Swim training theory

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ABSTRACT

MAGLISCHO E. Swim training theory. *Kinesiology*, Volume 2, No. 1, pp. 4-8, 1997. This paper will have two parts. The first will be a summary of the energy systems as they relate to swim training. A scheme for training the various energy systems will be presented in the second half of the paper. The two major types of training in that scheme are endurance and sprint. Three sub-categories of training will be identified within each of the two main categories. Suggestions will be provided for designing repeat sets that target each type of training. Finally the very important topic of balancing the six sub-categories of training will be discussed.

Key words: ENERGY METABOLISM, FORMS OF TRAINING, ENDURANCE TRAINING, SPRINT TRAINING, BALANCING TRAINING

The purpose of this paper is to present a plan of training all of the energy systems involved in swimming races. The information will be presented in two sections. The process of energy metabolism will be summarized in the first section and the various forms of training will be described in the second.

Energy metabolism summarized

Swimming from one end of the pool to another is made possible by the contraction of certain muscles. The muscles need energy to perform those contractions. Energy metabolism is the process through which the energy for muscular contraction is released and later replaced. The process of energy metabolism is illustrated in Figure 1.

Energy is contained within chemicals that are stored in the muscles. The principal chemical that supplies the energy for muscular contraction is *adenosine triphosphate (ATP).* It is stored in all muscle cells. ATP consists of one complex compound, adenosine, and three less complicated parts called phosphate groups. The three phosphate groups are considered high-energy bonds because each is bound to adenosine by a potential source of energy. The energy for muscular contraction is released when one of the bonds is broken, i.e., removed from the rest of the compound through stimulation by a nerve impulse. ATP is the only chemical, stored in muscles, that can supply energy for muscular contraction. Unfortunately, there is only enough to last a few seconds. Consequently, it must be replaced as rapidly as it is being used when athletes swim races. There are several additional substances stored in muscles that provide the energy for ATP replacement. They are *creatinephosphate (CP), glycogen, fat, and muscle proteins.* CP is the most rapid source of energy for ATP replacement. In one step, it releases the energy and phosphate that were lost in the metabolism of ATP. The muscles' supply of CP is also limited. There is only enough stored in muscles to last approximately 10-15 seconds. ATP and CP are collectively known as the *high- energy phosphates.* They provide most of the energy for getting races out fast in the first 25 meters. Muscle glycogen becomes the major source for ATP replacement when the CP supply is nearly depleted. *Anaerobic metabolism* is the term used to describe the first stage in the breakdown of muscle glycogen. It is the next fastest method for replacing ATP. It involves 11 steps and ends with the formation of lactic acid. The most various problem associated with anaerobic metabolism is that the accumulation of lactic acid cause muscle pH to drop below the neutral 7.0 causing acidosis. When this happens, swimmers lose coordination, power and speed.

