BACK TO SCHOOL with Dr. DAVID PYNE
MIX & MATCH OR STRAIGHT UP?
A VIEW ON WORKOUT DESIGN

One way to characterise Australian swimming coaches is to put them into one of two categories in terms of the basic design of their workouts … **mix and match** or **straight up**. The 'mix and match' coaches often the Individual Medley or Form Stroke specialist, create intricate masterpieces for each workout with tremendous variety – a mixture of all strokes, distances and drills – with a guarantee that the next 50m will always be different from the last. The 'straight up' coaches, in contrast, are more often your Freestyle and/or Distance merchants who don't waste time or whiteboard space with their five-line program that takes 15 seconds to write up, but two and half hours to complete. Why has this difference evolved and what does it mean for preparing the majority of swimmers who don't swim the 400m Individual Medley or the 1500m Freestyle?

The 'mix and match' type workout has largely evolved through the efforts and successes of our leading Individual Medley (IM) coaches. For IM swimmers, it is essential that all four strokes are developed in both isolation and combination. Some of the most eye-catching sets that I have seen are built around the creative (almost magical) integration of distances, intensities, work-rest ratios and strokes, all in the one set. I think we would all be proud of putting together some of these works of art. All competitive swimmers should develop and utilise each of the four strokes from an early age. This mixed approach will improve each of the strokes in its own right and be extremely useful in providing a broad background for developing a swimmer's main stroke to national and/or international level. There are some swimmers who rise through the ranks, even to the national team, who are a short a stroke or two and this is certainly limiting when attempting to design a full range of workouts.

For Breaststroke and Butterfly swimmers, a mixed approach is necessary to support the relatively high energetic demands of these particular strokes. For a given speed, Breaststroke and Butterfly requires a higher energy output than either Backstroke or Freestyle swimming. For this reason, it is not possible or desirable to complete the same volume of training with each stroke and consequently Backstroke and Freestyle should be used to support stroke specific work. This situation is changing a little at the elite level, with some of the more specialised programs, especially Breaststroke, utilising a higher percentage of form stroke than five or ten years ago.

The arguments for mixing strokes centre on the need to develop all the strokes, recruit of all the major muscle groups, practice the necessary transitions in IM swimming… Butterfly-Backstroke … Backstroke-Breaststroke … Breaststroke-Freestyle … and to meet the principle of a varying stimulus to maximise technical and physiological adaptations. This approach also requires the concentration (and commitment) of the swimmer throughout the workout. All coaches would agree that swimmers should continually work on the technical aspects of their swimming and concentrate on the correct pacing of each repeat. Having the swimmers think about their work should keep them focussed on the task at hand and is preferable to going to "sleep" halfway through a set of 1000's.

The counter argument put by the 'straight up' coaches is that all this is fine for IM switching but in large volumes is too broken and disjointed for a majority of swimmers. The argument goes that the swimmers (and their physiology) never get a chance to settle into some solid work before the next change is made. Both swimming skills and various physiological capacities may be developed more effectively through the controlled repetition of efforts with the requisite level of technical precision, and metabolic and neuromuscular specificity. The latter aspect would satisfy the requirements of overload and specificity which are fundamental principles governing the adaptations to training.

Therefore, the 'straight up' proponents contend that is generally better to have warm-ups and main sets undertaken in a simple format. This approach permits each aspect of training to be fully developed in isolation without interference from other forms or types of training. Warm-ups should take a general then specific orientation where some low to moderate intensity straight swimming (up to a total of 2000m) is undertaken initially before more specific drills or pace work is completed. This thinking also applies to aerobic or recovery sessions where simple straight sets are preferred … e.g. 4x800m on 11:00-1,3 alternating Freestyle/Backstroke by 100m intervals; and 2,4 Freestyle pull with fins, all swimming at a heart rate of 140bpm (or 60 beats below max). The 'straight up' coaches (and their swimmers) aren't bothered with the idea of mixing and matching too much in these aerobic sessions … they just want to get in and do the work with a minimum of effort and fuss.

'Straight up' swimming also permits coaches and swimmers more opportunity to perfect the technical aspects of the stroke. Everyone would acknowledge that it takes considerable time and patience to learn, refine or change stroke patterns. Movements that have been rehearsed thousands and thousands of times require a great deal of work to eliminate faults and reinforce correct techniques. The straight up converts would suggest that this process is more easily achieved in simple longer sets rather than mixed sets which change frequently in nature.

The arguments mounted against the 'straight up' philosophy include several performance, physiological and psychological reasons. Many coaches argue that an effective warm-up must include the full range of strokes, drills and intensities, in order to adequately prepare swimmers for the main set(s) of the session. Some swimmers waste the first part of the main set by not being able (ready) to start with the required pace. Coaches and swimmers also point to the potential problems with boredom and lack of concentration as one approaches the 5th 800m Freestyle repeat on an 11:00 cycle.

Of course, there is no correct answer to this question. On balance it is suggested that a combination of 'mixing and matching' and 'straight up' is best for most swimmers in age group or elite programs. More specialised work is recommended, at appropriate times, for elite swimmers and those specialising in the Individual Medley ('mix and match') and Distance Freestyle ('straight up') events. As always, the situation that coaches find themselves in will play a large role in determining the type of workouts that are needed. Why is it that too much of a good thing is never a good thing?

MODEL 14-DAY TAPER: TRANSITION FROM TRAINING TO RACING

One of the key challenges for a coach is the transition from training to racing. This process, commonly referred to as the taper, is a frequent topic of discussion amongst swimming coaches. Some swimmers, who are amongst the best trainers in your group, may not be able to convert increased fitness (resulting from a well-developed and executed training program) into peak racing speed. A proper taper program may help the swimmer take this next step. This article presents an outline of a standard 14-day taper for a competitive swimmer. It is not intended to be the definitive training program, but simply a means of examining some of the important features of tapering and to provide some ideas for your own planning.

The taper is the final part of a season's preparation and is characterised by a reduction in volume of training and the development of race speed. In a full taper for a major swimming competition it is common to reduce the volume of training by approximately a half (50%) to two-thirds (66%) of the peak weekly volume for that preparation. In most elite swimming programs, the weekly volume may reach a high of 60-80km. On this basis, the final two weeks of the preparation should be approximately 0.50x80km = 40km to 0.50x60km = 30km in volume. For minor and less important competitions, coaches may elect to "swim through' a Meet or just have a "mini-taper" of a couple of days. Whether you are planning a full or mini-taper the principles and guidelines are basically the same – reduce the volume and sharpen the speed of training.

There are many factors that influence the structure and dynamics of a taper. These include … the age and experience of the swimmer, event distance, current fitness level and training background. The 14-day program discussed here illustrates some of the features of a taper for an elite swimmer. All tapers need to be tailored to suit each individual swimmer's requirements.

