Chapter 2

Physiological Principles

This section will acquaint the reader with the concepts and terms that have traditionally been used to describe sports training and how it relates to kayaking. A subsequent section, "How Barton Trains," explains what Barton actually does and contrasts it to the traditional view. This way, the reader will have both a theoretical understanding of the matter as well as one concrete example.

Paddling a sprint boat is a mixture of aerobic (with oxygen) and anaerobic (without oxygen) work, with the proportion of each determined by the length of the event. The aerobic aspect is the most important for the 10,000m event and the anaerobic most important for the 500m. However, having a good aerobic base is useful for creating a good anaerobic one; consequently, the largest proportion of a sprint racer's training is aerobic.

Three Energy Systems

The body produces energy from three different systems (two of which are anaerobic and one aerobic) with the preponderance at any given time being on one of the systems. The maximum potential of each of these systems in an individual is determined at birth, and the percent of that potential reached is determined by hard training. Exactly when each system comes into play is determined by a combination of the intensity, duration of the exercise, and the duration of the rest period. Furthermore, the employment of the systems is not purely sequential; they operate to some extent at the same time. For purposes of clarity, they will be treated separately here.

The three systems are: the ATP-CP system (anaerobic), in which you operate at maximum intensity for a short period (less than about 15 seconds); the lactic acid system (anaerobic), in which you operate at very high intensity for up to about 180 seconds and thus produce lactic acid; and the O_2 system (aerobic), in which you operate at less intensity and thus can do so for much longer periods.

The graph below represents the three systems and the variables of duration and intensity of exercise. To represent intensity, *assume you are going at an all-out* *sprint the entire time.* This might occur, for example, if you attempted an all-out 1,000m sprint in a kayak. It should be borne in mind, of course, that a sprint race is not exactly like this, because you have to pace yourself in order to be able to produce a big kick at the end. Nonetheless, this graph gives an idea of what we are talking about:

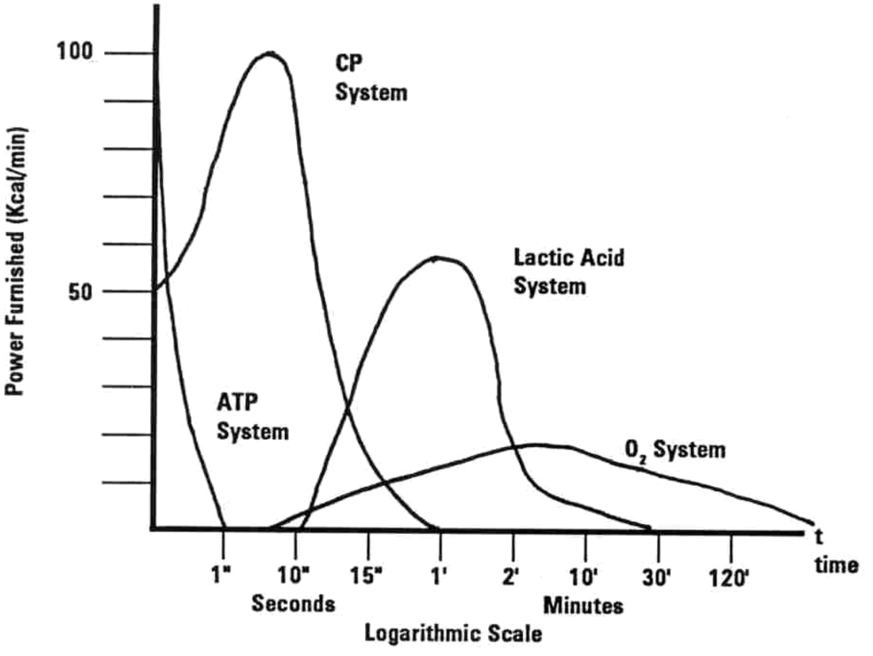

Figure 1

ATP-CP SYSTEM: This system has several names, each descriptive of some of its characteristics. It sometimes is called the anaerobic alactic system because while using it, you do not supply your oxygen needs from air taken in during exercise, so it is anaerobic. In fact, you may be holding your breath during the duration of this system (like a 50m sprint in a kayak). Yet the exercise does not go on long enough to produce perceptible amounts of lactic acid in the bloodstream (thus it is alactic). Sometimes the system simply is called the fast energy system because it is the fastest source of energy. Barton calls work on this system "speed work."

Adenosine triphosphate (ATP), is a compound necessary for muscular contraction to occur. Limited amounts of ATP are stored in the muscles and a very quick contraction, lasting a fraction of a second, uses it all. For any exercise lasting longer than this, another compound, creatine phosphate (CP), must be used. CP quickly breaks down to provide more energy, allowing a somewhat more prolonged muscular activity. However, the combined ATP-CP system is depleted after about 15 seconds. The 100-yard dash is the classic example of an event relying exclusively on the ATP-CP system. Any acceleration in a sprint boat would use it, too, such as the start or the final kick, or tactics in a 10,000m race like jumping on a wake or going around a turn. Anything requiring short bursts of energy at maximum intensity to re-accelerate the boat relies heavily on this system.

