The fifth stroke: the effect of learning the dolphin-kick technique on swimming speed in 22 novice swimmers.

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Abstract

Can novice swimmers learn to swim faster other than by practicing the 4 official surface strokes (butterfly, backstroke, breaststroke and front crawl)? The present study of 2 matched groups of 10 and 12 young swimmers (aged 9-10) of both genders was designed to answer this question. One group was taught the 4 official strokes in 23 standard swimming lessons. By copying the fastest-moving sea mammal, the other group performed underwater undulations (dolphin kicks) for between a third and a half of each of their 23 swimming lessons. The dolphin-kick group made greater progress in a 25-metre freestyle time trial with an in-water start (T= 3.48 in Student's T test; p<0.01) - emphasizing the potential of this technique in terms of pure speed. Novice swimmers could be benefit from learning this "fifth stroke".

Keywords:

Learning, swimming, dolphin kick, comparative analysis, the fifth stroke

Introduction

How does a human try to move through water as fast as possible? By pushing the water backwards, of course! So which aquatic mammals do that? None, of course!

It is rather surprising that swim teaching has not learnt from the propulsive modes used in nature. Front Crawl, Butterfly, Backstroke and Breaststroke swimmers move more like horses, elephants and rats than seals, killer whales and porpoises, whose propulsive techniques are much more geared to speed (Fish, 1993, Sfakiotakis, Lane, Davies, 1999, Arellano *et al.* 2003, Rohr & Fish, 2004, Loebbecke *et al.* 2009).

In contrast to most other terrestrial mammals, a child does not "naturally" know how to swim. This is undoubtedly due to the evolution of the species. In terrestrial locomotion, holding the body vertically, looking in the direction of movement, pushing with the legs and balancing with the arms are the opposite of what a human would need to do to be at ease in the water (Maglischo, 2003). This is one reason why experiments with "water babies" never cease to amaze us (Pansu, 2009). When immersed in warm water, babies (who are not yet affected by gait stereotypes and are less inclined to "freeze", due to fear of the unknown) are capable of reflex apnea, spontaneous pedalling and short swims. That said, the babies would still need a few more years before they "know how to swim"... In contrast, young dogs, horses, bears and elephants are capable of effective swimming from birth. To be functionally effective, they simply do what comes naturally.

If one accepts that humans cannot swim "naturally", they nevertheless continue to invent new bodily techniques: Breaststroke on the front and on the back, the over-arm stroke (swimming on the side), the Trudgen (named after its inventor in 1873, with alternate arm movements out of the water and a sharp scissor kick), the double over-arm stroke (alternate arm movements out of the water while beating the legs and with head out of the water). In 1922, Johnny Weissmuller broke the mythical one-minute barrier for 100 metres by putting his head in the water: the Front Crawl was born (Weissmuller, 1931). Backstroke came soon afterwards. Later, in the 200 metres Breaststroke final at the Helsinki Olympic Games (1952), all the swimmers brought their arms out of the water, in order to reduce forward resistance; the Butterfly (in which scissor kicks were authorized by the international governing body (FINA) up until 2002) was thus the last of the four official strokes to have been created. However, other strokes were still to come…

On January 23, 2008, the former Olympic medallist David Berkoff was interviewed by www.swimnetwork.com and was asked what had prompted him to start incorporating the dolphin kick in his racing 24 years previously: "*I did a 15 meter kick out off the start just to be a goof and I looked back and saw that I had just smoked* *everyone."* Interestingly, Berkoff (who was an anthropology student at the time) later became a member of the Delphys Foundation, which studied propulsion in dolphins (Van Eersel, 1993). Between 1984 and 1988, the American swimmer extended his dolphin-kick distance from 15 to 35m, and his 100 m backstroke times fell accordingly. *"What were your thoughts when FINA announced the rule change, effectively banning your underwater technique?"* asked David Cromwell, the journalist. The 15m limit on underwater swimming were imposed first on Backstroke (in 1988) and then on Butterfly (1996) and Freestyle (2001). Breaststroke was not concerned by this restriction, since the swimmers had to rapidly return to the surface for other reasons. "*The reason for outlawing my kicking so far was for 'safety' because they didn't want people to get hurt trying to do it. I pointed out that they have no problem with synchronized swimmers staying underwater for over a minute",* explained Berkoff. The men's 100 m records for all four official strokes are under one minute. In 50 m events, many Freestyle and Butterfly swimmers now hold their breath for the whole distance. In long-course, Olympic-size (50 m) pools and short-course (25 m) pools, there are respectively one and three opportunities to breathe before each turn if swimming underwater - about every 30 or 15 seconds, respectively. It is clear that the respiratory argument is not valid. A fifth swimming stroke is in the realm of the possible (Collard, 2009). So why has it been repressed? After all, if a new, higher-performance technique emerges in a sport where only the stopwatch matters, is it not logical to adopt it?

