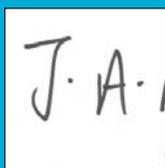


Strength
training for

SWIMMERS

A SPECIAL REPORT FROM



**PEAK
PERFORMANCE**

The research newsletter on
stamina, strength and fitness

Strength training for **SWIMMERS**

The *Peak Performance* Special Reports are published by
Electric Word plc, 67-71 Goswell Road, London, EC1V 7EP

First published in Great Britain by Electric Word plc 2002

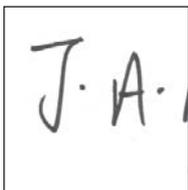
Printed by Printflow

Citybridge House, 235-245 Goswell Road, London EC1V 7JD

Publisher	Jonathan A. Pye
Editor	Bob Troop
Production Manager	Frances Peel-Yates
Designer	Charlie Thomas

The information contained in this publication is believed to be correct at the time of manufacture. Whilst care has been taken to ensure that the information is accurate, the publisher can accept no responsibility for any errors or omissions or for changes to details given.

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From the publisher

I must admit this special report surprised me a little. For one thing, it recommends that swimmers who want to get more competitive should spend less time in the pool and more time working out in the gym! Well honestly – when I was a kid dog-paddling in the water I was always told that swimming was the best exercise there was because it involved your whole body and not just your legs, like cycling or running. It just goes to show how much there is to learn if you want to improve. (And it probably explains why I'm still dog-paddling to this very day.)

Anyway, this special report has been prepared by the *Peak Performance* team of experts, including swim coaches and fitness specialists. It covers a wide range of subjects, not simply strength training, although that is a vital element in the mix. The report also looks at intensity, off-season training, weight training, equipment such as the swim bench, specific training for competition, and much else besides. As a bonus, the report also includes an instructive look at swim tapering as a method of improving performance.

I hope you enjoy the report and find it useful.

A handwritten signature in black ink that reads "J. A. Pye." The signature is written in a cursive, slightly slanted style.

Jonathan A Pye
Publisher

This strength-training programme can really boost your swim results

To optimise strength and power, competitive swimmers need to supplement their pool training with land training in the gym. For best effect, swimmers need to follow a programme of exercises that replicate their actions in the water as closely as possible.

Strength and conditioning experts around the world all agree that, for time spent in the gym to have a positive impact on your sports performance, you must ensure the exercises you perform – and the way you perform them – are related to your sporting movements in competition. For example, barbell squats involve ankle, knee and hip extensions in a vertical plane which are directly related to the mechanics of a vertical jump; thus the squat is a useful exercise for developing jump performance.

If we perform a basic analysis of the mechanics of the front crawl stroke, the main actions that produce forward propulsion through the water are:

- the ‘arm pull down’ through the water, which propels the swimmer forward and
- the ‘leg kick’, which alternates hip flexion and extension of the legs.

In addition, competitive swimming involves:

- the ‘dive start and push off turn’, which involves dynamic ankle, knee and hip extension.

When designing your strength programme, you should focus mainly on exercises related to these movements. Other exercises may use the same muscles as those involved in swimming, but only exercises which use the right muscles in a related mechanical movement will provide optimum training benefit.

A limitation of land training with weights for swimming is that the type of resistance you encounter when moving in the water is different from the resistance occurring when you move a weight through the air. In the water, the faster you pull or kick the greater the resistance applied back by the water; on land, a given weight requires a constant force to move it, regardless of the speed of movement.

Hydraulic-type resistance equipment that mimics aquatic resistance is expensive and not widely available. The best compromise when using regular equipment is to try to mimic the speed and nature of the swimming stroke. To this end, you should aim to perform the strength exercises with a smooth and constant force and select weights which allow the movement to be performed at a swimming-related speed. For example, the leg-kicking motion during front crawl is quite fast, so hip flexion and extension exercises which can be performed at a good speed would be best.

The following exercises are related to the mechanics of the front crawl stroke. For each component, the relevant exercises are described and their mechanical relationship to the stroke explained.

Arm pull down exercises

1. Cable rotational front and back pulls

Front pull. This is the mechanical equivalent to the pulling-through-the-water action in front crawl, as the hand comes diagonally across the body as it pulls down. For this exercise you need a high pulley machine with a simple handle grip.

Kneel down on one knee to the side of the machine. Take the hand nearest the pulley and grasp the handle with the hand high and slightly out to your side. Before you start the exercise make sure your back is straight, your shoulders are wide and your chin is tucked in. Pull the handle down and lower your arm across your body in a rotational movement until your hand is next to the opposite hip. Smoothly return the bar to the start position and continue, performing sets of 5-8 reps for maximum strength or 12-15 for strength endurance.

Try to keep your posture solid throughout the movement. Maintain a slight bend in the elbow as you pull, but focus your effort on the shoulder muscles only.

Rear pull. This exercise involves the opposite movement to the front pull and is useful for promoting a balanced strength about the shoulder joint. Specifically, the front pull trains the internal rotator cuff muscles and the rear pull trains the external muscles. To avoid shoulder injuries a balanced rotator cuff strength is important. For this exercise you need a low pulley machine with the simple handle grip.

Stand to the side of the machine and grasp the handle with the opposite hand. Make sure your back is straight, your shoulders wide and your chin tucked in. Start with your hand by the inside hip and fix a slight bend in the elbow. Pull the handle up and away from your body, rotating the arm up and out. Finish with the handle high and out to the side, with the palm of the hand facing forwards. Smoothly return the handle back and across to the opposite hip and continue. Again go for sets of 5-8 reps for maximum strength or 12-15 for strength endurance.

Keeping your posture solid during this exercise is quite difficult, as it is tempting to use your trunk muscles to help the rotation movement. However, you can train your core stability skills by keeping your navel pulled into your spine and relaxing your upper body so there are no additional movements apart from the arm raise and rotation.

In combination, the front and rear diagonal pull train almost every muscle in the shoulder joint and shoulder girdle. This makes them very useful exercises for any sport.

“In combination, the front and rear diagonal pull train almost every muscle in the shoulder joint and shoulder girdle.”

2. Medicine ball single arm overhead throw

This exercise develops the power of the latissimus and pectoral muscles in a functional manner for swimmers, involving a movement similar to the front crawl stroke. The aim of the throw is to improve the rate of force development in the shoulder by accelerating the arm hard to throw the ball. For this exercise you need a partner and 2-4kg ball. The small rubber

ones are best as they can be held in one hand.

Because the ball is quite heavy for one hand you will not be able to throw it far or move the arm very fast. This makes it ideal for swimming as the pull stroke is not that fast. The training effect comes from your attempts to accelerate the arm movement as fast as you can, thereby improving the power of the pull.

Lie on your back on the floor, with knees bent slightly so your lower back is comfortable. Grasp the ball in one hand with your arm up and behind your head, slightly bent at the elbow. Vigorously pull the arm up and down across your body, throwing the ball over the opposite knee. Get your partner to return the ball, and perform sets of 8-12 repetitions with each arm in turn.

Do not lift your head or pull up from the stomach as you throw. Focus on producing the power from the shoulder and pulling across the body as you do in front crawl.

3. Swiss ball body pulls

This is a 'closed kinetic chain' movement, where the moving limbs remain in contact with a fixed object – in this case the hands with the floor. Such movements are thought to be particularly functional for sports performance, so offering greater training benefits.

This exercise is performed in a horizontal prone position, with the arms pulling down under the body, matching the position and action of a swimmer in the pool.

Position yourself face down, with your lower legs on the Swiss ball and your hands on the floor supporting your weight, body parallel to the floor. This is the equivalent of a press-up position with your feet up. Slowly roll the ball up your legs while your arms extend out in front of you until you achieve a stretched position, with a straight line through your arms, shoulders, back, hips and legs. At this point your body will make a shallow angle with the floor and the ball will be positioned on your thighs. Then, keeping this perfect alignment of your body, push down through your hands into the floor and pull yourself back to the

press-up position. The ball should roll back down your legs as you do this. Perform sets of 8-12 repetitions.

The difficult part of the exercise is the pull back up. At this point you must use your stomach muscles to support your spine and focus on using a strong pull of the shoulder muscles to raise your body back to the parallel position. This exercise is not easy, but it is very beneficial for many sports, helping to develop core and shoulder strength.

Leg kick exercises

Hip extension and flexion kick

These exercises mimic the upwards and downwards phases of the swimmer's kick action, where the glutes and hamstrings extend and the hip flexors flex the leg at the hip. To perform these exercises you need a low pulley machine with an ankle strap attachment. Each leg is worked independently to increase the specificity for swimming, and the weights used should be relatively light so you can kick with good speed, as in the pool.

Hip extension. *Stand facing the low pulley machine, with the ankle strap attached to one leg. Lift this leg off the floor, taking up the slack of the cable, and place your balance solidly on the other leg. Hold onto the machine's frame with your hands to stabilise your upper body and check that your back is straight, with shoulders relaxed.*

Pull the cable back dynamically by extending the leg backwards until you feel you need to lean forwards, then bring it back in a controlled manner to the start position, retaining good posture. Continue pulling the leg back, focusing on the gluteals and hamstrings to kick back powerfully.

