The use of blood lactate by elite swimmers

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Introduction

Winning and losing, two words charged with very contrastive but actually so close feelings and emotions. Indeed, in swimming only a few hundredths of a second may decide upon success or defeat, upon fame or failure. In former years talent used to be a guarantee for success but since the sporting performances have reached very high levels it is not sufficient anymore. Today, competition sports is still a matter of talent of course, but even more of training and especially of "training efficiency". There is no room for any waste of time or effort. Every minute of training must be of benefit and help the athlete performing at his best on the big event.

From the conditioning perspective, maximizing training efficiency requires:

1. the determination of the right training objectives (=*"what"* do I have to train to become faster in the races I am preparing for)
2. the choice of the right type of workouts with carefully chosen intensities, volumes, rest breaks and intervals according to the training objective (=*"how"* do I have to build up the appropriate exercises)
3. the correct sequence of the various exercises within the different training periods (= *"when"* do I have to plan these exercises)

Since not every swimmer reacts and adapts in the same way to the same training program:

1. the training objectives, the type of workouts per training objective as well as the sequence of the various exercises will have to be individualised according to the actual physiological profile of the swimmer (weak and strong characteristics)
2. an ongoing individual evaluation of the evolution of the conditioning level (based on training, competition and testing results) according to the completed training program is absolutely required

A lot of reliable "tests" will therefore be included in the training program to assess the changes in the athlete's conditioning profile. As a result of this evaluation and for an optimal training process and a continuous improvement of the "training efficiency" the objectives, the types of exercises and their sequence may need some adjustments over time. Within this scopelactate tests are a very important "link" to maximize the training efficiency.

For many years, however, the interpretation and use of lactate in training was based on empirical assumptions lacking any scientific evidence about the real significance of blood lactate readings. As a consequence, coaches were faced with contradictory results, unrealistic interpretations and with inconsistent implementations in training. Success in competition was then rather a lucky strike than the result of a systematic, purposive and scientific founded procedure.

This article will present some new findings on basic lactate research which account for the misleading lactate interpretations and provide some new ways of working with lactate in order to minimize these misinterpretations and so increase the training efficiency.

Interpretation of Lactate Readings

It is known that the test protocol, the time of testing, the warming up may and even nutrition influence the lactate readings (Olbrecht 1989, Ivy 1981) but, these factors can easily be controlled in order not to disturb the interpretation of the blood lactate values. Much more difficult is to get the right insight in the origin of a blood lactate concentration. Over the last 5 years basic research corroborated that lactate is a very complex parameter mainly affected by the athlete's oxygen uptake, lactate production and elimination (Mader 1984). Depending on the characteristics of the effort, these 3 metabolic subprocesses will be activated differently. The same lactate concentrations measured after different types of efforts are thus the result of a different participation of the 3 metabolic processes and will consequently enclose a different message.

For a reliable interpretation of the lactate tests, we therefore tried to trace back lactate readings to the valuation of the determining "drivers" and found that the origin of most lactate values could be described as a function of the maximal oxygen uptake (=VO_2max) and the maximal glycolitic rate (=Vlamax) which are the most important physiological parameters to describe the conditioning profile in swimming and to define:

a) **the aerobic capacity:** VO_2max and
b) **the anaerobic capacity:** VLamax, also called the maximal lactate production rate

The aerobic and anaerobic capacities play a decisive part not only in determining the swimmer's maximal competition performance but also in the way the aerobic and anaerobic systems contribute in the metabolic energy supply during exercise and consequently in the way training exercises trigger the metabolic system to generate adaptations.

With the advanced evaluation model for the interpretation of lactate tests (Olbrecht 2000) by means of a simulation program that was patterned after Prof. Mader's theoretical model of metabolism (Mader 1984), we can now determine both the aerobic and anaerobic capacities of technically well skilled competitive swimmers and runners. Unlike the classical method of interpretation, where the assessment of the conditioning is directly based on the relation between lactate and speed, i.e. the position of the lactate curve in the lactate-speed diagram, this new evaluation technique uses the lactate values to determine the 2 decisive factors - the aerobic (VO_2max) and anaerobic capacities (VLamax) - that generate the lactate-speed relation.

