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Review Article

Triathlon: swimming for winning

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ABSTRACT

Olbrecht J. Triathlon: swimming for winning. *J. Hum. Sport Exerc.* Vol. 6, No. 2, pp. 233-246, 2011. Swimming performance in triathlon gradually gets of overriding importance in view of the final positioning in a race. It is important to end up swimming in the leading group(s) and to consider the impact of the swim stage on the 2 remaining sports disciplines in order to outbalance the athlete's effort and to be able to keep racing for a good position until the end of the race. Unlike cycling and running where the performance mainly depends on conditioning, the performance in swimming is a subtle combination of conditioning and technical abilities. Even elite swimmers may lose a lot of performance if their outstanding conditioning is not coupled with an excellent swimming technique. Triathletes very often suffer from a lack of technique and despite the wetsuit, which partially outbalances this shortcoming, they spend a lot of energy in the swim stage without reaping any success, energy which is then not on hand anymore for the rest of the race. Therefore, swimming technique should be the groundwork in the multi-year planning AND should be focussed on in each training session during the whole carrier of the triathlete. Monitoring the combination of time/stroke rate/stroke length is thus a must. Periodisation in triathlon is much more complex than in "single" sports. Not only the sports specific weaknesses/strengths of the athlete but also the intrinsic interaction between cycling, running and swimming on training effects and his swim-technical qualities will rule the periodisation. Additionally the level of technique will also set volume, intensity and form of training exercises. Simple to complex tests can help to make the right choice. This makes from triathlon an exciting sport, not only for the athlete but also for the coach and supporting teams. This article will summarise some practical implications on periodisation and on swimming training in triathlon. **Key words:** TECHNIQUE, PERIODISATION, TRAINING MONITORING, SWIMMING

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INTRODUCTION

Over the last years, swimming performance in triathlon gradually gets of overriding importance in view of the final positioning in a race. The shorter the triathlon event, the more triathletes , and men even more than women, need to be in the front at the end of the swim stage in order to start cycling in the leading group and so to make the most of their chances for an optimal final positioning (Vleck, 2008). It has been suggested, on the basis of higher lactate values after swimming than after the cycling and running stage, that the swimming effort affects the physiological reaction and the mechanical performance during the rest of the race (Bentley, 2002; Margaritis, 1996; Millet, 2001; Kreider, 1988a; Farber, 1991; Laursen, 2000). Unfortunately solid evidence for this suggestion was missing in these studies. The results varied due to methodological issues such as control on volume and intensity. Delextrat et al. (2003) provided serious evidence. They demonstrated that a similar cycling performance resulted in a significantly higher oxygen uptake, ventilation, respiration and heart rate when it was preceded by a short (intensive) swim of 750m at competition pace than when it was headed by a warming up on the ergo-cycle. They estimated a 15.5% lower mechanical efficiency. Interesting was that swimming arms alone during the same time period of the 750m swim, revealed a similar negative impact while intensive swim-kicking did not affect the physiological activity or the performance during cycling. Longer swim distances and lower relative intensities in both swimming and cycling seem to lower the degradation of mechanical efficiency and/or power output (Laursen, 2000).

Similar increases of metabolic activity for running after cycling were also observed (Hue, 1998; Kreider, 1988b). Reasons for the negative impact of a swim exercise on the remaining stages are suggested to be due to thermoregulation (increase of body temperature) (Kreider, 1988a; Delextrat, 2003), respiratory muscle fatigue (more intensive work of respiratory muscles during swimming) (Coast, 1993; Holmer, 1972; Mador, 1971; Delextrat, 2003) and the perturbation of muscle functionality (Bohnert, 1998).

Unlike cycling and running where the performance mainly depends on conditioning, the performance in swimming is a subtle combination of conditioning and technical abilities. For moderate to good swimmers the strong and consistent presence of stroke indices in the prediction models for 50 to 500 yard performances suggest that both stroke rate and length are among the primary determinants of swimming performance. Depending on the distance of the swimming performance these 2 variables may place differential demands on the reliance of particular energy system (Nagle, 2004). This can be extrapolated to elite swimmers. Their physiological capacities and power are very similar but the winners of big events are those who can keep stroke length and rate until the end of the race (row data Haljand, 2010). Building technical swim abilities should best be started at a young age and requires a lot of time. Since most triathletes do not complete this major training process, they do miss technical background which is a handicap not only for their competition performance but also for their trainability.