Hip flexion. *Stand with your back to the low pulley machine, with the ankle strap attached to one leg. Lift this leg off the floor, taking up the slack of the cable, and place your balance solidly on the other leg. Use a stick to support yourself, and check that your back is straight with your shoulders relaxed.*

Pull the cable dynamically by kicking the leg forwards. Pull the weight, using your hip flexor muscles at the top and front of

the thigh, until your leg reaches an angle of about 30° or you start to lean back. Smoothly return your leg to the start position, retaining good posture, and continue.

Perform sets of 10 reps at a fast speed and build up to sets of 20 or 30 for power endurance of this movement.

'Dive start and push-off turn' exercise

Barbell squat jumps

This exercise involves dynamic extension of the ankle, knee and hip joints and trains the calf, quadriceps and gluteal muscles to improve vertical jump performance. The vertical jump is mechanically related to the dive start and push-off turns involved in swimming: with the dive or turn, the ankle, knee and hip extension propels you forwards in the horizontal plane, while with the jump the leg extension propels you upwards in the vertical plane. Essentially, it's the same movement rotated by 90°!

‘The point of using a barbell to add weight to the squat is to help you to generate peak power.’

The point of using a barbell to add weight to the squat is to help you to generate peak power. If you perform the jump squat with body weight only, the jump will be very fast and high. With the addition of a moderate weight (about 30-40% of the 1 repetition max weight for the squat exercise), the jump will not be as high or fast, but the muscular power required to leave the ground will be maximal. This is based on the knowledge that peak power is achieved when the force used is about one third of the maximum force for that movement. Again, your goal is to attempt to achieve the fastest extension of the legs to maximise power production and training benefit. If you use 30-40% of 1 RM weight, I recommend 3-5 sets of 5 repetitions.

Stand with the barbell across the back of your shoulders. Squat down, bending at the hips and knee, making sure the weight goes down through the back half of your foot. When you reach the half squat position, drive up dynamically, rapidly extending your legs so that you leave the floor briefly. Absorb the landing with soft knees, then go smoothly into the squat again. Continue for 5 repetitions.

The bottom line

In summary:

- Strength and power training is essential for elite swimming performance.

- To optimise the benefit of land-based training, you must select exercises with mechanical relevance to the swimming action, particularly those movements which propel the swimmer through the water, such as the arm pull and leg kick.

- As the resistance in the water is different from the resistance provided by weight equipment on land, unless you have special hydraulic equipment, you must also focus on mimicking the speed and smooth movement of the swimming stroke when performing land-based exercises.

- Various exercises for the arm pull, leg kick, dive and turn movements are suggested, all with a good functional relationship to the swimming action. While this is not a definitive or exhaustive selection of exercises, especially as it focuses solely on front crawl, it involves highly specific swimming movements in terms of mechanics, positions and speed. When you design strength programmes for swimming performance or any other sport, be sure to think about each exercise in terms of its relevance to performance.

Raphael Brandon

If you want to improve your swim performance times, turn up the intensity and turn down the volume

It's probably fair to say that most swimmers and swim coaches believe that the number of hours spent in the pool is the main ingredient of swimming success. Distances of 6 to 10km per day are not uncommon in elite swimming circles. Is this really the key to success, or is there an alternative approach that can produce even better results? This article aims to stir up debate by suggesting that the traditional high-volume model of training will not optimise performance, especially for 100m and 200m swimmers.

The following ideas are not written from a swimming coach's view-point. Instead, they stem from published research into swim training, a scientific analysis of the demands of competitive swimming, and proven methods from running training that optimise performance. Swimmers need to read this piece with an open mind and then they may wish to apply some of the ideas to their own swim programmes.

The swim training research

Research into the effects of high-volume swim training on performance suggests that there is no advantage gained in increasing the metres per day. The legendary US physiologist Dave Costill has undertaken a great deal of research into swim training over the past three decades. In one study, his team of scientists looked at two groups of swimmers over a 25-week training period. Both groups began with once-a-day training, but group 2 increased their training to twice-a-day for a six-

week period for weeks 10-15. After this increase both groups continued on the same once-a-day regime. At no stage in the 25-week training period did group 2 show increased performance or increased aerobic capacity as a result of the extra training session for six weeks. What does this mean? Basically, the twice-a-day regime was a waste of time.

In another study, Costill tracked the performance of competitive swimmers over a four-year period. He compared a group that averaged 10km per day with a group that averaged 5km per day on changes in competitive performance times over 100, 200, 500 and 1600 yard distances. The improvement in swim times was identical for both groups, around 0.8% per year for all events. Again, even though one group did twice as much training, both groups benefited by the same amount in the long term.

Quoting Costill directly, 'Most competitive swimming events last less than two minutes. How can training for three to four hours per day at speeds that are markedly slower than competitive pace prepare the swimmer for the maximal efforts of competition?'

'Over the whole season the swimmers who made the biggest improvements were those who performed more of their training at higher paces. The volume of training had no influence on swim performance.'

The French scientists agree

Research from France supports Costill's research and his conclusions. A team of scientists analysed the training and performance of competitive 100m and 200m swimmers over a 44-week period. The findings were as follows. Most swimmers completed two training sessions per day. Swimmers trained at five specific intensities: these were swim speeds equivalent to 2 mmol/l blood lactate concentration, 4 mmol/l blood lactate concentration, 6 mmol/l blood lactate concentration pace, a high 10 mmol/l blood lactate concentration pace and finally, maximal sprint swimming. Over the whole season the swimmers who made the biggest improvements were those who performed more of their training at higher paces. The volume of training had no influence on swim performance.

The irresistible conclusion from this research is that faster and not longer training is the key to swimming success. Yet in spite of such research, the high-volume, low-intensity model of

training probably remains the most common practice amongst elite swimmers. Even sprint swimmers competing in 100m and 200m events favour clocking up the kilometres rather than focusing on more race-pace-specific training.

The ‘feel’ of the stroke

One reason for this high-volume bias may be that swimmers and swim coaches believe that swim technique, efficiency through the water and ‘feel’ of the stroke is optimised by spending many hours in the pool. I have heard swimmers say they do not feel comfortable in the water and confident about their technique unless they complete high doses of training. This is undoubtedly true on a subjective basis, but nevertheless the argument that high volume training equates to superior race technique has no logical basis. If you were a running coach and you recommended to a 100m sprinter that to optimise his sprint technique at maximum speed the best training plan would be to complete many miles a week at 10km pace, you would be laughed off the track! The track sprinter focuses only on workouts and technical drills at a high intensity. In fact, he or she positively avoids any low-intensity / high-volume training as this inhibits power development.

The same applies to swimming to a large extent. If a swimmer wants to increase his/her stroke efficiency and technique during a competition, then surely the best way to do this is to practise swimming at target race pace during training. The more training time spent at target race pace the more comfortable it will feel in competition. To quote Dave Costill again, ‘A large training volume prepares the athlete to tolerate a high volume of training but likely does little to benefit actual performance.’ When swimmers talk of ‘feeling’ comfortable in the water, they may only be referring to the sub-maximal speeds they perform in training and not the maximal efforts required in competition.

The downside of high volume

Having established from the research that increasing training volume has no benefit on swim performance, let’s now look at

the possible negative effects of high-volume training. Two consequences of high-volume training are depletion of glycogen muscle stores and fatigue of the fast-twitch muscle fibres. Both of these consequences will reduce the effectiveness of high-intensity race pace training sessions and will severely compromise any competitive performance. It is proven by research, with endurance athletes in general and particularly with swimmers, that high-volume training depletes glycogen stores. For example, Costill showed that 60 x 100 yard reps of swimming, with one minute rest between reps emptied the glycogen stores of both the slow- and fast-twitch muscle fibres. Since glycogen is the only fuel available for sustained high-intensity muscle contractions, it is essential for good swim performance. If you want to optimise the quality of your training, and achieve PB's in competition, then your glycogen stores must be full. Continued high-volume training may compromise this, reducing the quality of your important high-intensity training workouts.

Research has also shown that periods of high-volume training reduce the force production in the fast-twitch muscle fibres. Fast-twitch muscle fibres are essential for the high muscle power required to produce the fastest swim speeds. We know from research that sprint swimmers have quite high proportions of fast-twitch fibres, over 60% in the deltoid and quadriceps muscles. High-volume training does nothing for these fibres and, in fact, will dampen their force production by reducing the shortening velocity of the muscle contraction. In this way, high-volume training can change fast-twitch fibres into more slow-twitch types.

The benefits of tapering

This is probably why 'tapering' is so effective in improving performance for swimmers, since the fast-twitch fibres can recover during the period of low volume (see more on tapering later in this Special Report). It has been shown that maximal power increases after a tapering period of training, probably because the fast-twitch fibres recover their high-velocity

contraction properties. The French research discussed above analysed the effects of tapering on swim performance. In their study group, the swimmers who used the most severe tapers – reductions of about half normal training volume – produced the biggest improvements in swim performance.

This begs the following questions. If such dramatic tapers in training are required to optimise performance, probably to allow the fast-twitch fibres to recover to maximise power, then why are training volumes so high in the first place? Would it not be better if swimmers were able to develop power in a positive fashion during the training period?

If we examine the demands of the events, this will help answer these questions.

The metabolic demands of swimming

The shorter the swim event, the greater demand on the anaerobic energy systems. This applies especially to the 50m, 100m and 200m events which take from around 20 to 120 seconds.