A comparative study on calculated and measured oxygen uptake using this software for runners showed a very close likeness (fig.1).

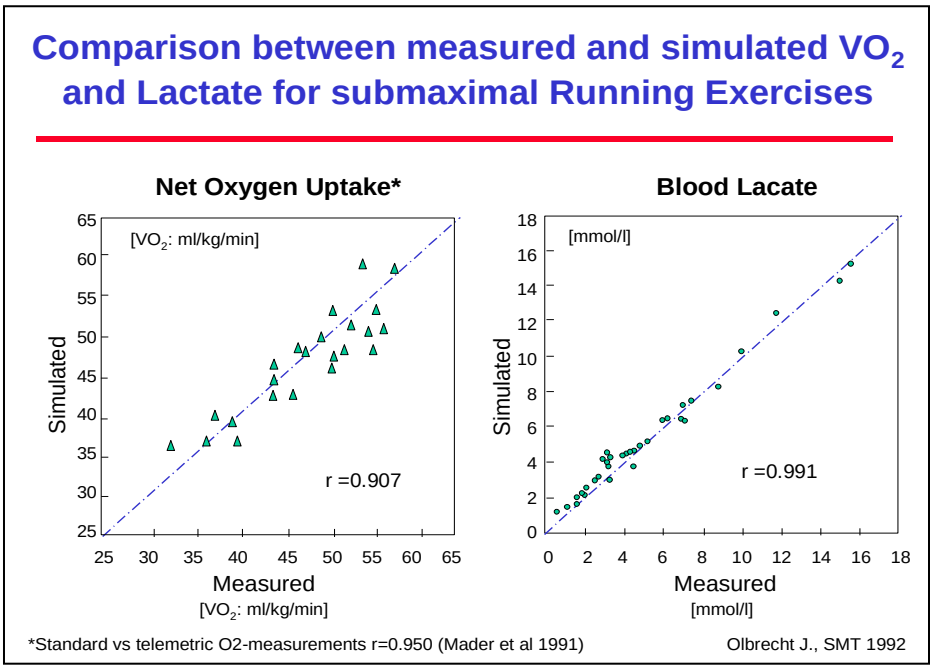


Fig. 1 Measured and simulated oxygen uptake (VO_2, left) and lactate (right) at different submaximal running efforts have proven to be quite similar (Olbrecht 1992).

The importance of unraveling the lactate readings into both capacities becomes obvious when comparing these results with those of a "classic" representation and interpretation of lactate test results.

Example 1: The shift of the lactate curve to the right is due to a decrease of the anaerobic capacity and not to an improvement of the aerobic capacity (fig. 2)

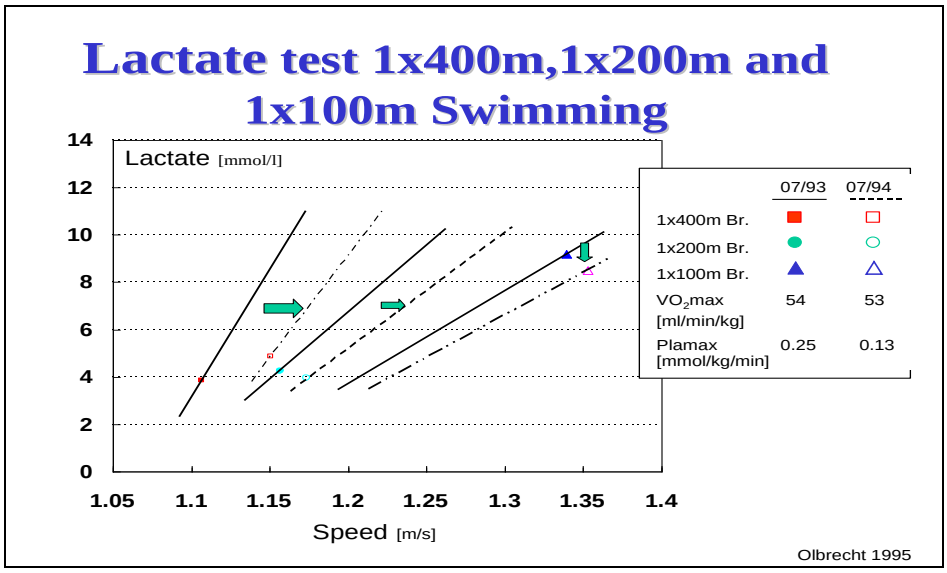


Fig. 2 The shift of the lactate curve to the right is due to a decrease of the anaerobic capacity and not to an improvement of the aerobic capacity.