1. Day: This model outlines the training plan during the final 14 days of a full preparation for a swimming competition. In the final few weeks it pays to focus in on the actual number of days to the meet and use this in the planning of the program. At the elite level, it is a common practice to throw away the normal Sunday to Saturday calendar. Whilst some swimmers grumble at giving up their weekends, a little inconvenience may be rewarded with a complete preparation and, hopefully, enhanced competitive results.

2. Microcycle: One feature that is used frequently in the planning of athletic training programs is the term microcycling. Microcycling refers to the planning of small blocks of training days from as little as two or three days up to seven days (a full training week). A number of microcycles make up a macrocycle (a few training weeks), with several macrocycles making a full mesocycle … i.e. a complete 12-16 week preparation. The process of balancing all these cycles is known as periodisation. A periodised training program involves a number of training cycles in which the volume and intensity of training is varied in order to maximise fitness and performance.

3. AM or PM: During most tapers, either one or two sessions of swimming training are undertaken each day. The usual practice, of course, is to have a morning (AM) and an afternoon (PM) session. On the days where only one session is planned, this can be undertaken in either the AM or PM depending on the usual schedule for the team. A common practice by elite coaches is to synchronise the timing of the morning session to coincide with the time of the heat sessions at the competition (normally around 0900 hours local time). Whilst this makes good sense, there is no need to go overboard. There are stories (legends) within Australian swimming of coaches having their final few training sessions at some very strange hours just to fit in with the timing of the meet.

4. Type: The type of session is indicated using a classification system that we have used at the Australian Institute of Sport and at the National Altitude Camps during 1994 and 1995. This system involves a simple five-point classification by intensity (and swimming speed)…

Level	
1	Represents low to moderate intensity aerobic training.
2	Represents moderate to high intensity anaerobic threshold training.
3	Represents high intensity **maximal oxygen** uptake training.
4	Represents high intensity **lactate** tolerance training.
5	Represents maximal effort short sprint training.

It can be misleading to assume that these levels only refer to the physiological intensity (energy cost) of a particular training session or set. More importantly, the aim is to increase the speed at a certain intensity or level … e.g. for Level 3 which is for high quality maximal oxygen uptake (aerobic) work (or heart rate sets as commonly referred to by many Australian coaches) a swimmer might be able to hold 1:05 for 100m Freestyle repeats at a heart rate of 170bpm. With a progression in training and fitness, this swimmer should be able to hold faster than 1:05 at the same heart rate on the same interval. A common mistake is to focus only on the physiological response … e.g. high heart rates … and not the swimming speed (or time per 100m) that the physiological response is associated with. Measuring heart rates is the most practical way of assessing-the physiological response, although more coaches now have access to blood lactate testing.

5. Volume (km): During the taper the volume of sessions is reduced relative to the levels achieved earlier in the preparation (endurance phase). By the final 14 days of the preparation, the volume of sessions should be in the range of 2-5km. This will depend on the coaches and swimmers requirements, and the type of session being planned. For sessions with some quality training, it will be necessary to swim a full 4km to accommodate the warm-up, main set, supplementary sets and swim downs. For shorter recovery (or where some short sprints are undertaken) it should be possible to complete all the necessary swimming in around 3km.

6. Weekly Vol. (km) and 7. Total (km): The final two weeks shown in this model taper have volumes of 36km and 24km for a (neat) total of 60km. This should be well within the capabilities of well-trained national level swimmers. Junior swimmers or those coming off an incomplete preparation may need to reduce this a little more. The focus during the taper is on the speed of swimming rather than the distance covered in training. However, it is important to support the high intensity sprint work with some low to moderate intensity aerobic training. Whilst some coaches and swimmers point to successes with the so-called "drop dead" taper, where the training volume is cut right back to just leave the sprint work, most elite coaches would recommend a more balanced approach right up to the day of competition.

8. Key Sets: As a general guide, a list of sets that may be used be on some important days of the 14-day taper, is presented. Note that the sequence of main sets is for an increase in intensity and speed in each three-day microcycle (microcycles 1, 2 and 3). This is known as a descending sequence, which is one popular method of planning. The reverse of this, where the intensity and speed decreases, is known as an ascending sequence.

In the same fashion as the reduction in the weekly and session volume, it is normal practice to reduce the volume of individual training sets. This process begins some 4-6 weeks before the meet. By the time of the taper in the last few weeks, the volume of sets will also be reduced by 50-75%. For example, main sets that were 2400-3000m in length during the volume and endurance phases should be reduced to around 800-1200m.

It is important to focus on speed during the taper. For most swimming events, this means the utilisation of short maximal effort sprints from 15-50m, combined with some pace 50's and pace 100's at l00-400m race speed. These efforts can be undertaken with either a dive or push start. Times should be recorded and compared with known competitive times and splits. Measurement of stroke rate and stroke counts is also useful. This process is being assisted by the computerised competitive analysis undertaken at the major meets by Dr. Bruce Mason of the Australian Institute of Sport, which documents the stroke patterns during competition.

The taper period often includes some "broken" swimming. This is a popular method of training involves the inclusion of very short rest periods into a maximal effort race distance swim … e.g. for a 200m swimmer this may be done as 4x50m with 10 seconds rest after each 50m, or 2x50m broken for 10 seconds at the 50m for a 100m swimmer. The total time for such work must be faster than normal race pace for effective training. It is also very valuable to conduct some time trials over race distance, as this is, of course, the most specific preparation that a swimmer can perform.

A FINAL COMMENT

The taper is an important part of the preparation. Like training in general, there is no single program that will suit every swimmer. The features of a taper discussed here may assist you in evaluating your own program and give you some ideas for the 1995/96 summer season.