The longer events, from 800m upwards, demand a larger contribution from the aerobic energy system. Evidence for this comes from the blood lactate concentrations following 100m and 200m competition swims, which are a very high 16-20 mmol / L. The high level of lactate in the blood suggests that a great deal of energy is derived from the anaerobic breakdown of glycogen, which results in the byproduct, lactic acid. The lactate ion half of the lactic acid diffuses into the blood stream; hence the increased concentration of lactate ions in the blood. Values of 16-20 mmol / L are among the highest levels seen in competitive sport, suggesting that sprint swim events are extremely anaerobic. This would support the argument for more high-intensity paced training and reduced slow high-volume training.

Some athletes and coaches are mistaken in thinking that high levels of blood lactate during sprint swimming mean that it is best to train so as to reduce blood lactate concentrations. This philosophy of training is based on the idea that high lactate is

bad and will have a negative impact on performance. This leads to training programmes that focus on ‘lactate threshold’ training to improve the turnover of lactate and enhance the ability of the aerobic systems to produce more of the energy required for the event.

What high levels of lactate mean

There are two problems with this model of training. The first is the sometimes mistaken assumption that high lactate levels are a bad thing. Remember, lactic acid is the by-product of anaerobic breakdown of glycogen. Lactic acid splits into the H⁺ ion and the lactate ion. It is the acidic H⁺ ion which is the bad guy, interfering with force production in the muscles and reducing the rate of glycolysis, thus slowing the athlete down. The lactate ion simply diffuses through the muscle and into the blood stream. There is no evidence to suggest lactate has any negative impact on muscle function or energy production. In fact, the lactate ion can be re-cycled in the energy production cycle and used positively to help produce energy. So high levels of lactate in the blood in itself are not bad; they are simply an indicator that a lot of anaerobic energy production is occurring. The actual training adaptation you want to take place is not a reduction in lactate production, but instead an increase in the buffering of the H⁺ ion. It’s the acid part and not the lactate part of lactic acid that produces fatigue, and so the more easily this is cleared from the body the better. By training at high intensities, where anaerobic glycolysis is the dominant energy source, and actually generating high levels of lactic acid, the body gets used to the increase in H⁺ in the muscles and is better able to buffer the acid.

‘High levels of lactate in the blood in itself are not bad; they are simply an indicator that a lot of anaerobic energy production is occurring’

High power means high anaerobic energy supply

The second problem is that in assuming you need to lower lactate levels, you are placing greater emphasis on aerobic energy production, like some sort of prejudice against the anaerobic system. Swimmers and coaches must understand that anaerobic glycolysis involves the fast breakdown of glycogen into energy-giving phosphates and aerobic glycolysis involves

a much slower breakdown. This means that maximal power and high speeds are impossible without the anaerobic energy systems, as the muscles would not get a fast enough supply of energy. Therefore, if you want high power you have to have high levels of anaerobic energy supply. For sprint swimming, anaerobic capacity is the plus factor and it needs to be developed. If an event places great demands on the anaerobic system, the athlete needs to become more anaerobic! This may seem odd to those with traditional beliefs about training, but it is true. By focusing on high-volume aerobic training to reduce lactate levels you are in fact compromising your anaerobic fitness, which is the most important aspect of fitness for competitive success in sprint swimming.

With this new thinking in mind, the answer to the question raised above, would it not be better for swimmers to develop power in a positive fashion rather than compromise it with high-volume training, is almost certainly YES.

Don't worry about high levels of lactate

Worry about high lactate concentrations in exercise performance misleads some athletes and coaches into concentrating on reducing lactate levels regardless of the event. For sprint swimmers, lactate threshold training with the aim of improving the swimmer's ability to keep lactate levels low is, I would argue, irrelevant. For swim distances up to and including 200m, the fact that the swimmer develops high levels of lactate does not matter; instead, it's probably a good thing because it shows the swimmer has a good anaerobic capacity. For swimmers competing in longer events, 800m and 1500m, for example, where the aerobic system is much more important, lactate threshold training would be relevant, as these swimmers need to be able to maintain an intensity level for much longer, relying on the aerobic energy system to do this.

The race pace model of training

As I've said, the research shows that higher volumes of training have no benefit on competitive performance. In addition, most

swim events last no longer than two minutes, and rely on a big contribution of the anaerobic energy systems. Spending more training time at high intensity levels, at race pace and above race pace will have greater benefit than swimming lots of kilometres per day at much slower than race speeds. This is also proved by research and supported by the argument that, to improve high-intensity performance, an athlete has to train at high intensity and develop the anaerobic systems.

In the world of running, due to the influence of pioneering physiologists and coaches such as England's Frank Horwill, France's Veronique Billat and the Americans Jack Daniels and Owen Anderson, the focus of training is on 'pace' rather than lactate levels or heart rates. By thinking in terms of pace to monitor the intensity of training, the athlete is switching into a performance mentality ensuring the training is specific to the competitive event. For example, middle-distance running coach Frank Horwill created a five-pace system of training. Briefly, this involves performing regular, quality training sessions at two paces higher than race pace, race pace itself and two paces slower than race pace. For example, if you are a 1500m runner, you will complete interval workouts at 400m, 800m, 1500m, 5000m and 10000m distance race paces.

This race pace model of training breeds a training philosophy that values high intensity ahead of high volume.

A good model for competitive swimmers?

These coaches also recognise that different events need different kinds of training. The 5km running event – which takes about 12-15 minutes – demands a higher level of aerobic training and 5km pace specific workouts, whereas 800m runners – who compete over two minutes – need a high level of anaerobic training and 800m pace workouts. I would argue that this kind of training model would serve competitive swimmers much better than the traditional high-volume approach.

There is evidence to show that the difference between swimmers who reach the Olympics and those who don't is due to the distance achieved per stroke, rather than the stroke

'There is evidence to show that the difference between swimmers who reach the Olympics and those who don't is due to the distance achieved per stroke'

frequency during a competitive race. The way to increase your distance per stroke is to increase the force generated by the active muscles and by achieving an optimum position in the water. This also supports the idea that high-intensity training, with the aim of developing power in the water at race pace, is the most important. 6-10km per day at slow speeds cannot be the way to achieve this!

Enhancing power at race speeds

How can swimmers change their training to enhance power at race speeds? Perhaps again, the running world may provide the answer to this question. The 100m swim takes about 50 seconds, and so is similar to the 400m running race; the 200m swim takes about 110 seconds, and so is similar to the 800m running race. Thus, it's more than possible that swimmers could imitate the training of middle-distance and long-sprint track athletes to improve their training.

For example, an international 800m runner will perform a preparation period of aerobic-capacity training. This will involve continuous running at 10k pace and slower plus interval training at 5k pace. The 200m swimmer's equivalent would be the usual high-volume training programme.

This base-training phase will then be followed by a more specific training phase which will continue with high-volume aerobic training, with more 5k and 10k pace runs and include some interval workouts for the anaerobic system, at 800m and 1500m paces, probably about three times a week. The 200m swimmer's equivalent could be to maintain a fairly high volume but more above-lactate-threshold pace workouts and race pace or close to race pace interval workouts three times a week. For example 10 x 100 m at 400m race pace with 60 seconds' rest.

The pre-competition phase

This phase is followed by a very intense pre-competition phase of training. The goal of this training phase is to maximise the anaerobic capacity of the athlete. Aerobic training is cut to a minimum maintenance level and high intensity anaerobic

sessions at 400m, 800m, and 1500m paces will be performed probably about five or six times a week. For the swimmer, this would involve a morning swim at an easy lactate-threshold pace or below and very high-quality race pace and faster than race pace interval workouts in the evening. For example 8 x 50m at 200m race pace with 60 seconds rest.

And then, competition

The competition phase will simply maintain aerobic and anaerobic fitness with maintenance training and plenty of recovery between races. For the swimmer this could involve some 'aerobic' slow speed workouts and some race pace and sprint workouts, probably only training five or six times in one week.

The best middle-distance runners will most likely perform a maximal sprint workout once a week throughout the whole year, to ensure speed is always being trained. Again, the swimmer could also incorporate this into his/her programme, eg, 10 x turn into 20m max sprint with three minutes' rest once a week.

I stated at the beginning that my aim was to stir up the debate and raise some questions about swim training and how to optimise performance. I have argued, based on the research, analysis of the energy system demands of swimming races and successful models of training in comparable track running events, that the best model of training for swimmers is to focus on more high-intensity training and less high-volume training. Specifically, swimmers would benefit from plenty of race-pace training to develop power and efficiency in the water at the speeds at which they wish to compete.

Raphael Brandon

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Here's an overview of the basics of technique for all strokes (plus a bit extra) and specific training needs

The efficiency of your swimming stroke is the key to success as a competing or training swimmer. An efficient stroke will significantly reduce wasted energy output through less drag in the water and a cleaner execution of hand and arm entry and recovery. Thus that little extra energy may provide you with an overall faster time. When your energy resources are depleted and you're hanging on to the end of your race, you will be the winner if you can hold your technique to that last tenth of a second. Every swimmer knows how easy it is to let one's technique drop off as you become more fatigued throughout a race – that burning sensation in the shoulders as you try to hold together your last few strokes to the wall is the hardest part of the race.

With regard to training for competitions, the season can last for up to 10 months or more, depending on whether you are at county, national or international level. In general, the season's training will reflect the level of the club or squad you are training with.

The season will be geared around the county or regional championships, the Grand Prix circuit, the national short and long-course championships, the European, World or Olympic Games or the World Cup Circuit. Whatever your level, this article aims to cover the different types of training sets/sessions you should carry out. Your individual ability and/or standard will determine the actual proportional breakdown of these sessions or cycles throughout the swimming season.