Example 2: A shift of the lactate curve to the right despite a decrease of the aerobic capacity (fig. 3)

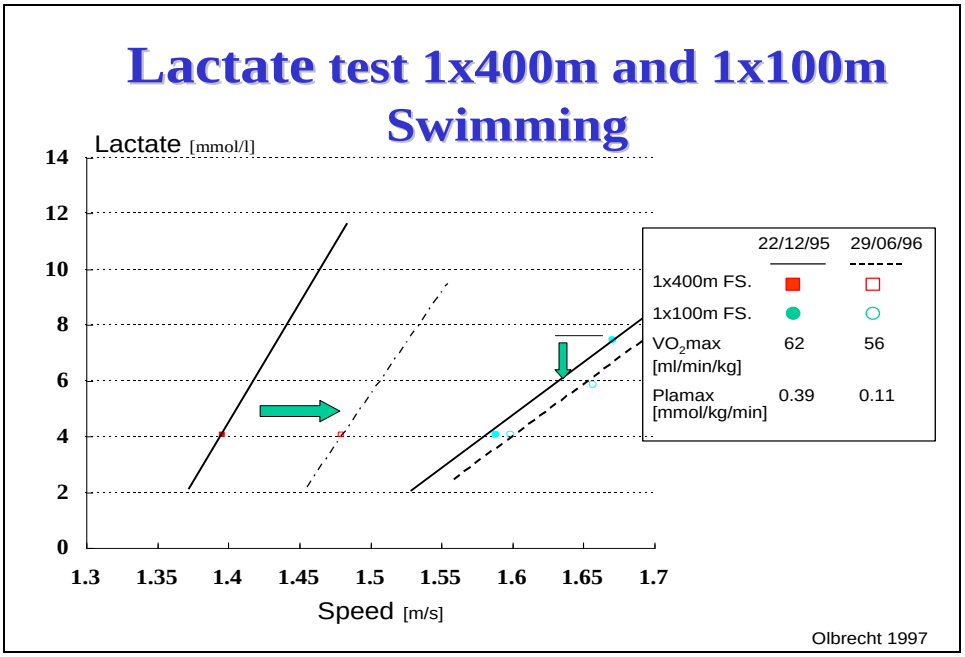
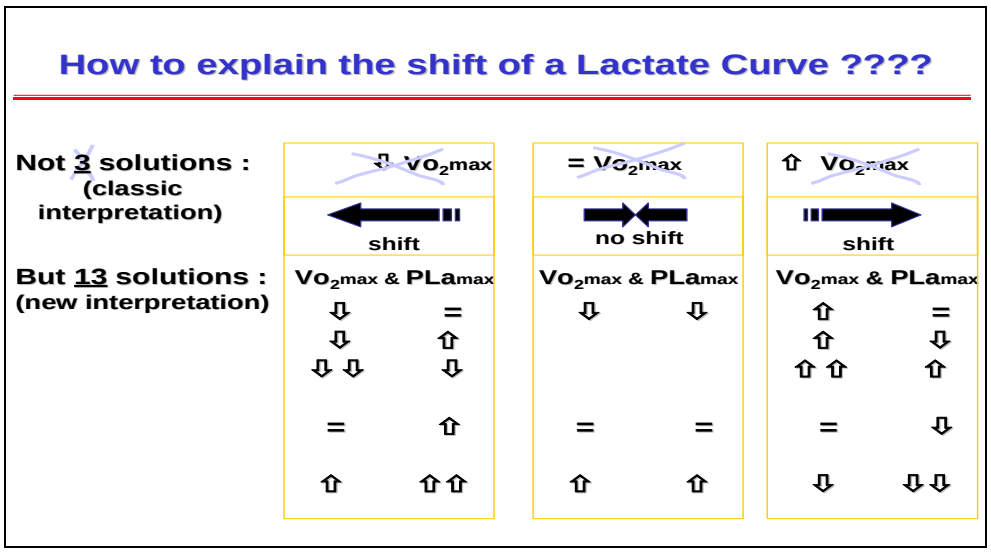


Fig. 3 A shift of the lactate curve to the right despite a decrease of the aerobic capacity.