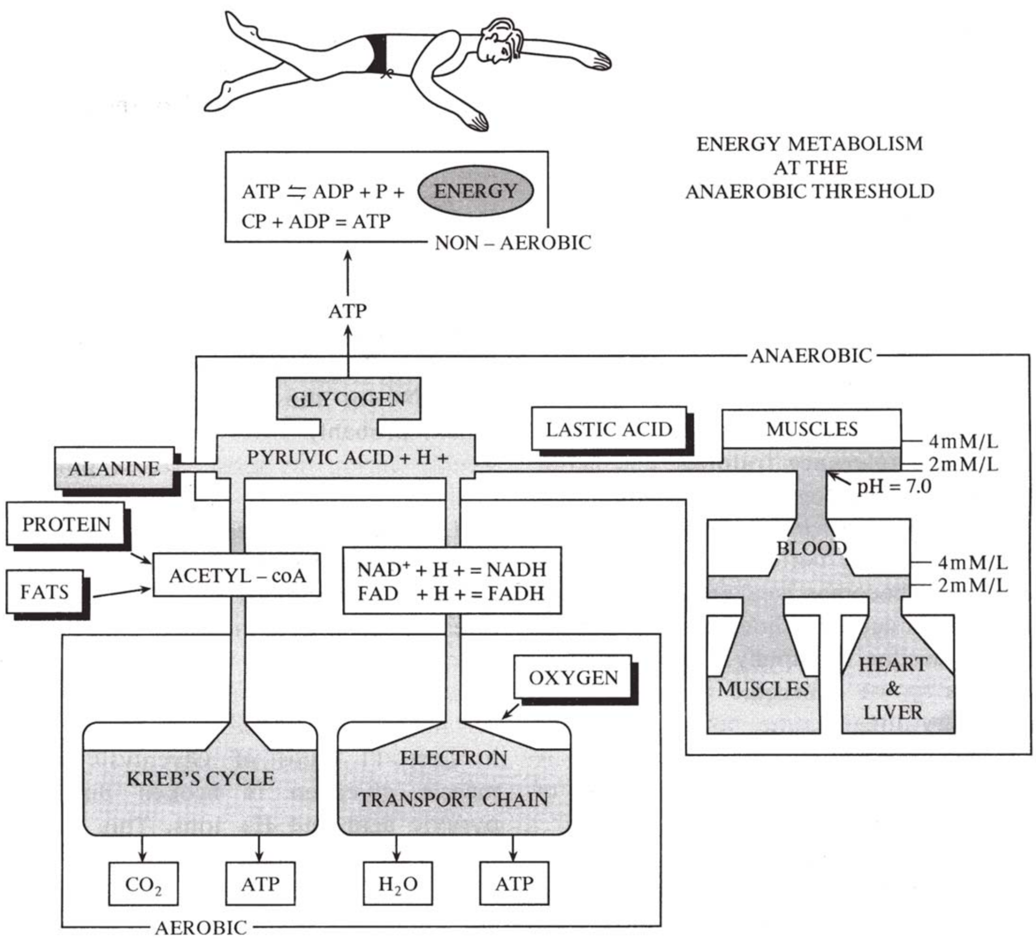

Figure 1. Energy metabolism in swimming.

A slower, but more efficient source of energy tor ATP replacement comes from the aerobic metabolism of glycogen. In this case, lactic acid is not formed, so athletes can continue for a long time without any serious decline of pH. *Aerobic metabolism* is the term for this process. It is slower because hundreds of steps are involved before ATP can be replaced. Consequently, race speeds cannot be maintained solely through aerobic metabolism. Athletes must supplement the energy released through aerobic metabolism with energy from anaerobic metabolism so they can swim fast enough to be competitive in training and competition. This fact notwithstanding, athletes who are well-trained require less energy from anaerobic sources during races. The most important effect of endurance training is to reduce the amount of anaerobic supplementation required to swim at race speed.

Blood testing is one method for estimating-the amount of this reduction. This method can quantify the lactate threshold which is the swimming speed where aerobic metabolism is stressed maximally and beyond which anaerobic metabolism becomes a major contributor of energy.

Fat and protein provide the energy used to replace ATP when the muscle glycogen supply is low and when athletes are swimming at slow speeds. Both can only be metabolized aerobically so the process of energy release is slower than when glycogen is used.

When athletes are well-fed, there is enough glycogen stored in muscles to support exercise for one to two hours depending on the intensity of the work. Fat and protein become major sources of energy after that. However, athletes should avoid using large amounts of protein for this purpose. They will literally cannibalize their own muscle tissue. Consequently, they will lose power and endurance. A diet where over one-half of the daily calories are complex carbohydrates will maintain muscle glycogen at a high level so less protein will be used for ATP replacement.

There are two general categories of training that swimmers should use to improve the various phases of the metabolic process. They are, *endurance* and *sprint* training. There are several subcategories within each of these two phases. These two general forms of training and the sub-categories within each will be discussed in the following sections.

Endurance training

This form of training improves aerobic metabolism so athletes can swim faster with less energy contributed from anaerobic metabolism. Thus, endurance training makes it possible for athletes to swim faster through the middle of races without becoming fatigued.

Effects of endurance training. Following is a list of the important physiological changes that are responsible for improving aerobic metabolism.

1. A reduction in the rate of lactic acid production when swimming at submaximal speeds. This is due to an increase in the oxygen supply to muscles. That increase is brought about by respiratory, circulatory and muscular changes that increase (a) open alveoli, (b) pulmonary diffusing capacity, (c) stroke volume, (d) the capillaries around muscles, (e) blood volume, (f) total hemoglobin, (g) the size and number of mitochondria in muscles.

2. An increase in the quantity of glycogen stored in swimming muscles. The amount can nearly double in well-trained athletes.

3. An increase in the activity of enzymes of aerobic metabolism.

4. An increase in the rate of removal of lactic acid from swimming muscles.

Sub-categories of endurance training. Endurance training should be conducted at three levels of intensity. They have been termed, *threshold, overload* and *basic,*

Threshold endurance training*.* This is the most effective type of endurance training. It overloads aerobic metabolism to the maximum without engaging anaerobic metabolism to any great extent. Endurance will improve as rapidly as it can when swimmers train at this intensity. The speed for threshold repeats should correspond to a particular swimmer's lactate threshold. The lactate threshold can be determined from blood testing, a T-30 test, or simply by swimming a long set of repeats (3500-4000 yds) on short rest at the fastest possible average speed.

