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Training Physiology

Bernard Savage
Swimming Program Manager
Victorian Institute of Sport
Sports Scientist
Australian Swimming Team

Introduction: This article covers sections of material for material for Unit 4 – Theory of Training Physiology of the Australian Swimming Level 2 Coaching Course. The title of the presentation is "Training Physiology" and the areas covered are as follows: training zones and training states as they apply to the sport of swimming, training prescription using the training zones, physiological testing including the 7x200 step test, the 10x100 step test, 7x50 stroke efficiency test and body composition, recovery and detecting and avoiding overtraining .

Training Zones: Classification systems of training zones are common across endurance based sports and swimming is no exception. The nomenclature will vary from sport to sport and even within a sport. The zones themselves are very similar and when used properly permit a systematic approach to training. There are two main considerations: is the system based on the underlying energy systems and does it work in practice. The systems generally involve 5 to 7 levels of training based on increasing speed and intensity of swimming. The system presented in Table 2 is a typical example.

Table 2. Example of training intensities in swimming.

Zone	Symbol	Time (seconds)	e.g (seconds)	HR (bpm)	La (mM)
Low-intensity aerobic	A1	AT+10-20	75-85	-70 to -50	< 2
Extensive Aerobic.	A2	AT +5-10	70-75	-40 to –50	< 2
Intensive Aerobic.	A3	AT+2-5	67-70	-30 to -40	2-3
Anaerobic Threshold	AT	AT	65	-20 to -30	3-6
Specific Pace	MVO_2	AT-2-5	62-65	-20 to max	5-10
Sprint	SP	ATP-PC	<30	n/a	n/a

This table illustrates a training classification system of six different zones. While many of the zones are described in terms of heart rate, blood lactate and perceived exertion, the most important consideration for the swimming coach is the prescription of training speeds. The most popular method among swim coaches is the time for 100m laps i.e. seconds/100m. In the low to moderate intensity training zones (A1,A2,A3) the range is quite large so training paces are prescribed in 5 second intervals are sufficient. However at the higher intensities (AT, MVO_2) a small change in pace can have significant physiological effects ie a small change in swimming speed has a large effect on heart rate and lactate production. For this reason these zones are prescribed in tighter 2 or 3 second ranges. Prescription of sprint efforts over 25m and less should be based around competition targets. Performance time and stroke parameters stroke rate and stroke count can all be used. Physiological variables such as heart rate and lactate are not relevant for this type of training. As the coach you may choose to use a different classification system but the fundamentals outlined here should be considered as should individual circumstances.

Training Prescription:

Aerobic Training: *Development of the aerobic base is fundamental to the overall success of the training program as it provides a* ***'platform'*** *for supply of higher energy demands*. Establishing an aerobic base allows the athlete to train longer and more intensely later in the season. This form of training promotes fat utilisation for fuel, increases blood supply to working muscles, increases the O_2 utilisation and results in lower heart rates and blood lactates for a given speed. The level of aerobic fitness will also affect lactate removal rates at higher exercise intensities.

Sample program:
Warm up

- 800m F/S/BK
- 8x50 IM order on 60
- 4x200 S/K/D/S main in 50s on 3.40
- 3x(6x100) w/30 sec Rec @ 6 as:
  - 3x fly/bk on 1.30/ 3x f/s on 1.20
  - 3x bk/brst on 1.30/ 3x f/s on 1.20
  - 3x brst/f/s on 1.30/ 3x f/s on 1.20
- 10x100 kick main (no gear) on 1.40/30
- 3x100 main as 75D/25S w/15m explosion end each 100 on 2.00
- 1x400 f/s pull as 200(5)/ 200 (3) on 6.00
- 10x50 bk kick w/fins on 50

TOTAL VOL: 6Km

Anaerobic Threshold Training: *Point at which metabolic demands of exercise can no longer be met by aerobic sources alone resulting in increasing anaerobic metabolism and increasing blood lactate.* This form of training increases the ability of the swimmer to deliver large amounts of O2 to the working muscle. This is the swimmers **aerobic capacity**. Adaptation to this form of training include increased O2 uptake and utilisation by the muscle, increased oxidative enzyme activity, improvements in both intracellular and extra-cellular buffering and improved removal and processing of blood lactate. These adaptations allow the athlete to swim further and faster while relying predominantly on aerobic energy sources. Target times for this form of training are derived from the step test results.

