2 PHYSIOLOGICAL PRINCIPLES

Whether you are coaching elite athletes for world class competition, preparing your paddlers for a multi-day sea expedition or simply need to ensure that your students get the best out of themselves and come to no harm... this chapter is for you. A good understanding of how our bodies work is an essential part of any coach's 'toolbox', whatever the level they are coaching.

INTRODUCTION

Physiology is the study of how our bodies function, how we produce the energy we need for paddling. Knowledge of the physiological or physical principles that apply to each canoesport discipline will further improve the paddler or coach's ability to interpret paddling performance. Our paddling performance is related to the interaction of the technical, tactical, psychological and physiological elements involved in our chosen discipline, as shown in Figure 1.

KEY POINT SUMMARY

- Paddlesport performance is determined by the interaction of technical, tactical, physiological and psychological factors. As paddlers we need to identify which factor is the rate-limiter at any stage in our development.

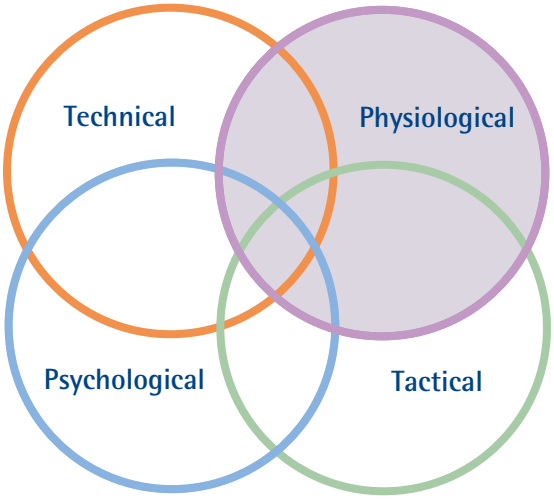


Fig. 1 The Relationship between the Components of Paddling Performance.

PADDLING PERFORMANCE

The relationship between the technical, tactical, physiological and psychological elements for any one of us must be viewed as dynamic. At any one time an individual paddler can be limited by physiological, psychological or skill-based (technical or tactical) constraints. The relative size of the four components will change over time, between disciplines and individuals. For example, the importance of the mental, physical and skill components may differ for playboaters, slalom canoeists and marathon paddlers.

The trick for us as paddlers, seeking to improve our performance, is to identify which of the components is our rate-limiter at any particular stage in our development. For example a kayaker or canoeist could have difficulties crossing a strong eddy fence. This could be due to skill errors (technical), such as not having all the blade pulling in the water, not being physically powerful enough to punch through the eddy line (physiological), a lack of understanding of the attack angle required (tactical), or anxiety created by the thought of capsize (psychological). A coach will need to be able to analyse performance and decide the underlying problem for a paddler. This chapter concerns the physiological aspects of paddlesport. Table 1 provides some examples of problems that might appear to be technical, tactical or psychological but in fact have a physiological root cause. Coaches and paddlers will need to be able to identify when a paddling rate-limiter has a physiological cause. Once identified this chapter can be used to help create physiological solutions for improving paddling performance.

As a highly skilful activity sport many chapters within this book will focus on the technical aspects of the sport. In the next chapter Chris Hodgson will provide details of psychological factors that can help to improve canoe and kayak performance. The main function of this chapter is to begin to examine the physiological principles that can usefully assist us as paddlers (these will be developed further in the Performance Coaching chapter in Part 2). Figure 2 identifies the major elements that can influence our physiological performance. There are, however, a number of factors in Figure 2 that have an interaction with the other two performance components, skill development and psychological principles. These factors, gender differences, growth and development and injury prevention and recovery, will be discussed in this chapter from a physiological perspective, but will

Symptom of Problem	Misleading Causal Component	Root Cause of Problem (Physiological Component)	Possible Solution
Poor forward paddling action during a sea paddling expedition.	Technical	Lack of local muscular endurance, aerobic fitness or poor nutrition during paddling could undermine physical ability during a day of paddling.	Aerobic Training – in-boat, Circuit Training, review of food and fluid intake during expeditions to highlight any useful changes.
Paddler appears anxious during the paddle out when taking part in surf sessions.	Psychological	Lack of power to build up speed quickly and punch through waves.	Mixture of strength training and in-boat drills to develop power for use during paddle out in surfing.
Paddler capsizes on eddy turns due to incorrect application of edge.	Tactical	Lack of core strength development to hold high degree of edge required in faster eddy turns.	Work on general strength and specific core stability – possible alternatives: in-boat exercises, weight training, circuit training, pilates, cross-training - cycling.

Table 1 Examples of misleading problem identification where the actual root cause is physiological.

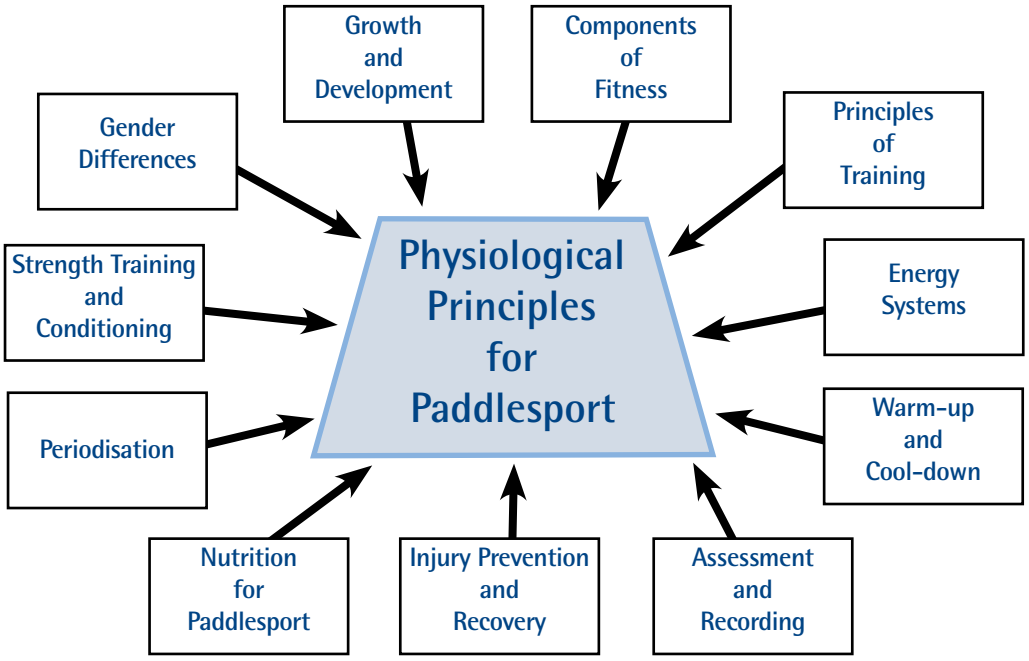


Fig. 2 The Physiological Principles for Paddlesport.

be discussed further in subsequent chapters in a discipline/skill or psychological context.

Improving Paddling Performance

To improve paddling performance it is beneficial to adopt a long-term approach to development. This chapter is based on such an approach, for the physical, mental and skill (technical and tactical) development of a paddler should be viewed with the future in mind.

COMPONENTS OF FITNESS

The physiological aspects of paddling are concerned with fitness. To develop any sort of training programme for canoe or kayak sport we must ask some fundamental questions about the nature of the activity. One of the key questions has to do with fitness and how it can help improve paddling ability. If we are fitter it will help us to improve our performance, whether this is seen through quicker times or improved decision making due to lower overall stress on the body.

We will first consider the mature adult system as this differs quite significantly from a child or adolescent. The young paddlers physiological system is discussed in Chapter10.