Muscle glycogen is the primary source of energy for this level of endurance training. Consequently, swimmers will not be able to do more than two sets within a 24 to 36 hour period without becoming depleted of this substance. For this reason, swimmers should probably swim only 3 to 5 threshold sets per week depending upon whether they are training once or twice per day.

Any repeat distance can be used for threshold training. The sets should be 2000 to 3000yds/mtrs in length for senior swimmers. They can be 800 to 2000 yds/mtrs for younger swimmers. The guideline that can be used for swimmers of any age or ability level is that threshold sets should require 20 to 40 minutes to complete.

Rest intervals should be short. They should be no more than 10 to 30 seconds on repeats of 400 meters and less. They can be 30 seconds to 1 minute for longer repeats.

The repeats should be swum in the fastest possible time the swimmers can maintain for the entire set. Less exact guidelines are that the heart rate should be 170 to 180. An effort rating of 8 or 9 on a 10 point scale also corresponds to the correct intensity.

Overload endurance training. Athletes should swim endurance repeats slightly above their lactate thresholds on occasion. This intensity of training provides a stimulus that encourages further improvements in aerobic capacity when it has plateaued. It is analogous to «maxing out» with weights. Overload training is particularly stressful and should be used sparingly, however.

Repeat distances of 25 to 2000 yds/mtrs can be used for this purpose. Sets should be 1200 to 2000 yds/mtrs in length or 15 to 25 minutes. Swimmers cannot swim even slightly above their threshold for much longer than this before severe acidosis occurs.

Rest intervals should also be short. They should be similar to those recommended for threshold training, although, they can be increased slightly to encourage athletes to swim faster.

The speed for repeats should be 1 to 2 seconds per 100 faster than a particular swimmer's average speeds on threshold sets. Heart rates should be maximum and sensations of effort should rate 9 or 10.

Muscle glycogen will be the primary energy source so swimmers can become depleted by doing too many overload sets each week. One or two per week is probably optimum.

Basic endurance training. This form of endurance swimming is done at moderate speeds. It will improve endurance but, at a slower rate than it can be improved by threshold and overload training, because aerobic metabolism will not be fully overloaded. However, it is the only kind of endurance training that can be used when athletes require time to replenish their muscle glycogen supplies. Much of the energy comes from fat metabolism so athletes can be replacing muscle glycogen faster than it is being used when they train at basic endurance speeds.

Some basic endurance swimming can, and, should be done every day. Any repeat distance can be used for basic endurance training. The sets should be a minimum of 1000 meters in length to provide time for a training effect. They can be as long as the time and motivation of swimmer's permits.

Rest periods should be very short. Send-off times that provide 5 to 30 seconds of rest are ideal.

The speed for basic endurance repeats should be 4 to 5 seconds per 100 slower than for threshold repeats.

Sprint Training

The purposes of this category of training is to improve swimming speed. This will help sprinters get their races out faster and it will help swimmers in all events to bring their races home faster. These purposes are achieved in three ways.

1. By improving buffering capacity.
2. By increasing the rate of anaerobic metabolism.
3. By increasing stroking power.

There are three sub-categories of sprint training that can accomplish these purposes. They have been termed, lactate tolerance training, lactate production training and power training.

Lactate tolerance training. The major purpose for this form of sprint training is to increase muscle buffering capacity. When a muscle buffers lactid acid, that substance becomes weaker so that more can be produced without causing muscle pH to decline as rapidly. This will allow athletes to use anaerobic metabolism for a slighlty longer time before becoming fatigued. Improved buffering capacity is particularly useful to athletes in races of 100 to 400 meters.

Another important aspect of improving buffering capacity may be psychological in nature. Athletes may improve their pain tolerance. Their power will be improved when they subject themselves to the pain of acidosis without «giving in».

The best repeat distances for lactate tolerance training are between 75 and 200 meters. They produce the highest rates of lactid acid accumulation. So, these distances should provide the greatest stimulus for buffering that substance. Fifty meters repeats can also be used if they are done in sets of 2 to 4 on short rest. Sets should be 600 to 1000 meters in length. Sets that are longer than this cannot be done at a sufficient intensity.