A wetsuit can partially outbalance the lack of swim technique. Tomikawa (2009) found the improvement of swimming performance in triathletes wearing a wetsuit not to be associated with physiological factors but with propulsion efficiency related to a gain in buoyancy and to drag reduction. No difference in VO_{2max} during a continuous progressive swimming test was found between swimming with a swimsuit (SS: 58.7 ± 3.6 $ml \cdot min^{-1} \cdot kg^{-1}$) and a wetsuit (WS: 59.8 ± 5.0 $ml \cdot min^{-1} \cdot kg^{-1}$) while blood lactate after a 400 m all out was 1.2 $mmol \cdot l^{-1}$ higher with WS as compared to SS (SS: 8.0 ± 1.0 $mmol \cdot l^{-1}$, WS 9.2 ± 1.3 $mmol \cdot l^{-1}$). The incremental blood lactate with WS can only explain a ca 5 s faster time for the 400m all-out (Mader, 1980), but the triathletes swam about 20 s faster as compared to SS. The sprint performance was also improved when wearing a WS without enhancing the maximal power output (POmax) nor the active drag (AD), both measured by the "perturbation method" (De Lucas, 2000). However for the same speed AD was decreased wearing WS. It was also found that triathletes with less skills in swimming achieved greater benefits from wearing a wetsuit than skilled swimmers.Another way to quantify the swim-technical performance is by the IdC, the Index of Coordination (Chollet, 2000). This index consists in the time that separates the beginning of the propulsive phase of one arm and the end of the propulsive phase of the other arm. It is expressed as a percentage of the mean duration of the stroke. When there is a lag time between the propulsive phases of the two arms, the stroke coordination is called "catch-up" (IdC < 0). When the propulsive phase of one arm starts when the other arm finishes it, the coordination is called "in opposition" (IdC = 0). When the propulsive phases of the two arms overlap, the coordination is called "superposition" (IdC > 0). The IdC for swimmers always increases with speed (Chollet 2003). For 19 French, Italian and Swiss elite triathletes, the IdC at submaximal swim speed (ca 84 and 94% of Vmax = 10 m sprint between 12.5 and 22.5 m) was slightly but not significantly higher than for elite swimmers, but the latest swam significantly faster. At Vmax, the triathletes, however, showed a significant reduction of IdC while elite swimmers continued to increase it (Figure 1). The lower swimming speed of triathletes was associated with a shorter stroke length (e.g. 1.70 versus 2.10 m at Vmax). Stroke rates were not statistically different (55.1 versus 51.2 $str \cdot min^{-1}$ at Vmax). With increasing swimming speed, triathletes increased the propulsive time less than the swimmers (3.4 ± 4.4% versus 8.5 ± 5.8; p<0.01) but also increased the recovery phase while swimmers decreased it (0.8 ± 2.2% versus -1.6 ± 2.8%; p<0.01). Moreover the triathletes reduced both the pull and propulsive phase while swimmers increased them (Millet, 2002).