However, there are some important points to remember about how the ATP-CP system works. Since it is quickly exhausted, its use for sharp bursts of energy is limited. After using it, the athlete would have to drop back into less intense work and allow his ATP-CP system to recover. He could not expect to complete even a 200m race relying totally on this system.

Figure 2 demonstrates that the more intense the work effort, the greater the energy per unit of time with the anaerobic systems (the ATP-CP and Lactic Acid systems).

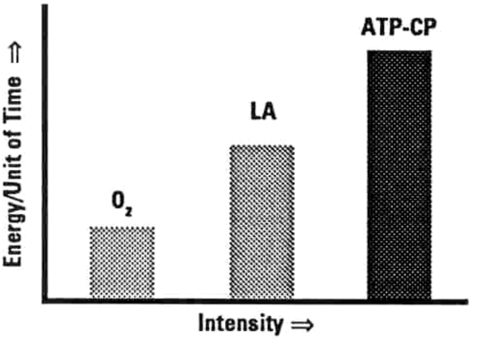

Figure 2

In an untrained person, ATP-CP is exhausted in about eight seconds. Through proper training, it can be made to last a few seconds longer. Specific training causes a larger storage of ATP-CP in the muscles. It takes about three minutes of complete rest to get a fairly complete restoration of ATP.

Proper training for maximizing the ATP-CP system would be short efforts of 15 seconds or less done at maximum intensity. For sprint training these are typically done as short sprints, or "buckets," (dragging a small bucket behind the boat) while making a maximum effort.

It doesn't take long to build up the ATP-CP system — two to three weeks at most. While ATP-CP is built up relatively quickly, it also is lost quickly through disuse. Since it doesn't take long to develop the ATP-CP system, it is usually the last of the three energy systems to be developed, with emphasis on it coming only in the few weeks before the major race. Since the other two systems take longer to develop, work on them is typically begun earlier in the yearly training. During the period of emphasis, the ATP-CP system may be worked daily, but more likely would be combined with other work (LA system) and targeted exclusively only every other day. Barton calls this "speed training".

LACTIC ACID SYSTEM: Sometimes this system is called the anaerobic lactic system because when using it, you are operating anaerobically and do it long enough to produce lactic acid. Barton calls work on this system "speed endurance" work, the term used by his coach, Paul Podgorski. Once ATP is depleted through the ATP-CP system described above, the body supplies ATP through another energy system, the Lactic Acid (LA) system. In this, the intensity of the work is very high (but not maximal) and oxygen debt is incurred while breaking down glycogen to supply ATP. However, the breaking down of glycogen in the absence of oxygen produces a waste substance called lactic acid, which inhibits muscular contraction as it accumulates in the exercising muscles. Lactic acid is the cause of the burning sensation in muscles during exercise and later muscle stiffness. Five hundred and 1,000m races make heavy demands upon the LA system. The ability to function with a high lactic add build-up and to dissipate it quickly in rest periods following exertion also is trainable. Intense efforts of between 30-120 seconds are one method of doing this. Having a good aerobic system also helps to re-oxygenate the muscles quickly and thus gets rid of the lactic add (also called lactate).

It takes about six to eight weeks of concentrated effort to build up the LA system, thus this system is the next to last one that the athlete should concentrate on, beginning as close as 8-12 weeks before the big race. During this period, the LA system should be worked about three to four times a week. Working the LA system one to two times a week is enough for maintenance, but not improvement.

It was noted earlier that the LA system is used in breaking down glycogen in the absence of oxygen. It is worth pointing out that carbohydrates are the prime source of glycogen. During normal physical activity, glycogen is formed by, and largely stored in, the liver and, to a lesser extent, muscles, being converted into glucose and released as needed. The best source of carbohydrates are complex carbohydrates such as vegetables and fruits, pasta and breads. Sprint athletes should incorporate a lot of complex carbohydrate in their diets.

The higher the glucose levels in an athlete's body, the longer he can exercise. The initial supply of glycogen lasts about 80 minutes. After that, additional glycogen has to be stored or added. A highly-trained athlete has a large capacity to store glycogen intramuscularly. It takes up to 48 hours to replenish liver glycogen, but only a few hours to replenish muscle glycogen. Thus, in a sprint workout lasting about an hour it would not be likely that the athlete would suffer significant liver glycogen depletion, although he would suffer depletion of muscle glycogen. Therefore, he would be able to have a second workout later in the day without adverse consequences. But if the workouts were long ones, say two hours, there could well be a significant depletion of liver glycogen and the athlete would need about 48 hours to replenish his stores. This is why some athletes follow the hard day, easy day cycle in training.

O_2 SYSTEM: This is sometimes called the aerobic system, for unlike the other two systems, it is not anaerobic and in using it, you supply your oxygen needs from the outside air during exertion. Barton and Podgorski call work on this system "endurance" work. In the O_2 system, glycogen is broken down into ATP in the presence of oxygen. With oxygen present, this system does not cause the build-up of lactic acid. However, lactic acid may well have been built up in previous work bouts because the LA system may have been used first. But in this case, transferring from the LA system to the O_2 system will allow lactic acid to dissipate somewhat. Furthermore, the O_2 system can actually use lactic acid as a small source of fuel. In a process known as the Cori cycle, which takes place in the liver, lactic acid is transformed into liver glycogen.