TABLE 1 – A MODEL-14 DAY TAPER

1 Day	14	13	12	11	10	9	8	7	6	5	4	3	2	1
2 Micro Cycle	1				2				3			4		
3 AM														
4 Type	[1]	[1.2]	[2]	Rest	[1]	[2]	[3]	Rest	[2]	[3]	[4]	[1.5]	[1.5]	[1.5]
5 Vol (km)	4	4	4	Day	4	4	3	Day	4	3	4	3	2	2
6 Week (km)	4	12	19		23	30	36		40	10	14	20	22	24
3 PM														
4 Type	[1.5]	[1.5]			[1.5]	[1.5]			[1.5]		[1]			
5 Vol (km)	4	3			3	3			3		3			
6 Week (km)	8	15	19		26	33	36		7	10	17	20	22	24
7 Total (km)	8	15	19		26	33	36		43	46	53	56	58	60
8 Key Sets	5 x 400 [1] 8 x 200 [1.2] 2 x 200 Broken [2]				3 x 800 [1] 12 x 100 [2] 200 Time Trial [3]				5 x 200 [1] 8 x 100 [2] 8 x 50 [3] 1 x 400 Bkn [2] 1 x 200 Bkn [3] 1 x 100 Bkn [4]			4 x 25 [5] 2 x 25 [5] 2 x 25 [5]		

Key: 1 = aerobic, 2 = threshold, 3 = Max VO_2, 4 = lactate tolerance, 5 = short sprint

TRAINING FOR MIDDLE-DISTANCE & DISTANCE SWIMMING EVENTS

The middle distance (400m) and distance (800m and 1500m) events require a highly developed level of endurance fitness. Historically, Australia has produced many champion distance swimmers. This trend continues with our successes in the Men's 1500m Freestyle and the Women's 800m Freestyle events at the international level in the last few years. Despite the great work of our leading swimmers, there is some concern about the next generation of-distance swimmers coming through. After the top two or three male and female distance swimmers, the standard drops away fairly quickly. The depth in these events appears to be considerably lower than in some of the form stroke and sprint events where the number of competitors in contention is comparatively much greater.

Inspection of the current world rankings shows that Australia is in good shape in the distance events. In the Men's events we have swimmers ranked at (1) Daniel Kowalski 7:50.28, (2) Kieren Perkins 7:50.80, (3) Glen Housman 7:54.66 and (21) Daniel Bates 8:12.10 for the 800m Freestyle, and (1) Kieren Perkins 14:58.92, (2) Daniel Kowalski 15:02.20, (9) Glen Housman 15:20.32 and (34) David Bates 15:35.91 for the 1500m Freestyle. For the women we have swimmers ranked at (1) Hayley Lewis 8:28.78, (19) Stacey Gartrell 8:42.05, (26) Chloe Flutter 8:45.95 and (48) Christina Thorpe 8:49.56 in 800m Freestyle, and (1) Hayley Lewis 16: 14.71, (8) Stacey Gartrell 16:28.89, (12) Simone Cotter 16:41.17, (13) Christina Thorpe 16:41.69, and (20) Chloe Flutter 16:50.98 in the 1500m Freestyle. On face value, this is a good situation; however we must not rest on our laurels. Success will not be a formality without a substantial and ongoing individual and team effort around Australia. It can take a whole generation of swimmers to regain quality and depth in particular events: witness the Men's Sprint Freestyle and Backstroke over the last few years.

Around the world there has been a move away from distance to shorter sprint-oriented events in the last few years. The times for female swimmers [400-1500m Freestyle], in particular, have plateaued over the last few years. We (and the rest of the world) have not progressed forward from days of Tracey Wickham and Michelle Ford (Janet Evans being the exception) and this is over 15 years ago. These events must surely be ripe for some young women to come in and take them to a new level in the same manner that Kieren Perkins has done in the Men's events. Our history, current successes and work-oriented training programs have stood us in good stead, however we must be careful that we do not let our hard-earned competitive edge slip away. Endurance work is the comer stone of the training program for the 800/1500m swimmer, and as has been discussed in previous articles, an important aspect of the preparation of all swimmers even the sprinters. I often think of the words of Forbes Carlile … "speed through endurance".

In simple terms, endurance fitness can be divided, depending on your terminology, into two categories … general endurance and specific endurance. General endurance refers to the capacity to perform submaximal physical activity, like swimming, running, walking, or manual tasks, over an extended period of time. This type of fitness is necessary for the efficient development of specific endurance fitness and then higher quality anaerobic and speed capacities. Specific endurance refers to the capacity to perform higher quality muscular work within the specific time frame of competitive events. For middle-distance and distance swimmers this means a maximal effort over 4-16 minutes for 400m to 1500m events.

The training of endurance fitness is based on two related principles … an understanding of the energy systems that underpin the various training sets, and utilisation of some system to classify different sessions that you use in your program. These two principles must be addressed correctly for effective endurance training and a higher level of competitive performance. All coaches should have a basic understanding of the continuum of energy sources that contribute to different swimming events; these aspects are covered in the Level 2 Coaching Accreditation Course. In terms of endurance swimming (and any endurance activity for that matter) the energy requirements (read training zones) can be divided into three areas…

1. Low-intensity aerobic endurance
2. Aerobic/anaerobic endurance (the so-called 'anaerobic threshold' or 'threshold')
3. Anaerobic endurance

At various times, each area will need to be addressed in the training program.

To develop low-intensity aerobic endurance, a swimmer's training speed must exceed the so-called 'aerobic threshold' (heart rate around 120-140bpm or 60-80 beats below maximum HR) but not the 'anaerobic threshold' (HR around 160-170bpm or 30-40 beats below maximum HR). All swimming should be conducted with 'good' technique and one often sees low-intensity aerobic work (recovery swimming and warm downs) being undertaken with 'poor technique'. This type of work will improve the ability to utilise fat as an energy substrate and limit the excessive use of carbohydrate. Don't neglect the technique of your swimmer. Gennadi Touretski often says that the slowest speed one should swim is the pace where a swimmer can still hold good technique: any slower would see a mechanically inefficient technique.

To develop the anaerobic threshold, a certain proportion of training must be undertaken at or close to anaerobic threshold speed (determined by the 5x200m Step Test, the 2000m test, or by the assessment of the coach). The term 'anaerobic endurance' is a slight misnomer in that swimming at this speed is dependent on the maximal capacity of aerobic pathways … i.e. the VO_2max), and the capacity of aerobic and anaerobic pathways to tolerate fatigue under conditions of insufficient oxygen supply and/or accelerating glycolytic flux. The key is to develop simultaneously the underlying physiological capacity … i.e. aerobic threshold (A1), anaerobic threshold (AT), maximal oxygen uptake (VO_2max)) and the respective swimming velocity (time (seconds) per 100m) in each of these areas. It is the latter aspect, the swimming speed at each physiological capacity … i.e. functional utilisation) that is correlated most highly with performance. The following example illustrates this point: three female distance swimmers may have maximal oxygen uptakes of 3.2, 3.8 and 4.4 litres per minute. However the determining factor is the speed at VO_2max, and a swimmer with a VO_2max of 3.8 litres per min^{-1} who can hold 64.0seconds per 100m (for a predicted 400m time of 4x64 seconds = 4:16.0 400m time) should beat her counterpart with a higher VO_2max of 4.4 litres per minute but who can only hold 65.0seconds per 100m at this level (predicted time 4x65 seconds = 4:20.0 400m time).