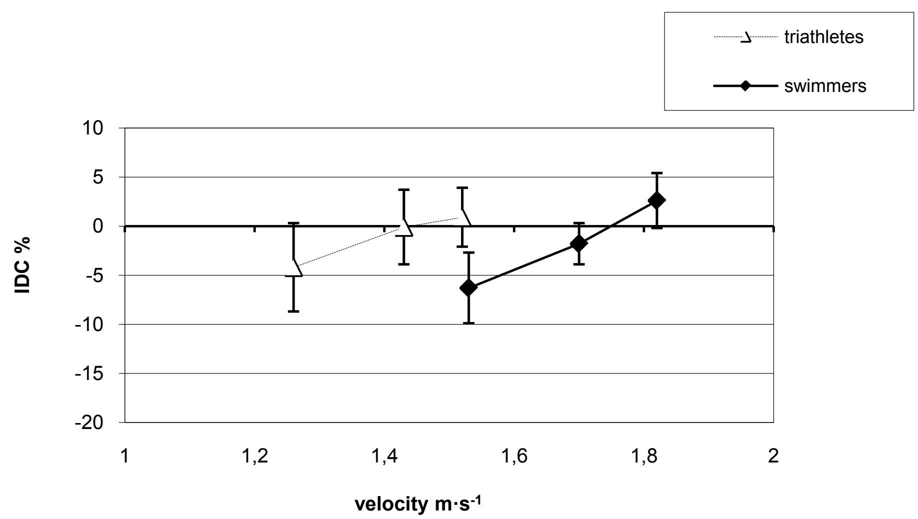

Figure 1. *Index of Coordination (IdC) according to swimming speed (triathletes and swimmers; Chollet, 2003).*

For running and cycling, modern-day triathletes are able to obtain similar VO_{2max} as single sport athletes despite dividing their training time among 3 disciplines (Suriano, 2010). VO_{2max} is a useful tool to assess the aerobic fitness, but other measures that are less expensive and requiring less experienced manpower such as peak aerobic power tests can be used. The determination of the peak aerobic power may be an appropriate measure for assessing triathletes since it is predictive for the overall triathlon performance and even stronger a predictor than VO_{2max} (Millet, 2003; Millet, 2004).

While VO_{2max} and peak aerobic power determine the maximal limit of the aerobic performance, submaximal tests seem to provide a better prediction of the endurance performance. Individuals with similar VO_{2max} can vary greatly in endurance power depending on the percentage of their VO_{2max} that they can sustain during a long lasting event (Costill, 1973; Coyle, 1988; Costill, 1972).

Periodisation in triathlon is much more complex than in "single" sports. Not only the sports specific weaknesses/strengths of the athlete but also the intrinsic interaction between cycling, running and swimming on training effects and his swim-technical qualities will rule the periodisation. Swimming requires more "specialist training" to achieve a good aerobic performance (Roels, 2003). Only little cross-training benefit from running and cycling is to be expected on swimming conditioning (Millet, 2002).

In this article we will work out these considerations in order to find a way to improve the efficiency of swim training for triathletes.

PLANNING AND PERIODISATION

Swimming fast depends on: (1) the ability to produce a high mechanical power output enabling the generation of high propulsive forces, (2) the ability to reduce drag, while (3) keeping low the power losses to pushed-away water (Toussaint 2005). These 3 criteria will contribute to a high propulsive swim efficiency.

This is a very difficult task since no fixed standard swimming pattern is applicable for all swimmers. Each swimmer individually has to look with his/her coach for the best way of swimming in order to meet the 3 requirements above. This is what coaches define as the never-ending-story: continuously looking for the best individual technique of a swimmer. Consequently a lot of time needs to be spent on technique right from the start of the triathlete's development. Thus, the multi-year plan of the triathlete in spe, will contain many sessions of drills and technique in the swimming pool... but with low volumes. Kyle published a practical overview of 10 rules to take into consideration on how to build a good swim technique for triathletes (Kyle, 2010).

Volume per training will only increase when the quality of the stroke pattern is sufficiently available and stable. A high mileage of swimming before mastering a good technique will not only prevent the swimmer from a continuous conditioning improvement over years but also increase the risk of shoulder injuries. Recording the stroke length is an easy and reliable measure to pragmatically control the stroke quality (technique). A stroke length near to 2 m at submaximal speed should be a benchmark for every triathlete before considerably increasing mileage and/or intensity of the swim training. Once the triathlete has made himself familiar with this stroke length, he will be instructed during specific technique sets to increase stroke rate but at the same time to maintain stroke length. The next step will be to keep the stroke length during the whole training session, even at higher speeds (e.g. sprints). Thus, the stroke length should first be improved and only thereafter the stroke rate. This will not only increase swimming velocity but will also provide the triathlete with the skill to adapt his stroke pattern to different swimming circumstances (wetsuit, competing in open water).

A further increase in stroke length at submaximal speed and the transfer of it into the whole training and/or into higher intensities will even later on remain important technical objectives for swim training. Very often this requires more swim-kicking support but, as shown in literature (Delextrat, 2003) and corroborated by the observation in "single" swimming, there seems to be more room for work by the legs in swimming without negatively affecting cycling or running.