The O_2 system takes longer than the ATP-CP or LA systems to produce energy, but it is by far the most efficient of the three once it starts. In a process known as the Krebs cycle, the O_2 system can use both carbohydrates and fats (for very long duration exercise) to produce energy.

A 10,000m race makes maximum demands upon the O_2 system. Since the race is so long, most of it has to be done aerobically. The 1,000m also places great emphasis on the O_2 system.

Having a good O_2 system also will help an athlete get through a long workout comprised largely of anaerobic segments. The sheer duration of the workout taxes his aerobic powers. Thus, his ability to do a lot of anaerobic work might be lessened because of a poor aerobic capacity. This is one reason it is thought best to begin a year-long cycle of training with emphasis on the O_2 system. A good O_2 system is necessary to support the high levels of intense training to come. This situation is depicted in Figure 3, which shows that the longer the work continues, the more total energy supplied comes from the O_2 system.

The real reason it is thought best to begin the yearly training cycle with emphasis on the O_2 system is because it takes longer to develop than the other three — at least three or four months. Top paddlers typically spend six months out of the year working on their aerobic systems. During this period, the O_2 system should be worked four to six times a week. It takes only two to three times a week to maintain it, though.

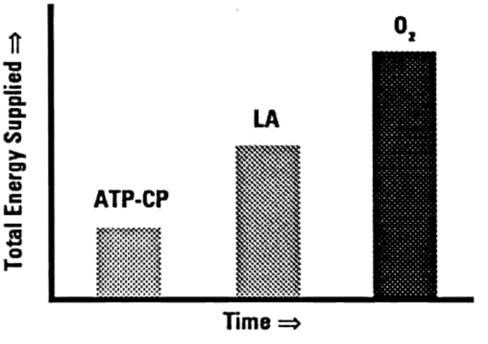

Figure 3

Traditional literature says maintenance can be done through general training, such as running, swimming, cross-country skiing, and biking, as well as boating. This procedure is followed by many top sprint boaters, including Barton. There is another school of thought, though, which says O_2 training only should be done in the boat. This school is represented by the phrase "runners don't kayak, so why should kayakers run?"

In this author's opinion, the answer as to who is right centers on whether the key link is the heart and lungs (cardio-respiratory system) or the specific muscles used in kayaking (peripheral musculature). If cardio-respiratory system development is the key, anything that works the heart and lungs is satisfactory, but if the peripheral musculature is the key, working those muscles— through paddling — would be the key. This author believes the latter is key and that is one reason why year-round paddling is best. He believes that the heart and lungs bring enough oxygen into a paddler's system, and it is the ability of the muscles used in kayaking to extract the oxygen and use it that is the crucial factor in kayaking.

There is a common belief that the O_2 system should be developed first, then the LA system and finally the ATP-CP system, as though they had to be done in that order. But there is some evidence that it is necessary to do some ATP-CP work all through the year in order to keep the stroke rate up. Thus, during the six months of basically aerobic training that Barton does, he will do some ATP-CP work twice a week as well.

Measurements of Aerobic and Anaerobic Power

VO_2 MAX. VO_2 MAX means the volume of maximum oxygen consumption. It has been determined in many sports that maximal aerobic power, i.e., O_2 system capability, is highly important to success. The same thing is true of sprint racing. Barton, for example, has a VO_2 MAX of between 65 and 70 milliliters per kilogram of body weight per minute (Ml/Kg/Min) which is very high, an upper body-produced value that is comparable to values produced by runners with their legs.

VO_2 MAX is the largest amount of oxygen per unit of time that can be transported by the heart and lungs and used in active muscle tissue. There are two ways of looking at VO_2 MAX. It can be expressed in liters of air per minute (I/ min), in which case it is proportional to body size and muscularity: the greater the size, the greater the VO_2 MAX. (Barton's would be about 5.2 liters per minute.) Or VO_2 MAX can be related to body weight and expressed as milliliters per kilogram of body weight per minute (ml/kg/min). The latter method is normally used with sprint athletes.

Anaerobic Threshold

At a certain point, a paddler approaching his VO_2 MAX starts to lapse into an anaerobic state. The point at which this occurs is called the anaerobic threshold. It starts to occur at about 70 percent of VO_2 MAX in the average untrained individual but at a higher percentage (85 percent or more) in the well-trained person.

Figure 4 depicts the situation: One paddler, "A," reaches his anaerobic threshold at point A. He can continue to do work but from here on, it will be in an anaerobic state (and therefore less efficient). The paddler reaching his anaerobic threshold at point B can do more work than A in an aerobic state, which means that B can do the extra work more easily than A. It could be true that A may be able to function better than B anaerobically and may even be able to beat B, but he must work harder than B to do so and thus it is less likely that A will be able to beat B.