In the last year or so at the AIS we have refined our classification system of training. We have rationalised the old seven point system into an easier to use five point system … [1] Aerobic, [2] Threshold, [3] Maximal Oxygen Uptake, [4] Lactate Tolerance and [5] Sprint. Using the 5-point system, it follows that levels [1] and [2] are used predominantly for continuous swimming or longer slower intervals with short to very short rest periods … e.g. 3x1000m on 14:00, 8x400m on 5:00, or 15x200m with a 10seconds rest interval. The higher intensity levels [3], [4] and [5] involve interval training with the combination of number, distance, intensity, type and rest periods being manipulated as required. This issue has been addressed in detail in a previous issue of Australian Swim Coach.

The development of endurance fitness should continue over the entire season or preparation. There is, of course, a particular emphasis on endurance during the initial conditioning phase in the first few weeks. However, endurance training should be maintained and continued right through the preparation up to the major competition. This applies to all swimmers and is, obviously, essential for middle-distance and distance swimmers. All three levels [1], [2] and [3] should be trained through the middle and final parts of the preparation. Physiological principles of recovery should be considered during high volume and intensity phases. Whilst ATP-PC energy stores can be replenished within a few minutes, and excess lactate removed within half an hour, it may take up to 48 hours to replace glycogen within the fast-twitch muscle fibres. This aspect of glycogen replacement and swimming training was dealt with by Dr Bob Treffene in his recent article.

One point that should be made is that the specificity of energy supply and consumption during a particular swimming event doesn't necessarily determine that training programs follow the same percentage breakdown. Whilst most experienced coaches are intuitively aware of this point, it is worthwhile for everyone involved in swimming, coaches, swimmers, parents, officials and sports scientists, to consider and evaluate their position on this issue. Simple inspection of most elite programs would reveal that more than 80% of swimming training is conducted at levels [1-3] and only a small percentage is performed at the higher intensities [4, 5]. This is even more pronounced for distance swimmers who must undertake larger volumes in total, and larger volumes of specific aerobic work, in their programs.

The total weekly training volume (km) is the most common means of quantifying the training load. Simple analysis shows that elite swimmers average somewhere around 40-50km of swimming per week through the training year. Endurance swimmers average about 20-50% more and weekly volumes may peak at 90-100km. However this is after a long build-up and such volumes should not be sustained for any extended period of time. It is far better to reduce the volume to around 60-80km per week and do it with good technique and speed. This is particularly important for younger swimmers who should concentrate on developing good technique in all the strokes within a balanced program of endurance and speed. There are too many young swimmers who have to endure programs of excessive volume and intensity. Many coaches acknowledge that overtraining is a problem, but apparently not in their program. Another important point is that volume should be increased gradually … one rule of thumb is to increase the load by 5-15% per week for both younger (5-10km/week) and older (10-15km/week) swimmers.

In one sense, training for endurance events is relatively simple compared to the complex demands of sprint and middle-distance events. The former simply requires building endurance (and associated speed) over a period of time, while the latter necessitates the integration of endurance, power and maximal speed. The notion that endurance swimmers just need loads of work is not far from the truth, but the secret of the best distance coaches is to do this with a high degree of technical precision and the lowest degree of undue stress. The best distance swimmers are the thoroughbreds of the pool, but if you don't manage them carefully, you could end up with a stable of draught horses.

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COACH, I CAN'T GET MY HEART UP (OR DOWN) … THE PHYSIOLOGY OF MEASURING HEART RATES

Introduction

The use of heart rate monitoring in swimming is almost universal in programs of all levels. The measurement of heart rate during swimming training is used for two main purposes … firstly, to control the training load (intensity) through the session … and secondly, to indicate changes in submaximal and maximal aerobic fitness levels during the season. A third application is the measurement of resting heart rate to indicate the current stage of the adaptation process. When combined with performances measures such as time, split times, stroke rate, stroke count, stroke mechanics (technique) and other physiological measures such as blood lactate, heart rate is a very useful monitoring tool for the coach. A key consideration, however, is that heart rate or any other measure, should not be used alone and can only be interpreted correctly in light of the other variables.

Training Zones

The control and prescription of training speeds by heart rate is the biggest application of heart rate testing in swimming. There are many different classification systems used by leading swimming coaches and sports scientists in Australia and around the world, although the validity of some has been questioned. The system used by the Australian Institute of Sport has been discussed previously in *Australian Swim Coach*. In recent years, many of the classification systems have been revised in order to accommodate individual differences in maximum heart rate levels. In their original form, the systems called for specific training sets to be defined by distinct levels of heart rate … e.g. low-intensity aerobic (A1) 120-140bpm, moderate-intensity aerobic (A2) 140-160bpm, anaerobic threshold (AT) 160-170bpm, and maximal oxygen uptake (VO_2max) 180-190bpm. These training zones were developed using a model maximum heart rate of 200bpm – for many young swimmers this is reasonably accurate, however for others these zones will lead to a significant under-or-over estimation of the appropriate training heart rate and speed. To overcome this problem, many coaches now give their training heart rates as a fixed increment from maximal heart rate for each individual swimmer – i.e. A1 (60-80bpm below max), A2 (50-60bpm below max), AT (30-40bpm below max), and VO_2max (10-20bpm below max).

For a swimmer with a maximum heart rate of 205bpm, the zones would be (in bpm)…

A1	A2	AT	MV02
125-145	145-165	165-175	185+

For a swimmer with a maximum heart rate of 185bpm the zones would be (in bpm)…

A1	A2	AT	MV02
105-125	125-145	145-155	165+

Finally, for short sprint work (25m and 50m) it is more appropriate to focus on the swimming and split times (and stroke mechanics) rather than the associated heart rates. For this type of work, the heart rate monitor should be replaced with the stopwatch. In this situation it is more important to know that a swimmer can hold, for example, 31.0 seconds for 50m Butterfly with a stroke count of 20 and a stroke rate of 38 strokes per minute, than the fact that the heart rate was, say 155bpm.

How to Measure Heart Rate

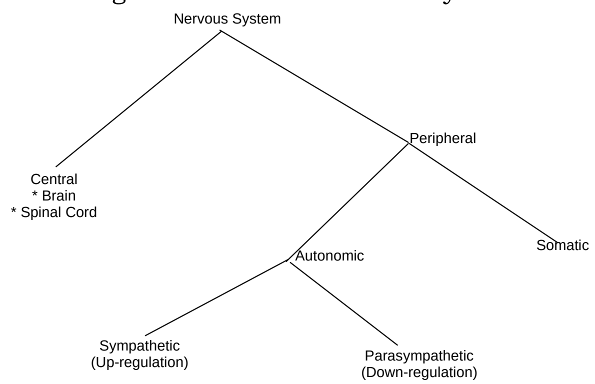
By far the most common way to measure heart rate has been the self-reported manual palpation (counting) of heart rate by swimmers over a fixed duration (most commonly 10 seconds). Whilst this is the most practical method it is also the most inaccurate. With correct instruction and some experience, swimmers can be become reasonably proficient and accurate with this technique. The older swimmer should be able to calculate his or her post-exercise heart rate with an accuracy of $\pm$6 beats per minute. This can give you a reasonable indication as to the relative cardiovascular response to the training set. Remember you are trying to have the swimmers count the number of beats in a given 10 second period (using the pace clock) and this needs to occur as soon as the swimmer touches the wall. The heart rate will start to recover to a lower level within a few seconds of rest. This approach should be accurate enough to identify which training zone the swimmer is in, but more sophisticated measures would be required to indicate small changes in the relationship between heart rate and swimming speed.

