Periodisation and Conditioning: A Contemporary Approach

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*Please note: while this article relates to swimming, the same periodisation principles can be applied to triathlon.

Good planning is one of the key elements of effective coaching and should be considered as a skill that must be learned, developed and practiced. Planning integrates the various aspects of training that contribute to swimming performance: swimming technique (skill), physical conditioning (fitness), mental skills training (psychology), as well as racing and training strategies. The topics addressed in this article include: physiological models of exercise and fatigue, the division of the training plan into macro-, meso- and micro-cycles, and description of the various stages or phases of the training plan. One approach is to use a 'top-down' process by initially examining the end product: how fast do you need to swim to win?

Competition and Training Speeds

The winning time for each gold medallist in the freestyle and form stroke events at the Sydney 2000 Olympic Games are shown in the following table. It is interesting to note differences between distances (in the freestyle events), between events (in the form strokes) and between male and female swimmers. The average pace per 100 m is also shown.

Event		*50 FS*	*100 FS*	*200 FS*	*400 FS*	*800 FS*	*1500 FS*
Male	Time	21.9	48.3	1.45.3	3.40.6	-	14.48.3
	sec/100	43.8	48.3	52.7	55.2	-	59.2
Female	Time	24.3	53.8	1.58.2	4.05.8	8.19.7	-
	sec/100	48.6	53.8	59.1	61.5	62.5	
Event		*100 Fly*	*200 Fly*	*100 BK*	*200 BK*	*100 BR*	*200 BR*
Male	Time	52.0	1.55.4	53.7	1.56.8	60.5	2.10.9
	sec/100	52.0	57.7	53.7	58.4	60.5	65.5
Female	Time	56.6	2.05.9	60.2	2.08.2	67.1	2.24.4
	sec/100	56.6	62.9	60.2	64.1	67.1	72.2

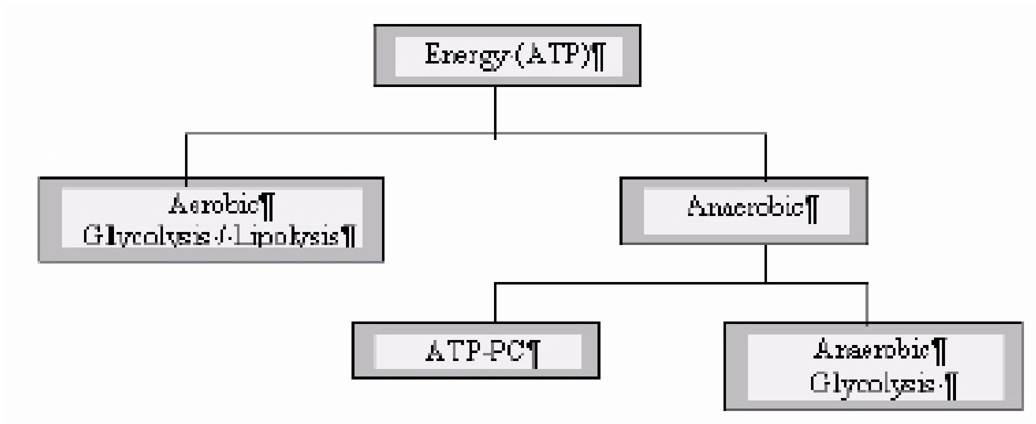
The percentage difference in average pace from the 50 m to the 1500 m FS is approximately 27%. For example, the typical highly-trained male freestyle swimmer could complete 100 m training intervals as slow as 80-90 seconds. The coach has the challenge of formulating training programs that cater for all speeds between 50 (fastest race pace) and 90 (slowest training pace) seconds per 100 m.

Energy Systems – The Traditional Approach

***Metabolism**:* An understanding of the energetic demands of training and competitive swimming is an essential requirement for coaches. The mechanical action of the different swimming strokes requires the skeletal muscles to variously contract, extend or remain static in length. This process requires the integration of neural signals from the motor cortex (nervous system) to the muscles. A chain of biochemical reactions within the muscle results in the transformation of potential chemical energy to the mechanical energy of muscle action. Energy metabolism is defined as the process of storing and releasing energy during exercise. Swimming training enhances these processes with improved fitness equating to 'more work – less fatigue'. Coaches need to understand the different energy systems and their influence on the training-induced adaptations required for competitive success.