Sample program:
Warm up

- 3x150 on 2.30 as 100 f/s(3)/ 50 bk
- 3x100 desc(1-3) on 1.30
- 3x100 IM desc(1-3) on 1.40
- 4x300 as:
  - 2x (50 kick/ 50 drill/ 50 swim) on 6.00
  - 2x IM 75 of each on 5.00
- 9x50 as:
  - 3x kick (1-3) on 70
  - 3x drill (1-3) on 70
  - 3x swim (1-3) on 70 to 200 pace or better

Main Set:

- 4x100 desc(1-4) to threshold on 2.00
- 24x100 main stroke on 1.40/30 at threshold

Swimdown:

- 2x600 on 4.30 as
  - f/s pull (3) neg split
  - f/s/bk kick w/fins by 50
- 2x400 as 150 drill/ 50 swim bk scull w/fins

TOTAL VOL: 7.5 Km

Maximal Oxygen Uptake Training: Traditionally this is know as heart rate training or race pace training. Training at these swimming speeds results in close to maximal heart rate and therefore

maximal oxygen uptake. This is also known as **aerobic power**. The metabolic conditions created by swimming at this speed are very close to those in a race and hence stimulates lactate removal processes at high intensity. It is important to note that the speed should be maintained across the duration of the set to maintain the training stimulus.
Obviously the higher the MVO_2 the more work that can be done aerobically, but this is not the only important factor. Time taken to attain VO_2max, or the **oxygen kinetics,** is also very important. Reducing this time will result in a greater percentage of the energy required for a race coming from aerobic sources. Target times for race pace training should be based on competition goal times. The step test can also be used for 100m intervals. The second 100m split of the last 200m step can be used as a guide to the speed the athlete should look to maintain across the set.

Sample Program:
Warmup:
- 8x150 as:
  - 2x 50 f/s/ 25 bk on 2.30
  - 2x 50 f/s/ 25 brst on 2.30
  - 2x 50 f/s/ 25 fly on 2.30
  - 2x main med on 2.30
- 12x50 as:
  - 3x kick main (1-3) on 70
  - 3x drill main (1-3) on 60
  - 6x swim main as:
    - 50 build on 75
    - 50 comp start sprint 25 on 75

Main Set:
- 3x (3x100 desc(1-3) on 2.00 + 8x50 on 60 @ race pace)

Swimdown:
- 6x50 main (drill/swim) on 60/50
  - -15m explode on 2/6
- 1x300 bk w/fins

2x150 f/s pull (3/5/7) & (7/5/3) on 2.15
2x100 kick/scull w/fins on 1.40

TOTAL VOL: 5.0 Km

Quality training: This training is for the anaerobic system. It is broken into two types, training the **anaerobic power** and the **anaerobic capacity**. Training the anaerobic power, or production training is designed to stimulate the anaerobic energy system to produce lactic acid. For the athlete to satisfy the energy demands of racing this system must be able to work quickly. To ensure the system is working maximally near to full recovery is required in between efforts. Tolerance training increases the ability to tolerate the high levels of acidity in the muscle, specifically increasing the intramuscular buffering. This system works on negative feedback, that is the more lactate that is produced, the slow the system works. Neutralising the acidity in the muscle allows the system to continue to produce lactic acid and energy, minimising fatigue.

Speed Training: in this form of training the physiological adaptations are important but so are the neuro-muscular adaptations. These are race and stroke specific and relate to specific motor patterns, rate of muscular contraction and firing sequencing. Proper technique is very important and swimmers should be relatively fresh when doing this form of training.