At the elite level, the most common method for measuring heart rate has been the use of the Precision Heart Rate Monitor, designed and built by Dr Bob Treffene in Brisbane. Many coaches will have used or seen one of these hand-held units in action. In the hands of a skilled operator … i.e. coach or scientist … they give good service and are particularly useful when working with large squads. The monitors need to be well maintained in order to sustain their useful working life. Most coaches will have also seen the Sports Tester-type heart rate monitor, which attaches to the chest and transmits a signal to a wristwatch receiver. These do work reasonably well but with elite swimmers undertaking fairly dynamic work … e.g. dive starts, tumble turns … it is a difficult to keep them in a fixed position on the body and to obtain a clear and reliable signal. A number of other devices have been developed to measure heart rate in swimmers but these tend to be limited in two key areas … a lack of accuracy at higher heart rates and a lack of durability in the rough and tumble of the pool environment.

Anatomy & Physiology of the Cardiovascular & Nervous Systems

To understand why heart rate can vary with fitness and fatigue levels it is necessary to examine some basic anatomy and physiology of the nervous system. The nervous system plays a major role in regulating the function of all the body's systems including the cardiovascular system. The heart rate is, of course, the most identifiable indicator of the activity of the cardiovascular system and a major contributor to the metabolic (power) output of a swimmer. In basic terms the nervous system is divided into two parts … the central nervous system (brain and spinal cord) and the peripheral nervous system (nerves that connect the different organs and tissues with the central nervous system) (see Figure 1).

Figure 1
Organisation of the nervous system



The peripheral nervous system is comprised of the somatic and autonomic components, with the autonomic nervous system that innervates (serves) the skeletal musculature being further divided into two branches … **sympathetic** and **parasympathetic**. These branches often produce opposite physiological effects. During strenuous exercise the sympathetic branch is stimulated, leading to release of adrenaline, increased heart rate, increased blood flow to muscles and eventually increased rates of metabolism and muscular contraction. This sympathetic activity remains elevated for some time after exercise. Problems may arise when sympathetic activity is chronically elevated during prolonged and intense training, particularly where recovery processes are not adequately restoring physiological equilibrium. On the other hand, one of the adaptations to training is for a reduction in sympathetic activity during training at a given speed. This is part of the explanation for the observation that heart rate is lower at submaximal speed after a successful period of training.

Why can't I get my Heart Rate down?

(i) At Rest

The measurement of resting heart rate is one of the most well known methods to monitor training adaptation. An increase in resting heart rate may be evidence of elevated sympathetic activity … e.g. a swimmer whose resting heart rate is normally around 50bpm … e.g. 48-52bpm … may be experiencing some sympathetic stimulation if the levels are sustained at 55-60bpm over a period of a few days. A single occurrence of an elevated resting heart rate may be attributable to any one of a number of reasons, and action only needs to be taken if the rise is evident over several successive days. Many swimmers use daily training logs and it is good practice for them to record measures such as resting heart rate as well as the length and quality of sleep. The resting heart rate should be taken first thing in the morning and before the swimmer rises from his or her bed.

(ii) During Training

Experience shows that the swimmer unable to control their heart rate during steady state aerobic work needs further aerobic training. In simple terms, the activity of the sympathetic nervous system, and the aerobic and cardiovascular fitness of the swimmer, need to be improved. Physiological testing has shown that the heart rate-swimming speed relationship is a good indicator of overall cardiovascular fitness. If control of heart rate is lost during so-called steady state or even paced swimming and a consistent elevation is observed … i.e. an upward drift … there will be a concomitant transference from fat to carbohydrate metabolism. An example of this would be a set such as 12x200m Freestyle/Backstroke holding 2:40 with HR of 150bpm on 3:00 cycle…

Time: 2:40 2:40 2:41 2:39 2:40 2:42 2:38 2:40 2:41 2:41 2:42 2:38
HR: 137 145 148 151 152 156 159 157 162 166 164 170

One of the goals of low to moderate intensity aerobic work is to improve fat metabolism and this will not be achieved if higher heart rates (and a greater contribution of carbohydrates to energy supply) is evident in aerobic work. The key to improving heart rate and metabolic control is a program of carefully monitored aerobic intervals on short to moderate rest. An example of this work would be a set such as 6x200m Freestyle holding 2:30 pace at a heart rate of 150bpm on a cycle of 3:00. Swimmers should be encouraged to strictly maintain the required heart rate (in this case 150±5bpm … i.e. a range from 145-155bpm) and the required time (in this case 2:30). Measurement of blood lactate and blood glucose levels in this situation is useful to determine the extent of metabolic control. After a few sessions of this type, an improvement in the control of aerobic work should be observed. One feature of better (and usually older and more mature) swimmers is their ability to undertake aerobic work at the appropriate intensity and pace. Younger and less disciplined swimmers often do not maintain good control of swimming times and intensities. Starting too fast early and not finishing on strongly, or swimming descending sets … i.e. where the speed gets faster with each repeat … when a steady pace was called for, are common mistakes.

Why can't I get my Heart Rate up?

The inability of a swimmer to get his or her heart rate up during training may be evidence of a disturbance or maladaptation in the parasympathetic nervous system. This is much less common than a **training-induced** sympathetic disturbance. The parasympathetic nervous system will tend to take over … i.e. compensate for … from the sympathetic system if the latter is exhausted by excessive training loads and/or inadequate recovery. A swimmer may sometimes exhibit the following signs during prolonged intense training: fatigue, lethargy, inability to maintain previous training levels, decreased body weight and, most notably with a parasympathetic disturbance, a decreased heart rate both at rest and during submaximal work (see Table 1). One of the most common signs is an extremely rapid return of the heart rate towards resting levels immediately upon the cessation of work. The lower heart rate can sometimes be mistaken for an improvement in fitness, but the full clinical picture (as the doctors would say) is one of deterioration rather than progress. Whilst we all strive for lower heart rates at a given submaximal speed, the combination of lower heart rates and other classical symptoms suggest a disturbance in the nervous system.