At its most basic level, to be fit is to be healthy or in good athletic condition. Fitness for paddling, however, is specific – fitness for sea paddling journeys means something very different than for slalom. As a paddler or coach you must be able to identify the components of fitness that are the most important to your discipline. This section identifies the major components of fitness that may impact to a greater or lesser extent on a paddler depending on their discipline. In developing a training programme for your discipline you will need to identify which of these components is fundamental to improving your performance.

KEY POINT SUMMARY

- Fitness is specific, so paddlers or their coaches need to be able to identify the key components of fitness for their discipline.

The components of fitness for paddlesport can be divided into those that are physically trainable, and will be discussed in this chapter, and those that are skill-related and are discussed within other chapters of this book. The components are identified in Table 2. The terminology used by sports scientists can differ, but within the context of this book the definitions of each of these components will be maintained by all authors.

Physiologically Trainable Components of Fitness	Skill Related Fitness Components
Muscular Endurance	Agility, Co-ordination, Balance } Dynamic Balance
Aerobic Capacity	
Anaerobic Power & Capacity	
- Speed	Reaction Time
- Strength	
Body Composition	
Mobility	

Table 2 The Components of Fitness

MUSCULAR ENDURANCE

Muscular endurance relates to the ability of a certain muscle or muscle group to maintain repeated muscular contractions against a given resistance. This resistance could represent a small percentage of your maximal contraction (see strength below) or a higher percentage. The closer a load is to your maximum the shorter the time that the movements can be maintained. For paddlesport an example of muscular endurance would be the ability to paddle for a day's white water paddling or on a sea journey. The load for each individual paddle stroke would be small, relative to the maximum thus enabling you to maintain the action for long periods of time. If you fatigue before the end of a day's paddling, one aspect you might need to develop would be your muscular endurance.

Photo 1 A day's sea journey requires muscular endurance.

AEROBIC CAPACITY

While muscular endurance relates to the ability of a muscle or group of muscles to maintain work without fatiguing, aerobic power or capacity refers to the ability of the body to produce energy for exercise involving the whole body over a relatively long period of time. Canoesport disciplines that last for longer than one and a half minutes will produce the energy for paddling largely through aerobic mechanisms. The term 'aerobic' means in the presence of oxygen . The body has a variety of systems or 'gears' that can be used to provide the energy we need for paddling, and the '3rd gear' or 'overdrive', (the aerobic system), uses oxygen to assist in the conversion of the food we eat into fuel for our paddling. A marathon paddler will require oxygen to produce energy for the several hours duration of the event. Aerobic capacity is often measured using maximal oxygen uptake. This represents the maximum amount of oxygen the body can use each minute to provide paddling energy. There are a variety of ways this can be measured or estimated such as through the multi-stage fitness test (Bleep test) or in a laboratory on a treadmill; it is also possible to measure this for kayak and canoesport. In a physiology laboratory a gas analyser can be used to examine how much oxygen a paddler uses per minute. This can give the paddler, their coach and the physiologist information about their aerobic fitness. You do not, however, need expensive equipment to estimate aerobic fitness and the section below on assessment tools provides details of a number of aerobic fitness tests that could easily be used or developed for use by any paddler. In addition, training for aerobic fitness will be addressed further below.

Photo 2 Marathon paddler

ANAEROBIC POWER & CAPACITY

As 'aerobic' refers to being in the presence of oxygen, 'anaerobic' relates to energy produced without the need for oxygen. Energy production utilising oxygen takes longer than anaerobic methods to become a main fuel source and is produced at a lower rate than can be achieved via anaerobic sources. Thus for events that last less than 1½ to 2 minutes, such as sprint events, a sprint finish or intermittent events (with sprints and recovery periods such as canoe polo or a surf kayak heat), anaerobic methods provide a major fuel source. Anaerobic mechanisms, ones that do not require oxygen to operate, provide the 1st and 2nd gears for our paddling energy production.

BODY COMPOSITION

Body composition refers to the chemical make-up of the body. For sports physiologists this basically refers to two components, fat mass and fat-free mass. Research into canoesport and body composition has concentrated on the body fat percentages for Olympic canoeists. This found that gold medallists were heavier than the average competitor for each event. This difference has been shown to be related to an increased muscle mass for the most successful canoeists. Body composition has health implications for all paddlers, however, as a non-weight bearing and non-weight categorised sport, percentage fat mass has fewer implications for performance than in other sports. In addition, if diet remains unchanged increased training volumes will normally lead to a positive shift in body composition (i.e. a decrease in fat percentage in relation to lean mass).

MOBILITY

The terms flexibility and mobility are often used interchangeably to refer to the range of motion about the joints of the body. Often linked in with warm-up and cool-down mobility and flexibility have a significant role to play for paddlers. Research indicates that most often mobilising exercises should be utilised during the warm-up to get joints and soft tissue ready for the movements they will encounter during the exercise and static flexibility – stretching – should be carried out during the cool-down when the muscles and soft tissues are thoroughly warm. A good range of motion in the wrists, shoulders, trunk and hips are important for the canoeist. Trunk rotation for a variety of kayak strokes and cross-deck paddling for open boaters, flexion and extension onto front and back decks for rolling rely on good levels of mobility


3a


3b

Photo 3a Surf kayaker taking off
Photo 3b Sprint start

and are improved by flexibility work carried as part of a training programme. Mobility is an excellent illustration of the close relationship between the physical and the skill-based elements of paddlesport. A lack of trunk rotation flexibility can easily become a rate-limiter for improvements with, for example, cartwheeling for playboaters. Hyper-mobility is also a concern for canoeists where too much shoulder flexibility can create problems with shoulder dislocations so there is a balance to be maintained. A balance between strength training to protect joints along with flexibility training to maintain and/or improve range of motion is a useful concern for us as paddlers. **See Appendix A.**


4

Photo 4 Freestyle paddler cartwheeling

DYNAMIC BALANCE

Physiologists describe three different balance-related components that are more meaningfully combined for canoesport and can be termed 'dynamic balance'. Balance is the ability to hold a static position such as a handstand for a length of time under control. Agility relates to a moving form of balance such that an agile athlete is able to make a series of movements with changes of direction but remain in balance. Co-ordination is the ability to effect efficient movements to achieve a goal. As individual components they have some relation to canoesport but, as a sport based on water rather than land, are more meaningful when combined to comprise 'dynamic balance'. In a paddlesport context this refers to the ability to use skilful co-ordinated movement to maintain position or make progress on the water. Balance and agility as part of this movement are fundamental to the body, boat and blade aspects of any particular stroke. Ian Coleman, in the Canoe and Kayak Handbook (page 149) describes the 'Dynamic Seating Position' as being the central foundation to the development of many boating skills. This 'locking' of the paddler into the boat is a first step in employing skilful dynamic balance for closed cockpit craft. For those using open boats, waveskis and open cockpit kayaks, whilst not always being locked into position, the need to adopt a position in the boat that allows for maximised body, boat and blade control is central to dynamic balance. Dynamic balance is very closely related to the skill aspects of all paddling disciplines.

REACTION TIME

Reaction time is the interval between the introduction of a stimulus and the beginning of a response. For example, on paddling a new river how quickly does a kayaker react to an event horizon and if necessary take evasive action – catching a 'must-make' eddy before a waterfall. It is a key aspect of sports performance and as such is defined by physiologists as one of the components of fitness. However, reaction time is much less trainable in a physiological context than components such as strength or aerobic endurance and is best developed as part of skills training.

