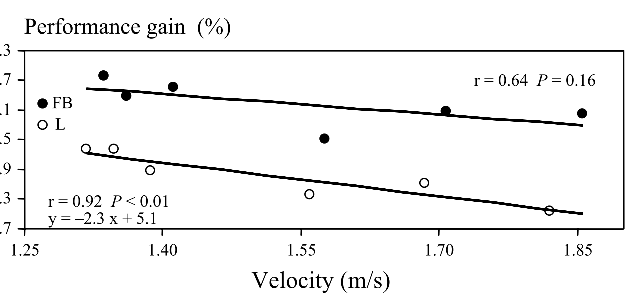

FIGURE 3—Relationship between the mean performance gain (%) in the six swimming distance and the mean swimming velocity when wearing an FB and an L fastskin suit and when compared with the normal swim condition. Measurements were performed in a 25-m pool.

TABLE 1. Mean (SD) values for velocity measured in a 25-m pool, perceived exertion, postexercice blood lactate concentration, stroke rate, and distance per stroke in normal swimming conditions and when wearing an FB suit and an L suit.

	FB	L	N
Velocity ($m \cdot s^{-1}$)	1.54 (0.22)	1.52 (0.22)*	1.49 (0.22)
Perceived exertion (points)	15.8 (1.5)*	16.2 (1.5)	16.2 (1.5)
Blood lactate (mM)	6.6 (3.0)	6.6 (3.2)	6.3 (3.1)
Stroke rate ($cycle \cdot min^{-1}$)	40.8 (7.6)	40.9 (7.5)	40.6 (7.8)
Distance per stroke ($m \cdot cycle^{-1}$)	2.29 (0.30)*	2.26 (0.29)*	2.24 (0.30)

* Significantly different from normal conditions, $P < 0.05$.

TABLE 2. Mean (SD) values for $\dot{V}O_2$, perceived exertion, postexercice blood lactate concentration, stroke rate, and distance per stroke in normal swimming conditions and when wearing an FB suit and an L suit at 90% of the maximal 1500-m swim velocity measured in a flume (1.23 ± 0.10 $m \cdot s^{-1}$).

	FL	L	N
$\dot{V}O_2$ ($L \cdot min^{-1}$)	3.027 (0.583)*	3.005 (0.602)*	3.192 (0.696)
Perceived exertion (points)	13.8 (1.5)*	14.1 (1.5)*	14.7 (1.6)
Blood lactate (mM)	3.0 (1.4)*	2.9 (1.6)*	3.5 (1.8)
Stroke rate ($cycle \cdot min^{-1}$)	32.1 (3.0)	32.3 (2.9)	32.7 (3.0)
Distance per stroke ($m \cdot cycle^{-1}$)	2.31 (0.28)	2.30 (0.29)	2.27 (0.29)

* Significantly different from normal conditions, $P < 0.05$.

statistically significant at any velocity (Fig. 4). With increasing velocity, drag increased monotonically in the three swimming conditions from 34.5 ± 7.1, 35.5 ± 6.9, and 39.9 ± 6.7 N, respectively, in V1 at 1.2 $m \cdot s^{-1}$ to 87.4 ± 15.8, 105.7 ± 17.2, and 109.9 ± 18.0 N, respectively, in V5 at 2.0 $m \cdot s^{-1}$.

Energy cost benefit. The energy cost of swimming was significantly reduced when wearing FB and L (4.5% ± 5. 4% and 5.5% ± 3.1%, respectively; $P < 0.05$) (Table 2). However, the difference between FB and L was not statistically significant. During the submaximal flume swim, the perception of the exercise was significantly lower when wearing FB or L than that in normal condition ($P < 0.05$). The postexercise blood lactate concentrations were also statistically lower ($P < 0.05$), indicating that wearing fastskin, at a given submaximal velocity, reduced the relative exercise intensity. The decrease in stroke rate and the increase in distance per stroke did not reach statistical significance (Table 2, $P = 0.10$ and 0.08). For all these variables, the difference between FB and L was not statistically significant.

DISCUSSION

The main finding of this study was that wearing an FB or a leg suit (L) gave a performance benefit when compared with wearing an N racing suit. This benefit was related to a reduced drag, which resulted in a greater distance per stroke and a reduced oxygen consumption. This study did not find a statistical difference between FB and L when comparing drag and oxygen cost of swimming, although FB was better than L.

Performance benefit. Until the present, only one experiment studied the performance effect of wearing a sleeveless, full qtorso, ankle-length fastskin suit (12). The performance was on average 2% higher while wearing the FB, but this was accompanied by a significant increase of 4% in $\dot{V}O_2$ and 10% in blood lactate concentration. The authors concluded that swimmers chose to swim at a harder intensity when wearing FB and that a psychological advantage of wearing FB could not be discounted. However, in their study, authors found that the ratings of perceived exertion were not significantly different between the two conditions and that the faster velocity was related to a longer stroke length and unchanged stroke rate. In the present study, a longer stroke length and an unchanged stroke rate were also observed. However, the ratings of perception exertion were lower, and the blood lactate concentrations were not different between conditions, contrasting with the data of Robert et al. (12) and discounting, in this study, a possible psychological effect.