Sprint Training: This type of work is very specific to 50m and 100m specialists. For the sprinters there are some key factors that need to be considered when programming specific sets. These are explosive strength need for acceleration, Vmax or the maximal swimming velocity they can attain, speed endurance 1 for 50m specialists and speed endurance 2 for 100m swimmers. For these swimmers the threshold takes on lower importance, as does the high heart rate swimming. Everything should be geared towards the athlete swimming as close to race speeds and stroke rates as possible. As a general rule these athletes also need longer to recover from hard sessions.

Physiology Testing:

The Step Test (7x200m): This test forms part of the national testing protocol and is used to both monitor adaptations to training as well as prescribe training zones for the swimmers. As of this year only 200m swimmers and above will perform this test. The protocol is as follows:

7x200m intervals on 5.00 descending 1-7

swims must be even paced with no large difference in the 100m splits

target times are set by adding 30 seconds to predicted time and descending by 5 seconds each swim

time, heart rate, blood lactate are recorded at the end of each swim

stroke rate is taken on the 4^{th} 50m interval and the athlete also counts stokes on this leg

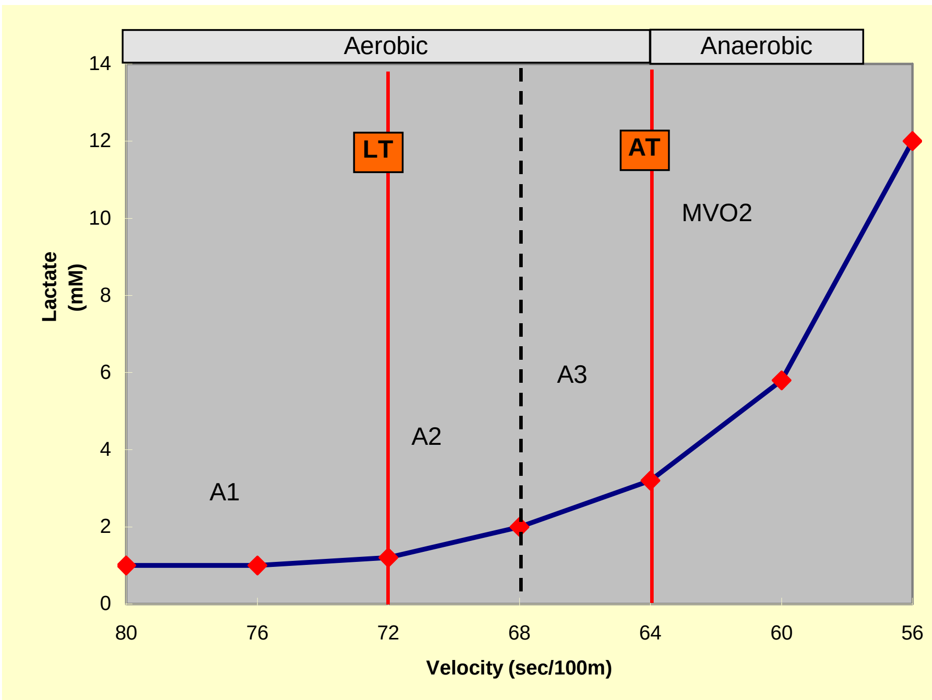

Figure 1: The training zones in relation to the velocity-lactate curve

Interpretation of the results must be done on an individual basis. It is also important that the swimmer has done the test on their main stroke as the physiological responses vary between the four competitive strokes. When interpreting the results a number of things need to be considered.

1. Has the heart rate-velocity and lactate-velocity curves moved and if they have in what direction.
2. Was there a change in the final time and how does it relate to the personal best time
3. Were the swims evenly paced and descended correctly
4. Were the results for the stroke mechanics consistent with the physiological data
5. Have the training details been recorded and how do they compare to the lead up to the previous tests.

Training velocities are prescribed using the relationship between blood lactate and swimming velocity and between heart rate and swimming velocity. The method used to do this will vary however the D-max method (Cheng et al 1982) is widely used around Australia. Figure 1 shows the training zones and their location in relation to the lactate-velocity curve

Changes in fitness can be assessed both subjectively, looking for obvious changes in the curve suggesting improvement, plateauing, or detraining, and objectively, through seeing changes in the velocities for given training zones. Figures 2a, and 2b illustrate graphical changes for improvements in the aerobic base and anaerobic threshold respectively.