Technique

When considering your swimming technique for any stroke, analysis should follow the format described below, in the following order:

1. Leg kick
2. Arm cycle
3. Timing
4. Breathing

The leg kick will control the body position in the water, while the arm cycle will provide the propulsive force. The timing between the two is vital to the efficiency of the given stroke in order to provide a greater speed through the water with minimum wasted energy. Finally, breathing technique should be analysed to ensure that when you breathe your overall technique is not disrupted in any way that would cause a breakdown in efficiency.

Freestyle

The main propulsive force of the freestyle stroke is the arm cycle. The legs add only 10% of total speed through the water, depending on whether you use a 2-, 4-, 6-, or 8-beat kick. The main function of the legs is to help keep the body balanced and efficient to allow the arms to do their work and keep the body moving when the arm cycle is at its weakest point. The arm cycle is described as follows:

Recovery

Elbow leaves the water first, with a high elbow, hand relaxed directly under the elbow, trailing fingers on the water, then reach forwards to the entry position.

Entry & catch

Thumb first, hand slightly cupped, reach further forwards and out (laterally) to 'catch' the water to prepare for the out sweep – dropping the shoulder (upon the reach) slightly will help in the 'catch' and also in the recovery of the other arm.

Out sweep

Press the water laterally to the body with only slight elbow flexion and begin to rotate the hand at the wrist medially.

In sweep

Press the water towards the hips through further flexion of the elbow and wrist as you feel the body being pulled over the hand.

Press

With the hand at the hip and palm facing towards the feet, press the water back by extending the arm to approximately 90% of full extension, keeping in line with the body to reduce drag. The arm is ready for the recovery, elbow first!

Backstroke

Because of the required shoulder roll during backstroke swimming and a slightly weaker arm cycle, the legs play a more important part in adding a propulsive force to the stroke. The key, however, is to ensure that the feet work just under the water surface and not above it, to ensure that the full kicking movement is propulsive and not against thin air. The arm cycle is described as follows:

Recovery

Thumb first, arm fully extended, rotate the arm laterally through the shoulder joint, keeping in line with the body, gradually turning the hand laterally at the wrist ready for the entry. Allowing the opposite shoulder to drop will lift the recovery shoulder to help balance the stroke and create a more powerful propulsive phase.

Entry & catch

Little finger first, drop the shoulder to allow a reach and 'catch' the water with the hand cupped. The arm should flex slightly at the elbow to assist in the catch.

Down sweep

Continue to flex the arm at the elbow as you press laterally, then

‘The key is to ensure that the feet work just under the water surface and not above it, to ensure that the full kicking movement is propulsive and not against thin air’

downwards as you pull the hand towards the shoulder and chest, keeping that shoulder in the drop position.

Press

With the arm close to the body, press the water towards the feet in line with the body, ensuring full arm extension is achieved.

Butterfly

This is a stroke where timing of the kick and the arm cycle are paramount. An inadequate butterfly technique can waste a huge amount of energy because of the double arm movement on recovery and propulsion, and also the double leg kick. Practice makes perfect, and the more efficient you can make this stroke the more power you will be able to generate where it is needed. The arm cycle is as follows:

Recovery

Both arms break the water simultaneously, hand and forearms first, the arms swing outwards, elbows slightly flexed as they both continue to swing round and meet forward of the head, thumb and fingers first.

Entry & catch

Fingers first, the hands cup and catch the water simultaneously in preparation for the out sweep (the big kick finishes).

Out sweep

Together, the arms press laterally, and the arm begins to flex at the elbow (the small kick starts).

In sweep

As the arms continue to flex, the hands turn medially and press towards the body (in small kick finishes).

Press

As the hands come close to the body, they then press towards the feet, fully extending the arms at the elbow in preparation for the

quick 'flick' out of the water and to recovery (the big kick starts).

Breaststroke

The final competitive swimming stroke to analyse is, like butterfly, controlled by the efficient timing of the leg kick and arm cycle in order to give the most effective end result – a faster swim! The arm cycle is as follows:

Reach & glide

Both hands, thumbs together, reach forward, fully extending the arm at the elbow (the leg kick starts to push back to continue the forward movement) – the arms will stay in this position until the kick is completed by the feet touching.

Out sweep

The hands rotate laterally, cupped to catch the water, and press laterally with slight flexion of the arm at the elbow.

In sweep

The arms continue to flex at the elbow as the press on the water is now turned medially towards the chest (the legs flex at the knee and hips to prepare for the kick).

Recovery

Once at the chest, the hands meet in the centre, elbows flexed close to the chest to reduce drag, and recover together over the water at the beginning, but then dive in to the reach and glide.

Training sets/sessions

Depending on which training cycle you are in, you will often cover varying sessions on endurance/stamina work and speed/power work. There are hundreds of different swim sets you could carry out through a certain training cycle. Below are examples of what to include in those sessions, at what intensity, and how much rest should be given. These examples are to be used as a 'main set' for a single training session. A quality warm-up and 'lead-in' set should be completed first, followed by a

recovery set and cool-down, depending on the length of the session, training cycle, etc.

Endurance

Any competitive swimmer (or serious health-club swimmer) must incorporate this type of training throughout their season or given cycle. This will build their physiological aerobic base from which to develop more specifically for their needs, whether it be simply fitness or distance-based swims (400m or 1500m) or sprint-based swims (50m or 100m).

Basic endurance

This involves working at a heart-rate level of 65-75% HR max for a period of 15-60 minutes. Rest within the sets should be between 10-30 seconds depending on the distance repeats you are swimming. Examples include:

- 1. 20 x 100m repeats – 10-15sec RI 60-75% HR max (2000m)**
 - 2. 5 x 400m repeats – 20-25sec RI 60-75% HR max (2000m)**
- (RI = Rest Interval)

Threshold endurance

This involves working at a heart rate level of 80-85% HR max, for a period of 15-45 minutes. Rest within the sets should be between 10-30 seconds depending on the distance repeats you are swimming. Examples include:

- 1. 10 x 200m repeats – 15sec RI 80-85% HR max (2000m)**

Overload endurance

Occasional endurance sets should involve this type of training, whereby you swim at a heart rate level of 85-90% HR max for a period of 15-30 minutes. Rest intervals within the set should be no longer than 30 seconds depending on the distance repeats you are swimming. The main aim of this type of training is to work for a solid length of time at a high intensity with little rest to ensure the working muscle groups achieve overload. As you

know, without achieving overload, progression will not occur within a given time scale. Examples include:

1. **5 x 200m repeats – 15sec RI 85-90% HR max**
10 x 100m repeats – 10sec RI 80-85% HR max
(overall: 2000m)
2. **3 x 400m repeats – 20-25sec RI 85-90% HR max**
4 x 300m repeats – 15-20sec RI 85-90% HR max
(overall: 2400m)

Sprint

Sprint training adds the anaerobic fitness base to the aerobic base you have developed with your endurance training. It works on the two anaerobic energy systems – the creatine phosphate energy system and the lactate energy system. Training involves short, fast repeats with good rest intervals to ensure you can overload both these energy systems. The additional benefit of sprint training is muscle adaptation to the speed-type exercise, as well as the aerobic benefits trained earlier. Working the fast-twitch muscle fibres will increase their number and size in a given muscle as well as the speed of excitation. The following examples of training sets are to be used as a ‘main set’ as with the previous endurance examples.

Working the fast-twitch muscle fibres will increase their number and size in a given muscle as well as the speed of excitation

Lactate tolerance

This involves working at a heart rate level of 90-95% HR max, with substantial rest periods within the given set. The aim is to work close to maximum speed and then to rest (for between three and five minutes) in order to give time for some lactate to be broken down and eliminated. Examples include:

1. **6 x 50m repeats – 4min RI Maximum pace**
2. **4 x 100m repeats – 5min RI Maximum pace**

Lactate production

The aim of this type of set is also to exercise at close to maximum but with less rest (between one and three minutes)

in order for your body to experience exercising with lactate build-up in your system. This therefore involves working at a heart rate level of 90-95% HR max. Examples include:

- 1. 10 x 50m repeats – 1min RI Maximum pace**
- 2. 6 x 100m repeats – 2min RI Maximum pace**

One final area of a training session is swimming ‘drills’. The aim is to slow the stroke down and to concentrate on and practise the key areas of technique, whether it be the high area recovery on freestyle, the symmetrical arm cycle of the butterfly, the timing of the kick and pull on breaststroke, or the shoulder roll on the backstroke arm cycle. These can form part of the warm-up or lead-in set or even the recovery set.

More specific work can be done with the use of a float and a pull buoy. For example, kicking drills with or without flippers/with or without a float, speed or endurance kick sets depending on your current training cycle. Again, these sets could be used as part of the warm-up, lead-in set or recovery set.

Matthew Coulson

These workouts are guaranteed to give you the maximum bang for your training buck

The aim of this article is to outline how to design your strength routines, in terms of intensity and content, to make sure you get the optimum gains in strength for the time spent in the gym. I'll begin by discussing the best intensity and volume for strength improvements. However, I will also be discussing max strength-training methods, which are not the same as body building.