In the base period of a macro cycle in triathlon, it is common to focus on only one discipline per week. This enables to emphasise the endurance training of that specific sport. If technique development is the main objective of the swimming program, it imperatively should be focussed on in the first week of the meso cycle and the fractions of the swim set should be kept short. If, however, it is the conditional development of swimming that is the main objective, it can be planned during any week of the working phase of the meso cycle for well technically skilled athletes, while for less skilled athletes it should still be scheduled in the first week of the meso cycle. Moreover longer fractions and/or higher volumes can here be used. For well technically skilled triathletes swimming in the second part of the meso cycle can support recovery.

Anticipating the negative interaction of swimming on the physiology and mechanics of running and cycling, the training intensity in running and possibly in cycling will be reduced in the base period of the macro cycle if the main focus of the week is on swimming or if swimming precedes a running or cycling training on the same day. During the competition preparation phase, the intensity of swimming and cycling and/or running may be high when it is endurance power that is focussed.

In the second part of the base period of a macro cycle it is very useful to stress the metabolic power in swimming. At this stage the athletes are still not too fatigued to perform correctly this kind of swim exercise and will benefit the most from this type of conditioning training. It will also allow to switch the swim training objective from "improving" to "maintaining conditioning" once volume/intensity of running and cycling become more important. This way of periodisation can bypass the rather negative interaction of swimming on the training effect of running and cycling and vice versa. In the last meso cycle of the base period, just before entering the competition preparation phase, the aerobic capacity has to be re-boosted in swimming whereas volume/intensity in running and cycling is minimised. This allows the triathlete to recover from voluminous work in running and cycling and, at the same time, to refresh the aerobic capacity in swimming just before starting aerobic power in 2 or 3 sports at the same time (grouped).

TRAINING EXERCISES AND TRAINING MONITORING

Exercise volume, intensity, interval (fraction) and rest are the only training elements a coach can modulate to provoke adaptations in the conditional and technical performance components. However, the adaptations to training stimuli vary from one component to the other and from one athlete to the other regarding response time and amplitude. Consequently the success of training depends on a well balanced content and timing of training stimuli, tuned to the athlete's specific needs and training response capabilities. A systematic program is therefore required not only to detect the needs of each athlete individually but also to monitor the real execution of the training exercises as well as the development of the main components. This will enable to reveal for each athlete the optimal training content and timing.

A scientific training support will not only consist in transferring research findings into training praxis, but also in applying a scientific methodology to reveal for each athlete the priorities as well as the most effective training structures (periodisation) to meet the training objectives.

There is no need for huge research to disclose that swimming performance in triathlon (even in the sprint event) is endurance driven. However, while mainly the aerobic, and to a small extend the anaerobic power, determine the swimming performance in competition, it is the aerobic and anaerobic capacity that determine which training objective and what intensity or form of training exercise are most appropriate to improve competition performance (Olbrecht, 2000).

According to Mader's model (Mader, 1984, 2003), firstly published in 1984, which mathematically describes the regulation of ATP-rephosphorylation in human skeletal muscle during and after exercise, the activation of the aerobic and lactic anaerobic (glycolysis, pH adjusted) metabolism can be calculated based on their maximal metabolic activity rate. We therefore label both maximal activity rates as respectively the aerobic or oxidative (VO_{2max}) and anaerobic or glycolitic (VLa_{max}) capacity while the involved part of both capacities during exercise respectively represents the aerobic and anaerobic power (Olbrecht, 2000).

This model also shows evidence that a given lactate after a submaximal swim may result from many combinations of maximal oxidative and glycolitic rates. An estimation of the endurance performance based on a submaximal performance at a fix/individual lactate threshold or on a lactate-speed relation will reflect rather power than capacity. It can therefore be a very good prediction reference for competition performance (Costill, 1973; Coyle, 1988; Costill, 1972) but a very misleading marker to deduce training intensities or to trace changes in the aerobic and anaerobic capacities (Olbrecht, 2010) due to training. Literature also shows that a number of factors beside variations in aerobic fitness (Costill, 1973), such as fibre size (Bishop, 2000) and percentage of type I muscle fibres (Coyle, 1991) may be responsible for the differences in lactate thresholds between subjects.