Every swimmer and coach knows that a lack of fitness is highlighted by an increase in submaximal heart rates. At the same low to moderate speeds, a swimmer's heart rate will be lower as they get fitter. Or expressed another way, they can swim faster at the same heart rate. Physiologists use heart rate in this way to track changes in general cardiovascular fitness with standard test sets such as the 5x200m or 10x100m incremental step tests.

Table 1: Comparison of the signs and symptoms of sympathetic and parasympathetic nervous system disturbance in athletes undertaking prolonged and/or intensive training

Sympathetic Disturbance	Parasympathetic Disturbance
Increased resting heart rate	Decreased resting and exercise heart rates
Increased resting blood pressure	Normal blood pressure
Normal recovery of heart rate after exercise	Rapid recovery of heart rate after exercise
Decreased body weight	Normal body weight
Poor appetite	Normal appetite
Sleep disturbance	Sleep patterns may be normal
Irritable and emotional	Depressed and apathetic
	Decreased ability to metabolise glycogen
Rapid recovery (days-weeks)	Decreased blood lactate levels
	Decreased physical work capacity
	Slower recovery (weeks-months)

What are 'Heart Rate' Sets?

Within the culture of Australian swimming, particularly at the elite level, the term 'heart rate set' is well known to most coaches. Coined by leading Australian physiologist 'Heart Rate Bob' Treffene, the term 'heart rate set' refers to a high intensity aerobic set designed to improve endurance fitness including the so-called maximal oxygen uptake (VO_2max). Many coaches would be familiar with the sets of 2000m to 3000m (30 minutes work) at a pace that elicits a heart rate 10 beats from maximum level … e.g. 20x100m Butterfly/Backstroke aiming for 185bpm on a 1:45 cycle (for a swimmer with a maximum heart rate of 195bpm). These sets when properly designed and monitored are a very effective way to improve aerobic fitness. Given their high intensity and associated stress, they need to be introduced and developed gradually in order to avoid excessive fatigue. A maximum of two or three heart rate sets per week is recommended for well-conditioned swimmers.

What do I do if the Heart Rate is unexpectedly up or down?

The easy answer to this question is **MORE RECOVERY**. Irrespective of the origin of the disturbance in the nervous system … i.e. sympathetic or parasympathetic … the appropriate course of action is to review and implement appropriate recovery practices. In terms of planning, this may mean the need for a reduction in volume and intensity of training, an increase in the absolute and/or relative volume of low- to moderate-intensity aerobic recovery work. If the majority of swimmers in the squad are breaking down or not responding to training it is prudent to review the short- and medium-term training plans. If a quality session is planned it is a good idea to change this to a low- to moderate-intensity aerobic workout. In more severe cases of fatigue it may be more appropriate to skip the session altogether. The other area to be considered is the aggressive use of recovery modalities such as massage, hot or cold therapies with showers, spas and plunge pools. Replacement of fluids and adequate nutrition is also an essential component of the recovery process.

Summary

1. The use of heart rate is almost universal within swimming programs at all levels and is an effective tool to prescribe training loads and monitor changes in aerobic fitness levels.
2. Heart rate is most easily measured by swimmers themselves with self-reported palpitation at the neck or chest. Elite coaches commonly use the Precision Heart Rate Monitor to assess the cardiovascular demands of particular training sets.
3. The regulation of heart rate is governed by the sympathetic and parasympathetic branches of the autonomic nervous system. With sympathetic disturbance, heart rates are normally higher, whilst disturbance of the parasympathetic system is characterised by lower heart rates.
4. A lack of fitness will be evident with higher heart rates at submaximal speeds. Further attention to training in well-controlled moderate-intensity aerobic sets should improve cardiovascular fitness.
5. Over stimulation of the sympathetic nervous system can lead to the physiological and psychological signs and symptoms of overtraining … e.g. an increased resting heart rate and/or higher heart rates during submaximal work.
6. An exhausted sympathetic nervous system may result in the parasympathetic system becoming dominant. This may lead to unusual depression of the heart rate at rest and during exercise, with a concomitant reduction in physical work capacity.
7. An understanding of the physiological responses to acute work and prolonged training will assist the coach in interpreting heart rate measurements and ultimately in optimising the training program.
8. The term 'heart rate set' refers to a high intensity maximal aerobic (VO_2max) set where the intensity of the set is controlled by heart rate (and swimming times). Swimmers are encouraged to swim at the appropriate pace necessary to elevate and hold the post-exercise heart rate at level that is approximately 10 beats below each individual swimmers maximum heart rate.
9. A disturbance in the sympathetic and/or parasympathetic nervous system as indicated by heart rate responses at rest or during exercise should be addressed immediately. Training programs may need to be adjusted and recovery programs emphasised. The timing of the return to full training should be determined on a case-by-case basis.

THE PHYSIOLOGICAL BASIS OF FATIGUE

Introduction

In one sense, competitive swimming is a battle against fatigue on two fronts. Firstly, during competition, it is normally a race between getting to the wall before the onset of debilitating fatigue – the experience of one US swimmer being overtaken in the last 10m is well known to all coaches. All swimmers can swim 25m faster than 100m race pace – unfortunately only the best swimmers can maintain that pace or something near to it over the full race distance. Secondly, the substantial training loads required to support high levels of competitive performance, are themselves are a battle against fatigue. Endurance can be defined as the ability to resist or delay the onset of fatigue – with fatigue itself defined as the loss of force production or power output.

What are the physiological causes of fatigue? Many of the causes have been identified and have received considerable publicity in both the scientific and sporting communities. This is particularly evident in relation to the so-called metabolic causes of fatigue such as depletion of fuels (e.g. muscle glycogen) and the accumulation of metabolic end products (e.g. lactate). These concepts are familiar to most coaches. Whilst experience, scientific research and routine monitoring have shown repeatedly that these metabolic factors can be limiting factors of performance, it is apparent that other factors influence the ability to sustain a given power output (swimming speed). These factors include: the need to maintain homeostasis of fluid and electrolyte levels in the general circulation and within skeletal muscles, regulatory mechanisms in skeletal muscle, neuromuscular fatigue and the often neglected concept of Neuro psychophysiology (will power).