***Energy Systems**:* Energy metabolism is based on the concepts of fuel sources, fuel utilisation and contribution of different energy systems to various sporting activities. There are four basic energy compounds: the primary energy compound ATP (adenosine triphosphate), and the three secondary energy compounds of creatine phosphate (CP), glycogen (carbohydrate) and fat (see Figure 1). ATP is the body's primary energy currency, however there is only sufficient ATP in the muscle to sustain a short burst of muscular effort (a few seconds in duration). Even in the shortest competitive swimming event, the 50m sprint where performance times range from approximately 20 to 40 seconds depending on the age, gender, event and level of the swimmer, ATP must be constantly replenished from other sources in the muscle. These additional sources of energy are derived from foodstuffs with the principal substrates (fuels) being carbohydrate, fat and protein. ATP is the currency (energy) used in the cells of the body and powers all cellular functions including muscular contraction.

Figure 1. Replenishment of ATP from different energy sources.



Short term energy supply for high intensity exercise such as the 50 m sprint events are obtained from substances already in the muscle, without the need for oxygen. These energy supplies are consequently termed *anaerobic energy* and come from high energy phosphate substances in the muscle (the ATP-PC or ATP-PhosphoCreatine system), or from carbohydrate stores in the muscle metabolised in the absence of oxygen (the Anaerobic Glycolysis or Lactic Acid system).

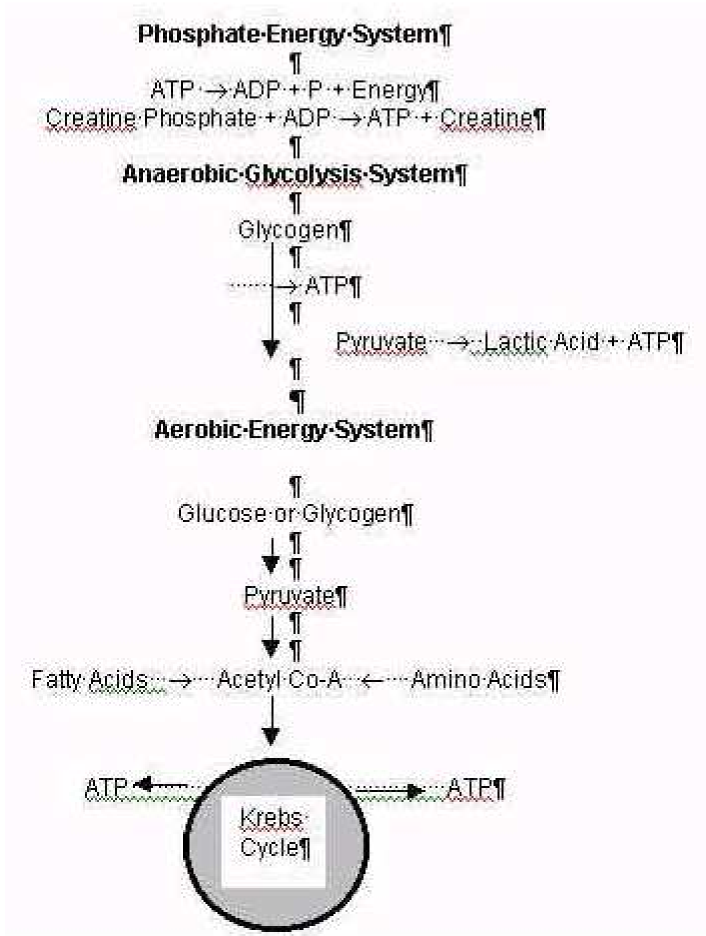
The ATP-PC system involves a series of chemical reactions producing energy. The ATP in the muscle and another high energy compound, creatine phosphate, collectively provide enough energy for 5 – 10 seconds of activity. This system releases a tremendous amount of energy but is exhausted within a few contractions.