The results can also be used to assess lactate tolerance. The rate of acceleration of blood lactate accumulation is indicative of this and is assessed using the differential velocity between lactate concentrations of 5.0 mMol and 10.0 mMol (Holoroyd and Swanick, 1993, Pyne et al, 1999). This provides a useful tool for assessing the efficiency of the athlete in the MVO2 area (Pyne et al, 1999)

There are several factors that can influence the lactate and heart rate curves and can therefore influence the test result or the interpretation of them. Glycogen depletion can cause a swimmers lactate response to be decreased and this will be accompanied by slower times during the final stages in the test. This can also affect the swimmers perceived exertion or subjective rating of the difficulty ie the swimmer will perceive the swim to be hard however the lactate response will not mirror this assessment.

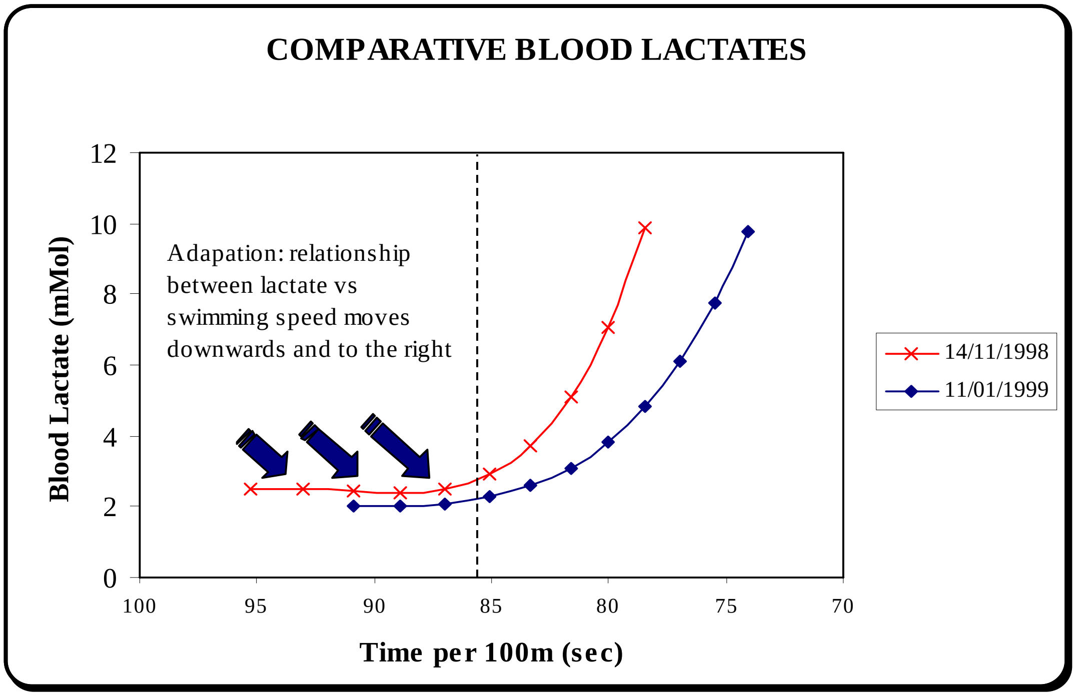

Figure 2a: Graphical changes indicating improvement in aerobic base

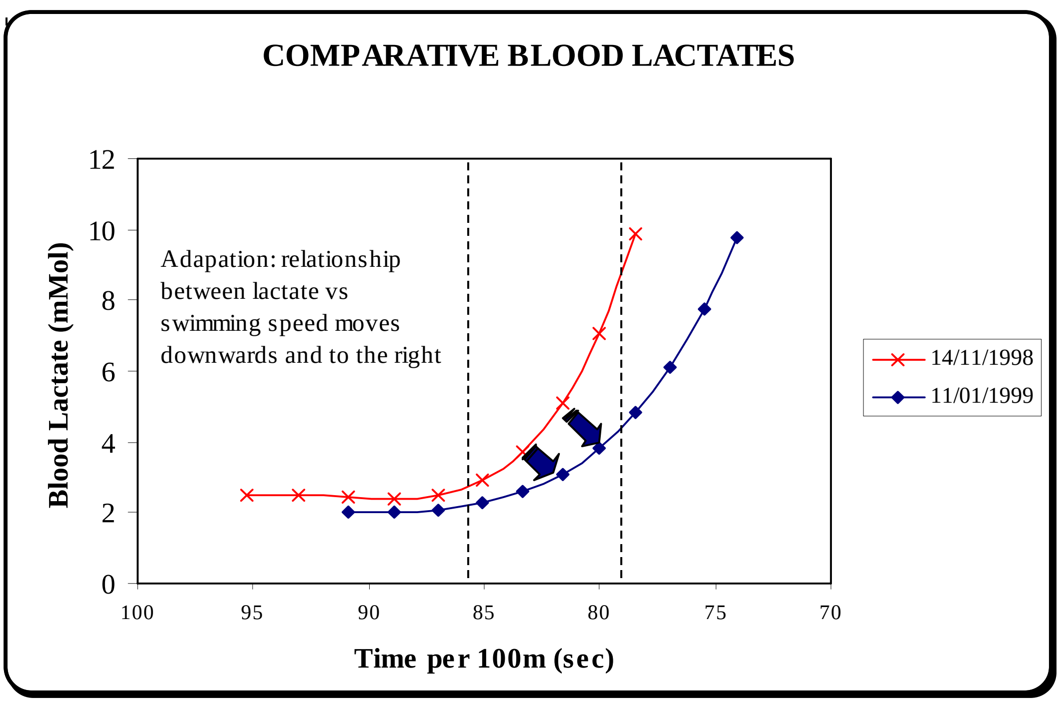

Figure 2b: Graphical changes indicating improvement in anaerobic threshold

Changes in the lactate and heart rate curve can also be the result of changes in the swimmers technique. Indeed what may at first appear to be an improvement in fitness may have resulted purely from the swimmer increasing their stroke efficiency. This is why it is important to measure the stroke parameters at the same point in the tests so these can be used in the overall analysis of the results form the test. This will allow a much more informed and relevant interpretation of the results.

The Step Test (8x100m): This test has been added to the national testing protocol for the sprint swimmers, or those specialising in 50m and 100m events. The rationale behind is that the results from the 7x200m test are not specific or relevant to this group of athletes. Then 10x100m test gives an assessment of the aerobic fitness of the athlete but also gives data which is specific to the shorter events, ie a stand up 100m time trial. The protocol is as follows:

10x100m intervals swum as 3x(3x100m) w/200m recovery between each set
5 minute rest then a stand up 100m time trial
the blocks are swum as 1. Aerobic, 2. Anaerobic threshold, 3. Heart rate
the first 9 100m intervals are on 2.00 cycle, the 200 recovery on 4.00
heart rate. Stroke rate and stroke count are recorded for every interval
blood lactate is measured after each block of 100m intervals, and 3-5 minutes post the final swim to attain the peak value.