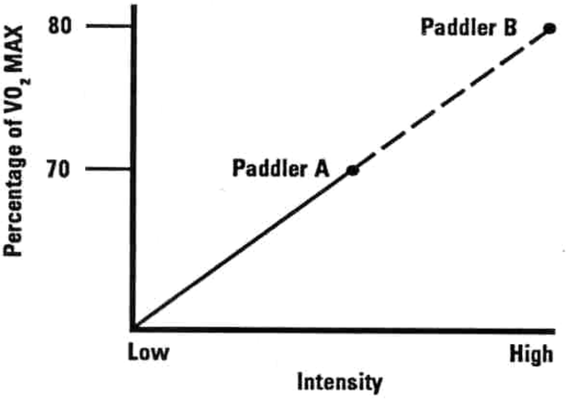

Figure 4

Once a paddler is in an anaerobic state, it is important to know how long he can stay there, and how anaerobically he can function. The current method of measuring this is to measure the amount of lactic acid, or lactate, present in the blood. It is typically reported in milligrams percent, which is simply the amount of lactate per unit of blood, expressed as a percentage.

The blood is not drawn immediately after exertion because peak levels of lactate are usually reached three to five minutes after exertion. It takes that long for the lactate to be washed out of the muscles and into the blood stream. The higher the lactate levels, the more anaerobically the paddler has functioned.

In passing, it should be pointed out that measuring the amount of lactate in the general bloodstream is really only an indirect way of inferring what went on in the muscle cells. At present, it is impossible to get into the muscle cells during exercise and thus know exactly how much lactic acid was built up. Perhaps in the future a more direct method will be developed.

The concept of anaerobic threshold is important for sprint paddlers because they do most of their races at anaerobic threshold, delving deeply into the anaerobic state only at the end. It is believed that the best way to improve anaerobic threshold — increase the amount of work an athlete can do before he lapses into an anaerobic state — is by doing a lot of training at anaerobic threshold or at levels alternating just below and just above it— "teasing" it. It is possible to precisely calculate an athlete's anaerobic threshold and thus give him a heart rate at which to train in order to best improve anaerobic threshold. Barton does not use this method, nor does he talk about the concept of anaerobic threshold at all. In all likelihood, though, his years of experience have allowed him to build an intuitive sense of where his anaerobic threshold is and he "teases" it in his training.

Types of Training

Sprint training encompasses all three energy systems, but the bulk of it is aerobic training. Sometimes the training could be a mixture of systems, particularly the aerobic and lactic systems.

At one extreme of the aerobic/anaerobic spectrum there is long, continuous paddling, which is as purely aerobic as you can get. At the other extreme there are, for example, 10- or 20-second efforts at all-out intensity, with two to three minutes of rest between them. A workout consisting of two to three minutes of work with 45 seconds of rest between efforts could be part aerobic and part anaerobic.

Intensity Scale

Before we review the different training methods, it is necessary to say a few words about intensity. In order to achieve maximum effectiveness, any kind of training must be done with the proper intensity. Traditionally, percent of maximum heart rate has been used as a guide, as shown in Figure 5.

Intensity Scale	Pct. Maximum Heart Rate
Low	30-40%
Light	50-64
Medium	65-74
High	75-84
Sub-Maximum	85-94
Maximum	95-100

Figure 5

Continuous Paddling

Continuous paddling is the core of training, being done throughout the year. There is, however, controversy over what both the optimal duration and the intensity levels should be. At one extreme is the late Dr. Ernst Van Awaken and Arthur Lydiard, the famous New Zealand track coach who coached Olympic champions in running and whose methods have been used successfully by New Zealand sprint paddlers.

Lydiard believes in "marathon conditioning runs" which are of very long duration (two hours) and of medium intensity on the scale above. Lydiard believes the intensity for this work can be too high, in which case it starts to tax the LA system rather than concentrating exclusively on the O_2 system. When this happens, Lydiard believes, the training has become inefficient. A more direct stimulus to the O_2 system — and hence its quicker development — would occur at a lower intensity level.

Lydiard's methods have been adapted to flatwater kayaking with great success. For part of their training year the New Zealand team, which has since 1982 been winning medals in the World Championships and Olympic Games, has two days a week when they paddle 10 kilometers in the morning and 15 in the afternoon. All the other days during this time of the year they paddle 10 kilometers during one of their two workouts a day. Yet they race distances of only 500m and 1,000m.

Often overlooked in Lydiard's plan is the fact that the marathon conditioning sessions occupy only part of the training year. He also advocates whopping doses of highly anaerobic interval training later on. Essentially, Lydiard is concerned not only with giving his disciples a good endurance base for the race itself, but more importantly for a middle distance event, he is concerned with getting the athlete into shape to withstand the really hard anaerobic training that comes later. The New Zealand flatwater team does exactly the same thing. During part of their training year they undergo a large amount of anaerobic sprint training.