▶ A Skilful Activity

Paddlesport is clearly a skilful activity, within all disciplines, and as such any fitness training needs to be balanced with skill development. Improvements in fitness can help skill development and lead to improved performance. With the highly varied nature


5a


5b

Photo 5a Carving a bottom turn
Photo 5b Open boater shifting weight

of paddlesport and the confines of this chapter it would be impossible to examine the components of fitness important to every canoe discipline. With your knowledge of the sport, however, you should be able to identify the main components. The key texts listed at the end of this chapter can give you further useful information to assist you with this process.

▶ PRINCIPLES OF TRAINING

To improve our paddling we must focus on the performance model and decide which of the components (technical, tactical, psychological, physiological or a combination of all four) needs to be addressed to make further progress. If we decide to develop our physical fitness there are a number of key principles that should guide us as paddlers when designing training programmes.

OVERLOAD PRINCIPLE

The Overload Principle is based on research that has shown the body will respond to training loads above those that it normally meets. If a sedentary person takes up a training programme all exercises would be new and would therefore be overloading their body. This will bring about physiological adaptations for

that individual, or in other words, improvements in their fitness. A paddler must apply this same principle when designing a training programme. To improve fitness we must train with loads that are above those that we would normally meet. To do this we can adjust the frequency, intensity or time (FIT) for which we train. Frequency is the number of times per week we train, intensity is the level at which we work (for example, at what percentage of our heart rate maximum we work) and time being the duration of each training session. Each of these parameters can be manipulated in programme design to create a training overload through which to achieve an improvement in fitness.

KEY POINT SUMMARY

- The principles of fitness should be used as guidelines for the development of any training programme.

PROGRESSION PRINCIPLE

The principle of progression is very closely linked with that of overload. As physiological adaptation takes place (as we become fitter) a training load that was an overload will decrease in its difficulty. To continue to progress in our training the FIT of training need to be adjusted to cater for improvements in fitness. We must progressively increase the training overload. An example of this can be made with weight training. You decide that a resistance (weight) training programme would improve your paddling and design a programme that you carry out 3 times per week at a local gym. The load for each exercise in the initial weeks will represent an overload, however, as you get fitter you will need to increase the weight lifted to maintain progress. A simple way to do this is to use the 2 for 2 rule. If you can complete two repetitions more than the assigned repetition goal in the last set of an exercise over two consecutive sessions, you should increase the weight lifted. For example, if for biceps curl you are performing three sets of 10 repetitions but in the last set, for two sessions in a row, you can complete 12 reps it is time to increase the load. By adjusting the FIT you can manipulate any aspect of your training to maintain a progressive overload.

SPECIFICITY PRINCIPLE

Research into physiological adaptations has provided us with a number of guidelines regarding specificity of training. The specificity of training principle refers to the need for training to be particular to the desired goals.

Photo 6 Weight training being used to develop strength

▶ Resistance Training Specificity

Resistance training is commonly employed by athletes from many sports including paddlesport to help improve performance. Research tells us that resistance training can help improve strength, power, speed and muscular endurance, all of which can be beneficial, to a greater or lesser extent (depending on our discipline) to our paddling performance. The goals of resistance training can be different by design, and as such, should be made specific to the discipline. Firstly, the exercises selected should be specific to the activity chosen. For example upper body exercises for a kayaker should take priority over lower body exercises and movements made with weights should match as closely as possible movements made in the activity. Secondly, strength gains have been found to match the speed at which training was carried out. For example if training was carried out at slow speed to develop strength the maximal expression of strength would be found moving at that slow speed. If you are training for an explosive event that requires power then training speeds should reflect this to maximise possible gains.

▶ Conditioning Training Specificity

A number of studies have been carried out regarding specificity and conditioning that can be of benefit to us as paddlers designing training programmes. Training results are specific to the muscles trained and there is often little transfer to other muscles even between events like running and swimming. One good illustration of this is a study that involved 15 healthy but sedentary subjects swim training for one hour per day, 3 days per week, for 10 weeks. All subjects carried out swimming and running tests at the start and end of the study. Not surprisingly, the results found a 1.5% improvement in the running test scores for the

group, but an 11% change in the swim test scores. When training for a specific activity such as kayaking or canoeing the training overload should engage the specific muscles and energy systems used for the discipline. In other words, if you wish to get fit for paddling you need to train in your boat as a regular part of your programme.

In a similar fashion to the speed aspect of resistance training, discussed above, the conditioning aspects of training should match the activity for which you are training. Sprint training for anaerobic sprint events, endurance training for aerobic events and a mixed protocol for intermittent events such as canoe polo.

▶ Programme Specificity

There are a number of aspects with regard to programme design where specificity needs to be addressed. In developing a training schedule the focus of training should move from generalised to more specific training as time comes closer to competition. This will be addressed further in the section below on periodisation. The time at which training is carried out should match competition or performance times as closely as possible. Research has shown that adaptations to training are specific to the time of day during which the training took place. If you are training for a slalom event which will take place in the morning it is better if you can do some of your training at this same time of day. Paddlers training for the DW race also need to consider training their bodies to work during the night. In a similar way research has found that modelling competition in training can help make adaptations specific to the event. It is important for you, as a paddler or coach, to know about the aerobic and anaerobic contributions to energy production for your discipline. Training should mimic or 'model' these relative contributions.

REGRESSION PRINCIPLE

When an athlete stops training they will lose any gains they have made relatively rapidly. The effects of detraining can be seen very clearly in anyone who has broken a leg or arm and had it kept in plaster for six weeks. When the plaster is removed the resulting atrophy (loss in muscle size) is due to detraining or regression. The regression principle states that ceasing training, dependent upon the period and degree of detraining (ranging from normal active life but no training to complete bed-rest), will result in a loss of fitness gains made through previous training. This has clear implications for breaks in training or off-season phases and the need to maintain some level of fitness.

Photo 7 Canoe Polo

It is for this reason that many top athletes have recovery phase training programmes to maintain a reasonable level of fitness before commencing pre-season training. The same principle can guide planning the training programme for any level of paddler.

INDIVIDUALISATION PRINCIPLE

If you set two very similar wild water racing paddlers on a training programme the response of each to training would vary for each aspect of training. Individualisation, whilst making sound physiological sense, is a fundamental coaching principle. Just as skill development sessions should be devised on an individual basis, training programmes should be developed in response to each paddler's fitness assessment results (see below) and their training goals. Research tells us that optimal training benefits are obtained through individually developed programmes. This does not, however, mean that all training should be carried out individually.

VARIATION PRINCIPLE

Adding variety such as by changing the venue, number of paddlers training or by having changes in training programme can help with motivation and enable a paddler to avoid any boredom with training.

Photo 8 Training in groups is good for motivation

Dependent upon the level of performance the training volume for a canoeist can be up to and over 1,000 hours per year, as such the paddler or their coach needs to add variety to the programme to maintain enthusiasm. Variation in training loads can help not only with motivation but also assist in avoiding overtraining illnesses. Training close to your maximum in every session can overstress the body. By adding variety to sessions, for instance by having hard and easy training days, a paddler can avoid such illnesses or injuries. This can be achieved by manipulating the FIT in a training programme, a central aspect of the next section which deals with long-term training programme development – Periodisation.

PERIODISATION

Periodisation is based upon the General Adaptation Syndrome (GAS) - the body responds to a situation of stress (in the case of training the stress is the different forms of exercise that can be undertaken) by first showing alarm - shock to body and muscle soreness, then adaptation which leads to improvement of performance and finally exhaustion when a body is able to make no further improvement as a result of the training. If training is not reduced at this stage an overtrained state may occur. Periodisation is a system of training programme design through which a paddler can best develop their training overtime, to peak for a major event or for a competition season, without going into the exhaustion phase.