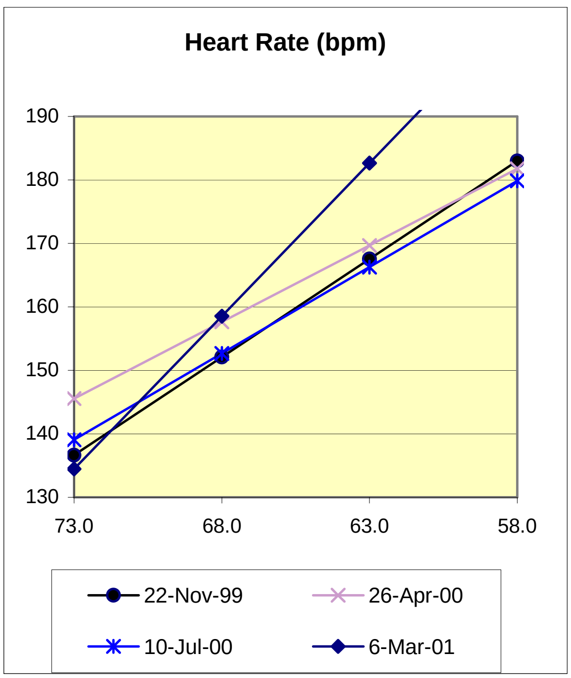

Figure 3a: heart rate-velocity relationship

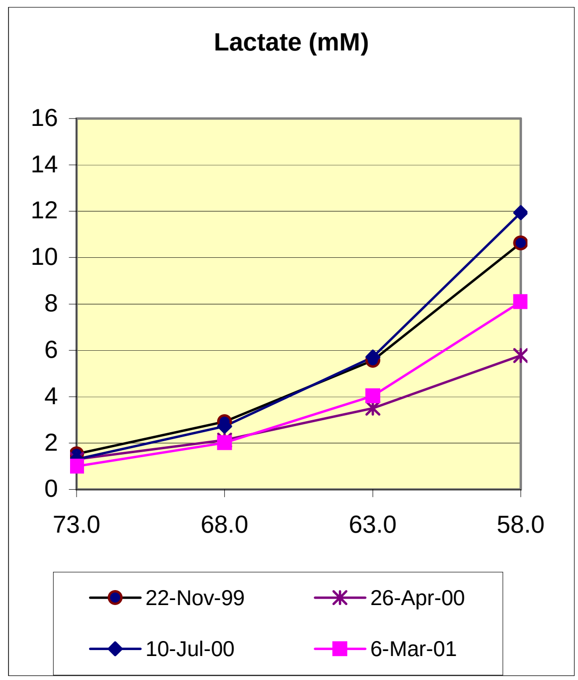

Figure 3b: lactate-velocity relationship

The data is plotted as shown in figures 3a and 3b. The heart rate for the 3 intervals making up the blocks is averaged to give one heart rate value. The same is done for time giving an average velocity for the block of 3x100m. Interpretation of the results is similar to that for the 7x200m step test. A lower heart rate response for a given speed, a lower lactate for a given swim speed, more efficient stroke mechanics through the test, fast time for the final 100m time trial and higher lactate, indicating an improvement in the anaerobic system.

Stroke Efficiency Test 6x50m: This test is used to assess the swimmers technique. A series of progressively fast 50m intervals are swum. This establishes the relationship between swim velocity (V) and the stroke parameters of stoke rate (SR) and distance per stroke (DPS). The following equations are important in relation this test:

$$V = SR \times DPS$$
$$V = SR\ (\text{cycles/sec}) \times DPS\ (\text{m/s})$$
$$DPS = [V \times 60] / SR$$

Target times for the 50s are based on the expected best 50m time for the day. 10 seconds is added so each 50m is descended 2 seconds. It is important that the athlete does not start too quickly and does not have a large drop from the 5th to the 6th 50m interval. Stroke data is recorded between the flags and the time for this segment is also recorded. Stroke rate is recorded twice, once in each half of the pool. The location of this recorded should be standardised. At the 15m and 35m mark is the recommended location.
This test provides a qualitative analysis of the stroke mechanics of the athlete. These results should be considered by the coach bearing in mind their own subjective analysis of the technique. These results are very individual and the plots for stroke rate-time and distance per stroke-time will look different between individuals and also across the four competitive strokes. Figure 4a and 4b illustrate the plots