If different capacities can result in the same lactate-speed relation, it is quite obvious that, despite the same lactate in training, athletes may undergo different training load depending on their capacities and, consequently, show different training response (Olbrecht, 2010). This explains the coaches' remarks that some triathletes are even unable to complete a swim set at 2 $mmol \cdot l^{-1}$.

Therefore it will be the aerobic and anaerobic capacities and not the lactate-speed relation as such, that will be predominantly involved to set the training objectives and the range of affordable training intensity and load (Olbrecht, 2000). Any performance, however, will depend on the extent to which the athlete appeals to both capacities. The extent to use both, the aerobic and anaerobic capacities, is considered as respectively the aerobic and anaerobic power (always part of the capacities).

It is possible to define both capacities using a simulation model based on blood lactate measured after submaximal exercises (Olbrecht, 1992, 2010). In swimming however, the outcome risks a technique bias. Less swim technically skilled triathletes (unfortunately there are many) will rather end up with underestimated capacities for swimming. Therefore this test procedure is rather used in running and cycling. For swimming we are often forced, due to the swim technical weakness of the triathlete, to use a classic lactate test and to outbalance the lactate-speed relation with an estimation of the aerobic and anaerobic capacities based on training observations (Capacities' level chart, Table 1).

Table 1. *Capacities' Level Chart: chart of criteria to estimate the swimmers' level (high and low) of aerobic and anaerobic capacity (Olbrecht, 2000, p 135).*

	Low **Anaerobic**	**Capacity** *High*	
	No better competition performances after intense or extensive and voluminous work	Performs very good even when not tapered	
High	No real feeling of exhaustion after races and impression of being able to swim faster	Several best times during successive days of competitions	*High*
	Swimmer performs best in competition shortly (4-6 days) after voluminous training	Very fast recovery from training and competition	
A	Swimmer does not like short interval workouts or fartlek exercises	Reaches high lactates after short and long events	**A**
E	No clear improvement of competition results if taper lasts longer than 1 week	Is fast on short and long events	**E**
R	No high lactates after maximal short as well as long distance events		**R**
O	Competition best times on long distances are relatively better than on short events		**O**
B	Best times in long and short course pools are nearly the same		**B**
I			**I**
C		Reaches high lactates after short and rather low values after long events	**C**
	Develops overuse-injuries easily	Swimmer "dies" in last part of event	
	No high lactates after maximal short events, but high values possible after long events	Only 1 (or 2) good events in competitions of more than 1 day	
Low	Bad results on long events and moderate performances in short competitions	Bad results on long events but very good in short races	*Low*
	Slow recovery from training and competition	Best performances after long rest	
	Low **Anaerobic**	**Capacity** *High*	

However, it would be too simplistic to assume that the coach's job only consists in improving both the aerobic and anaerobic capacities. Both capacities need to be developed in the right proportion to each other in order to achieve the best performance in competition. A long distance athlete with a too high anaerobic capacity for example, will not be able to activate his aerobic capacity to its highest level. He will show a poor aerobic power and therefore perform poorly in long distance competitions despite a good aerobic capacity. So, according to the outcome of both capacities, the main conditioning objective for a triathlete might be to increase further both capacities, to increase the aerobic capacity while suppressing the anaerobic capacity, or to improve aerobic power while maintaining the aerobic capacity. According to the main training objective and the level of capacities volume, intensity, fraction and rest will then be modulated (Table 2).

Table 2. *Classification of training exercises according to their main training effect (improving the aerobic or anaerobic capacity, or the aerobic or anaerobic power) and with the description of volume, intensity, Interval (fraction) and rest for each class.*

Classification of Training Exercises

	Aerobic Capacity (=AEC)		Anaerobic Capacity (=ANC)		Aerobic Power (=AEP)		Anaerobic Power (=ANP)	
Type of swimmer	S	L	S	L	(S) M	L	S	M (L)
Volume*	Long	Very High	Moderate	High	110-90% Comp. distance		110-90% Comp. distance	
Interval	Short (100-300m)	Long (300-800m)	Very Short (25-75m)		Short progresses to Long (50-100m) => (100-300m)		Short (25-100m)	
Intensity	Extensive alternated with intensive and short intervals in the same or next training session		Intensive nearly all-out		Race Pace or somewhat faster		All-out	
Rest	Short (40-20s)	(20-10s)	Long >= 2x swim time (35s-1:30min)		Short progress. to very short (45-30s) => (10-20s)		Short (10-20s)	
	8x100m R=20s 1,3 fast	6x500m R=20s 1,2 (50fast/50slow)	6x(3x50m) R=1:20min P/3	4x3x50m All Out R=60s	5x75m R=45s to 3x125m R=15s	12x100m R=30s to 5x300m R=20s	Brokens / Comp.Test 4x50m R=10s 25+50+25+50m R=5-10s	