The following table summarizes all the possibilities leading to a left, right or no shift of the lactate curve (tab. 1).



Tab. 1 All the possibilities leading to a left, right or no shift of the lactate curve.

However, it would be too simplistic to assume that the coach's job only consists in improving both the swimmer's aerobic and anaerobic capacities. Indeed, the aerobic and anaerobic capacities need

to be developed in the right proportion to each other in order to achieve the best performance in competition.

Examples:

- A distance swimmer with a too high anaerobic capacity cannot activate his aerobic (endurance) capacity to its highest level. He will therefore register poor performances in long distance competitions despite a good aerobic capacity.

- A sprinter with a too low aerobic capacity will acidify more quickly and will therefore not be able to activate his anaerobic capacity to its highest level. He will therefore register poor performances in short distance competitions despite an excellent anaerobic capacity.

Adjusting both the aerobic and anaerobic capacities to each other (fine-tuning) is one of the main objectives of the pre-competition phase.

The aerobic and anaerobic capacities are to be considered as the maximal performance limit. In competition, however, only a percentage of these capacities will be involved. This percentage can, to a certain extent, be improved by specific training exercises. The ability to use the capacities is labeled as "power", so consequently both remaining aspects of the conditioning profile are:

c) **the aerobic power:** which represents the percentage of the aerobic capacity that can be used in competition

d) **the anaerobic power:** which represents the percentage of the anaerobic capacity that can be used in competition

Since the aerobic/anaerobic threshold (lactate threshold or $MaxLa_{ss}$, fixed or individual, aerobic or anaerobic threshold) is not a primary and basic component of the conditioning profile, but rather a derivation of the contribution of the aerobic and anaerobic capacities during a long lasting submaximal effort, we chose to abandon its assessment for defining the conditioning profile and/or its use for providing training advice. This does of course not mean that the aerobic/anaerobic threshold is meaningless. Indeed, there is a very close relation between the aerobic/anaerobic threshold and the performance in a competition event lasting longer than 2 minutes. But, in order to trace back the key components of the swimmer's conditioning profile, the assessment of the aerobic and anaerobic capacities proved to be a much more significant and appropriate procedure (for more information see internet www. lactate.com).

This approach is thus quite different from most other lactate testing procedures which, to describe the conditioning profile of the swimmer, use:

- a single speed such as the speed at the lactate or some other anaerobic threshold (e.g. the speed at 4 mmol/l) or,
- the slope and/or shape of the lactate curve

Indeed, this new model discloses the metabolic process behind blood lactate values and provides insight into the often paradoxical evaluations of the conditioning profile as well as the often contradictory and discrepant training advice emanating from the classical method of interpretation.

A comparison between the classic interpretation of the shift of the lactate curve (move to the right and the left is explained by respectively an increase and decrease of VO_2max) and the interpretation based on the use of the simulation program for determining the aerobic and anaerobic capacities, reveals that only about 60% of the classic interpretations of the aerobic capacity fits with the more sophisticated valuation (fig. 4). This means that out of 5 lactate tests classically evaluated, on average 2 interpretations are incorrect and will inevitably lead to a wrong training advice