Continuous paddling causes the body to create a better oxygen transport system. It causes the creation of new capillary beds in the muscles used for paddling, as well as the enlargement of existing capillary beds. It also improves the efficiency of the heart, which is shown by a lower resting pulse rate. All of these things result in an increase in the time that hemoglobin-rich blood is in contact with muscle cells, thus delivering more oxygen to them and enabling them to perform longer.

Variable Intensity Training

This can be done either according to a set plan, or according to the whim of the athlete at the moment, in which case it is called "fartlek training." The goal of this type of training is to practice changing speeds, as in a race. Whenever the athlete speeds up, he is introducing an anaerobic component into his workout. He starts to go into oxygen debt and builds up lactic acid. The lactic acid level is allowed to fall during the less intensive piece that comes next. The types of variable intensity training are:

1. Climbing intensity — gradually going from a slower pace to a faster one and then holding it. The athlete typically goes through four phases:
    a. After the warm-up, he paddles at a medium intensity for 60-90 seconds (or strokes on one side, if he prefers to do it this way).
    b. He raises the pace to high intensity and does 10 seconds at that pace.
    c. He then does 10-20 seconds at submaximal intensity.
    d. Finally he does 5-10 seconds at maximal intensity, before letting the pace drop down and starting over.

The goal of the final intensity phase is more to instill a sense of paddling fast than to improve endurance. In a workout the athlete might mix five of these buildups in with his normal aerobic paddling.

2. Fartlek Training. There are two different types of fartlek training:

    a. Spontaneous. The paddler decides on the timing and duration of the spurts spontaneously. He varies the length of the pieces and changes the intensity according to how he feels at the moment.

    b. On set courses. The paddler has little finish lines all over the course (bridges, rocks, etc). He tries to get to each line as quickly as possible. He can vary the speeds.

Fartlek methods train the athlete to go from one intensity to another as well as to feel the proper tempo. Therefore, the pieces should not be too long — not more than 90 seconds at high intensity, 30 at submaximal and 10 at maximum. Pieces at low or middle intensity make up periods of active rest. If the work periods last more than 120 seconds, the training shifts from pure fartlek to endurance training with bits of fartlek thrown in.

Interval Training

The key to interval training is that intermittent work — bouts of exertion followed by rest — guarantees that the work will be done at sufficient intensity, which is necessary for maximum improvement of the energy system in question. This is contrasted to steady-state work in which there is no rest interval, only one long work interval, and thus the intensity level is of necessity much lower.

Intermittent work also improves heart stroke volume, the amount of blood pumped with each heart beat. Stroke volume is one of the two key factors in determining the total amount of blood pumped by the heart (the other is heart rate). The higher the stroke volume, the more blood pumped by the heart, and thus the more oxygen is transported to the exercising muscles. It is the highest not during the work interval, but in the rest period after it. With interval training, there are many recovery periods, and thus stroke volume reaches its highest level many times during the workout. This contrasts with steady-state paddling in which there is only one rest interval (at the end). Achieving maximum stroke volume many times per workout over many weeks of interval training provides a greater stimulus for improving stroke volume.

Then why not just do interval training all the time, and skip steady state endurance paddling altogether? In the first place, a year-round of interval training would be too hard and cause burn-out. Secondly, there is some evidence that while interval training will improve VO_2 MAX and anaerobic threshold the quickest, the improvements are not as long-lasting as they are if achieved through steady-state training. For these reasons, and variety, most sprint athletes use a combination of steady-state and interval training.

Five Variables

Interval training involves the interrelationship of five variables:

- Duration of work interval
- Intensity of work interval
- Duration and type of rest interval

- Number of repetitions/sets
- Number of interval workouts per week

Changing any one of these variables changes the nature of the interval training. To devise his own program of interval training, the boater and/or his coach must know how to manipulate them. A discussion of the variables and how they interrelate follows.

Duration of Work Interval

As we can see from the preceding discussion of the three energy systems, the duration of the work interval has an effect on which energy system is emphasized. To target the ATP-CP system, short bouts of intense effort are best. These would be all-out 15-second sprints, followed by 45-60 seconds of rest. This will allow the ATP-CP system to be used over and over again at maximum intensity (as long as the rest period is right — see below), which is ideal for stimulating it adequately. The short work interval prevents the onset of fatigue by preventing the build-up of lactic acid. A long rest allows ATP-CP stores to be replenished.

To emphasize the LA system, intense sprints of 40-120 seconds are best. This trains the body to operate with high levels of lactic acid (particularly with 90-120 second work intervals).

To emphasize the O_2 system, an even longer work interval of, for example, five minutes (or more), is good. Since the work goes on for some time, it is aerobic.

Intensity of Work Interval

In order to achieve maximum effectiveness in interval training, work intervals must be done with the right intensity.

To target the ATP-CP system, the work interval has to be done at maximum intensity. Paddlers typically do this as a series of sprints in the boat, but it also could be done on a paddling ergometer, which is done fairly often in slalom training.

To emphasize the LA system, work interval intensity should be "submaximal," as shown on the intensity scale above. This is typically done in the boat.

To emphasize the O_2 system, the intensity should be "high," as shown on the intensity scale above. Many people think that very low intensity work is fine for developing the O_2 system. While there may be some O_2 development at very low intensity, there is much more rapid improvement if the intensity is high.