The ATP stores are rapidly replenished so that further energy is available within 30-60 seconds and stores are completely restored within 3-5 minutes. The replacement of ATP requires oxygen and this is one reason underlining the importance of interval training (varying bouts of work and recovery) and swim downs.

The anaerobic glycolysis system or the ‘lactic acid system’ involves metabolism of blood glucose and muscle glycogen in the absence of oxygen. This system is the dominant contributor to high-intensity exercise of 30 seconds to 3 minutes duration. However the accumulation of lactic acid within the muscle can compromise muscle contraction leading to fatigue.

The aerobic energy system involves the metabolism of carbohydrate (aerobic glycolysis) and fat (aerobic lipolysis) in the presence of oxygen. Exercise of greater than 60 sec in duration becomes increasingly aerobic. This systems produces ATP more efficiently than anaerobic glycolysis and is limited by the availability of muscle glycogen: which equates to approximately two hours of continuous exercise.

Figure 2. A schematic diagram showing the generation of ATP via the phosphate, anaerobic glycolytic and aerobic energy systems.



Aerobic or oxidative energy metabolism can be maintained at a submaximal level for extended periods as long as substrates (fuels) are available. Oxidation of fuels occurs in the Krebs Cycle located within the mitochondria of muscle cells. As the intensity of swimming increases, the speed at which the biochemical reactions proceed also increases. The primary fuels for the aerobic system are carbohydrates and fats. Because carbohydrate is the main fuel source and its supply limited, the body adapts to using alternative fuels such as fat to protect the diminishing reserves of carbohydrate. This transfer from carbohydrate to fat metabolism is referred to as 'carbohydrate sparing'. In training, a substantial proportion of work is completed at an intensity of swimming below the lactate or anaerobic threshold (i.e. the speed above which the blood lactate concentration starts to rise) and is primarily fuelled by lipid or fat metabolism.

Energy Contributions to Swimming Events: Short explosive sprints events such as the 50m events are predominantly anaerobic in nature. Middle-distance events (100 to 400m) are a combination of anaerobic and aerobic energy. Long distance events such as the 800 and 1500m and open water swimming are predominantly aerobic in nature. Table 1 shows the relative contribution of the three energy systems to the various swimming events.

Table 1. Contribution of energy systems to different swimming events.

Event	%ATP-PC	%Anaerobic Glycolysis	%Aerobic
50 m	55	40	5
100 m	15	50	35
200 m	10	30	60
400 m	5	25	70
1500 m	0	15	85

Physiological Models – A Contemporary Approach

The preceding model of energy systems has been the conventional approach to understanding exercise and the planning of training over the last 30 years. However the results of scientific investigation combined with clinical, laboratory and field experience suggest that this model has significant limitations and should be revised (Noakes, 2000). Noakes argues that the old idea that fatigue develops when the capacity of the cardiovascular systems to provide oxygen to the exercising muscles falls behind their demand inducing "anaerobic" metabolism is unsatisfactory. He cites four main reasons: i) the heart and not the skeletal muscles would be affected first by anaerobiosis, ii) no study has definitively established the presence of anaerobiosis and hypoxia in skeletal muscle during maximal exercise, and iii) the traditional energy systems model is unable to explain why fatigue ensues during prolonged exercise, at altitude and in hot conditions, and iv) cardiorespiratory (maximal oxygen uptake) and metabolic (lactate threshold) measures are only modest predictors of performance. Noakes (2000) proposes a new physiological model to explain exercise performance and fatigue. This revised model consists of the original cardiovascular / anaerobic model and four additional models that regulate short duration, maximal or prolonged submaximal exercise. They are:

- The cardiovascular / anaerobic model
- The energy supply / energy depletion model
- The muscle recruitment (central fatigue) / muscle power model
- The biomechanical model
- The psychological / motivational model

The energy supply / energy depletion model is based on the concept that the availability (supply) of a substrate (oxygen) to muscle is a limiting factor in exercise performance. The second part of this model proposes that fatigue during high intensity exercise may result from the inability to supply ATP to contracting muscle at rates sufficiently fast to sustain exercise. This model is therefore consistent with the old three energy systems model where performance in events of different durations is determined by the capacity to produce ATP by the phosphagen, anaerobic glycolysis, aerobic glycolytic and aerobic lipolytic systems.