Critics of the "Berkoff blast-off" (the nickname given by the media to Berkoff's long underwater kicks) have rightly pointed out that the American's world record time has been beaten many times since 1988 by backstroke swimmers limited to 15 m of full immersion (including Berkoff himself, at the 1992 Barcelona Olympics). Berkoff does not deny the fact that competitive swimming has progressed, despite the restriction on the distance swum underwater. But in the interview, he cannot help coming back to the potential of the dolphin kick by citing other excellent underwater kickers: Michael Phelps' teammate Ryan Lochte, for example. During a training session in the summer of 2009, Lochte was caught "over the speed limit" by recording 20.8 seconds for 50 m underwater, with a single breath before the turn at 25 m. This constitutes the all-time best performance for any technique over this distance with an in-water start. In an official competition in Charlotte (USA) in May 2009, Michael Phelps finished his victorious 200 m "freestyle" event by replacing traditional crawl-style kicking with underwater kicks.

Short-course (25 m) events: performances recorded by the men's semi-final winners	Year	Mean time (s)	Underwater distance after the dive start (m)**	Underwater distance after the turn (m)**	Distance underwater as a percentage of the total distance	Mean number of arm strokes at the water surface
100 m butterfly	1982	54,1	7	5	22%	40
	2002	51,4	13	11	46%	28,5
	2008*	50,3	14	11	47%	28
	2010	51,3	13	11	46%	28
100 m backstroke	1982	56,3	7	4	19%	60,5
	2002	52,2	15	10	45%	51
	2008*	50,1	15	14	57%	39,5
	2010	50,3	15	13	54%	42
100 m breaststroke	1982	62,2	7	6	25%	45,5
	2002	59,7	11	9	38%	38
	2008*	58	13	10	43%	34
	2010	58,3	13	10	43%	34,5
100 m freestyle	1982	49,4	10	4	22%	68
	2002	48,2	12	6	30%	59
	2008*	45,6	13	10	43%	52
	2010	47,5	13	7	34%	55,5

* with polyurethane swim suit; ** rounded to the nearest whole number.

Table 1: Comparison of several performance indicators in the 100 m semi-finals at the European Short-Course Championships. The less time the swimmers spent at the surface, the faster they went. However, the swimmers spent more time at the surface than underwater. In 1982, the underwater distance was unrestricted; in 2002-2008-2010, it was limited to 15 m after each turn, i.e. 60 m over 100

Table 1 shows the men's 100 m times for the four official strokes and for four international events. At the time of the 1982 European Short-Course Championships, there was no restriction on the distance swum underwater after the start or after a turn. The 1982, 2002 and 2010 European Championships were those in which competitors did not use swimsuits, which significantly improved passive lift and hydrodynamics. For the 2010 season and after having ignored the issue for nearly a decade, the FINA finally decided to apply the rules, which prohibited these combinations. In 2002, 2008 and 2010, the swimmers had to return to the surface before the 15m line in the Backstroke, Freestyle (Front Crawl) and Butterfly. However, 15 m accounts for nearly two-thirds of a 25 m length. The swimmers were therefore potentially able to spend more time underwater than at the surface.

This is hardly a surprise. Competitive swimmers swim faster now than they did twenty years ago. What is more surprising is to see that in the "olden days", the swimmers hurried back to the surface after the turns – despite the fact that nothing obliged them to do so! People were so convinced at the time that underwater swimming was less effective.