There are several ways to ensure the proper intensity in a workout, although really good athletes can do it just by feel. The first is to buy a heart rate monitor. This is particularly useful for an inexperienced athlete doing aerobic work who has been advised through tests what the optimum heart rate range to work in is, and he shouldn't go above or below that. After a while, he can feel the proper rate and doesn't need the monitor any more. For anaerobic training, the important thing is simply to have the boaters go really hard, and the best way to do that is to have them race each other. The boaters' competitiveness stimulates them to more intense exertions. This method commonly was used by New Zealand sprint paddlers. Another way is to use the stopwatch over a set distance or a combination of this and competitive workouts.

Rest Interval

Duration of Rest Interval	Pct. ATP-CP Restored
< 10 seconds	very little
30 seconds	50%
60 seconds	15%
90 seconds	88%
120 seconds	95%
180 seconds	99%

Figure 6

In a general sense, the rest interval simply allows the body to recharge so another intense interval can be attempted. Scientifically, the length of the interval and the type of activity that goes on during it are aimed specifically at controlling the recovery of the ATP-CP system. By controlling the recovery of the ATP-CP system, one can help determine which energy system is emphasized during the workout. Figure 6 shows the percent of ATP-CP restored according to the duration of rest.

If one wishes to emphasize the ATP-CP system, long rest intervals are indicated because they allow for a complete replenishment of ATP-CP. The rest should be complete rest, no activity except stretching, easy paddling and so on.

To emphasize the LA system in the rest interval, there are two ways, one more extreme and exhausting than the other. In the first, the rest period is two or three times (or more) the work period and the recovery is complete. This might be a series of 90-second sprints with an easy paddle between work bouts ("rest-relief"). The result of this method is to dissipate lactic acid so the body is ready for another intense effort.

In the second method, however, the rest is short (say, half the work period), and involves medium intensity work. This kind of rest interval is called "work-relief." It partially blocks restoration of ATP-CP, thus meaning the next interval will be undertaken with the LA system, at ever-increasing levels of lactate. Figure 7 shows how this works:

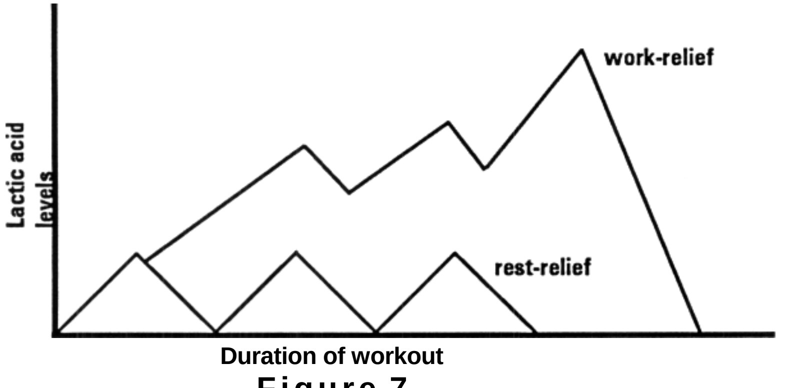

Figure 7

As can be seen above, with work-relief, each new work interval is undertaken at higher lactic acid levels, so that at the end of the workout, the level is very high and the boater has to work with higher amounts of lactic acid than he does with rest-relief.

The reader may well ask, "If the recovery is incomplete, how can the next interval be done at the highest possible intensity?" This brings us to an important concept Intensity regarding the LA system means intensity RELATIVE TO YOUR

CAPACITY at the time of exertion, not just relative to your absolute maximum. A workout of this sort, highly stressing the LA system would be: 10 X 200m at all-out intensity, with "turn-around rest," that is, turning the boat around as soon as it crosses the finish line and lining it up for another start, without ever really stopping to rest. These are very exhausting workouts and cannot be repeated every day.

To target the O_2 system, the rest interval should be short because there has been neither great depletion of ATP-CP nor great build-up of lactic acid in lower intensity work. Furthermore, the rest interval should be rest-relief, since a work-relief interval might produce lactic acid and thus make the next interval emphasize the LA system more.

Number of Repetitions/Sets

What is presented throughout this book are the levels for elite paddlers. The reader must understand that there is a great deal of difference between what the World Champion can and should attempt in training and what an intermediate should attempt. When an intermediate tries to do too much too soon he can actually get worse. With that in mind, the levels here are targets to work up to over many years of training, not levels to jump into.

Sets are groups of repetitions. The purpose of sets is to break up the total number of repetitions with a longer rest interval before starting the next set of repetitions. This added rest allows for more intensive work during work intervals.