The muscle recruitment (central fatigue) / muscle power model provides an alternate view to the first two models and proposes that it is not the rate of supply of energy to muscle that limits its performance, but rather the processes involved in skeletal muscle recruitment, excitation and contraction. The central nervous systems play a key regulatory role in muscle contraction. Increased concentrations of the brain neurotransmitters serotonin and dopamine increase the flow of neural impulses to the muscles enhancing performance. In contrast, reduced neurotransmitter concentration (I.e. reduced central neural drive) will result in fatigue and termination of maximal intensity exercise. The muscle power model holds that athletes with superior athletic ability have muscles with a superior capacity to generate force.
The biomechanical model proposes that the greater the muscle's capacity to act as a spring, the less torque it must produce and hence the more efficient it is. Those muscle fibres with greater elasticity and efficiency will enhance performance by slowing both the rate of accumulation of fatiguing agents in the muscle and the rise in body temperature. Another possible benefit is that elastic muscle fibres are more fatigue resistance and less liable to damage that develops during repeated contractions. The psychological / motivational model holds that the ability to sustain exercise performance results from a conscious effort. Again both sporting experience and experimental observations point to the importance of motivation and instances where this seemingly overrides any physiological limitation.
This revised approach and concept of the combined physiological models is appealing on theoretical and conceptual grounds and merits attention from the sporting community.

Basics of Periodisation and Conditioning

Periodisation of training: The process of periodisation is defined as division of the annual training plan into smaller and more manageable parts to ensure correct peaking for the main competition of the year. Periodisation of training was popularised in the 1960's and 1970's as coaching become more comprehensive and systematic. Authors such as Bompa and Matveyev popularised the use of periodised training in both team and individual sports. The annual plan is divided sequentially into the mesocycle (long term cycle), macrocycle (multi- week training cycle), microcycle (weekly training cycle) and the daily training sessions. The combination of different training cycles within the annual plan will depend on the specific goals of the competition cycle.

The Mesocycle (Major Preparation): The mesocycle in the context of swimming refers to the preparation for a major competition. For age group swimmers, this usually is the summer season leading into district, state or national age group championships. For senior swimmers, the mesocycle refers to the summer preparation for the national championships (selection trials in March) or the winter preparation for the major international meet of the year (usually August/September). On this basis, senior swimmers generally have two mesocycles per year. Figure 3 shows a typical mesocycle plan for a senior group of swimmers preparing for World Cup (Short Course) meets in January and February as part of the overall plan leading to the Australian Championships (Long Course) in March. The evolution of modern training methodology has lead to the development of terminology such as basic endurance, general endurance, specific endurance, preparatory, quality, taper, competitive and transition phases. These phases form the basis of the annual training plan. Despite their widespread use there is no common terminology for all these different phases of training.

Figure 3. Typical 16 week training plan for senior swimmers preparing for World Cup races in January and ultimately for the National Championships in March/April

	Preparation for the Summer Program						
Date	October	November	November	December	January	January	February
Meso-Cycle	Preparation				Competition		Transition
Competition			Local Meet	Local Meet	World Cup	World Cup	
Macro-Cycle	Basic Endurance	General Endurance	Specific Endurance	Quality	Taper	Comp.	Transition
Micro-Cycle Week No.	1,2	3,4	5,6,7	8,9,10	11,12,13	14	15,16

The next step is to develop the training plan in terms of the training volume and intensity (Figure 4). The main features of the general phase are: a modest training volume to start the season; the volume increases in a gradual manner with small 5-10 km increases per week; training intensity is low, and emphasis is placed on dry-land conditioning including flexibility, circuits, weight training and other games and aerobic activities.