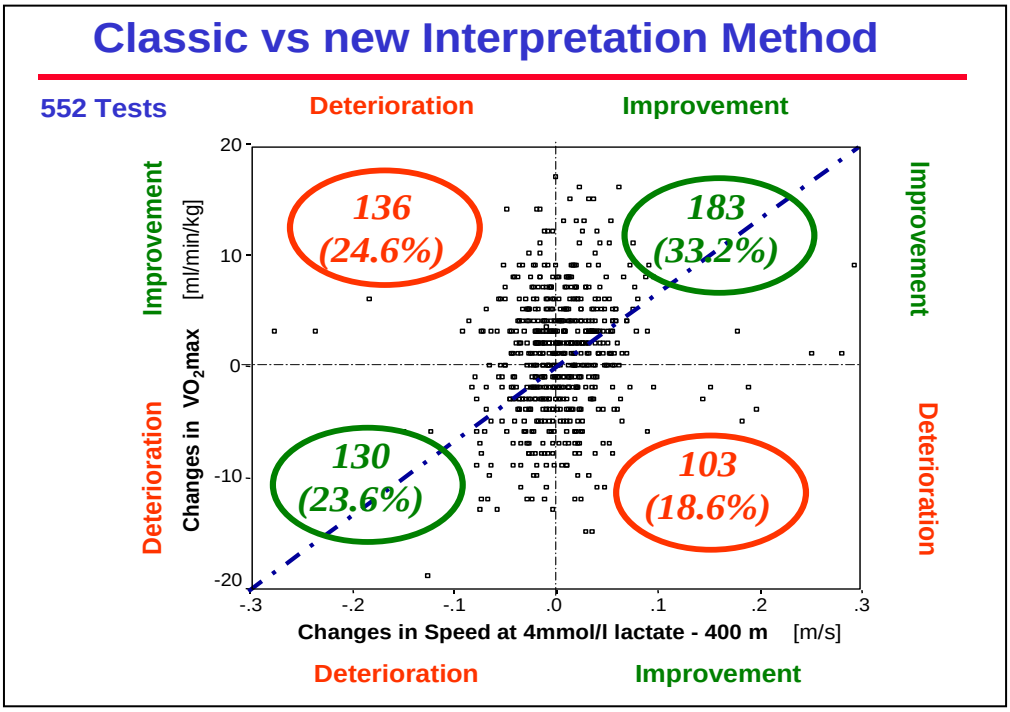


Fig. 4 About 60% of the classic interpretations of the aerobic capacity (VO_2max) fits in with the more sophisticated valuation.

To match the training exercises with the previously determined objectives we set up criteria to classify the different training exercises in 4 groups (details see Olbrecht 2000). Each group has a main training effect on one of the 4 aspects of the conditioning profile:

1. **Aerobic capacity exercises**
2. **Anaerobic capacity exercises**
3. **Aerobic power exercises**
4. **Anaerobic power exercises**

The criteria are based on 4 elements which can vary according to the biological adaptations the coach wants the exercise to induce. These features are:

1. the distance (or volume) of the exercise
2. the intensity (= speed)
3. the rest
4. the interval (length of the exercise = fraction)

Thanks to this classification system the coach can “give full vent” to his fantasy and ingenuity to create whatever training workout; as long as the exercise meets the requirements of the class corresponding to the planned training objective, he can be assured that the exercise induces the

training effect he wished for. Designing an exercise to induce just one specific biological adaptation is impossible. Most of the time there is a major effect (= class effect) coupled with a secondary (minor) effect whether desired or not.

Moreover the simulation program enables to evaluate the impact on the metabolic system of a planned workout. The following example simulates the metabolic impact of a 6 x 400 m set with 30 sec rest, for 3 swimmers with different aerobic and anaerobic capacities, at 4 different paces. The paces are chosen so that each swimmer would reach blood lactate concentrations of 1, 2, 3 and 4 mmol/l at the end of the workout (fig. 5). Swimmer A has both a higher aerobic and anaerobic capacity than swimmer B (see right upper part of the graph). Nevertheless, the capacities of both swimmers result in the same lactate curve (see lower right) and in the same swimming speeds that produce 1, 2, 3 and 4 mmol/l lactate after the simulated workout (see lower left). Despite the same lactate curve, the same swimming speed and the same lactate concentration during the 6 x 400 m interval set, the aerobic and anaerobic capacities of swimmer A are definitely less charged than those of swimmer B; indeed from 1 till 4 mmol/l swimmer A uses his aerobic and anaerobic capacities respectively for 74 till 78% of VO_2max (aerobic capacity) and for 6 to 10% of VLamax (anaerobic capacity) while swimmer B, for the same range of lactate values, uses his aerobic capacity for 83 to 86% and his anaerobic capacity for 15 to 22% (see upper left). This training set will, thus, affect both swimmers differently and induce different training adaptations, i.e. an improvement of aerobic capacity in swimmer A and an improvement of aerobic power in swimmer B. If swimmers A and B perform the same training program in the same way for several weeks, swimmer B will run a higher risk for overtraining because he will be stressing both his aerobic and anaerobic metabolism more intensely.