Since the original model of periodisation was proposed by Matveyev in 1965, a number of variations in programme have been developed to suit athletes from different sports. Boaters from every discipline and level of performance now have a wide range of periodisation options from which they can develop an appropriate training programme. As well as avoiding overtraining, having a periodised programme can help a canoeist avoid boredom with training through having a phased programme and knowledge of what is coming next in preparation for an event. The athlete can see clearly why they are training and how they are progressing to their goal. This aspect of physiology can be closely linked with the psychological tool of goal-setting that Chris Hodgson will discuss in the next chapter. Before designing a programme for a paddler it would be useful to have read both sections from this book.

See also Chapters 18, 20 and Appendix B.

KEY POINT SUMMARY

- Periodisation, dividing the training year into manageable and progressive sections, is an excellent way to set realistic goals for the paddler and to enable him or her to identify exactly where they are in the progress towards a main competition or event.

Phases

The concept behind periodisation is to divide the training year into distinct phases. These phases build upon one another to prepare a paddler for a specific event or season of performance. Programmes can be designed over a short or long period of time and be designed individually for each paddler. The possible units within a periodised programme are detailed in Table 3. The most common lengths of time for a periodised programme would be between several weeks and one year depending on the level of performance and age of the paddler. Within periodisation these phases of training have specific names. A macrocycle is the largest unit of a programme such as a training year; this is divided into a number of mesocycles which last for one to several months. Mesocycles are divided into microcycles which are typically one week long. By dividing the programme in this way it is possible for a paddler to see what they are doing for the next training session, how this fits with their week's training and how this builds up to the next mesocycle and how that leads to the event for which they are training.

PROGRAMME DESIGN

The basis behind the success of periodised training is the variation for the volume (quantity) and intensity (quality) of training. Figure 3 provides a model of how the relationship between volume and intensity of training is managed through a periodised programme. The paddler or their coach needs to manage the volume and intensity through the programme so as to avoid overtraining. During the early part of training the volume of training is kept high with a much lower intensity. As time comes closer to the main event the intensity is designed to rise to performance level and as a result the volume of training decreases dramatically. As can be seen, the model training period (macrocycle) is divided into four mesocycles. Each one of these would then be divided into a series of microcycles. The hypertrophy phase is a preparatory phase and is designed to 'get the body ready to train', con-

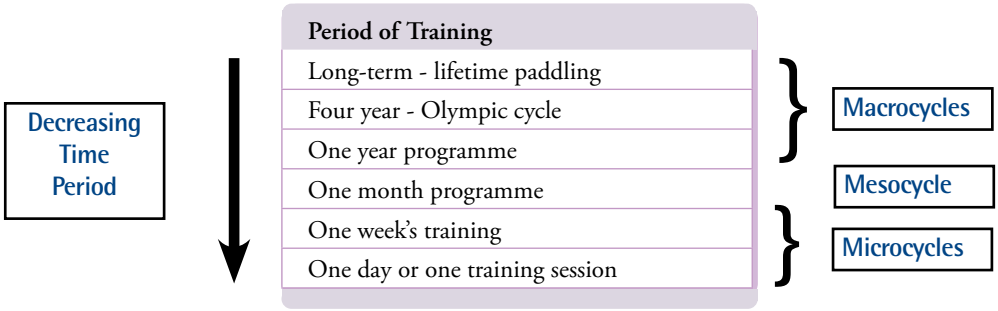


Table 3 Possible Training Units Within a Periodised Programme

centrating on increasing muscle mass and endurance. The strength phase sees the cross-over between intensity and volume of training with quantity decreasing to allow a greater focus on the quality of the sessions. The strength and the strength/power phases represent the key phases of training when the hard work is completed by the paddler, ready for the final peaking phases that taper training in order to be rested and in peak condition for the competition.

When To Carry Out Fitness Assessments

The next section looks at the variety of tests that can be used to assess a paddler's fitness. They are based upon the components of fitness and should be devised into a battery or group of tests according to the phase of training. A fitness assessment would be carried out with a canoeist to evaluate how a training programme was working. For instance, has strength improved at the end of the strength phase? If strength has not improved the programme might not have included the correct exercises, reps and sets to bring about an improvement and may need alteration for future events. Completing a battery of testing is normally hard work for a paddler as they will want to do their best and as such the schedule needs to be well thought out. If following a periodised programme the tests undertaken should reflect the phase of training. At the start of a macrocycle, like that for instance at the start of a training year, a complete battery of testing might be carried out to assess baseline fitness levels. From this the training programme could be designed and re-testing phases be linked with the completion of each specific mesocycle, i.e. hypertrophy or strength.

KEY POINT SUMMARY

- The phases in a training programme are designed to build one upon the next. The hypertrophy phase is a foundation stage to get the body ready for the hard training to come. The strength phase is a physically hard stage for any athlete and should provide the strength base for the speed and power development in the strength/power phase. In the peaking phase the quantity or training is reduced but the quality is maintained as the paddler nears the event for which they are training.

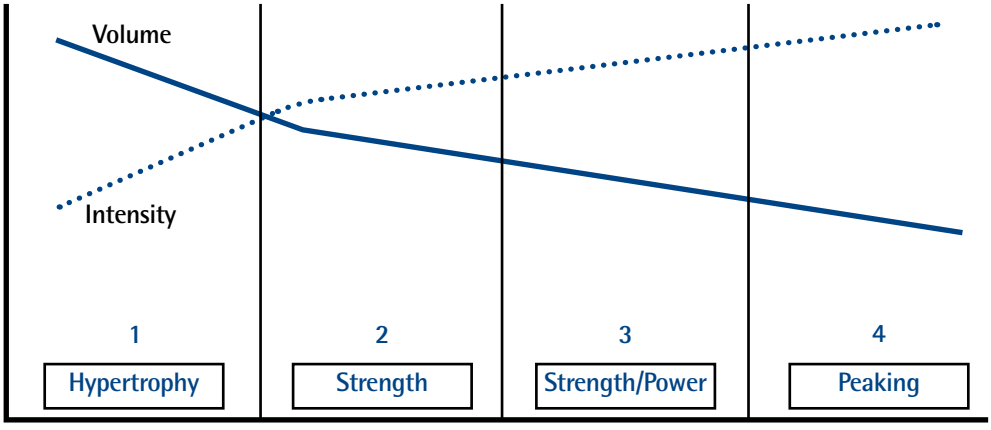


Fig. 3 General Periodisation Model shown over 4 Mesocycles

PROGRAMME ASSESSMENT

There are a wide variety of assessment tools available that can be used in paddlesport. A key question though, is why we should use them?

There are three main reasons why assessing fitness is important to the paddler or their coach:

1. If you do not test you cannot know the level at which to set the training programme a paddler should follow. Similarly, if you do not carry out testing at the end of a phase of training you will be unable to decide if the programme is working.
2. If you do carry out a testing programme it can help to give you or your paddler some positive feedback that the hard work in training is working and can provide excellent information for setting realistic training goals for the next phase of training (as mentioned above, goal setting with paddlers will be covered in more detail in the next chapter).
3. If you do not carry out testing for a programme a paddler is following you will have an incomplete profile of the paddler. The paddler and coach need a more complete picture in their search for the developmental rate-limiter at any particular stage.

This is made possible by:

- Using video to analyse technique and tactical development.
- Good communication with an athlete about their psychological preparation.
- Physiological assessments of fitness improvement.

It is possible for the paddler or their coach to have a more complete picture in the search for the developmental rate-limiter at any particular stage.

Photo 9 Paddlers being tested

Choosing The Tests

The battery of tests you decide upon for a programme will be based on the components of fitness for your discipline. The exact components of fitness will be different for each area of canoe and kayak sport and the exact schedule of tests you decide to use should reflect this.

This section will be split into three main parts:

1. Aspects of assessment that can be common across disciplines.
2. Discipline-specific assessment tools.
3. A short section with guidelines for the organisation of a testing schedule.