Determining the frequency of interval workouts has to be done by each individual. So many factors enter into it that it is difficult to generalize. It depends on how experienced the paddler is, what time of year it is, how many total workouts the paddler is doing during that period, and a host of other things. In general, however, it is typical that with each successive year, the frequency will increase — as will the number of repetitions — up to a certain point when the paddler attains elite levels of conditioning and then simply maintains (or even decreases a little) that high level year after year, while perhaps improving the overall quality of what he is doing through innovative ideas and just plain experience. Basically, the developing paddler should strive to do as much as he can, but still recover from it. Checking the resting pulse rate every morning when you wake up is one way to tell. If it is five or six beats above normal, then that is a strong indicator that the paddler has not fully recovered and that he should not do a hard workout until the pulse comes down. Otherwise, he will start an overtraining syndrome.

Repeats

Repeats are done over the race distance and there is complete recovery between each bout of work. Thus, each work period is at very high intensity, that is, there is a larger anaerobic component to it. Repeats develop explosiveness and speed endurance. An example would be 10 x 1,000m with five minutes of rest.

Time Trials

Time trials should be held on a standardized course (one not affected by changing water levels, wind, etc.). Furthermore, the length of the time trial course should be the same as the race course for which the paddler is preparing. It is not specific enough to do time trials on a 1,000m course when the actual race will be 500m, for example.

Doing time trials at regular intervals lets the athlete check progress during the year. Once the race season starts, he can even view some races as time trials.

Progressive Overload

Gradually increasing the number and intensity of intervals is the aim of training. This can be done by 1) doing each work bout at a faster pace; 2) cutting down on the rest period; 3) doing more work intervals in the workout; or 4) a combination of the three. One way to decide when to increase the intensity is to check the post-exercise heart rate. The rate is taken 90 seconds after the last interval of the workout. A lower heart rate following several identical workouts means that it is time to increase the intensity.

Discussion

It is important to understand the interrelationship between the five variables which make up interval training. By not ensuring proper intensity or proper rest, the wrong energy system might be emphasized. For example, if the aim is to emphasize the ATP-CP system, 15-second work bouts at maximum intensity followed by two to three minutes rest are best. This will allow the system to be used over and over again at maximum intensity. If, on the other hand, one were to do 15-second all-out sprints with only 20-30 seconds rest, the work would become more lactic because there would be ever-increasing amounts of lactic acid in the muscles.

To target the LA system, one good way would be through submaximal intensity 30 to 90 second sprints, followed by two to five minutes of rest. But if the intensity level is too low, there is no development of the LA system, while there might be some development of the O_2 system.

To emphasize the O_2 system, one good way might be eight-minute intervals of high intensity with two minutes of rest. But if the intervals were shorter, for example three-four minutes and of submaximal intensity, the work would be more anaerobic, although the work intervals would be too long for it to be completely anaerobic.

There also can be problems in misusing the number of repetitions or interval workout frequency. If the intensity is increased too quickly, an overtraining effect might occur and the paddler is forced to take a lot of time off in order to recover.

Thus, while it is easy to make mistakes in arranging all the variables in interval training and wind up emphasizing a system you did not intend to, it also is possible to do combination workouts in which two or more systems are worked in the same workout, indeed the same interval, such as a basically aerobic workout with some short accelerations (ATP-CP development), or longer sprints (LA development) thrown in.

Muscle

Paddling a kayak involves the use of endurance (slow-twitch) and power (fast-twitch) muscle fiber. Paddlers should be sure to develop both in their training.

Some individuals, because they are born with a higher proportion of one kind than another, tend unwittingly to stress that kind in their training and neglect the development of the other. In this case, they may have a deficiency for the type of event they wish to specialize in.

Slow Twitch — Fast Twitch

It is muscle development combined with cardiovascular conditioning that permits the intensity and volume of training necessary to maximize the body's responses to training. If muscles are not sufficiently developed, the athlete cannot sustain a high enough workload to stimulate the energy systems adequately.

There are two main types of skeletal muscle fiber: an endurance type, called "slow-twitch" and a speed and power type, called "fast-twitch." There are actually two sub-types of fast-twitch fiber as well; fast-twitch A, a slow-fatiguing fast-twitch fiber; and fast-twitch B, a fast-fatiguing fast-twitch fiber.

Slow-twitch muscle fiber requires a steady supply of oxygen, storing it for the onset of work but quickly requiring its replenishment from outside air. These fibers are very resistant to fatigue, having access to the oxygen supply through a highly developed network of capillaries.

While slow-twitch fibers are suited for endurance tasks, fast-twitch fibers may be called upon instantly for speed and power without having to wait several minutes for the oxygen supply to be replenished from the outside air. Weight training and high intensity training increases the size of these fibers and their ability to break down glycogen and use it to do work. The more fast-twitch fibers an athlete has, the faster he may fatigue, being able to work at top speed for only a very short time.

At birth, each individual is endowed with a certain proportion of each fiber, thus giving some people greater potential to become power athletes, such as sprinters, and other people greater potential to become endurance athletes, such as marathoners. From all the evidence, Barton in all probability has an unusually high percentage of slow-twitch muscle fiber, which means that he is predisposed to success in the longer events.