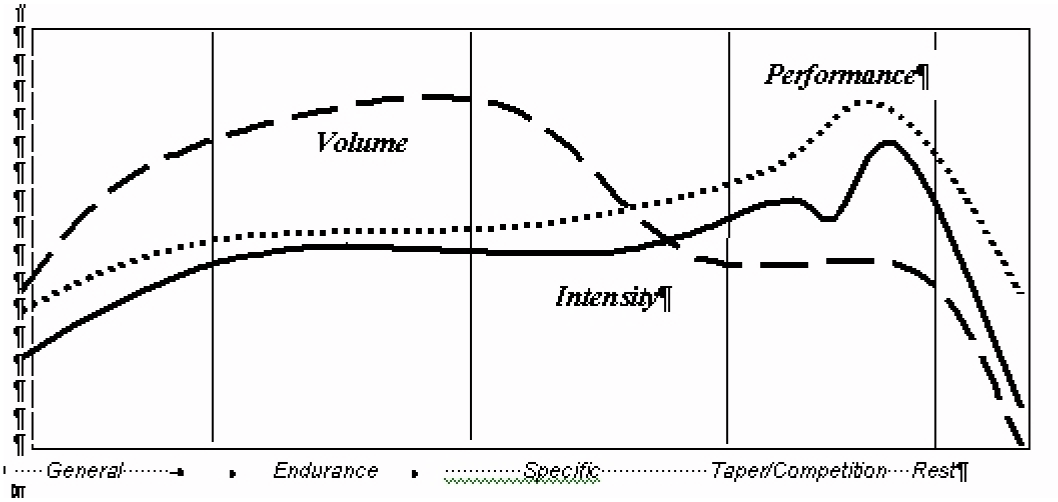
The main features of the endurance phase are: continuing increases in training volume; gradual introduction of higher intensity aerobic work to the level of the anaerobic threshold; and emphasis on skill and technique development before moving to the higher training speeds and intensities. In simple terms, training volume elicits improvements in general endurance fitness while training intensity develops the specific fitness required for racing and competitive success.

The main features of the specific phase are: increasing development of the anaerobic threshold, maximal oxygen uptake and race pace training capacities; ongoing manipulation of training volume and intensity to achieve continuing improvement; individualised training volume, intensity and recovery; ongoing development of skill particularly at race speeds.

The main features of the taper/competition phase are: a taper with reducing training volume and recovery to maintain basic fitness and develop race fitness; training volume is gradually reduced reaching about 20% of the peak weekly mileage at the time of competition; race pace and pacing strategies are finalised through use of descending sets, broken swims and time trials.

The main features of the rest phase are: maintaining an active approach with at least three low- to moderate- intensity aerobic swims completed each week; specialised programs to target weaknesses in individual fitness profiles; and dietary control to prevent excessive weight gain.

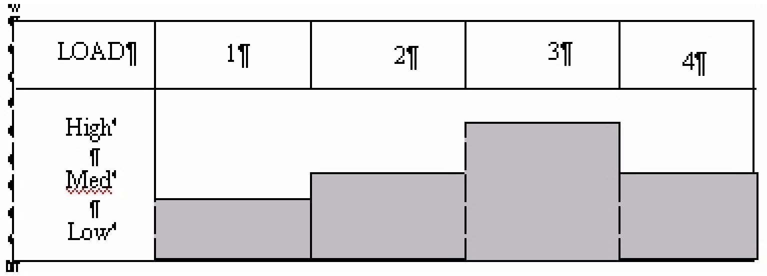
Figure 4. A typical schematic plan for a 16 week training preparation for swimmers.



The Macrocycle (2-6 week blocks): The term, macro, is derived from the Greek term, *makros*, meaning large in size. In competitive sports, a training macrocycle represents a training block or phase of between 2 – 6 weeks (microcycles). The duration of a macrocycle depends on the objectives and type of training used in each stage of the annual plan. In physiological terms, the macrocycle is used to develop or improve a specific aspect of fitness. The overall aim is to improve competitive performance as well as specific training factors. The classical structure of a macrocycle involves two to four 'developmental' or 'accumulation' microcycles followed by a concluding 'intensification' or 'tuning' microcycle.