KEY POINT SUMMARY

- Keeping race results, video clips and height and weight measures for a paddler can form the basis of monitoring long-term paddler development.

GENERIC PADDLING ASSESSMENT TOOLS

For all paddlers, especially growing ones, it is useful to keep a record of height and weight. Keeping previous race, performance and test records is a really useful way of monitoring development for a paddler. Although most often used as a coaching tool, a video clip diary kept over time can additionally provide an excellent record of performance development in skill based tests.

Photo 10 Using video to record progress

DISCIPLINE-SPECIFIC ASSESSMENT TOOLS

The development of a battery of tests should be specific to the components of fitness relevant to each discipline. When designing a battery of tests it is really useful to be inventive. It would be impossible in a chapter such as this to decide on a battery of tests for each paddlesport discipline. The tests described are

therefore examples that you should modify and adapt as you feel is most appropriate for your discipline.

KEY POINT SUMMARY

- In order to evaluate whether a training programme is working – checking whether the paddler is getting fitter- you need to assess its impact. Tests should be specific to the discipline, the components of fitness and carried out before and after the phase of training.

Muscular Endurance

A variety of 'body weight resistance' circuit training style exercises or in-boat paddling drills can be used to assess muscular endurance. The key with these exercises is to maintain the quality of the movements throughout the test time. Exercises can be carried out on a singular basis, such as how many sit-ups can be completed in a minute, or in a mini-circuit, for example with press-ups, sit-ups, tricep dips, star jumps for 30 seconds on each activity. The type of exercises would be determined by the paddlesport discipline and could include appropriate in-boat drills.

Aerobic Capacity

The traditional gold standard (seen as the most accurate measure) for assessment of aerobic capacity is the maximal oxygen uptake or $\dot{V}0_{2max}$ test (the$\dot{V}$of $\dot{V}0_{2max}$ stands for volume, the dot above the V shows it is measured per minute, the O2 means oxygen and the max being short for maximum). In a laboratory setting the test is carried out using a treadmill, cycle ergometer (literally a work measuring device), rowing machine or kayak ergometer. The testing device to be used is based on the athlete's sport due to the specificity of fitness. After a warm-up the athlete being tested will then complete an 8 to 12 minute protocol designed to take them to their maximum work rate with increases in the workload at regular increments throughout the test. The test time is designed to allow the aerobic or oxygen transport system to get to its maximum. During the test the amount of oxygen consumed for each stage, up to the athlete's maximum, is recorded. The aerobically fitter the athlete the longer they will be able to carry on the test and the higher the amount of oxygen they will be able to use to produce energy.

One of the useful benefits of this test is that heart rate (HR) and oxygen consumption have a very close


11a


11b

Photo 11a $\dot{V}0_{2max}$ *test using paddle ergometer*
Photo 11b $\dot{V}0_{2max}$ *test using treadmill (if no paddle ergometer available)*

AEROBIC CAPACITY TESTS

The$\dot{V}0_{2max}$ test requires laboratory facilities that are expensive and difficult to come by. Fortunately, due to the relationship between HR and oxygen consumption, many sub-maximal* aerobic tests and maximal tests based on HR have been developed for assessing aerobic fitness.

These include:

- ***1.5 mile run.***
- ***Coopers 12 minute run.***
- ***Queen's College Step Test.***
- ***Multi-Stage Fitness Test (Bleep Test).***
- ***Rockport Walk.***
- ***Astrand-Rhyming Nomogram.***

* Sub-maximal tests do not take an athlete to maximum but use a level below maximum to estimate maximum.

KEY POINT SUMMARY

- In order to evaluate whether a training programme is working – checking whether the paddler is getting fitter – you need to assess its impact. Tests should be specific to the discipline, the components of fitness and be carried out before and after the phase of training.

linear relationship. This is not really surprising as it is the heart that pumps the oxygen we need for paddling round to the working muscles. The harder you work at each stage in the test, the more oxygen you need to use and the harder the heart needs to work to supply the required oxygen.

In addition, a number of performance-related tests, where time to complete a test is the parameter measured, have been developed for work with rowers and paddlers. These include 1000m, 2000m, or further timed distance tests. The key concept with all these tests is to match as closely as possible the requirements of the paddling discipline to the test to be used. Research has shown that kayakers, being tested for aerobic fitness, score higher on a kayak ergometer than they do on a treadmill (running) or a cycle ergometer and higher still when they are tested in their own boats. Specificity as a principle of training is as important for testing as it is for training. The use of HR monitors as a training tool will be discussed further in the section on strength training and conditioning below.

▶ Anaerobic Power And Capacity

Exercises for the assessment of anaerobic power are covered in discussion of the next two components of fitness: strength and power/speed. Anaerobic capacity assessment would need to be based around the anaerobic demands of the activity. As mentioned in the components of fitness section above, anaerobic energy production related to capacity relates to the '2nd gear' of energy production for events such as 200m – 500m sprints, sprint finishes in distance races or for intermittent events such as canoe polo. Again activities would be best carried out in-boat but could also be carried out on Concept II rowers or arm ergometers. The duration or nature of the test should reflect the discipline for which the assessment is being devised. There is a wide variety of tests that can be used to assess anaerobic capacity, some of which were not developed for canoe and kayak but could be easily adapted and adopted by an inventive coach. The demands of the discipline should dictate the test to be employed with a paddler.

Photo 12 Basketball Sprint Test

ANAEROBIC CAPACITY TESTS

There are a variety of anaerobic tests that can be used to assess a training programme. Choose or develop ones that are most specific to your discipline and the type of training being undertaken. Where possible they should be carried out in-boat.

- ***The basketball sprint test*** - could be adapted to use in a boat on a marked course. This test involves four out and back increasing distance sprints. The distances would need to be adapted to the activity, i.e. canoe polo etc. The time taken should be recorded.

- ***6 x 150m rowing anaerobic test*** on Concept II with 30 seconds recovery between each sprint, time being recorded for each sprint.

- ***Varying distance repeat sprints*** - straight course or out and back course - then five minutes recovery with a repeat immediately after. The time taken for each sprint being recorded.

- '***T'-Test*** - Marked 'T'-shaped course where you paddle out to top of the 'T', scull sideways to the edge of the top of the 'T', back to other top edge of the 'T', and back to the middle where you paddle backwards to the finish line. The time to complete the course is recorded.

Strength

Assessment of strength development would need to be based around the most appropriate exercises for the paddlesport discipline. The methods for assessing could include one repetition maximum lifts, for instance the maximum amount that can be lifted for one repetition for bench press, or a 5-10 repetition maximum could be utilised. The number of repetitions should be based upon the discipline or the age of the athletes (see the section on growth and development below). Exercises, depending on the experience of the paddlers, could be carried out as free weight Olympic lifts or on multi-gym machines. The advantage with free weights is that they tend to require groups of muscles to work together, to lift the bar and control sideways movement, and so more closely match paddling whereby canoeists use muscles working in groups, i.e. forward paddling requires co-ordinated leg, back, abdominals and arm movement.

Power/Speed

The most appropriate method for assessing power in paddlesport would be to do this in-boat where possible. Short courses could be set to assess take-off power or sprint speed. For flat water paddlers this would be very close to boat-based skill work. Power assessment for surf kayakers would most logically be based around the four or five power strokes needed to pick up a wave and could be measured on flat or moving water and be assessed by the distance travelled after the power strokes. Out of boat power tests could be carried out on a Concept II rower or with an arm crank ergometer, both of which can usually be found in the gyms at fitness centres.