Currently, by far the most common strength-training format would be three sets of 8-12 reps of each exercise. Give or take a few minor variations on a theme, this is generally what you would see when watching many gym routines. Recently, however, research has questioned this practice of three sets of each exercise. For example, Feigenbaum and Pollock (1997) reviewed eight well-controlled studies comparing variations in sets of strength routines. No studies showed two sets to be significantly superior to one, and only one study showed three sets to be significantly superior to one or two.

In the light of this, when last year the American College of Sports Medicine published their latest Position Stand on Health and Fitness Training, they recommended adults should perform one set of 8-12 reps two-to-three times per week for optimum strength benefits. Some of you may be surprised. Only one set? What good will that do? However, we have to examine exactly what the ACSM specifies, and I quote: '...1 set of 8-12 RM or to near-fatigue should be completed...or for older persons, 1-15 RM may be more appropriate....'

What this means

The key element of this recommendation is that the resistance intensity has been clearly defined as 8-12 RM. RM stands for the Repetition Maximum and refers to the number of reps that can be performed before fatigue inhibits the completion of a further rep with correct form. (When we get tired we can always force a few extra ones by cheating on the technique, but this doesn't count when assessing RM.)

The following example should make this clear. An exerciser is tested for his bench press performance. After a warm-up trial on a suitably easy weight, plus a couple of minutes' rest, he is given a 60kg bar to bench. He performs nine reps with correct technique but just fails while attempting to push up the tenth rep and requires a little assistance. Thus 60kg is the 10 RM load for this exerciser. According to the ACSM, this makes 60kg an ideal training weight for strength development, and if he performed one set at 60kg 2-3 times a week he should significantly improve his bench press strength. After a few sessions he will be able to complete 10 reps without assistance, then 11 reps and then 12. By this stage, 60kg has become his 12 RM load. To ensure the best results and to stay within the ACSM guidelines, our exerciser now needs to put the weight up. This is because, for max strength gains, the optimal range has been proven to be 8-12 RM, or even 4-8 RM for power sports. Decreasing the relative load to 12-20 RM would favour the development of muscular endurance and muscle toning.

When designing strength exercises the most important variable is the RM value for each exercise

The key is the RM value

Thus when designing strength exercises the most important variable is the RM value for each exercise. The number of sets performed at this level seems to be less influential. As long ago as 1962, Berger showed that 12 weeks of 3 times a week training produced a 22% increase in bench-press strength with one set of 6-10 RM, 22% increase for two sets of 6-10 RM and 25% increase from three sets of 6-10 RM – hardly a major difference for three times as much volume. Results

like this are also found in more recent studies of both upper- and lower-body exercises.

When you next design a strength programme, instead of three sets of 8-12 reps, try one set of 8-12 RM. There is a subtle but significant difference between 8-12 reps and 8-12 RM, since the latter specifies the intensity of the training. Remember that it is the intensity and not the volume of the weight training that has the largest influence on its effectiveness. As Feigenbaum and Pollock have said most recently (1999): “One common factor in all effective strength programmes is the inclusion of at least one set of the maximal or near-maximal number of repetitions for each exercise performed”.

Popular practice for exercisers is to perform the usual three sets of 10, using a weight that allows the first set to be moderate, the second to feel a bit tough and the third very difficult or to fatigue. However, while this satisfies the above recommendation that at least one set is maximal, the weight intensity is probably too low. If our exerciser trains at a weight intensity where he can complete three sets of 10, I would estimate that this weight intensity is at least his 15 RM load, and maybe higher. This places the training intensity outside the optimum range for strength results. If we go back to our earlier bench presser, instead of the newly recommended one set to maximum at 60kg, he would perform three sets of 10 at around 45-50kg. The chances are the former will give him a greater return in strength gains from less time invested.

The reason for multiple sets

So why do we all do three sets of 10 when a single set of 10 RM will do just as well, if not better? What we need to remember is that, unfortunately, research studies often last no more than three months and often involve moderately trained subjects. Both the length of the training schedule and the status of the exerciser are crucial to the outcome of the training programme. In other words, to be strictly correct, it is only proven that one set of 8-12 RM is best for moderately trained subjects for an initial training period.

Thus, multiple-set training programmes are recommended to ensure that the training stimulus is progressive and will continue to stress the body sufficiently so as to produce further strength improvements. This means, for most *PP* readers or their charges, that multiple-set programmes are probably most suitable. However, just because you feel you need the extra volume that multiple sets provide, don't forget that you must stay within the optimum-intensity range of 4-12 RM. Practically, this means the exerciser still performs each set to the maximum and takes generous rest periods to allow for multiple sets. For example, our aforementioned bench presser has now decided to up the volume of his workouts. Let's say he was currently performing one set at 65kg, which was his 10 RM load. To perform a second set, he would need 3-5 minutes rest. If he only took one minute's rest, having just completed one maximum set, he would be unlikely to perform more than five reps the second time round. Intensity is the key, and so, if you don't take enough rest, you won't be able to push enough weight. Remember that there is no point increasing to multiple sets if you end up decreasing to a sub-optimal intensity. Thus the recommended protocol for multiple sets for strength gains would be 2-4 sets of 4-12 RM with 3-5 minutes rest.

Practical issues

So far we have established, in theory, the most effective design for strength improvements. The crucial point is that the training load must be within the 4-12 RM range. Initially, one set to maximum will be sufficient, but for long-term improvement for elite athletes multiple sets will no doubt be required. Having established the theory, let's now look at a few practical issues regarding the content of the workout to ensure that our strength routines are fully effective. These issues are: exercise selection, exercise order, and warm-up sets.

The main point about exercise selection is the athlete's training goal. The content of the workout must relate directly to the desired training effect. The goals may vary greatly, depending

on the athlete's sport, position or event. There are too many variations to be covered here, but I will give some examples to illustrate the point and try to pass on some useful tips.

If the training goal is for general strength development, then I would suggest selecting about eight exercises that involve large muscle groups and cover as much of the body as possible. For example, the following eight exercises cover pretty well all major muscle groups: leg press, leg curls, bench press, lat pull downs, biceps curls, triceps press, ab crunch and back extension. One would perform sets of 8-12 RM of each of these exercises.

Sport-related training

If the strength training is related to a sport, then the choice of exercises must be functional. This is because training effects are very specific. To ensure that the strength you develop in the gym brings about an improvement in performance, the strength exercise must be biomechanically related to the sporting movements. This is known as the 'carry-over effect'. For example, squats are a functional exercise because they train the quads, hamstrings and gluteals in a way that is related to running and jumping. In contrast, the knee-extension exercise involves only knee extension, training the quads in isolation. This has no functional relevance to running or jumping, so improving your strength on this exercise won't improve your ability to run or jump. It may, however, improve your ability to kick.

Free weights are also considered more functional because the trainee has to use the synergistic small muscles to stabilise the movement as well as the large prime-mover muscles to execute the movement. This means, for example, that an exercise such as the barbell lunge, if performed with correct technique encouraging good alignment and upper body pressure, should develop body core stability as well as leg strength. This also highlights the point that quality technique and instruction are paramount for optimum strength improvements.

‘To ensure that the strength you develop in the gym brings about an improvement in performance, the strength exercise must be biomechanically related to the sporting movements’

Don't forget muscle balance

Another practical point to consider in exercise selection is muscle balance. It is essential that both sides of the body are developed evenly and that opposing muscle groups have the correct relative strength to each other. Any imbalances may lead to injury or instability during sports movements. For this reason, you should always design workouts that result in balanced strength development. For instance, with every upper-body push or press exercise also include a row or pull exercise. With some sports, a major goal of strength training is to redress imbalances between sides. For example, tennis players often have a dominant arm and uneven trunk strength. One solution to this would be choosing exercises that work each side individually, thus giving the weaker side a chance to catch up.

Exercise order...

The final practical point regarding exercise selection is the order of the exercises in the workout. It is recommended that large-muscle group exercises and the most important exercises in the workout should precede small-muscle or single-joint exercises. For example, a sprinter may be using this type of programme:

- * Power clean
- * Squats
- * Bench press
- * Barbell lunge
- * Lat pull down
- * Lateral raise
- * Bent-over lateral raise
- * Triceps press
- * Twisted crunch

The power clean and squats come first because they are the most functionally important exercises for the sprinter. The power clean precedes the squat because technically it is a more difficult movement. The bench, lat pull and lunge come next because they all involve large muscle mass. The shoulder and triceps exercises come next because they are single-joint

movements. The twisted crunch comes last because trunk strength is always required for good stability and technique in any exercise. Thus the trunk exercises should come at the end of a routine so that trunk-muscle fatigue doesn't compromise technique during other exercises.

...and warm-up

The correct warm-up is also essential if weight training is to be fully effective. I recommend starting with some easy aerobic activity for about five minutes, in particular a rowing machine because it involves both upper and lower body. The next stage of the warm-up would be a choice of active mobility exercises for the whole body. The purpose of these exercises is to take each major joint through its active range of motion with any loading before the workout begins.

The most important element of warming up for strength training is to perform warm-up sets before each new muscle group or movement is trained. The purpose of warm-up sets is to gradually prepare the muscle for the maximal intensity loads to come. Remember, if we want to perform sets of 4-12 RM, that means going to maximum. The correct load for the warm-up set would be about 60% of the training weight.