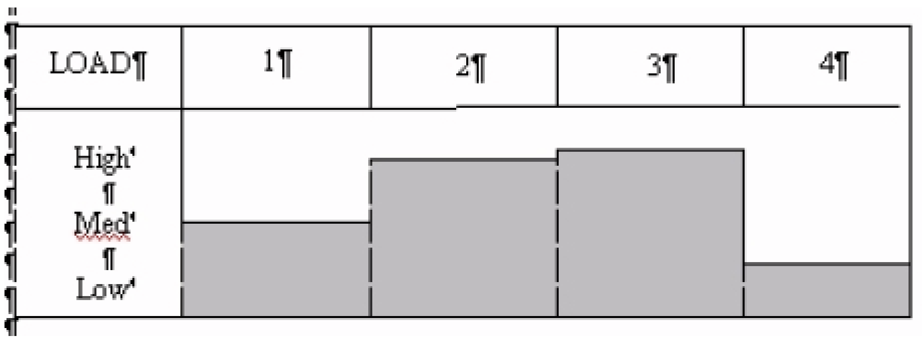
The overall training load can be considered as the product of training intensity and training volume i.e. training load = volume x intensity. There is usually an incremental increase in either training volume or intensity throughout a macrocycle. It should be noted that increasing the training load is achieved in a wave- like pattern with systematic changes in training volume and intensity. The usual practice is to increase training volume in endurance-oriented macrocycles, but decrease the volume during the taper and competition microcycles. In contrast, during speed-oriented macrocycles training intensity increases as training volumes declines. In general, higher training volumes are generally achieved with lower training intensity, and likewise, higher training intensity is achieved with lower training volume. Figure 4 shows a typical 4-week training macrocycle. This example illustrates a standard incremental build-up in training load that could be either training volume or training intensity. Experience has shown that three weeks of increasing training loads represents the usual limit of positive adaptation. Beyond three weeks, increasing fatigue tends to limit the benefits accrued from training. In practice small increments in training loads of approximately 5% are suggested: a common mistake is to increase loads too rapidly which can lead to excessive fatigue, injury or illness. With increasing fitness, the training loads in recovery weeks (as shown in week 4 in this example) can be maintained at higher levels than could be sustained earlier in the training season.

Figure 4. A standard 4 week macrocycle with increasing loads and a recovery week.



In contrast to Figure 4, the macrocycle used in Figure 5 is more typical of the taper or pre-competition when training volume and loads start to decrease. There is only a modest increase in training load from week 2 to week 3 before a substantial drop from week 3 to week 4 prior to the competition. The aim of this sequence is to eliminate or reduce any residual fatigue and sharpen swimmers for subsequent competition.

Figure 5. A pre-competition or taper macrocycle.



The Microcycle (Weekly and Daily): The term microcycle coming from Greek term, *mikros*, meaning small, and the Latin term, *cyclus*, refers to a sequence of training that is repeated regularly. In the context of swimming training, the microcycle refers to the weekly 7-day training plan (Monday to Sunday). The microcycle is probably the most important and functional tool in the planning of training. The structure and content of the weekly microcycle determines the quality and nature of the training stimulus. Variation of the training volume and intensity within and between microcycles is a fundamental aspect of coaching. In a given day, one to three training sessions can be completed in the pool with supplementary dry- land work to target specific and general aspects of conditioning.

Similarly to the planning of macrocycles, the training load of a given microcycle is determined by the combination of training volume, training load and recovery periods. Again the objectives of the microcycle will determine the specific nature of the training load. Various types of training microcycles have been developed in swimming. Depending on the age and level of the squad, microcycles need to accommodate from 5 to 20 training sessions (pool and dry- land) in a given week.

Various microcycle structures such as 3+1 (three sessions on, one session off), 5+1 and cycles with one peak or two peaks can be used (Figures 6-9). Volume and intensity of sessions within a microcycle are based on the training zones or classification system used by individual coaches. A certain degree of flexibility is required to account for variations in individual levels of fitness and fatigue.

Figure 6. A simple seven session training week (microcycle) for younger swimmers. This shows the emphasis on a Saturday commitment to swimming leaving the priority to schooling through the week.