This study is the first to compare the performance benefit of wearing two kinds of fastskin suits: a shoulder-to-ankle (FB) and a waist-to-ankle (L) fastskin suit. When wearing the FB, the performance gain was 1.8 times greater than when wearing the L suit (3.8% vs 1.8%) and corresponded to a 0.75-s higher performance benefit than when wearing the L suit for an averaged 64.55 s performance and a 100-m swim. Thus, from the present analysis, swimmers should be clearly advised to wear an FB and not an L suit. However, when analyzing individual data, out the 84 swims, 21 swam faster with an L suit. Out the 14 swimmers, 2 complained about the difficulty of swimming in a too tight suit. Possibly, there is a suit adaptation that has to fit with the individual morphology or technique. These observations all together may explain why all kinds of suits are also used at the top level of swimming.

Drag benefit. The average FB benefit reported for drag (6.2%) with the five velocities and the two kinds of fastskin used was close to the 4% reduction reported on the Web site of Speedo with the full-length fastskin suit and was close to the 5% to 10% found by Benjanuvatra et al. (1). The reduction is supposed to be due, for a part, to the elastane fabric. Indeed, elastane is a hydrophobic fabric that does not trap the microscopic water drops. It provides a smooth surface that creates lower frictional drag and that reduces the amount of skin surface in contact with water (8). Two different technologies are used to fabric fastskin suits from

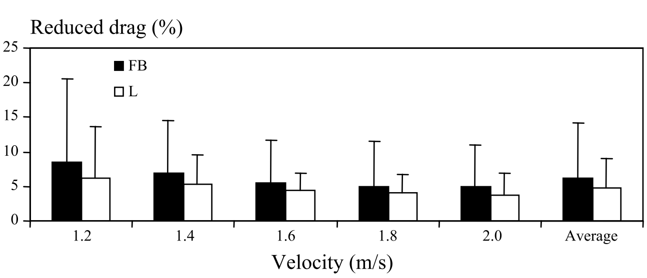

FIGURE 4—Passive drag gain (%) in the five swimming velocities when wearing an FB and an L fastskin suit and when compared with the normal swim condition. Measurements were performed in a flume.

APPLIED SCIENCES

TABLE 3. Comparisons of studies on fastskin suits, shaving, and wet suits.

Study	Suit	Performance	Drag (%)	$\dot{V}O_2$ (%)	Velocity ($m \cdot s^{-1}$)
Benjanuvatra et al. (1)	Shoulder to ankle		4–10		1.6–2.8
Chatard and Wilson (6)	Shoulder to ankle	3.6	6	4.5	1.2–2.00
Present study	Waist to ankle	1.8	4	5.5	1.2–2.00
Mollendorf et al. (10)	Shoulder to ankle		5.2		0.2–2.2
	Shoulder to knee		10.1		0.2–2.2
	Waist to ankle		4.5		0.2–2.2
	Waist to knee		3.1		0.2–2.2
Roberts et al. (12)	Shoulder to ankle	2	1.1–4		2.0–2.2
Starling et al. (14)	Torso swim suit	0		4.1	1.33
Sharp and Costill (13)	Shaving			9	1.14
Cordain and Kopriva (7)	Long wet suit	3			1.43–1.55
Chatard et al. (4)	Long wet suit	6	14–22	7–20	1.10–1.30
Parson and Day (11)	Long wet suit	7			0.85–0.91
Toussaint et al. (15)	Long wet suit	5 (estimated)	12–16		1.10–1.50
Trappe et al. (18)	Long wet suit			16–34	0.90–1.31
Mean	Fastskin suit	2.7	5.3	7.5	0.2–2.8
Mean	Wet suits	5.3	16.5	19.8	0.9–1.50

Gains in performance, decrease of drag, and decrease of $\dot{V}O_2$ are expressed in percentage of measurements made when wearing an N suit for a given range of velocities.

elastane. They correspond to either woven fabric (Arena type) or knitted fabric (Speedo type). Woven fabric should be more advantageous because it can be stretched with no deformation when compared with knitted fabric (8). However, this has never been scientifically demonstrated.

Another part of the drag reduction could be due to the pressure drag reduction of the fastskin suits (9). Indeed, fastskin Speedo are textured with ridges, known as "riblets," used as vortex generators minimizing separated flow over irregular shapes reducing the turbulent flow and drag (17). Unfortunately, in the present study, five different brands of fastskin suit were studied, and it was not possible to statistically separate the effect of fastskin with and without riblets.