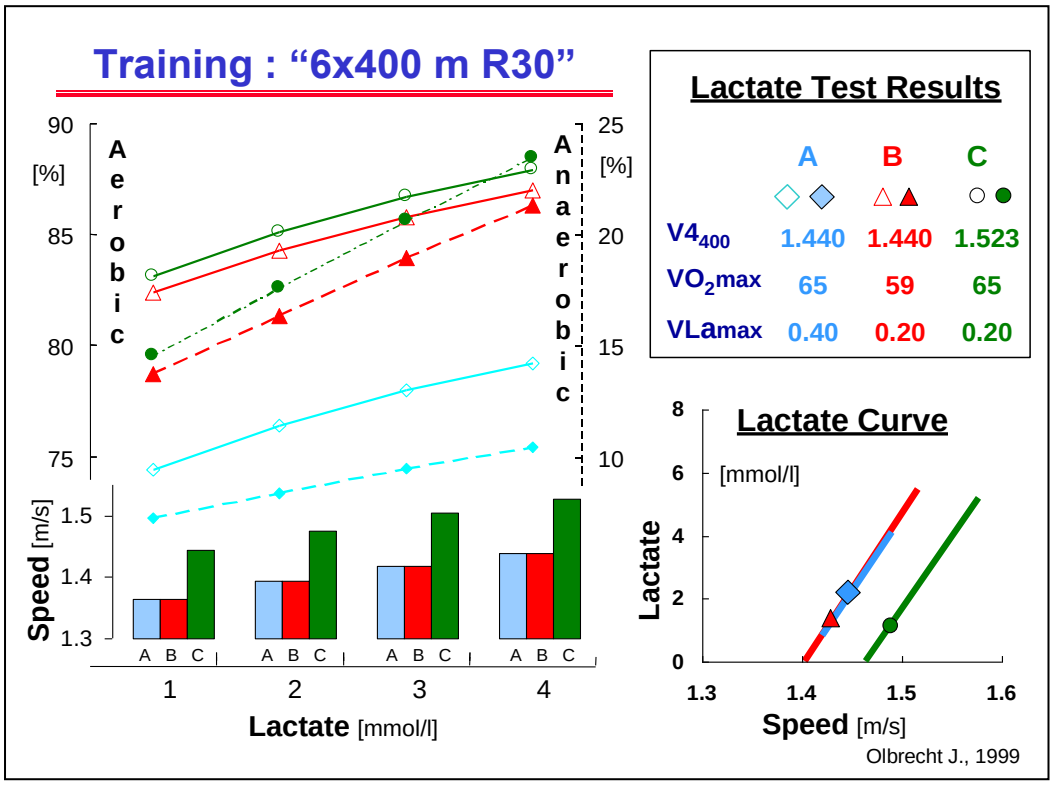


Fig. 5 Different metabolic impact of a 6 x 400 m with 30 sec rest leading to 1, 2, 3 and 4 mmol/l at the end of the set for 3 swimmers (A, B and C) with different aerobic and anaerobic capacities. These results were obtained by simulation (see text).

Swimmer C is a classic example of a good long distance swimmer with a good aerobic and a weak anaerobic capacity. For this swimmer, the 6 x 400 m at 1, 2, 3 and 4 mmol/l lactate will lead to a much higher training load on his metabolic system than for swimmers A and B. In order to decrease the training load to a normal level both swimmers C and B will have to slow down on the 6 x 400 m and train at lower lactate levels than swimmer A.

Results

We have evaluated over 200 elite swimmers in the last 6 years using this simulation approach. A lot of them belong to the National Dutch, Belgian and Brazilian Swimming Team and participated at the 2000 Olympic Games of Sydney. Figure 6 presents the mean aerobic and anaerobic capacity results observed in female and male sprinters, middle and long distance swimmers. In table 2 you will find the results of the top 3 swimmers for each stroke (freestyle, backstroke, butterfly (test in freestyle) and breaststroke).