Over the last 20 years, the distances swum underwater have more or less doubled. Accordingly, the mean number of arm strokes per length has fallen. The differences between 1982 and 2002 are highly significant ($p<0.01$ in a chi-squared test). There were only slight changes for the simultaneous strokes (breaststroke and butterfly) between 2002 and 2008. In contrast, the backstroke and crawl swimmers gained four metres underwater per 25 m length. In 2008, the semi-finals were marked by new European records (backstroke: a 3-second improvement in 6 years) and new world records (freestyle: just over 45 seconds for 100 m). For each stroke, there is a rank correlation $K = +1$ between the race time and the proportion of the race spent dolphin-kicking.

Although humans are not as well suited to an aquatic milieu as many other terrestrial mammals, they compensate by virtue of their ingeniousness, their quest for performance and efficiency and, above all, their ability to learn. This prompts some key questions. What if the current swimming strokes are just *milestones* in the process of adaptation to an aquatic milieu? And it is possible to go faster by swimming underwater than by using the four official strokes? After having conquered terra firma, some animal species have returned to the water (with the help of appropriate genetic adjustments (Thewissen *and al.* 2007)). This odyssey has been accompanied by a huge shift in propulsive mechanisms: pull-and-push limb movements have given way to whole-body undulations (Fish, 1996, Thewissen, 1998).

Man's learning ability sets him apart from most other animals. Culture is also a unique feature. Although dolphin-kicking is not at all natural, it is hardly more difficult and no more artificial than the backstroke, breaststroke, butterfly or crawl. This is the hypothesis, which we set out to test in the present study.

Method. Learning to dolphin-kick: an experiment.

New approaches to swim teaching.

In about two thirds of cases, a child's first ever movements in water are based on "doggy paddle". The remaining third involve variants of breaststroke-type scissor kicks, which are less efficient due to the resistance caused by bringing the knees forward after the scissor kick (Maillard, Pelayo, 2000). Propulsion is mainly provided by synchronised leg pedalling and semi-propulsive balancing with the arms (Catteau & Garoff, 1968, Pelayo *et al.* 1999). It is understandable that most novice swimmers first adopt a propulsive approach, with alternate leg movements and use of the arms to provide balance; the swimmers' initial reaction is to do in the water as they do on land (Catteau, 2008). This symmetric, trot-like coordination is observed in dogs, elephants and most terrestrial mammals, which occasionally go into the water. Semi-aquatic species (such as opossums) use gallop-type coordination, with asymmetry in the propulsive contributions of the limbs on the same body side. This may well be the sign of on-going adaptation (Alexander, 1988, Berta *et al.* 1989). Undulations - the following adaptive step - are simply the aquatic equivalent of terrestrial leaping (Fish, 1996).

In order to move through water more effectively, a child must first move from a "trot" to a "gallop". This can be achieved by the use of a single, small, very flexible flipper (but not a monofin, which probably inhibits the novice swimmers and their will to "pedal". Pedalling with a flipper on one foot and nothing on the other is not at all easy! Children asked to fetch an object in under the water spontaneously bend their knees less and rely more on this "hypertrophied" limb. Pedalling is replaced by oscillation of the flippered foot. Novices soon realize how effective the flipper can be, so that when use of the latter becomes facultative, they continue to employ it. The initial symmetric, alternate pedalling action turns into an asymmetric, gallop-type movement. The non-flippered foot follows the movement of the palmed foot with a slight lag. The swim trainer can also ask the children to change feet. However, our experiments showed that the children decide very quickly on their preferred foot - just as all riders know whether their horse leads its gallop with the right forelimb or the left forelimb.

After galloping, the next step is undulation. Novice swimmers can be given several scenarios. In "Flipper the Dolphin", the swimmer wears two flippers and (in the vertical position and with the arms crossed on the torso) must keep his/her head out of the water for around ten seconds. On his/her back, front or side, the swimmer can also undulate his/her whole body at the surface by starting the movement at the abdomen and propagating through to the toes. When swimming on the front, use of a tuba removes the need to raise the head and thus enables longer practice sessions. All such exercises should be performed extremely slowly, in order to concentrate on the undulation of separate body segments. The swimmer starts with his/her arms alongside the body. Next, the arms are stretched out in front on either side of the head, in order to offer less resistance to forward motion. Afterwards, the same exercises can be performed underwater but without trying to swim quickly (Quick, 2005). Flippers on each foot can be used - if only because of how much children like them and the potential for combining underwater swimming on the back and on the front in the "Porpoise Game". Flippers also make it possible to perform an obstacle race, with the lane ropes as hurdles.