Body Composition

The most accurate and easily available method for body composition assessment would be using skinfold callipers. The reading list at the end of the chapter provides details of books that cover the necessary techniques. The key concerns with this aspect of fitness assessment are the reliability of measurements (see below) and the way in which results are used. As a society we have become obsessed with body size and shape. When assessing body composition we need to be sensitive in handling results; who really needs to know, and do we really need to know about a particular paddler's result?

Mobility

In-boat mobility assessments would again be the most appropriate for assessing flexibility of paddlers.

Photo 13 Sit and Reach Test

These should be based around functional discipline-specific movements, i.e. trunk rotation and flexion/extension of the lower back, with the aim being to develop appropriate levels of mobility for all aspects of your paddling. In addition, the 'sit and reach' flexibility test could be used to provide a general out of boat assessment of mobility. Photo 13 (sit and reach test) provides a picture of the test apparatus, which should be carried out after a warm-up, with straight legs, at a slow speed and with three trials. The best of the three trials - how far the paddler can reach (in centimetres) is recorded. *(This uses facilities available in any gym, for more paddler-specific tests see Chapter 18).*

Advanced Assessment Tools

There are a number of advanced assessment tools that can be employed for testing paddler fitness. As mentioned above the $\dot{V}0_{2max}$ test has traditionally been the gold standard measure or predictor of aerobic fitness. More recently, however, research has shown that lactate threshold is a more accurate predictor of success in aerobic events. The measurement of lactate levels is based on studies showing that, as an athlete increases their effort towards maximum, they increase the amount of lactate they produce. With regard to assessment of fitness levels, the testing of lactate levels relies on the fact that in shorter duration events that do not allow the aerobic system to come to full power when operating near to or at maximal levels, the anaerobic (lactic acid system) has to contribute some of the energy produced. A result of this is the release of the metabolic by-product lactic acid into the blood. The harder an athlete is working the more lactate is produced. Knowledge of this allows coaches and sports scientists to assess time and lactate production after a set distance run, paddle or swim. If fitness is improving over time then lower lactate levels should be recorded for successive tests.

KEY POINT SUMMARY

- Lactic acid is produced in glycolysis when there is insufficient oxygen to enable the aerobic system to continue the breakdown of carbohydrates. Once lactic acid is produced it quickly dissociates to form lactate and a free hydrogen ion which is what causes the rise in acidity in the muscle and blood. The terms lactic acid and lactate are often used interchangeably.

Lactate produced by working muscles can be transported to the heart (where it can be used as a direct fuel source), non-working muscles or to the liver where it can be converted into fuel sources for energy production. The lactate threshold represents a level of work after which an athlete's removal of lactate from the blood cannot keep pace with production. After this threshold, lactate begins to accumulate in the blood and will lead to an athlete having to stop exercising due to the lactate in the working muscles and blood. Research has found that for aerobic events, the higher percentage of an athlete's $\dot{V}0_{2max}$ at which this occurs the better for performance in races. In other words, if two marathon paddlers had the same $\dot{V}0_{2max}$ but one could operate at 90% of this and the other could operate at 85% before passing their lactate threshold the first paddler would be able to operate at a higher workrate/speed and would complete the race first. Researchers have shown that knowledge of the level at which lactate threshold occurs is a better predictor of performance than $\dot{V}0_{2max}$ alone. As a result many sports scientists are now using a test of lactate threshold as a measure of aerobic ability/performance for elite athletes.

GUIDELINES FOR TESTING

There are a number of useful principles that can be followed to assist with designing and administering the tests to be used and the order in which they are used.

▶ Validity Of The Test

Does the test measure what it really should measure? For example, does the distance paddled assess the aerobic system, the anaerobic system or a combination of both? How does the test match the requirements of your discipline? There are many tests that can be employed for each component of fitness and you need to select the most valid. Are they specific to your discipline?

▶ Reliability Of The Test

There are two aspects of reliability that you need to consider, test-retest reliability and inter-tester reliability. If you test someone one day and then retest again the next day, before any changes in their fitness have taken place you should get very close to the same score if the test is reliable. If scores are different this may be due to a lack of test-retest reliability with the test. In a similar way, there may be situations where two people carry out the testing for a paddle. In a reliable test a paddler would achieve their score regardless of who was testing; if so, the test can be said to have inter-tester reliability. It should not matter who is carrying out the test – an effective test needs to provide consistent results.

KEY POINT SUMMARY

- Tests need to be valid and reliable measures of performance. An analogy for this can be drawn from archery. The validity of a test refers to the ability of the arrow to hit the target and the reliability refers to the consistency with which the target is hit with each arrow.

▶ Ordering Of Tests

An element that is highly specific for paddlesport fitness assessment is that of environmental factors. Due to the nature of our sport, changes in weather, the river, the boat, etc. can have a significant influence on test results. That is not to say testing should be abandoned if there is a change in environmental factors, but they should certainly be recorded and taken into account when evaluating results. The period before testing can also have an influence on results, for instance a really heavy training session the night before testing can influence testing results. When administering a test battery you should try to mimic as closely as possible the lead-in to the previous tests and where possible allow paddlers to take tests in a rested state. Each time a battery of tests is carried out they should ideally be carried out in the same order to enable you to evaluate like with like. The order in which a paddler performs a series of tests will also influence the levels they achieve. For example, scores for strength tests will be negatively influenced by any maximal aerobic test carried out before the strength test, whereas aerobic results, after

an appropriate rest, are not detrimentally affected by strength assessment.

The following assessment schedule is therefore proposed:

- Non-exercising tests – Height, weight, body composition
- Maximal strength tests
- Flexibility and agility tests
- Sprint tests
- Muscular endurance tests
- Maximal aerobic or anaerobic tests

If you are worried that having one test before another might influence the score achieved on the latter, consider completing testing on different days rather than one.

NUTRITION

Our diet provides the fuel for our paddling. This section will examine our nutritional requirements, guidelines for a balanced diet, modifications for power and endurance athletes and suggestions for pre-competition, during exercise and recovery meals. How our bodies use the food we have eaten, to provide the energy we need for paddling, will then be covered in the next section on energy systems.

THE SIX NUTRIENTS FOR HEALTH

The food we eat is vital for our health and providing the energy we need for our paddling and daily lives. Carbohydrates, fats and protein make up the main nutrients in our food and provide energy for our bodies. Vitamins, minerals and water, while not providing energy directly, assist the body with energy production, transport of nutrients, removal of waste products, health and immunity from illness.

Carbohydrates

These form a major source of energy for the muscles and brain in the form of sugars and starches. There are several ways of classifying carbohydrates according to the structure. Carbohydrates that are of one simple sugar are monosaccharides (glucose or fructose), and disaccharides such as sucrose or lactose are formed of two monosaccharides. Sucrose, (household sugar) is made from a glucose and a fructose.

KEY POINT SUMMARY

- A balanced diet is a healthy diet and will form the foundation for successful performance and, except at elite level or due to illness, very little in the way of supplements are required.

The largest carbohydrate units are polysaccharides which include starch and glycogen. Both are composed entirely of glucose units, with glycogen being the form in which glucose is stored in the body to provide energy. Very often nutritionists talk in terms of simple (monosaccharides and disaccharides) and complex carbohydrates (polysaccharides). Simple and complex carbohydrates have also been known to athletes as quick and slow 'carbs', with simple sugars being thought of as less useful than complex carbohydrates that enter the bloodstream more slowly. This is not entirely true as the food's glycemic index (see recovery meals below and reading list), amount eaten, and food preparation also affect the speed of entry to the blood.