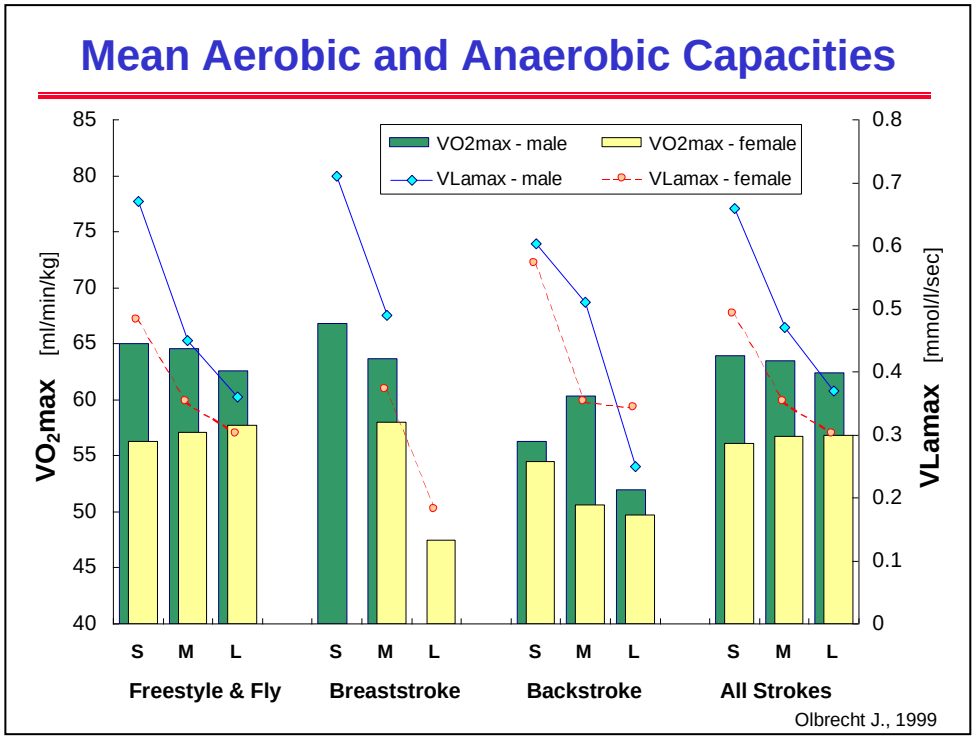


Fig. 6 Mean aerobic and anaerobic capacity calculated for female and male sprinters, middle and long distance swimmers. Due to the specific dynamics of the oxygen uptake, the measured VO_2max will always be underestimated.

WOMEN		Top 3 level Range of Best Times (50 m pool) (times)	(initials)	Range of Capacities Aerobic	Anaerobic
SPRINT	50m	24.88 - 25.91 - 26.04	IDB - GC - TB	64 - 64 - 64	0.55 - 0.74 - 0.95
FREE	100-200m	54.89 - 56.33 - 56.90	IDB - TB - MVR	64 - 64 - 63	0.55 - 0.95 - 0.76
	400m	4:10.52 - 4:11.71 - 4:12.10	KV - IA - CG	67 - 68 - 63	0.37 - 0.60 - 0.4
	800m	8:31.60 - 8:34.56 - 8:36.51	KV - IA -CG	67 - 68 - 63	0.37 - 0.60 - 0.40
BACK	100-200m	2:16.53 - 1:03.54 - 1:05.01	SW - BS - SVD	59 - 57 - 56	0.46 - 0.63 - 0.61
BREAST	100-200m	2:27.66 - 1:10.17 - 1:12.52	BB - IK - HB	66 - 73 - 60	0.74 - 1.04 - 0.54
FLY*	100-200m	58.43 - 1:01.11 - 1:01.44	IDB - GC - FD	64 - 64 - 68	0.55 - 0.74 - 0.61