Rest periods should be long enough to permit swimmers to recover from acidosis so that each repeat (or combination of 50 repeats) can be done at a high quality. Three to seven minutes should be sufficient. Athletes should swim easy between repeats to hasten recovery.

Athletes should swim at near maximum speeds on these repeats. They should be at least 85% to 95% of race speed. Heart rates should be maximum and sensations of effort should rate as 10's. Under-distance repeats of this type can also be swum at race speed to improve the athlete's sense of pace.

This kind of training is very stressful. One or two sets per week are probably optimum for most swimmers. Sprinters should probably swim three to four sets weekly during the most intense portions of their seasons.

Lactate production training. The primary purpose for this type of training is to increase swimming speed. An increased rate of anaerobic metabolism provides energy to the muscles faster. That rate can be augmented by increasing the activity of certain of the enzymes that are involved in first 11 steps of Glycolysis where muscle glycogen is broken down to pyruvic acid and H^+ ions. This will be particularly important after the first 10 to 15 seconds of races, when the CP supply has diminished. Lactate production training should make it possible tor athletes to sprint faster in 50 and 100 events and at the end of all races.

The best repeat distances for this purpose are 25 to 50 meters in length. These distances are long enough to encourage high rates of lactic acid production without being so long that they produce acidosis. Acidosis will reduce the rate of anaerobic metabolism and defeat the purpose of this form of training. The optimum length of sets is probably 300 to 800 meters.

The rest intervals should be 1 to 3 minutes in length to permit the removal of lactic acid so subsequent repeats can also be done at fast speeds. Speeds should be maximum. Efforts should also be maximum but swimmers should not experience pain. Pain indicates acidosis and, as mentioned, acidosis will reduce the rate of lactic acid production.

Lactate production training can be done in small amounts every day. Three to four sets weekly should be sufficient to produce the desired effect, however.

Power training. An increase in stroking power is the desired outcome from this form of sprint training. The reasons why improved stroking power will increase swimming speed should be obvious. Swimmers will be able to exert more force at faster turnover rates. At one time we believed that this improvement had to do with the high energy phosphates. It is now apparent that they have very little to do with it. Increases of muscular strength and neuromuscular recruitment patterns are probably the principal adaptations that allow swimmers to stroke with more power.

The best repeat distances are 5 to 25 meters in length. They allow athletes to swim as fast or faster than they swim in races. So, they will overload muscular power by stroking with great force at fast turnover rates. Sets should probably be 100 to 300 meters in length.

Rest intervals should be 30 seconds to 3 minutes to allow replacement of creatine phosphate so athletes can swim as fast as possible. Efforts should be maximum. Pain should not be felt, however, because acidosis should not take place.

Athletes should use competition turnover rates in these repeats. They should also try to maintain the longest possible stroke length at those rates of turnover. Three to five sets weekly should be sufficient to increase muscular power.

Swimming against resistance in the water may aid the improvement of power. This form of training has been termed *sprint-resisted.* Athletes should be sure to maintain competition turnover rates and the longest possible stroke lengths at those rates.

Another innovation in power training has been to use devices that assist swimmers to sprint faster than they can sprint unassisted. This form of training has, for obvious reasons, been termed *sprint-assisted.* Sprinting with fins and hand paddles are effective ways to perform this type of training. Swimming with the "snap-back" of surgical tubing is also excellent for this purpose. Sprint-assisted training may produce a type of speed-overload that cannot be achieved in any other manner. Swimmers will naturally use fast turnover rates in this kind of training. They should also be encouraged to maintain the longest possible stroke lengths at those rates.

Balancing training

The proportions of these six categories of training probably have as much to do with a swimmer's success as does their training mileage. Where endurance training is concerned, the overuse of threshold and overload training can result in muscle glycogen depletion and overtraining. The overuse of sprint training can cause saturation and lack of motivation. Too much lactate tolerance training may also precipitate overtraining. The following proportions of the weekly mileage are recommended, based on these considerations.

Warm-up and swim down:	15-20%
Threshold and overload endurance training:	20-25%
Basic endurance:	40-50%
Sprint training:	5-10%

These proportions are ideal for middle distance swimmers. Distance swimmers do not need to change them, however. They will be doing a greater quantity of endurance training at these same percentages because they are swimming more mileage each week; so they should stay at the low end of the percentage range for sprint training because of that additional mileage. Sprinters should probably reduce the threshold training by 5 to 10% and they should icrease the amounts of lactate tolerance and lactate production training by 2 to 5% each during the most intense portions of their season.

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