Metabolic Causes of Fatigue

The carbohydrate and muscle glycogen story is well known to most coaches. The body's reserves of carbohydrates (blood glucose, liver glycogen and muscle glycogen) are relatively limited and will be depleted rapidly during long and/or intensive training sessions. The training and competitive performance of a glycogen depleted swimmer will be significantly limited. Dr David Costill, a leading US Sports Scientist, has conducted a number of studies, which have highlighted the deleterious impact of successive days of swimming training on muscle glycogen levels. Fortunately, the depletion of glycogen reserves can be reversed rapidly with an adequate dietary intake of carbohydrate and the use of high-energy carbohydrate sports drinks during and after training. These issues have been dealt with in detail by Dr Louise Burke in previous issues of *Australian Swim Coach.*

Metabolic End Products

One of the main end products of the anaerobic metabolism of glycogen is lactic acid (the so-called lactic acid energy system). This system is an important contributor to the energy requirements of most competitive swimming races. Increased dependence on this energy pathway will lead to an accumulation of lactic acid within the muscle and eventually the general circulation (bloodstream) – the accumulation occurs when the production rate of lactic acid exceeds the removal rate. The lactic acid produced dissociates (splits) into the lactate anion and the hydrogen ion. Excessive accumulation of the hydrogen ion – beyond a level which can be adequately handled by buffering systems within the muscle and circulation – will lead to a metabolic acidosis indicated by a reduction in muscle and blood pH. A significant drop in the intramuscular pH will severely limit muscular contraction, as a number of rate limiting enzymes are pH sensitive. This sequence of events has been studied for many years and is well understood by scientists. This work has also led to the examination of the potential benefits of supplements such as bicarbonate and creatine phosphate, which increase the body's natural buffering capacity, limit the deleterious effects of lactic acid accumulation and thus sustain (or improve) swimming performance.

Non-Metabolic Factors

The view that the physiological causes of fatigue are simply metabolic in origin may have limited our understanding of the training process of elite swimmers. Attributing fatigue exclusively to depletion of carbohydrates and/or the accumulation of lactate is an oversimplification. Whilst it is known that muscular fatigue is largely influenced by these metabolic processes, there is evidence showing dissociation between a reduction in power output and changes in metabolic variables such as ATP turnover and lactic acid accumulation. Counsilman and Counsilman (1993) point out that the ability to resist fatigue, delay its onset or even increase work output as the swimmer fatigues, involves a complex sequence of physiological events of which energy depletion and waste product accumulation constitute only one link. Most coaches will have observed the phenomena where a swimmer at the end of long hard quality set is able to produce his or her fastest repeat, when presumably, they are becoming quite fatigued. Although some swimmers may **SAVE** themselves for a big final effort, it is apparent that other swimmers who have been right at the limit are able to find something extra for the finish.

Neuro psychophysiology – The Importance of Will Power

The answer to this paradox is thought to lie in the relationship between neural, physiological and psychological factors. Study of these relationships has led to the emergence of a new scientific field of study – Neuro psychophysiology and various cousins such as Neuro psycho immunology. Scientists contend that the ability to combine and optimise the various parts of this pathway – from the central nervous system, to the peripheral nerves, and finally the control of skeletal muscle contraction – may offer an explanation for these phenomena. This concept might also explain the observation that it is always difficult to swim a really fast time trial in training, and it requires a high-level competition for swimmers to perform at or near their best.

It appears that the extra sense of urgency, motivation and/or psychological pressure of high-level competition is the catalyst for the full activation of this pathway. To win an Olympic Gold Medal the coach and swimmer must achieve something special. The willpower to sustain intense training over many months and the willpower to beat all opponents to the wall during competition may be one difference between good and great swimmers. The question is how can the psychophysiological pathway be improved or controlled so that it is optimised at the right time? The answer or indeed the parameters to this question are unknown at present. What is clear is that coaches need to be aware of both the physiological and psychological development of their swimmers. If a coach can develop the skills to master and overcome physiological and psychophysiological factors of fatigue in their swimmers in training, the probability of success in competition should rise accordingly. The ability to harness this potential and have a swimmer **swim above themselves** is the key to international success. Is this one of the secrets of the great Australian swimming coaches … the motivators such as Don Talbot, Laurie Lawrence and Bill Sweetenham, and the cajolers such as Forbes Carlile, John Carew, Terry Gathercole and Joe King?

HOW TO MONITOR BODY COMPOSITION

One of the most frequently asked questions by coaches is the measurement of body fat (skinfold testing). Skinfold testing is used to monitor body composition and provide an indirect assessment of the proportions of lean body mass (bone, muscle, connective tissue, etc.) and fat mass. It is generally accepted that body composition is one of the factors that contributes to performance. The science of measuring body composition is known as anthropometry. This article deals with the some of the issues relating to skinfold testing and provides a description of how skinfolds are measured. The information is provided in general terms and should not be considered as a definitive or scientific guide to the measurement of skinfolds.

How important are skinfolds to performance? This is quite a difficult question to answer. My initial response to coaches and swimmers is that our experience shows that body fat is one of the important factors that contribute to performance, but not the only one. We all know of swimmers who have been successful at all levels of swimming, even at the international level, with body fat that was or could have been above desired levels. Having skinfolds under control may provide a small edge that could potentially be the difference that separates the winners, placegetters and also fans.

What is the optimal body fat (skinfolds) level for older age group and senior swimmers? Again this is a difficult question to answer and there is considerable individual variation between swimmers. My approach is to provide, initially, some general guidelines for coaches and swimmers based on well-established levels for elite male and female swimmers.

When skinfold testing is repeated for a given individual, it is more appropriate to zone in each swimmers individual sum of skinfolds. After skinfolds have been measured several times over a season, it is then possible to establish target levels for each individual swimmer. This is the way that we have worked with the National Team and Australian Institute of Sport swimmers.

An important concept in this area is the relationship between body fat and body drag. Body drag is defined as the amount of resistance that the body encounters while moving through the water, and is influenced by body size, the speed of swimming, buoyancy and other mechanical factors. Our concern here is the effect of body size and buoyancy on drag and performance. Like many factors, there is considerable individual variation in the relationship between body fat and performance. Above a certain individual level, an increase in body fat will be deleterious to performance due to increased body drag. Although increased body fat is likely to enhance buoyancy, the increase in body drag will offset any advantage resulting from improved buoyancy. The two other key factors that influence this relationship are gender and distance of the event. Clearly, females carry more fat than males as a biological requirement, and distance swimmers carry more than sprint swimmers. The higher body fat levels of ultra-endurance (long distance) swimmers is obvious to all onlookers.

Whilst the measurement of skinfolds has largely been left to the sport scientists it is a fairly easy technique to learn and one that can be mastered with some practice. The only equipment required is a good Set of skinfold callipers (approx $350) and an accurate set of scales (battery operated or mains power that measure to 0.1kg divisions) (approx $250). Simple bathroom scales are a lot cheaper but are too variable in their readings. Although this is a considerable outlay, the equipment should, if used properly and well looked after, last many years. In the last year, a number of accredited courses have been conducted to teach interested individuals the basic skills of anthropometry … i.e. the measurement of body dimensions … to standards set by the International Society for the Advancement of Kinanthropometry (ISAK). The Level 1 course would be suitable for coaches interested in learning these techniques. Contact the Institute/Academy of Sport in your State for further details.