**depends on conditioning level* — *Sprint and technique are not in this classification*

Adapted: J. Olbrecht:Schwimmen, Lernen und Optimieren 1994

Beside lactate; other measures like the maximal performance in an extended exercise (e.g. Cooper test,...), the heart rate or gas-exchange (ergo-spirometry) are certainly useful to support the optimisation of the training efficiency. However they all have their advantages and disadvantages. It is therefore very important to use these measures appropriately in accordance with the reliability of information they provide (Table 3).

Table 3. *Main outcome with advantages and disadvantages of different ways to assess the aerobic endurance and to monitor endurance training.*

	Maximal extended exercise test	**Lactate test**	**Heart rate test**	**Ergo-spirometry**
OUTCOME	Metabolic power as predictor for maximal performances Rough estimation of training intensity and competition performance	Detailed information on metabolic profile/activity to determine: objectives & periodisation intensity & exercise form	Holistic impact on the athlete regarding: training load recovery environment	Aerobic and anaerobic activity
PRO	Sport specific Non invasive Very easy to carry out Reflects indirectly the limit of metabolic power	Sport specific Easy to carry out Motivation independent (if submaximal)	Sport specific Very easy to record Complementary to metabolic data	Most direct measure of aerobic endurance Reflects metabolic power
CON	Motivation influences results No detailed assessment of aerobic and anaerobic activity	Very complex and difficult interpretation	If used to identify types/intensity of training exercises	Rarely sport specific Experienced people needed Accuracy of devices VO_2max vs VO_2peak confusion

The maximal extended exercise test is the easiest to carry out; no special expertise is required to do such a test and it is almost sport specific. It needs however a high commitment of the athlete to go all-out in order to obtain reliable results. It is the most indirect way to assess the aerobic endurance but you will not be able to estimate the exact contribution of the aerobic and anaerobic metabolism. To assess training intensity (% of maximal performance), the performance in a maximal extended exercise test is more reliable than heart rate.

The information provided by the heart rate gives an excellent indication of the general fitness of an athlete and a good reflection on how the body is assimilating training in combination with the environment. The estimation of training intensity for athletes based on heart rate, however, lacks any scientific validity. Many have tried to relate heart rates to the metabolic characteristics of a specific effort or exercise but in fact, despite a same heart rate, different forms of exercises will induce different metabolic responses. Heart rate increases when an athlete works harder/longer, but the metabolic significance of a given effort cannot be deduced by means of heart rate frequencies. Pragmatically, variations in heart rate in training may still be beneficial in terms of variations in training intensity (primary requirement for supercompensation), but a coach will never be able to define correctly the type of metabolic activity nor its extend that goes together with a given heart rate. Within this metabolic perspective, training intensities expressed as a percentage of the maximal performance of an extended test are therefore more reliable.

The use of heart rate or its derivates reflecting the activity of the autonomic nervous system (ANS), however, may be useful to design and control individual training (Garet, 2004). Swim performance was found to correlate individually with nocturnal ANS activity as reflected by Heart Rate Variability indices. Indeed the decrease in ANS activity during intensive training correlated with the loss of performance and the rebound in ANS activity during tapering with the gain in performance. Interestingly, the speed of the rebound during the tapering period varied from swimmer to swimmer. Other derivates of ANS activity such as EPOC, nocturnal recovery index... may also enable to assess training load (Kaikkonen, 2010) and recovery from training load (Kaikkonen, 2007) and so to adjust training programs according to the athletes' training-response capacity. Over the last years, power output and heart rate recovery (the change in heart rate in the 60 s of recovery immediately after exercise) for 3 submaximal efforts carried out at a pre-fixed percentage of the maximal heart rate (LSCT; Lambert Submaximal Cycle Test (Lamberts, 2010)) have been investigated to assess recovery during some weeks of training. In triathlon this procedure may be of interest for cycling or running but for swimming the first question that has to be solved is whether the outcome is biased by the variation in swim efficiency or not.