The experimental protocol.

We wanted to establish whether or not regular dolphin kick practice aids swimming performance. To this end, we took a group of novices with no fear of the water and who were capable of swimming time trials of over distances where speed is more important than endurance. We used a very simple test: a 25-metre freestyle time trial (with "freestyle" in its broadest sense, i.e. no limitations). In order to avoid the technical problem of diving, we used an in-water start. To avoid having to take account of the reaction time, the stopwatch was triggered by the push-off. In addition to the absolute speed over 25 m, we measured the distance kicked underwater (i.e. from the starting wall to the point at which the swimmer's head broke the surface before the first arm stroke). The swimmers were unaware of the goal of the experiment, which was therefore run under single-blind conditions. At no time were the participants told to swim underwater in order to go faster. The only instruction given was "swim as fast as you can to the other end of the pool" (25 m); we wanted to see whether the swimmers chose to swim underwater because it was faster rather than because the trainer had told them to.

Along with an "underwater group", we also studied a control group, which was comparable in terms of swimming ability, gender, age and experience, but were not given any training in the dolphin-kick technique. The total absence of dolphin kicking in the control group was expected to highlight the effect of undulation in the underwater group. The control group followed a standard, 4-stroke learning programme recommended by the French swimming federation and is referred to as the "surface group"[1].

Two groups of around fifteen children (aged 9-10) participated in this longitudinal study. The swimmers trained twice a week, with 23 sessions in all. The first problem was matching the two populations. To this end, we selected comparable subjects from the two groups after a pre-intervention 25 m freestyle time. This method of

[1] We thank Mathilde Lefranc (a sports science student at the University of Caen) for leading the specific dolphin-kick sessions and collecting the data. We also thank Nicolas Cantel and Nicolas Leroux, swimming teachers at the Herouville-Saint-Clair club (the control "surface group") and the Pays de Saint-Lô club (the interventional "underwater group"), respectively.

selection produced two matched sets of 10 and 12 swimmers (Fig. 1) in the underwater and surface groups, respectively. It should be noted that at this age, performance in a 25-metre time trial (about 20-30 seconds) is gender-independent. The start of season also gave us an opportunity to perform a 100 m freestyle test. With a mean pre-invention time ($M_{i\text{-pre-intervention}}$) of 133.05 seconds, the underwater group (n=10) was significantly slower (T= 2.14, $p<0.05$) than the surface group ($M_{s\text{-pre-intervention}}$ = 121.3 seconds) for a distance over which good breathing technique is important (Pelayo *et al.* 1999). We decided to look at whether the two groups improved over 100 m after their respective training programmes - even though this distance was not the study's primary endpoint.

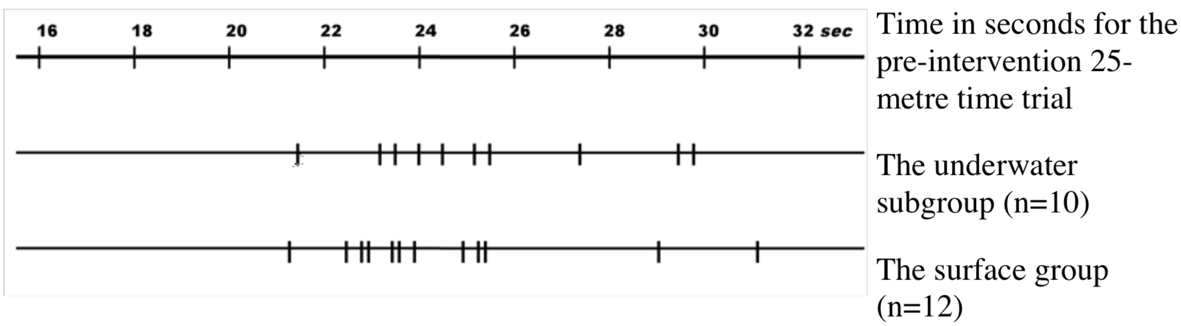

Figure 1: Distribution of the 25 m times in the pre-intervention time trial. The time distribution shows that the two groups were well matched (i.e. comparable in a Student's T-test, *T*= 0.76): one can consider that the two groups were sampled from the same population.