	M	T	W	Th	F	S	S
AM	**Off**	**Off**	**Off**	**Off**	**Off**	T	**Off**
PM	T	T	T	T	T	T	**Off**

Figure 7. A nine session training week (microcycle) for senior swimmers characterised by half day recoveries and a 3 + 1 (three sessions on, one session off) approach.

	M	T	W	Th	F	S	S
AM	T	T	T	T	T	T	**Off**
PM	T	**Off**	T	**Off**	T	**Off**	**Off**

Figure 8. A ten session training week (microcycle) for senior swimmers characterised by a 5 + 1 (five sessions on, one session off) approach.

	M	T	W	Th	F	S	S
AM	T	T	T	T	T	T	**Off**
PM	T	T	**Off**	T	T	**Off**	**Off**

Figure 9. A specialised 7 day microcycle for use by senior swimmers in specific high volume training camps. A 3 + 3 + 2 cycle is used for a total of 16 sessions in the cycle including a fell recovery day. This type of cycle is useful for accumulating high training volumes (up to 100 km per week).

	M	T	W	Th	F	S	S
AM	T	T	T	T	T	T	**Off**
Noon	T	T	T	T	T	T	**Off**
PM	T	T	**Off**	T	T	**Off**	**Off**

The Taper

The tapering strategy used by swimmers to optimize competition performance has been defined as "a progressive non- linear reduction of the training load during a variable period of time, in an attempt to reduce the physiological and psychological stress of daily training and optimize sports performance" (Mujika et al 2001). The taper has been shown to elicit significant improvements in performance. These performance gains have variously been attributed to increased levels of muscular force and power, and improvements in neuromuscular, hematological, and hormonal

function, and psychological status of the athletes.
We conducted a study to determine the magnitude of the taper on competitive performance in swimmers at the 2000 Olympic Games (Mujika et al. 2001). Olympic swimmers who took part in the same event or events at the Melbourne Grand Prix 21-28 days before the Sydney 2000 Olympics were studied. A total of 99 performances (50 male, 49 female) were analysed. The overall performance improvement for all swimmers was 2.18 ± 1.50%, (range -1.14% to 6.02%). A total of 91 of the 99 analyzed performances were faster after the taper and only 8 performances were slower. The % improvement with taper was significantly higher in males (2.57 ± 1.45%) than in females (1.78 ± 1.45%). The magnitude was similar for all competition events, and achieved by swimmers from different countries and performance levels. This information provides a quantitative framework for coaches and swimmers to set realistic performance goals based on individual pre-taper performance levels.

Making it work – putting theory into practice

One of the fundamental requirements of coaching is well organised and planned training to ensure the achievement of training objectives. A well organised, methodical and systematic approach will assist the coach and athlete achieve a high level of training and competitive performance. Good planning is based on knowledge and experience of swimming and consideration of individual circumstances.
At the elite level, long term plans are usually based on the four year Olympic cycle with the intermediate goals of the national championships and major international meets held annually. The annual training plan is based around a competitive season (for age group swimmers) or the build-up to a specific major championship (senior swimmers). The aim of the annual plan is to produce the highest level of performance at the major meet(s) of the year.
There are several features of planning common to all swimming programs: To develop the competitive level, the main training objective (e.g. endurance, speed, strength) must be established and developed as a priority; long term plans often have to be modified to achieve short term goals; and given the cyclical nature of the swimming action and the energetics of the competitive events, training is usually characterised by moderate to high training volumes and a rhythmical approach.
Olbrecht (2000) divides the planning of swimming training into two distinct phases. The design phase involves preparation of the training plan by: i) analysis of each individual swimmer's current performance level and training background, ii) setting of intermediate performance objectives, and iii) determination and design of the training plan. The realisation phase involves the daily processes of 'execution' and 'steering'. This refers to the daily adjustments to the program and training sets to account for individual variation in adaptation. Coaches must continually monitor the responses to training to ensure that an adequate stimulus is maintained, proper technique is used, and fatigue levels kept under control.

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