Ergo-spirometry is the most direct way to measure oxygen uptake and aerobic endurance power. But, strong expertise is needed to perform the test correctly and even despite good practice and equipment, the accuracy of oxygen uptake measurements remains lower than of biochemical analyses. Based on an accuracy of ±2% for lactate (Gutmann, 1974; D'Auria, 2000) and of ±0.04% for the oxygen uptake measurements, the accuracy-dependent difference in performance is 5 times higher for oxygen uptake measures than for lactate. In swimming and running practice, this means that respectively an error in performance of 1s/100m and 5s/km is related to the accuracy of the measurement and that, using spirometry, it is not possible to make a distinction in performance between athletes if, e.g. their running performance does not differ with more than 5s/km. With lactate measures on the contrary, it is possible to acknowledge differences in running performance of 1s/km between athletes.

A measured oxygen uptake always refers to that part of the aerobic capacity the athlete appeals to. Therefore this measure reflects the aerobic power and not the aerobic capacity. We therefore like to label the highest measured oxygen uptake as VO_{2peak} and not as VO_{2max}. The benefit of the information for training optimisation provided by ergo-spirometry does rarely compensate its restricted sports specificity and time consuming procedure. Therefore, it is preferable to do this type of test only once a year or even once every 2 years.

According to the importance of a good swim technique for a good swimming performance, stroke mechanism should constantly be focussed on in training, whether it is regeneration or intensive work that is on the program. Less swim skilled triathletes can use "golf-swimming" to support their motor-learning for an efficient swim stroke (Kyle, 2010); the swimmer who can make the smallest sum of swim time added to the number of strokes wins. Counting the strokes remains for all levels of swimmers/triathletes a useful tool. It helps the athlete concentrate on technique during the whole swim set and, combined with the task to reduce stroke rate for the required intensity (swim time), it continuously forces him to look for a longer stroke length. Once the improvement of stroke length is acquired, it is important to return to normal stroke rates and to limit the gliding or recovery phase. This will avoid an increase of active drag due to the intracycle-speed variation that is linked with a longer gliding/recovery phase.

Apnea training can also improve stroke length and seems to positively affect swimming coordination. After 3 months of breath-hold (apnea) training, swimming performance (clean velocity and 50m time) was not improved, but stroke rate decreased while stroke length and IdC increased, showing a greater propulsive continuity of both arms (Lemaître, 2009). The evaluation of the coordination (IdC) is more difficult since a good analysis requires video analysis which is not always feasible in training.

In contrast to elite swimmers in competition, triathletes do not have an own lane to compete in, nor super lane-ropes to break waves eliminating as much as possible any external disturbance of the stroke mechanism. On the other hand, drafting in triathlon swimming is allowed in competition and it has been observed that the use of drafting tactics shows a 3.2% performance improvement, for a 400 m distance, with a 3.4% stroke frequency reduction and an increase in distance per stroke of 6.2% (Chatard, 1998; Chollet, 2000). A triathlete must as well be able to maximally exploit the advantage of drafting and of wearing a wetsuit to cope with all external disturbances during the swim stage. Therefore he will have to train flexibility in stroke length and rate appropriately. Group-starts in one lane or even swimming closely side by side during training sets are certainly triathlon specific exercises that will help to provide the athletes with a stroke rate/length flexibility to cope well with competition situations.

CONCLUSION

Swimming performance in triathlon gradually gets of overriding importance in view of the final positioning in a race and although it requires a subtle combination of conditioning and technique, triathletes almost exclusively focuss on conditioning and too often neglect technique. Planning and periodisation (technique before volume) as well as training execution (active concentration on technique) should always provide an answer to a demand of swim-skill building or automation. The monitoring of training intensity and of the adaptations should therefore not only be focussed on metabolic measures but should always be linked with a swim technical evaluation. Stroke length seems to be the most important variable that can easily be used to control and improve the technical performance of a swimming triathlete.

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