After the time trials, each group underwent a specific training programme. The novice swimmers in the underwater group had to spend between a third and a half of each one-hour session practicing undulation, whereas the novice swimmers in the surface group were taught a standard programme based on crawl, backstroke, breaststroke and butterfly. After 23 sessions, we used a post-intervention time trial (identical to the pre-intervention time trial) to measure the progress produced by the swim training. The swimmers in the underwater group had swum 29% less distance in training than those in the surface group (44,150 m versus 61,800 m), on average. This was due to the fact that the repeated breath-hold exercises in the underwater group (with 16,775 m swum underwater, i.e. 38% of the total distance swum) required longer phases of passive, stationary recovery and active recovery (slow swimming, either on the back or on the front with the head well clear of the water).

Results. Greater progress over 25 m, thanks to the dolphin kick.

None of the participants were absent on the day of the post-intervention time trial. Both groups performed better in the post-intervention time trial than in the pre-intervention time trial (Table 2). Once at the surface, all the participants used a crawl technique to swim to the other end of the pool.

	Pre-intervention time trial: 25 m freestyle	**Activity between the tests**	**Post-intervention time trial: 25 m freestyle**	**Change /M**	**Significant change in a T-test?**
Underwater group (test group)	M_i = 24.89 *sec* (σi = 2.71)	23 sessions One third to one half of the time devoted to the dolphin kick	Mi = 23.95 *sec* (σi = 2.12)	Δi = -0.94 *sec*	YES, $p<0.01$
Surface group (control group)	M_s = 24.42 *sec* (σs = 2.97)	23 sessions of standard, 4-stroke training	Ms = 24.06 *sec* (σs = 2.45)	Δs = -0.36 *sec*	NO

Table 2: Test results. Only the underwater group improved significantly for a 25 m freestyle time trial after 23 swimming lessons.

It is noteworthy that the underwater group's improvement was significantly greater: after having spent a fair proportion of their time practising the dolphin kick, the children were able to swim faster.

As demonstrated by Pierre Parlebas and Eric Dugas (1998), learning corresponds to series of transfers. Here, two types of transfer are involved. Intraspecific transfer corresponds to the effect of learning a new technique or tactical approach on the performance of an activity. For example, the acquisition of a new type of motor coordination (the dolphin kick) has a positive effect on distance swum underwater. This type of transfer was observed in the underwater group (Fig. 2). Without being told to do so, the swimmers swum 2 metres further underwater in the post-intervention time trial than in the pre-intervention time trial (a significant increase according to Student's T-test: T=4.19, $p<0.01$). The control group lost 0.42 m (a non-significant decrease). The standard deviations were notably higher in the underwater group: σi = 2.23 in the pre-intervention time trial (versus 1.23 for the control group) and σs = 1.74 in the post-intervention time trial (versus 2.02 for the control group).

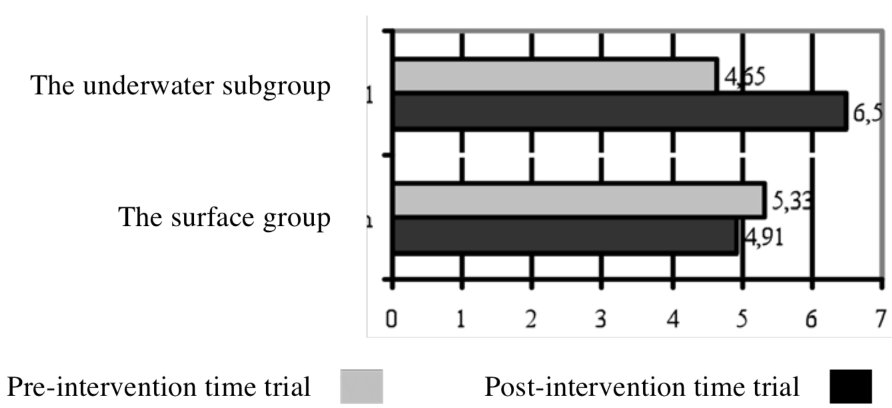

Figure 2: Change in the distance swum underwater at the start of the 25 m freestyle time trial in the 2 groups of swimmers. Without being told to do so, the underwater group swum 2 metres further underwater in the post-intervention time trial than in the pre-intervention time trial (T= 4.19, significant at p<0.01). The surface group did not show a significant progression or regression (T= 1.14).