It's best to perform each of these warm-up sets immediately before the exercise. For example, a sprinter following the routine outlined above would start his workout with a warm-up set of power cleans. Then he would perform his training set of power cleans. He wouldn't need a warm-up set for squats because the power clean movement would be sufficient. He would then precede both bench press and lat pull downs with a warm-up set. The lunges, shoulder and triceps exercises wouldn't require warm-up sets because the muscles involved would be already warm from the large multi-muscle exercises that preceded them. This is another important reason for putting large muscle mass exercises first in the routine order.

Note that there are no stretching exercises involved in the warm-up. Despite their popularity, stretching exercises are not proven to be an effective part of a warm-up. In fact, stretching

‘Despite their popularity, stretching exercises are not proven to be an effective part of a warm-up’

may actually be inappropriate for strength training because it relaxes the muscles, reducing force development potential by inhibiting the stretch reflex.

In summary, to optimise strength gains design your workouts so that you train at the 4-12 RM intensity, taking long rests to facilitate multiple sets to maximum. Think carefully about the exercises included in your workout, asking if they are functionally relevant to your training goal, and whether they will promote muscle balance and stability. Finally, design the workout using the most appropriate order of exercises so that the most important muscles are training first and the correct warm-up procedures are used.

Raphael Brandon

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This reliable test of aerobic capacity is non-invasive and easy to do

Various methods of determining optimum training thresholds and adequate measures of aerobic and anaerobic capacity are currently used. These include the assessment of lactate threshold (anaerobic threshold), lactate sprint sets, the onset of blood lactate accumulation (OBLA), the lactate minimum (LM), maximum oxygen consumption (VO_2max) and the use of heart-rate sets. The reasons why these tests are used are:

1. to check on any changes the swimmers may experience as a result of the period of training (eg, any enhancement or deterioration in aerobic or anaerobic capacity), and
2. to set specific training intensities which are likely to improve the swimmer's level of competitive fitness.

The lactate threshold (LaT) determination is specifically employed to assess endurance potential and is the point at which blood lactate begins to accumulate above resting levels during exercise of increasing intensity. With light to moderate exercise intensity blood lactate remains slightly above resting levels, whereas after more intense efforts lactate accumulates more rapidly. Controversy surrounding this procedure stems from the fact that the muscles produce lactic acid before the threshold is reached, although it is being removed by slow oxidative muscle fibres; thus a clear break point is not always apparent. Because of this, set lactate values are frequently used. An arbitrary value of 4mM represents the point at which blood lactate accumulation begins and is a standard point of reference known as OBLA.

The lactate minimum (LM) test is another way of identifying the individual anaerobic threshold and has shown promise for

prescribing the optimal pace for endurance training. First, the test requires a high level of blood lactate which can be achieved by performing two 50m sprints. This is followed by a series of five or six 300m swims at gradually increasing speeds. The idea is that normal recovery causes blood lactate concentrations to decrease at test speeds lower than the LM and to increase when it has been surpassed. The LM is the speed at which the rate of entry of lactic acid into the blood exceeds the rate of removal.

Lactate testing is not ideal since it involves blood sampling, requires experienced personnel and can be relatively expensive and time-consuming even though it can give an accurate individual assessment. Nevertheless, there is a need to use objective measures which are non-invasive, require inexpensive equipment, and are yet easy to perform. One such measure is that of Critical Swim Speed (CSS).

Critical Swim Speed (CSS)

The concept of CSS has proven a valid and reliable measure of aerobic capacity. The advantages are that it is non-invasive, practical for all coaches, and the only equipment needed is a stop-watch. It is defined as 'the swimming speed that can theoretically be maintained continuously without exhaustion'. It is the highest sustainable work rate which enables lactate to remain in steady-state (where production equals removal).

In 1991, the researcher Wakayoshi swam subjects at six various speeds in a swim flume. The subjects swam until exhaustion at each speed, with the time (T) recorded (in seconds) and the distance (D) calculated (speed x T). A regression line (with the equation $D = a + bT$) was then plotted between D (in metres) and T. The slope of that line (b) determined the CSS (which is given as speed in m/s) while the intercept on the Y-axis is the Anaerobic Swim Capacity (ASC) (a).

In a second study (1992), Wakayoshi provided a practical method for coaches to determine CSS in a normal swimming pool. Subjects swam four distances (50m, 100m, 200m and 400m) at maximum pace and the time was recorded in seconds. A regression graph was then plotted and the CSS and ASC

‘The concept of CSS has proven a valid and reliable measure of aerobic capacity’

determined. Significant correlations were also found between the CSS in the pool and the velocity at OBLA (V-OBLA), also between V-OBLA and CSS in the flume and CSS in the pool and CSS in the flume. It was then concluded that CSS, which could be determined by a non-invasive method, should be utilised as a standard value for establishing the optimum training intensity in each swimmer.

A different procedure

Another researcher, Ginn (1993), used two maximum swims to determine the CSS (50m and 400m) and stressed that they should take place during training, from a push start, and not to use competition times. The procedure used to calculate CSS was different from that of Wakayoshi. The following formula was used:

$$\text{CSS} = \frac{d_2 - d_1}{t_2 - t_1}$$

where $d_2 = 400\text{m}$, $d_1 = 50\text{m}$, $t_2 = \text{time for } 400\text{m}$, and $t_1 = \text{time for } 50\text{m}$ (in seconds).

The result of this is the CSS which is given in metres per second (m/s). For example, if a swimmer performs a 50m in 30.2s and a 400m in 290.5s, CSS is calculated as below:

$$\begin{aligned} \text{CSS} &= \frac{400 - 50}{290.5 - 30.2} \\ &= \frac{350}{260.3} \\ &= 1.34 \text{ m/s} \end{aligned}$$

Ginn then put forward that the obtained value for CSS can be used to determine training times for sets of different distances. For example, for a suggested set of 6 x 400m, the time per repetition would be calculated as follows:

$$\begin{aligned}
 \text{Time per repetition} &= \frac{\text{distance required}}{\text{CSS}} \\
 &= \frac{400\text{m}}{1.3446 \text{ m/s}} \\
 &= 297.49\text{s} \\
 &= 4\text{min } 57.5\text{s}
 \end{aligned}$$

Ginn later related a lot of his CSS work to actual training programmes and found that it is about 80-85% of maximum 100m swim speed, or 90-95% of 400m swim speed. A system of training intensities was devised and is illustrated in Table 1.

Table 1. A simple system of training intensity levels based on calculations of CSS

<u>Training Level</u>	<u>% of speed</u>	<u>% of max 400m*</u>
Level 1	75-80	>75
Level 2	80-90	75-85
Level 3	90-100	85-95
Level 4	100	100
Level 5	100-110	105

* These are approximate only and will vary for individual swimmers

This classification system provides intensities which approximate the categories published some years ago and used in the preparation of Barcelona Gold Medallist Alexandre Popov (*Touretski, 1993*).

A third researcher

Cooper in 1996 studied eight competitive swimmers who were efficient in both the front crawl and breaststroke, and determined the CSS for both strokes. Lactate thresholds were

also determined as well as velocity for OBLA (4mM lactate). The three swimming speeds (m.s-1) were then compared and the results are shown in Table 2.

Table 2. Mean parameter values obtained during breaststroke and front crawl testing

	CSS (m.s-1)	Tlac (m.s-1)	Vobla (m.s-1)
Breaststroke	1.02	1.03	1.05
Front crawl	1.34	1.25	1.32

Tlac = Lactate threshold Vobla = Velocity at obla (4mM)

More recently, Coulson in 1997 studied the effects of training on the CSS to find out if aerobic/anaerobic training increases/decreases the CSS (comparing sprinters and middle-distance swimmers) and what variations of maximum swims could be used to determine CSS. Twelve subjects (seven male and five female) were tested at three periods of the swimming season. These were pre-season (September), post-aerobic training (November), and post-anaerobic training (December). Four maximum swims (50m, 100m, 200m and 400m) were used for a regression line to be plotted and CSS calculated. The hypothesis put forward was that aerobic training increases CSS and anaerobic training increases ASC. This was due to the expected 'shifts' in the regression line (ie, making it more or less steep and so altering the slope and the intercept).

The results showed a significant increase in CSS as a result of aerobic training (1.38 m.s-1 to 1.42 m.s-1 was the average for the group as a whole) which was maintained as a result of anaerobic training. This was specifically noticeable in the sprint swimmers compared to the middle-distance swimmers, as they would be more prone to changes in their aerobic capacity due to their high anaerobic composition. Table 3 illustrates the mean CSS for the two groups of swimmers.

Table 3. Mean Critical Swim Speeds for sprinters and middle-distance swimmers

	sprinters			middle-distance		
	CSS(m.s-1)			CSS(m.s-1)		
	Pre-season	Post-Aerobic	Post-Anaerobic	Pre-season	Post-Aerobic	Post-Anaerobic
Mean	1.37	1.43	1.43	1.40	1.40	1.41

It was concluded that CSS could be used by swimming coaches as a sensitive measure of training. If coaches have only a limited time to assess the CSS, how many maximum swims need to be performed? Coulson in 1997 examined two, three and four maximum swims and found that the two-trial test of 200m and 400m proved to be the most suitable method for CSS determination compared to the four-trial set (which was classed as the 'gold standard'.)

Conclusions

The use of CSS is a valuable and reliable test of aerobic capacity and is sensitive to changes in training. It is a concept which is practical for all coaches, inexpensive, non-invasive, does not require qualified personnel, and the only piece of equipment needed is a stop-watch.