Fats

Fats, also known as lipids, provide highly concentrated stores of energy. Fats are broken down in the body to form smaller units such as triglycerides, free fatty acids and cholesterol. Fats form an important part of our diet and serve several functions within the body, such as providing energy (70% when we are at rest), support of organs in the body and storing fat soluble vitamins. The most basic unit of fats are free fatty acids which occur as saturated or unsaturated fats. Saturated fats tend to be solid at room temperature and derived from animal fats whereas unsaturated fats (monosaturated or polyunsaturated) tend to be liquid at room temperature. Saturated fats have been linked with a higher risk of cardiovascular disease than unsaturated fats.

Proteins

These are nitrogen-containing food stuffs that provide the basis for building and repairing muscles, other tissues, red blood cells and hormones. Proteins are broken down in the body into amino acids. Twenty amino acids have been identified as necessary for our growth and metabolism. Importantly, nine of these are essential within our diet as they cannot be produced within the body. Complete proteins, such as meats, fish, eggs and milk, contain all of the essential proteins. Protein derived from plants and grains

cannot individually provide all the essential proteins and so vegetarians need to gain their protein from a variety of sources.

▶ Vitamins

Although required in relatively small quantities, vitamins form an essential part of our diet, assisting the body with chemical reactions for energy production, promoting growth and maintaining health.

▶ Minerals

Are found throughout the body, for example as iron in red blood cells or as calcium in bones and are essential for allowing cells to function normally.

▶ Water

We are made up of approximately 60% water and it is second only to oxygen in its importance to our bodies. Within our bodies water assists with maintaining body temperature, carrying nutrients and waste products, along with assisting cell function.

GUIDELINES FOR A HEALTHY DIET

A healthy diet is the basis for sound nutrition and the need for supplements and dietary manipulation is seldom necessary if a paddler has a sound diet. Figure 4, below, provides a guide to the food groups that form the basis of a healthy diet, which can in a natural way provide all the nutrients necessary for a healthy athletic life. In percentage terms for the 'big 3' that make up the bulk of our diet, it is recommended by researchers that we consume 55-60% of our calories through carbohydrates, up to 30%, but ideally less than this, through fats (with under 10% saturated fats) and 10-15% from proteins.

Figure 4 provides the recommended daily servings for the food groups within the pyramid. For the bread group, an example serving size for bread would be 1 slice, or half cup (cooked) of pasta or rice. For the fruits and vegetables groups examples of serving would be an apple, a small banana, a medium tomato, or a small stalk of broccoli. For the milk and meat groups, example serving sizes would be 1 egg, 1/3 of a can (small) of tuna or 3oz chicken breast (about the size of a pack of cards).

In addition to the basic diet there are some useful considerations you can make in your diet to improve upon these basic guidelines. Variety, moderation and naturalness will add to a healthy diet. There is no one food that can provide all the nutrients we need, having variety with meals helps us to gain all the nutrients

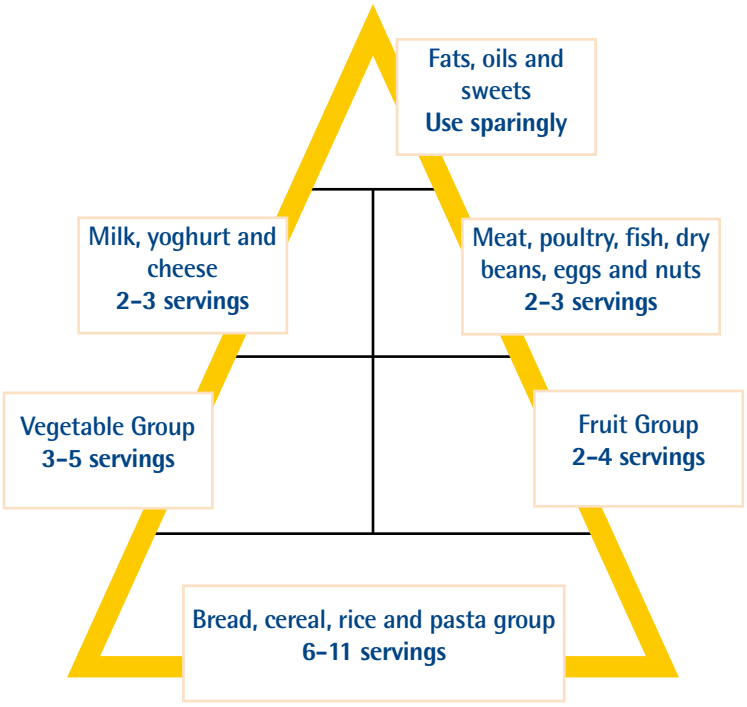


Fig. 4 The Food Guide Pyramid with Suggested Daily Servings

we need. There is nothing wrong with having 'treats' occasionally; these add variety to the diet and increase enjoyment of your food - the secret to this is moderation and cutting back in other areas. The more natural your food is, that is the less it has been processed by manufacturers before you consume it, the better. Processed food tends to have fewer nutrients than natural foods. Choosing wholemeal bread over white bread or cooking foods yourself rather than buying processed meals can help to retain the nutrients in the food you eat. In Britain people are encouraged to eat 5 portions of fruit and vegetables a day. The food pyramid includes fruit and vegetables - both can contribute to the five a day, selecting both in your diet helps in the variety you get in your diet. It is better to eat a mixture of fruits and vegetables rather than eating 5 apples a day. Including fibre in your diet will aid digestion and can be found in whole wheat grains, some cereals, beans and peas.

KEY POINT SUMMARY

- As well as the basic healthy diet, adding variety, moderation and naturalness to the food we eat will help our paddling performance. What we eat does count in our paddling.

▶ Modifications For Paddlers In Power And Endurance Disciplines

The main manipulation of diet for us as paddlers concerns the overall energy expenditure we have in our daily lives. The more exercise and training a canoeist takes part in the greater the energy expenditure. The daily energy requirements for sedentary people are 2000-2500kcal for women and 2500-3000kcal for men whereas those involved in kayaking may need 30% and more above these levels. Paddlers involved in the Devizes to Westminster or similar marathon races may expend in the region of 5000 - 6000kcal per day and would need to replace as much as possible of this during the race. So to a large extent modifications in diet for paddlers involve increasing total calorific (food) intake rather than changing the percentages of our daily intake.

Paddlers involved in power events can benefit from some additional protein intake, but the requirements for athletic performance are far less than people often imagine. There is not normally a need for a paddler in a power-based discipline to take protein supplement or drinks. It is recommended that power athletes do not exceed 1.4 - 1.8g of protein per kg of body weight. Thus a 75kg paddler each day would need between 105-135g of protein. By way of example, an 8oz chicken breast would provide about 70g of protein.

▶ Pre-Competition, During Exercise And Recovery Meals

Research tells us that canoeists do benefit from a pre-training or pre-competition meal. Ideally this meal should be eaten 3 – 4 hours before the event, be low in fat, protein and fibre, high in carbohydrate and include fluid to help maintain hydration. This meal should also comprise foods with which you are familiar. It is better to eat foods that you know suit you than to try some new suggestion just before you go into a competition.

Maintaining blood glucose levels during exercise through ingesting carbohydrates has been shown to improve exercise performance. For intermittent disciplines such as canoe polo this would be best achieved through a sports drink. For paddling events of longer duration, such as a day white water or sea paddling, the maintenance of blood glucose levels can be maintained through sports drinks, and or, a mixture of carbohydrate snacks such as wine gums, jelly babies, dried fruits, cereal bars or sandwiches. Sports drinks can also help with maintaining hydration as they are absorbed more readily than water and can assist with replacement of minerals lost through sweating.


14

Photo 14 Sea paddler snacking

KEY POINT SUMMARY

- After a paddling session a meal including protein and carbohydrate helps with tissue repair and restoring glycogen stores.