Interspecific transfer occurs when newly acquired know-how is transferred to another type of motor action. This is potentially the case for motor behaviour in underwater and freestyle swimming over 100 m, where good respiratory skills are essential. The underwater group's performance level over 100 m certainly improved significantly between the pre- and post-intervention time trials ($M_{post\text{-}intervention}$ = 121.3 seconds, i.e. a gain of 14.1 seconds, T= 3.29, p<0.01). However, the control surface group improved to a similar extent ($M_{post\text{-}intervention}$ = 110.9 seconds, i.e. a significant gain of 10.4 seconds; T= 4.49, p<0.001). The 100m results must be interpreted with caution, since the two groups were initially matched for 25 m and not for 100 m. Furthermore, a calculation based on the pre-intervention 100m time trial showed that two samples could not be considered as having been sampled from the same population. Hence, the significant difference between the groups' performance levels in the 100m pre-intervention time trial means that firm conclusions cannot be drawn for this longer distance.

In contrast, a comparison of the data in Table 2 and in Fig. 2 suggests the occurrence of positive, inter-specific transfer. After learning, the underwater group swam further underwater and this new know-how had an influence on their freestyle speed over 25 (three quarters of which were swum at the surface). On the basis of the present results, one can even state that the interspecific transfer in the underwater group (a 0.94 second gain over 25 m and a significant difference between pre- and post-intervention time trials; T= 3.48, p<0.01) was greater than the intraspecific transfer in the surface group (a 0.36 second gain, T= 1.44, non-significant). By focusing on learning the four strokes, the members of the surface group had indeed progressed in terms of their surface performance but less so than the swimmers having focused on underwater swimming during their lessons.

Discussion. A plea for a fifth official stroke.

To practice dolphin-kick precociously allows the swimmer to use it in different technics. It can probably help toward faster swimming. This teaching enables to better understand both the different strokes and the different efficiency principles behind them.

Swimming (like any bodily technique) is an artificially constructed system which deeply fashions the personality of its executors in given ways. In contrast to other animals, humans invent their "effective traditional acts" from scratch (Mauss, 1934, p. 371). "Effective" means "producing the expected effect" and "that alone", aptly commented François Sigaut (2002) with respect to Mauss's phrase. Although bodily techniques are traditional, they can undergo change. Mauss emphasized that when swimming, humans "*have lost the ability to swallow water and spit it out*" (p. 367). "*That [loss] was stupid",* he added*, "but I still end up doing it: I cannot get rid of my [ancestral] technique"*.

Cultural transmission is analogous to genetic transmission in that (while being fundamentally conservative) it tends to undergo mutation. This is the hypothesis defended by the ethnologist Richard Dawkins in *The Selfish Gene* (1989). Just as genes are faithful replicators (and organisms are the genes' "survival capsules"), "memes" are cultural, selective units, i.e. social entities with the ability to survive. Memes take evolution to another level: that of meta-evolution. Sporting, religious and educational institutions exist because (i) they can replicate themselves and (ii) the agents, which use them as vectors, have a greater ability to "survive". If this is not the case, the social rules will evolve. "*Geoffrey Chaucer,* wrote Dawkins, *could not hold a conversation with a modern Englishman…*" He added that "*Language seems to `evolve' by non-genetic means, and at a rate which is orders of magnitude faster than genetic evolution."* (p. 257). However, none of the links in the unbroken, 20-generation chain between Chaucer and contemporary Englishmen were actively seeking to introduce this sort of change. The everyday use of language, learning techniques and the cultural melting pot have given birth to what Geoffrey Chaucer would consider a monstrosity.

It may be that underwater swimming techniques are the new "monstrosities" of swimming. If these monstrosities possess new dynamic, potentials for action, they will eventually replicate better than their predecessors and their contemporaries. As time goes by, they will appear to be self-evident and will become the norm; those who complained about or fought against these new techniques will forget about them until yet another new approach arises (following a "memic mutation") and "takes up the gauntlet". For the time being, swimmers (even novices) who swim outrageously far underwater are perhaps the discrete vectors of swimming's new replicators.

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