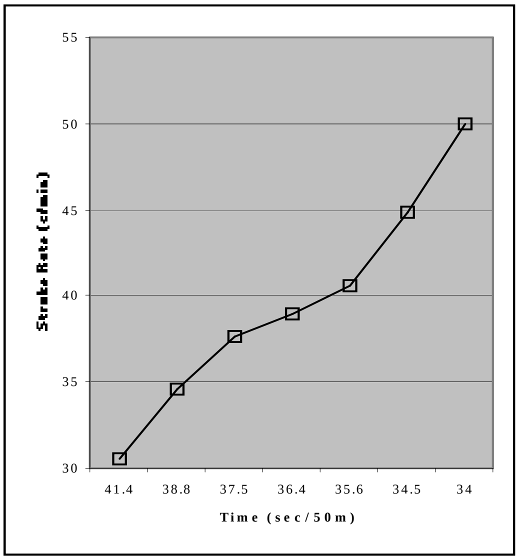

Fig 4a: Stroke Rate (c/sec) vs Time (sec)

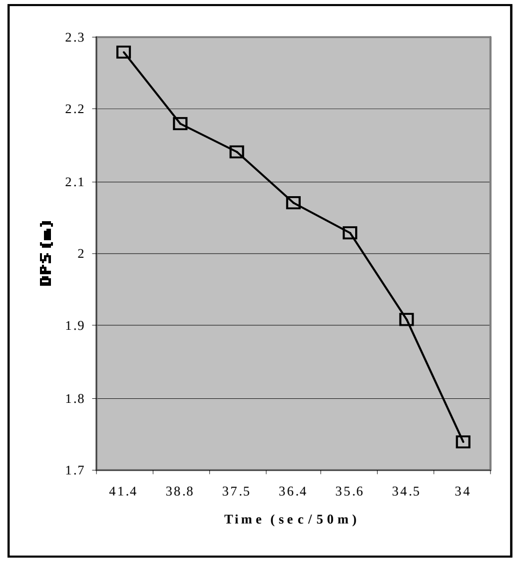

Fig 4b: DPS (m) vs Time (sec)

for stroke rate-time and distance per stroke-time.

Anthropometry: This involves measurement of the height, body mass, and sum of 7 skinfolds. This testing should be conducted at regular intervals, with an individual profile being developed for each athlete. Height and body mass measurements in younger swimmers can help monitor the growth and development of the swimmer.
The measurement of sum of skinfolds and body mass can be used to give an estimation of the lean body mass and the fat mass. In practice however the sum of skinfolds is sufficient for assessment of changes in body composition. To ensure accuracy, the same person, using the same callipers should conduct the measurements. There is the potential for large variation between measurers and between callipers. Furthermore it is preferable that the measurer be an accredited anthropometrist.

For a more detailed outline of the test protocols discussed here and the reporting and interpretation on the results please refer to Pyne et al (2000)

Recovery

The importance of recovery has been known for a long time however more recently a number of methods have grown in popularity. Recovery is multi-factorial so therefore it is important that more than one method is used. The more frequently used methods include massage, stretching, yoga, active recovery and more recently contrast therapy.

Contrast therapy or hot/cold therapy is where the athlete spends time immersed in an ice bath followed by time in either a spa or sauna. The exact mechanisms are as yet not known but the anecdotal evidence strongly suggests that this form of recovery technique has some positive benefits both physiologically and neurally. Typically the protocol is 30 seconds in the ice bath followed by 3-4 minutes in the spa or sauna with 3-5 rotations through depending on the athlete. The best temperature for the cold water is not known however it appears that the more the athlete is exposed to this technique, the colder the water needs to be for them to feel as though they are getting benefit. This presents some problems particularly when athletes have significantly raised core temperatures as immersion of the whole body in water <3^{o}C can be dangerous.

Overtraining

A prolonged state of fatigue that does not dissipate with rest and recovery. Overtraining is characterised by poor training and racing. A distinction needs to be made between overreaching and overtraining. Overreaching refers to the normal daily fatigue that is a fundamental part of high-level athletic training. Athletes should be encouraged to see fatigue as a feature of training to be respected and not necessarily feared. Overtraining refers to poor training and racing over an extended period of time that doesn't, at least initially, respond to rest and recovery. Careful management of training loads and the inclusion of sufficient rest and recovery will maximise the benefits obtained from training and minimise the risk of overtraining.

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