A step-by-step guide to determining CSS – Standardised warm-up, 1000m choice swim

Method one

- 1 Subjects swim either four maximal swimmers (50m, 100m, 200m, and 400m) or two maximal swims (200m and 400m). Good recovery is important so sufficient rest between swims must be given.
- 2 Swims must be from a push and not a dive start.
- 3 Record the swimmer's time for each swim (in seconds).
- 4 Plot a graph of distance (in metres) against time (in seconds). Distance on the Y-axis and time on the X-axis.

- 5 Join the two or four points by means of a straight line.
- 6 Calculate the slope (or gradient) of this line. The figure produced is the CSS and is given in metres per second.

Method 2

- 1 Swim two maximal swims (400m and 50m only) from a push and not a dive start.
- 2 Record the time for each swim in seconds.
- 3 Calculate CSS using the formula.
- 4 To determine training times for sets, use the formula.

Matthew Coulson, Jeremy Cooper and Don MacLaren

Competitive swimmers and their coaches are constantly seeking new and effective methods to improve performance. Here's one

Swimsuit design, goggle design, shaving down and warming-up techniques are all currently used, but the most important element is the training itself and the factors affecting it, particularly in the few days before competition. A common practice used by swimmers and coaches is the well-established technique of tapering, whereby the training volume of a swimmer is drastically reduced 7-21 days pre-competition (*Costill, 1985, Johns et al, 1992*). This tapering is associated with many physiological alterations that have a positive impact on swimming performance, and these will be closely looked at in this review.

Components of tapering

Tapering can be controlled through three variables, (a) frequency of sessions per week, (b) intensity of each session, and (c) the duration of the taper in general. *Costill et al (1985;1991)* studied various taper schedules and found that these three variables provided some insight into actual performance improvement.

The first common characteristic with tapering is that training is reduced in an *incremental* fashion as opposed to a general training reduction (eg, 15,000m per week to 10,000m). Tapering has become the preferred method of the two because, as *Costill et al (1991) and Johns et al (1992)* demonstrated, muscular

power is enhanced and performance improved significantly after 10-21 days taper with competitive swimmers. *Houmard et al (1990)* demonstrated (with runners) that with a reduction in training volume to 70% of normal, 5k race performance or muscular power were not improved. Research thus favours tapered training.

A successful taper should also incorporate a drastic reduction in volume. Tapers that improve swimming performance have been found to consist of 60-90% reduction in weekly training volume (*Costill et al, 1985, 1991*). These positive effects are thought to be primarily mediated by a recovery phenomenon from previous days or weeks of intense training (*Houmard, 1991*). This recuperation can only occur if training volume is drastically reduced. In distance runners, it was found that a seven-day, 62% reduction in weekly training volume did not improve performance, determined by an exercise time to exhaustion test (*Sheply et al, 1992*). In contrast, a 90% reduction in weekly training volume over seven days resulted in a 22% extension in time to exhaustion. It therefore appears that a huge reduction in weekly training is required in order to recover and allow the rebound effect to occur.

‘A successful taper should also incorporate a drastic reduction in volume.’

Intensity

With regard to the type of training while tapering, it commonly takes the form of interval work, with sufficient recovery in order to maximise exercise intensity (*Costill et al, 1991; Johns et al, 1992*). Training at an intensity of 70% VO_2max either maintained or actually worsened performance (*McConnell et al, 1993*). In contrast, tapers involving training at 90% VO_2max improved performance (*Costill et al, 1985, 1991*). The reasons behind this were put forward by *Houmard (1991)* who said that intense exercise may be necessary to maintain training-associated adaptations with the reduction in training volume during the tapering period. Intense interval work, when coupled with a reduction in training volume, may also provide a unique stimulus to the musculoskeletal system which results in adaptations conducive to improving performance.

Frequency

Exercise frequency is concerned with the number of sessions performed each week (*Houmard and Johns, 1994*). The reduction in training volume cannot be achieved at the expense of a drastic reduction in frequency. *Neufer et al (1987)* examined the effects of swim-reduced training on swimming power and blood-lactate production after submaximal exercise. Two regimes were examined: (1) 80% reduction in training volume, 50% in frequency, and (2) 95% reduction in volume and 85% in training frequency. Results of the study found that swimming power significantly decreased after only seven days and submaximal blood lactate levels increased after 28 days of either reduced-training regime. These changes were indicative of a loss of training-associated adaptations and, most likely, a decrement in performance. The reduction in training schedules here were quite dramatic. Studies in which performance-related variables were maintained or improved incorporated only a 20-50% reduction (*Costill et al, 1985; Sheply et al, 1992*). Heart rate changes have also been reported by *Houmard et al (1989)*, who found an increase during submaximal exercise in distance runners after a 10-day, 50% reduction in training frequency. It can therefore be concluded that weekly training frequency should be reduced by no more than 50% during taper. *Houmard (1991)* actually suggests a reduction of no more than 20%. During periods of optimal performance, swimmers often refer to having 'a good feel of the water'. It is this 'feel' that is lost or reduced with too dramatic a reduction in training frequency, and for that reason I would support Houmard's suggestion of no more than 20% reduction in frequency.

Duration

How long should a taper programme last? *Yamamoto et al (1988)* compared the effects of either a 45-day or a 15-day taper on blood haematocrit and haemoglobin in national class swimmers. They observed that peak performance values were obtained seven days into the taper, and that this would be the

optimum taper duration, with anything longer resulting in performance loss. Unfortunately, though, this study didn't measure actual swimming performance. Studies that did involve performance assessment with tapering have reported improvements with tapers lasting from 7-21 days (*Costill et al, 1985, 1991; Houmard et al, 1994; Johns et al 1992*). However, the effects of a more prolonged taper have not yet been thoroughly investigated, *Houmard et al (1992)* suggest a taper lasting 21 days would only maintain, rather than improve, actual performance.

The physiological effects of taper

Maximal Oxygen Consumption (VO_2 max): this well-established method has proven to be very reliable in assessing cardiorespiratory fitness levels. It is the maximum amount of oxygen utilised during incremental exercise to exhaustion. It is more commonly produced through treadmill or cycle ergometry but it can be used by swimmers in the actual pool. This is achieved by either tethered swimming where the resistance is incrementally increased, or a free swim at maximal speed with oxygen consumption calculated from expired gases obtained 20-40 seconds post-exercise (*Neufer et al, 1987*). With swimming training, VO_2 max increases quite significantly by some 14-25% (*Kieres & Plowman, 1991*). However, VO_2 max was unchanged with a 21-day taper in nine elite swimmers (*Van Handel et al, 1988*). Other studies have reported improved performance with taper with VO_2 max remaining unchanged. (*Houmard et al, 1994*). Alterations in performance which are independent of VO_2 max must therefore be associated with muscular adaptations rather than the oxygen delivery (*Sheply et al, 1992*). This could be the case with tapering, as muscular power in swimmers has been reported to improve while tapering.

Submaximal measures

Variables commonly used as indices of submaximal exercise efficiency in swimmers include oxygen uptake, heart rate, blood

lactate and stroke distance. *Costill et al (1991)* reported no differences in post-exercise blood balance (lactate, pH and bicarbonate), and heart rate with a 14-day taper. Also, *Van Handel et al (1988)* reported no significant differences in post-exercise lactate profiles with a 20-day taper. *Johns et al (1992)* finally reported no alterations in $\dot{V}O_{2\max}$, post-lactate levels and stroke distance with either a 10-day or 14-day taper. In contrast to these stroke-distance findings, *Costill et al (1991)* reported increases with a taper programme. However, swimmers commonly remove body hair (shave down) before competitions and during taper in order to minimise resistance. *Johns et al (1992)* actually reported increases in stroke distance as a result of shaving down after 10 days' tapering (with no improvements in the other variables).

Blood measures

A restoration of haemoglobin/haematocrit prior to competition is desirable, as it may enhance actual oxygen-carrying capacity and thus performance. *Yamamoto et al (1988)* reported peak haemoglobin levels after seven days' taper. Similar results have also been reported by means of differing tapers (*Burke et al, 1982*). Elevations in these variables may be associated with a decrease in exercise-induced haemolysis from a reduction in training volume (*Houmard et al, 1991*). Plasma creatine kinase (CK) level is hypothesised to be positively related to a degree of muscular cellular damage (*Noakes, 1985*), but quality research is still required to demonstrate this.

Skeletal muscle

Muscle biopsy studies in runners and cyclists have demonstrated a consistent elevation in muscle glycogen (15-35%) with tapering. To date there have been no studies on the effects on competitive swimmers when tapering. The finding, though, is important, in that the benefits which could be achieved due to the greater availability of energy substrate are vast, since its positive links with endurance performance are commonly accepted (*Costill et al, 1991*). *Shepley et al (1992)*

also reported increases in oxidative enzymes with taper, providing a huge benefit to endurance performance. It is likely that similar adaptations with taper would occur in swimmers, but nothing has been directly documented.

Muscular power

Costill et al (1991) reported significant improvements in dry-land (swim bench) and tethered-swimming power with a 14-day taper. *Johns et al (1992)* also found gains in tethered-swimming power with a 10- and 14-day taper. As a result of endurance training, muscular power is decreased because of the residual fatigue or inhibition of neural or intrinsic muscle properties (*Dudley & Djamil, 1985*). Because of the training elite swimmers undergo (3-4 hours per day, 10,000m per day), muscular power would be expected to reduce. It would appear, though, that sufficient tapering allows restoration of power while maintaining the endurance-related metabolic benefits gained (*Houmard & Johns, 1994*). The actual ability to exert power is highly related to swimming performance (*Costill et al, 1983*). It is therefore concluded that the improvement in power with taper is probably the major factor responsible for the improvement in competitive swimming performance (*Houmard & Johns (1994)*).