I have, with the assistance of Dr. Louise Burke, measured the body composition of all National Team swimmers since 1987. Table 1 shows the mean height, body mass and sum of skinfold levels for our elite swimmers in this period. Based on these results, we can advise coaches and swimmers of the general guidelines that can be applied. It must be re-emphasised that these are guidelines only and the far better approach is to work on each swimmer's individual level. Each swimmer has a record sheet of their results collected over time. This summary is made available to the swimmer, his or her coach, and when appropriate, the National Head Coach. Confidentiality is important, particularly in the sensitive area of body weight and skinfolds, and scientists and coaches must respect this at all times.

Table 1: Height, weight and sum of skinfolds values for elite Australian swimmers in the period 1988-1994 (8 sites for males, 7 sites for females)

	Males	Females
Height (cm)	187.0±6.0	172.9±4.0
Weight (kg)	81.8±7.0	64.8±6.1
Skinfolds (mm)	52.5±9.7	63.3±11.4

To assess body composition, three measures are normally taken: height (cm), weight (or more correctly mass) (kg), and sum of skinfolds (mm). The sum of skinfolds is the total of all the different sites measured. The practice of converting the sum into a body fat percentage is now largely out of favour around the world, although it is still widely used in the USA. It is important to also measure weight with skinfolds. The body weight is divided into two parts (or components): the fat mass and the lean body mass. By measuring skinfolds and body mass it is possible to obtain an indirect estimation of the change in both components. If body weight and skinfold both increase, then it is likely that the increased weight is due to extra body fat. If body weight increases and skinfolds stay the same or are lower, it is likely that the extra weight is lean body mass. If body weight decreases and skinfolds stay the same or are higher, it is likely that the lean body mass has declined (i.e. a loss of skeletal muscle tissue). Your dietitian or sports scientist can be consulted here if further advice is needed.

How do we measure the skinfolds? Here is a general description of the sites and techniques used for skin-fold testing. All skinfold testing that I have conducted, for the National Team, at National Event Program camps, and at the Australian Institute of Sport, has used 8 sites for males and 7 sites for females. Some other states have used a different number of sites and at slightly different locations. There is an effort being made to standardise the sites across Australia – this should occur sometime in 1995. Again you may need to check with the Institute/Academy of Sport in your state to find out the latest.

1. Landmarking

Landmarks are identifiable skeletal points, which generally lie close to the body's surface and are the markers, which identify the exact location of the measurement site. The landmark should be identified with the left hand, usually the thumb. The eight sites most commonly used are…

1. Biceps – half way along in a vertical axis.
2. Triceps – half way along in a vertical axis.
3. Subscapular – below inferior angle of scapula in an oblique axis.
4. Mid Axilla or Iliac Crest – vertical fold in the mid-axillary line (armpit)
5. Suprailiac – above hip taken at a 45° angle.
6. Abdomen – vertical fold taken 5cm from right hand side of navel.
7. Thigh – half way along in a vertical axis.
8. Calf – vertical fold on medial (inside) aspect of calf at the level of the maximum circumference.

2. Taking the Skinfold

The skinfold should be raised using the left hand between the thumb and the index finger, picking up a fold which contains a double layer of both adipose tissue and skin and avoiding muscle tissue. The fold is held throughout the measurement. The callipers are applied to the fold at a right angle so that there is 1cm between the near edge of the fingers and the nearest edge of the calliper face. The reading of the dial is made two seconds after the complete release of the calliper trigger. In the case of large skinfolds the needle may still be moving at this point. All measurements are made on the right hand side of the body and recorded on the appropriate recording sheet.

3. Calculation of Sum of Skinfolds

Rather than using the doubly-indirect method of estimating percent body fat from body density estimates which are in turn derived from skinfold measurements, it is now common practice to report the sum of skinfolds rather than a percent body fat. The number of sites selected will depend on the history, current practice or preference of the athlete, coach or scientist. The primary aim is to use skinfolds that are in agreement with those recommended by the ISAK. In this way the axilla skinfold is likely to be phased out because it does not meet ISAK specifications. The sum of skinfolds is easily calculated by adding the skinfold for each of the sites (7 or 8 depending on how many sites were used).

One of the most important considerations is to determine what is a significant change in body mass and skinfold. We can all probably relate a story or two where a coach has "spat the dummy" when one of his or her swimmers' skinfolds or body weight has gone up marginally. Some swimmers, particularly the females, can become upset or paranoid at even the slightest increase. Scientists have now worked out statistically how much the skinfolds need to go up or down to represent a significant biological change. Studies have shown that the so-called technical error of measurement for skinfold testing is normally about 2-3mm. This represents the measurement error attributable to the tester in his or her measurement of skinfolds. Although procedures are standardised there will always be a difference between testers. By allowing a conservative margin of 2xTEM we arrive at the measurement error of approximately 5mm. (This is for fairly lean athletes – the value will be greater for individuals with higher levels of body fat). The crux of the issue is this – if the change in skinfold is greater than the measurement error … i.e. >5mm, then the observed change is likely to be a biological change (i.e. a true and significant increase or decrease in body fat). If the difference in skinfolds is less than the measurement error … i.e. <5mm, then there is no significant biological change in body fat. This is a key concept and must be explained and continually reinforced to swimmers each time their skinfolds are measured. Even experienced and mature swimmers (and coaches!) need reminding here.

There are, of course, several factors that influence body weight on a daily basis. These include … the amount and weight of clothing, the recent ingestion of food and drink, hydration status, and any recent visit (or prolonged absence!) to the toilet. These factors, either alone or in combination, may result in body weight changes of up to 2 to 3 kilograms, even in a single day. It is advisable that skinfolds be measured before any training or exercise session. Changes in the distribution of fluid between different body compartments may affect the skinfold readings. To overcome or control for some of these factors it is suggested that weight and skinfolds be measured at the same time (and in the same circumstances) for each testing session.

Having swimmers make weight and skinfold targets is often a contentious area for the swimmer and the coach. This area requires ongoing vigilance and discipline by the swimmer, coach, dietitian and scientist. Every squad in Australia will have several swimmers (mostly females but often males as well) that do not manage and/or are concerned with the body composition – diet connection. Occasionally there are underlying problems that may not be apparent to onlookers but could be causing significant psychological, medical and performance problems. We speak of course of the various eating disorders such as bulimia and anorexia nervosa. It is not the intention of this article to deal with the eating disorder story. This can be a complex, frustrating and difficult area to manage. If in doubt, medical and professional staff should be consulted. Whilst the negative side of poor body image, skinfolds and weigh-ins is often given publicity, the positive benefits of a swimmer making weight and skinfold targets should not be underestimated. Many a swimmer has left the skinfold room armed with the knowledge and confidence that they have been highly dedicated and disciplined and is on track to swim fast at the next Meet.