MEN		Top 3 level Range of Best Times (50 m pool) (times)	(initials)	Range of Capacities Aerobic	Anaerobic
SPRINT	50m	22.06 - 22.54 - 22.87	PVH - MV - JK	84 - 72 - 77	1.00 - 1.25 - 1.03
FREE	100-200m	1:46.41 - 1:50.49 - 49.87	PVH - JK - MV	86 - 77 - 72	0.97 - 1.03 - 1.25
	400m	3:54.46 - 3:55.56 - 4:02.95	MW - PVH - BR	80 - 80 - 73	0.88 - 0.79 - 0.66
	1500m	15:30.61 - 15:47.55 - 16:30.55	MW - SR - SM	80 - 79 - 77	0.88 - 0.81 - 0.88
BACK	100-200m	1:59.64 - 57.10 - 2:01.51	SM - KEZ - RR	79 - 72 - 74	0.75 - 0.86 - 0.72
BREAST	100-200m	1:00.80 - 1:02.50 - 1:02.80	FDB - MW - MF	73 - 76 - 77	0.99 - 0.80 - 0.89
FLY*	100-200m	53.68 - 54.08 - 1:59.20	SA - KJ - FS	77 - 78 - 73	0.68 - 1.09 - 0.94

Tab. 2 Range of the best aerobic and anaerobic capacities of the top 3 swimmers together with a range of their long course best times. * Fly swimmers are tested in freestyle.

Conclusion

Maximal training efficiency is at least as important as talent to achieve success in big swimming events. Lactate tests are an important tool to improve training efficiency. Unlike the classical method of lactate interpretation, where the assessment of the conditioning is directly based on the relation between lactate and speed, i.e. the position of the lactate curve in the lactate-speed diagram or its shape, the new evaluation technique traces back lactate readings to the valuation of its determining factors - the aerobic (VO_2max) and anaerobic capacities (VLamax). Both capacities:

- are key factors in the determination of the individual metabolic profile
- reveal the missing conditioning factors to be faster in competition and consequently the main training objectives
- can be used to simulate on computer the individual metabolic response that can be expected on different types of training exercises. According to the results of the simulation we then decide whether the metabolic reaction induced by a workout serves the purpose of the training objectives or not

References

Ivy J.L., D.L. Costill, P.J. Vanhandel, D.A. Essig and R.W. Lower: Alternation in the lactate threshold with changes in substrate availability. Int. J. Sports Med. 2, 139-142, 1981

Busse M., N. Maasen, D. Böning: Die Leistungslaktatkurve - Kriterium der aeroben Kapazität oder Indiz für das Muskelglycogen? In: Rieckert H. (Ed): Sportmedizin - Kurzbestimmungen, Berlin 1987

Mader A.: Eine Theorie zur Berechnung der Dynamik und des steady state von Phosphorylierungszustande und Stoffwechselaktivität der Muskelzelle als Folge des Energiebedarfs, Habilitation , Deutsche Sporthochschule Köln, Köln 1984

Olbrecht J.: Metabolische Beanschpruchung bei Wettkampfschwimmern unterschiedlicher Leistungsfähigkeit. Stephanie Naglschmidt Verlag, Stuttgart, 1991

Olbrecht J., A. Mader, H. Heck and W. Hollmann: Das Laktat-Schwimmgeschwindig-keitsverhalten in Abhängigkeit von unterschiedlichen Testbedingungen. In: Böning D., K.M. Braumann, M.W. Busse, N. Maasen and W. Schmidt (eds). Sport - Rettung oder Risiko für die Gesundheit. Deutscher Ärzte-Verlag, Köln, 413-417, 1989

Olbrecht J., A. Mader, H. Heck and W. Hollmann: Laktaattests, hulpmiddel of bron van ergernis? Algoritme voor de interpretatie van laktaattests aan de hand van praktische voorbeelden uit de atletiek. In: Sportmedische Tijdingen 51, 84-97, 1992

Olbrecht J.: Science of Winning: Planning, Periodizing and Optimizing Swim Training, Luton UK, 2000

Synopsis

Top performances are a matter of talent but even more of “training efficiency”. Lactate is a valid parameter to structure the training process and so to monitor "training efficiency", provided it's interpretation is appropriate. This is rarely the case with the classic interpretation. We therefore developed a new interpretation methodology that enables us to trace back the origin of the lactate value in order to understand and to define the underlying capacities (aerobic and anaerobic) of the metabolic. This article will present some new findings on basic lactate research which account for the misleading lactate interpretations and provide some new ways of working with lactate in order to minimize these misinterpretations and so increase the training efficiency.