Elastane reduces friction drag. However, friction drag should have little importance in passive drag, accounting for less than 5% of the total drag. Pressure drag (mainly related to the body frontal area) represents 40% to 80% of the total drag, whereas wave drag (mainly related to the height via the Froude number, $Fr = V/g \times \text{height}$) represents 15% to 60 % (17,19). Friction drag should be reduced also as active swimming increases pressure and wave-making drags because of arms and legs motion (1,17). Thus, a reduction of friction drag is probably not enough to explain the total drag reduction found in the present study. Fastskin may also have reduced pressure drag. Indeed, when swimming with fastskin, swimmers reported feeling of swimming in a higher position than without fastskin, implying a reduction of the body frontal area. Furthermore, at increasing velocity, the relative role of friction drag is also reduced when compared with pressure and wave drag. This phenomenon could explain why the gain in performance was reduced for the shorter distances and the higher velocities. However, because shaving was demonstrated to reduce greatly the energy cost of swimming, it is also possible that friction drag is generally underestimated (13). Whatever the discussion on friction drag, the 6% reduction in total drag found in the present study and associated with a 3.2% reduction in time performance was not surprising. Indeed, according to Toussaint et al. (17), a 7.5% reduction in drag should correspond theoretically to a 2.5% time reduction, close to the 3.2% found here.

Another important point of this study was the finding of a 30% higher drag reduction for FB when compared with L. This reduction was thus proportional to the covered surface of the skin. The present study fails to find a statistical difference between the two kinds of suits. These data confirmed the study of Mollendorf et al. (10). These authors found a 15% higher drag reduction when comparing shoulder-to-ankle suit with waist-to-ankle suit. However, the drag reduction was not statistically significant either. A lack of a statistically significant difference in drag was also found in the studies of Robert et al. (12) and Toussaint et al. (17). When comparing the same 2 $m \cdot s^{-1}$ drag-towing velocity, drag was to be 4% lower than that in the Robert et al. (12) study, close to the 4% to 5% found in the present study. In measuring active drag with the MAD system, Toussaint et al. (17) did not find any drag difference either. Drag measurements were made with swimmers wearing a pull buoy. Swimmers also had to have in view fixed pads to contact at each stroke to maintain the same distance per stroke. The question arises as to whether or not this method changes swimming technique enough to remove a possible benefit of wearing a fastskin suit. Another question is to what extent passive drag can reflect active drag. Passive drag was demonstrated to be a good evaluator of the swimming aptitude, although more related to the gliding aptitude than to active swimming (3).

Energy cost benefit. The lack of difference between FB and L was also observed when comparing the energy cost of swimming. Even when eliminating the two subjects who were uncomfortable in swimming with the FB, the lack of difference still persisted. It is pointed out that there was no difference with the Borg scale or the blood lactate concentration or the distance per stroke. Unfortunately, in the submaximal condition, no reason was found to explain why no difference was found between the two kinds of suits, contrasting with performance and drag results.

When comparing FB and L together with N, the average decrease in energy cost of swimming in a fastskin suit of 5% was equivalent to the 4% reduction in $\dot{V}O_2$ found by Starling et al. (14) when comparing a torso suit with a standard suit, but half the 9% reduction reported after the removal of all body hair (18). In these studies, blood lactate concentrations were found to be, respectively, 16% and 23% lower versus 17% in the present study. A gain in distance per stroke was also reported contrasting with the lack of difference found in the present study.

Comparison between wet and fastskin suits. Table 3 compares the wet and the fastskin results of different studies found in the literature. Wearing a wet suit gave an average performance benefit twice than that of fastskin, whereas drag and energy cost benefit were 2.6 to 3.1 times higher. The main difference between wet and fastskin suit is the buoyancy. On average, a 2- to 4-mm-thick neoprene suit increases HL by 4 kg (4,5), whereas most of fastskin suits do not change it. Although neoprene and elastane fabric are very different fabric, the neoprene surface is very smooth and also reduces friction drag. However, the question remains of how much the pressure drag is reduced. Clearly, performance benefit follows drag and energy cost benefit. However, performance gain is not proportional to the benefits of drag and energy cost reduction. Once again, the question remains to determine the relationship of passive or active drag or energy cost at a given intensity when compared with maximal performance measured in real swimming conditions.

CONCLUSION

Wearing an FB or a leg suit gave a significant performance benefit when compared with wearing an N racing suit. The perception of the exercise was significantly lower when wearing FB than N, whereas there was no statistical difference when wearing L compared with N. FB and L significantly reduced passive drag, which was associated with a decreased energy cost of submaximal swimming and an increased distance per stroke at the same stroke rates, and reduced freestyle performance time. However, this study did not show a statistical difference between FB and L when comparing drag and oxygen cost of swimming.

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