“Consistent research suggests that an improvement of 3% in swimming performance can be achieved as a result of tapering”

What about actual swim performance?

Consistent research suggests that an improvement of 3% in swimming performance can be achieved as a result of tapering. *Costill et al (1985)* compared swim performance during normal training and with a 14-day taper. Swimming performance in all strokes improved by an average of 3.1% with tapering. Similar results were reported again by *Costill et al (1990)*, who assessed performance after two tapers in the same competitive season. *Johns et al (1992)* also demonstrated a 3% improvement after a 10- and 14-day taper programme in swimmers over a variety of distances and strokes. And we mustn't forget the shaving down carried out by swimmers, which could also have affected performances (*Sharp et al, 1988*).

What to be aware of

In order to produce the best possible results from tapering, both coaches and swimmers need to be aware of the following factors:

- 1 The awkward feeling associated with the first few days of tapering.
- 2 The individuality of the taper process (this is an *absolutely vital* consideration). Every athlete will respond to taper differently, so communication between coach and swimmer is of the utmost importance.
- 3 Mini-tapers and retapers (throughout the season for more than one competition).
- 4 Shaving and mental preparation.
- 5 Realistic estimation of performance goals.

Conclusions

When planning any form of tapering programme I would recommend the following points. The training incorporated into the programme should be reduced in an incremental fashion with a 60-90% reduction in training volume. Training intensities should take the form of high interval work (90% VO₂max) with sufficient rest between sets. The frequency of training should be reduced by no more than 20% in order for the swimmers to maintain their 'feel' of the water, and, finally, duration of the taper programme should be decided on an individual basis (because of varying responses to tapers) and last between seven and 21 days.

Matthew Coulson

WHAT THE PAPERS SAY

This American study shows which type of weight-training improves performance

Most exercise scientists and swimming coaches agree that the development of muscular strength and power are essential elements in swim training and important predictors of competitive success.

The problem lies in figuring out *how* to develop that strength and power, since several scientific studies have shown that traditional weight-training programmes may improve swimmers' generalised muscle strength without influencing actual swim performances.

To evaluate strength-building programmes for swimmers, scientists at Ball State University in the United States divided 10 highly trained male collegiate swimmers into two groups. Members of both groups maintained a daily swimming volume of about 5,600 metres, with most of the work consisting of intervals designed to produce an exercise intensity of greater than 85% VO_2max (over 90% of maximal heart rate).

Group one...

Strength training was conducted twice a week for six weeks, but the two groups used different resistance-training techniques. One group utilised a weight-assisted dip and pull-up training device designed to strengthen tricep and latissimus dorsi (upper back) muscle groups (both the tricep and latissimus dorsi muscles are believed to provide a considerable amount of the propulsive force during competitive front-crawl type swimming). This first group completed three sets of dips and pull-ups per workout, with as many repetitions as it took to reach complete fatigue during each set.

...and group two

The second group carried out traditional weight-training routines, with lat pull-downs, elbow extensions, elbow flexions, bent-arm

flies, quadriceps extensions, and hamstring flexions serving as mainstays of the programme. The lat pull-downs, quadriceps extensions, and hamstring flexions were completed on Nautilus and Universal machines, while the rest of the exercises were done with free weights. All swimmers performed three sets of each exercise with eight to 12 reps per set, using increasing resistance over time.

In the study, the six weeks of swim and strength training were followed by six weeks of swim-only workouts. Over the 12-week period, there were no differences between the two groups in lean body mass or % body fat. However, the weight-assisted dip and pull-up swimmers fared slightly better, compared to the traditional strength trainers. For one thing, they improved their 22.9 metre front crawl sprint time by 0.3 seconds, from 11.2 to 10.9 seconds, while the traditional people failed to improve.

“A key problem is that the gains in strength don’t always “transfer” from the gym into the water.”

In a 365.8-metre front-crawl time trial, the two groups had equivalent performance times and stroke rates and travelled about the same distance per stroke. However, the dip and pull-up people did achieve a greater improvement in power while exercising on a biokinetic swim bench at a swim speed of 2.66 metres per second (a biokinetic swim bench is a mechanical device that measures muscle power on dry land as a swimmer mimics typical swimming movements). In addition, there was a trend for the dip and pull-up swimmers to increase muscle power to a greater extent during actual swimming, although the difference wasn’t statistically significant.

Conclusion?

Since swimming speed is correlated with upper-body strength, it seems that upgrading upper-body strength should help athletes swim faster. However, a key problem is that the gains in strength don’t always ‘transfer’ from the gym into the water. In the Ball State study, dip and pull-up swimmers roughly doubled the number of dips and pull-ups they could complete over a period of six weeks, and they also achieved more pronounced improvements in swim performance and power, compared to the traditionally trained athletes. Weight-assisted dips and pull-ups may be more

like typical swimming motions, compared to routine strength-training routines, and therefore might be better at improving actual swim-stroke power. Conveniently, dip and pull-up training devices are small enough to fit on pool decks, a real advantage for athletes who don't have access or time to use a real weight-training facility.

Reference

"Effects of Weight Assisted Dry-Land Strength Training on Swimming Performance," Journal of Strength and Conditioning Research, vol. 8(4), pp. 209-213, 1994

Is the swim bench a mechanical ergogenic aid to training?

A quick glance at most swimming magazines will reveal ads for this piece of equipment. Its value to clubs and competitive swimmers is very much a topic of current debate in sports science. Although swimming strokes each involve a unique, integrated pattern of neuro-muscular and joint actions, the body position and movements involved in swim-bench exercise suggest that this type of training may effectively imitate actual swimming. The potential advantage over true swimming, of course, is the possibility of increasing resistance to movement in excess of that usually encountered. Thus the overload principle of training can be allowed to take effect – the artificially increased training stimulus should hopefully result in greater power gains. Another use may be in observing an individual swimmer's stroke pattern so that immediate instruction and feedback can be given. Those who can afford it can also have a computer-interfaced system for analysis of power output and movement pattern on-screen.

What this study showed

A recent Japanese study has compared the peak oxygen uptake between swim-bench exercise and arm-stroke-only swimming. The

“The researchers found that swim-bench work, when performed at the maximum intensity possible, required over 20% less oxygen than arm-stroke-only swimming”

researchers found that swim-bench work, when performed at the maximum intensity possible, required over 20% less oxygen than arm-stroke-only swimming. A possible reason for this appears when one considers that oxygen requirements are very highly related to the size of the muscle mass involved in the exercise – in other words, does swim-bench work use less muscle? Most swim-benches require the user to work against a resistance while pulling the arm to the rear position, but during the recovery little or no resistance is felt, or the arm may even be drawn forward. However, during actual swimming, voluntary recovery must take place with some considerable physical effort, which ultimately has an oxygen cost associated with it.

An additional reason may be that the torso is completely supported on most swim-benches, whereas during swimming the postural muscles of the upper body must be recruited to both maintain optimum horizontal positioning and initiate rotation around the head-feet axis.

In summary, this recent research suggests that the cardiovascular stress induced during swim-bench exercise is not comparable to that met in arm-stroke-only swimming. Thus, if the perceived advantage of swim-bench exercise still exists, it should certainly be combined with significant amounts of traditional training to ensure a proper training stimulus (Ogita and Taniguchi, *'The comparison of peak oxygen uptake between swim-bench exercise and arm stroke'*).

Reference

European Journal of Applied Physiology, 1995, vol.71, pp 295-300)

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PEAK PERFORMANCE

The research newsletter on
stamina, strength and fitness

Every year, British sport is becoming much more competitive. The financial rewards are huge and there is enormous pressure on our coaches to find ways of improving performance. So where do the best coaches get their training advice? How can you tap into the same advice to improve your strength, speed and stamina?

The answers are in the *Peak Performance* newsletter. It's written for all those interested in getting the best performance out of themselves. In it you'll find the same performance-boosting techniques and training shortcuts used by the world's top coaches and the world's most successful competitors – the ones that came back with medals from the Olympics.

In each issue you'll discover new, tested techniques that coaches and sports therapists are currently using to extend the limits of sporting achievement (our achievements at the last Olympics revealed the value of this knowledge). These are for you to use in your own sport. See for yourself some examples of recent research that we passed on to our readers:

- ◆ **How can you take maximum benefit from drafting and let your competitors help cut your times? *PP* reveals the secrets of a scientific study that will give you the edge.**
- ◆ **“Swimmer’s shoulder” and “breast-stroke knee” are common injuries amongst competitive swimmers. *PP* explains how to avoid and treat these nagging swimming injuries.**
- ◆ **Can being fatter make you a faster swimmer?**
- ◆ **Read the amazing results of a study on the effect of exercise on the immune system of elite swimmers and how to get the most out of your own training.**
- ◆ **Access to millions of pounds of sport research**

The days when training was left to amateur theorists are now gone. Sports scientists have taken over. Substantial amounts of money are pouring into worldwide research and these scientists spend millions of pounds searching for ways to improve the performance of competitive athletes and sports people.

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