There are two factors that complicate the discussion of fast-twitch and slow-twitch fibers:

- It is hard to determine accurately what proportion of each an individual has. In the first place, different muscles within the same person have different proportions. Thus, if we are talking about the application to paddling, testing the leg muscles is not going to help. Secondly, different areas within the same muscles have different proportions and thus several samples have to be taken from the same muscle in order to get an accurate reading. Since this involves taking a little "bite" (muscle biopsy) out of the muscle several times, most athletes, understandably, are reluctant to permit it.

- While an individual may be born with a certain proportion of fast-twitch fibers, training can "bend" the fibers somewhat, making fast-twitch fibers function more like endurance fibers. Long duration paddles at high intensity can do this.

A sprint race consists of both endurance and power components. Endurance is simply the ability to get down the course without becoming so tired that you slow down. Power comes into play in things like accelerating the boat at crucial points, such as the start or final kick.

Continuous long distance paddles improve the function of slow-twitch fibers and improve endurance. Many paddlers use running or other endurance training (such as biking or swimming) to improve their endurance for paddling. While this certainly improves general endurance, it is not specific enough for maximum improvement in paddling the sprint boat, simply because different muscles are used in paddling the boat than in running or swimming.

Furthermore, if all the paddling is done at slow speeds, muscular power typically diminishes over time. This is because the slow paddling does not activate the fast-twitch fibers and the fibers lose some of their capacity for speed through disuse. Power training will prevent this.

When most people hear the term "power training," they think of weight training, since this traditionally has been the method for developing power in sprint racing. It should be borne in mind, however, that weightlifting, if it is done improperly, may not simulate the actual motion of the joints and limbs as used in paddling, and strength developed in one particular joint motion will not necessarily transfer to other joint motions. Also, heavy lifting seems to develop a non-explosive power.

In constructing a weightlifting routine for sprint racing, the following points should be kept in mind:

- Make the lifts as specific to paddling movements as possible.
- Select a moderate weight which allows you to move as fast as, or faster than, you would in competition.
- Before each repetition, the muscle to be strengthened should not be stretched to increase the amount of force produced and developed. If a muscle is stretched, it contracts with greater force. Stretch receptors in the muscles and tendons produce what is called the "stretch reflex." But since the use of the stretch reflex does not promote pure strength work — it supplies "free" work —it is a form of cheating and should be avoided.
- Try to vary the grip or plane of movement in the weight exercise to ensure that all parts of the muscle get developed.
- Begin with adequate warm-ups to minimize injury risk.

Paddle Relaxed

The ability to relax while paddling is the sign of a top boater. If muscle coordination is high, the boater finds it easier to relax during paddling, further lowering his energy cost. Here are two points to think about in training and racing:

- Reduce tension in all muscles not directly involved in moving the arms, back and trunk. For example, head movements and shoulder hunching, facial grimaces and so on, should be eliminated.
- Practice paddling at a given pace with as little energy as possible.

Muscle Elasticity

It is the timing of muscle forces which distinguishes the good paddler from the excellent one. Precise timing of back, torso twist, arm and hand movements allows the paddler to make use of the elasticity inherent in muscle tissue. Because a stretched muscle automatically rebounds to its resting length, it has the capacity to do "free" work and so increases the force, power, and efficiency of your movements. Some experts think this elasticity can account for half the total energy used to do work.

Repetitive work, like paddling forward, is performed at a cadence that the individual feels is the most comfortable or efficient. He chooses the cadence probably because of muscle elasticity. If he moves too slowly, certain muscles must contract isometrically to prevent this elastic force from acting. As a result, a slow paddle may become more fatiguing to him than a faster one, even though the total work is reduced. Effective use of muscle elasticity requires that he moves at some minimum speed.

Warm-Up/Warm-Down

Adequate warm-up before paddling reduces the resistance of muscle and connective tissue to joint movements since cellular tissues become more pliable with increased temperature. Warming up also prepares muscles for work by supplying them more blood and oxygen. Warmth accelerates the speed of the chemical reactions responsible for liberating energy from within the muscle.

Without a warm-up, muscles are shocked into sudden, vigorous exertion without an adequate oxygen supply, forcing the muscle to furnish much of the energy anaerobically for the first one or two minutes. An oxygen debt is created along with the production of a small but perceptible amount of lactic acid. This oxygen debt will be repaid in the ensuing minutes of exercise and result in the oxidization of the lactic acid. This process requires more energy than if a smaller oxygen debt was formed during the warm-up. Thus, warm-up enhances performance and decreases injury potential, an important point for the older athlete whose connective tissue and joint structure is no longer supple.

Adequate warm-down is equally important because it helps to dissipate lactic acid built up in the exercising muscle and bloodstream during a training session. Thus, it accelerates recuperation before the next session. Warm-down also stretches the muscles that have been used. Paddling is a repetitive activity which may cause stiffness in joints and muscle tightness. For this reason, particularly after a long session, there should be some light paddling and stretching to restore flexibility to the paddling muscles, including the latissimus, trapezius, deltoids, pectorals, biceps, triceps, forearms, and hamstrings.

A warm shower facilitates this warm-down and stretching, but sometimes it is difficult for paddlers coming off the water to get to a shower quickly. In this case, changing into warm, dry clothes is a reasonable substitute.