After a paddling session, as a recovery meal, both carbohydrates and proteins are beneficial. The meal should be eaten as soon as possible after completing canoeing. The glycemic index of the food is also important for the post-exercise meal. Carbohydrates that have a high glycemic index and more quickly enter the bloodstream are more beneficial in the process of replacing glycogen stores in the muscles. These include baked potatoes, cereals and bread. Eating protein as part of the post-exercise meal will help with muscle repair and building. Research indicates that eating a combined carbohydrate and protein meal can help with the building process. If it is not possible to eat a meal after finishing paddling, a sports drink can help with energy replacement and will also help with replacing fluid loss which needs to be addressed after training or competition.

ENERGY SYSTEMS

This important section within the chapter contains information about how the food we take into our bodies is used to provide the energy we need for different paddling disciplines. It is also intended to make clear the differences between aerobic and anaerobic energy production that is essential knowledge for a paddler in making decisions about the components of fitness relevant to their discipline. The basis for understanding energy production is to understand where this takes place – within the cells of our bodies. This section will begin with a review of what we are made up from – cells, then look at anaerobic and aerobic energy systems along with information about muscle fibre types and the adaptations to the body brought about by training.

THE CELLULAR BASIS FOR LIFE

The foundation of all living things is the cell – the smallest unit capable of carrying out all the processes associated with life. Humans are made up of many different cells that work in co-ordinated groups to accomplish functions within the body. The body's systems - skeletal, muscular, respiratory and nervous etc. - are made up from cells working in co-operative units. All cells have specialised functions that contribute to the functioning of the body and are dependent on the other groups of cells carrying out their functions to maintain life. For example muscle cells use energy to bring about movement, but are dependent on the circulatory system (blood and blood vessels)

Photo 15 Paddler drinking sports drink

for supplying oxygen, the food necessary to produce energy and for removing the waste products that result from energy production. Cells within the body have to work co-operatively in this integrated fashion for us to sustain life. The various cells within our bodies, while serving different functions, all require energy for the roles they play and have the same basic structure. As can be seen from Figure 5, a simplified diagram of cell structure under an electron microscope, all cells have a similar structure. Most cells have three main parts, the cell membrane (outer skin), the nucleus and the contents of the cell, the cytoplasm. It is this structure that enables cells to produce the energy required for us to go paddling.

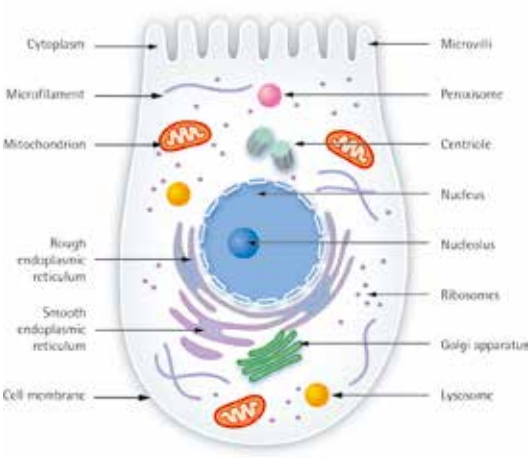


Fig. 5 The structure of a 'typical' cell

The cell membrane is a very thin structure that encloses every cell and keeps it separate from its surrounding environment. The nucleus, normally the largest single unit in the cell, contains the deoxyribonucleic acid (DNA), the blueprint for controlling the

operations of the cell. The cytoplasm comprises the inside of the cell except for the nucleus. It is made up of a gel-like substance, cytosol, which houses and protects six main sorts of small structures called organelles. These organelles (meaning small organs or structures) serve a variety of roles for the cell. In Figure 5 one of these organelles, a mitochondria, is shown as it is vital in the process of energy production. Mitochondria are the power plants of the cell and they are responsible for producing about 90% of our energy.

KEY POINT SUMMARY

- All cells in the body need energy to carry out the work they do. Cells comprise a cell membrane that separates the cell from other parts of the body, a nucleus that controls the cell's functions, and the rest of the cell which is known as the cytoplasm. Within the cytoplasm are mitochondria - tiny organs that are the power plant for energy production.

The key concept to take from this section is that energy production does not take place within some 'factory' or a particular organ within the body. The body is made up of cells, every one of which needs energy to carry out its work. When we go paddling the muscles that we use, which are made up of cells, each with a nucleus, cell membrane and cytoplasm (containing mitochondria) produce the energy they need to allow us to paddle. The energy produced comes from the food we eat - carbohydrates broken down to glucose in the body, fats broken down to free fatty acids (FFA) and proteins broken down to amino acids that are mainly responsible for growth and repair, but can be used for energy production.

ENERGY PRODUCTION

Energy production for use by the body begins with digestion or breakdown of our food after we have eaten. The process of digestion can be thought of as the mining or drilling for crude oil or the fuel that we need for energy production. The crude forms of fuel produced after digestion are glucose, FFA and amino acids. These crude fuels are shipped (via the blood) to cells throughout the body where they are converted into the refined fuel of Adenosine Triphosphate (ATP). Adenosine triphosphate, shown in Figure 6, is the 'petrol' for our bodies – the fuel every cell uses to do work.

▶ Adenosine Triphosphate (ATP)

Adenosine triphosphate is named as such because it has one adenosine molecule bonded (joined) to three phosphate molecules. It is these bonds that make ATP the 'petrol' for our bodies, for each one is created using energy, but when created, stores energy for work. ATP stores large amounts of energy in each of these bonds so that when a bond is broken it will release the stored energy to allow a cell to do its work, for instance when the energy muscles need to contract and bring about movement. The most common breakdown of ATP is for one phosphate to be broken from the chain to release energy and leave behind the free phosphate and ADP (Adenosine diphosphate). This energy release reaction is shown in Figure 7.

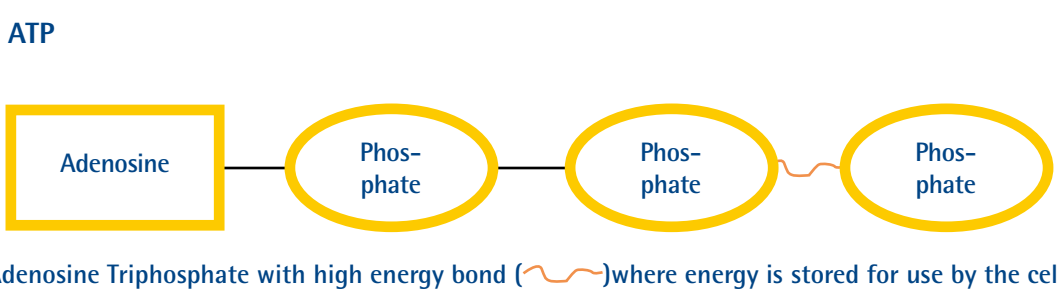
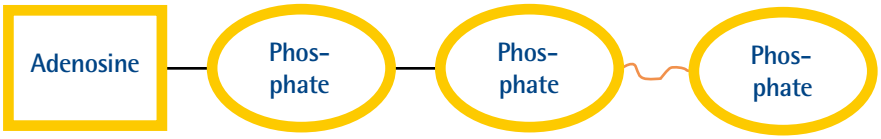


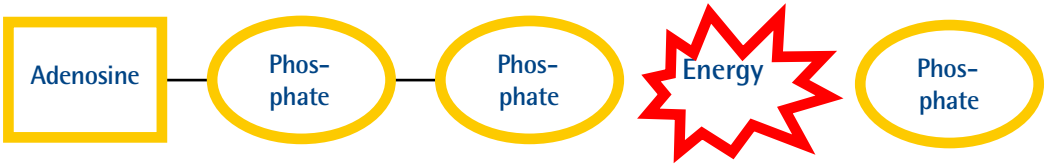
Fig. 6 Adenosine Triphosphate

Stored ATP



Adenosine Triphosphate with high energy bond (~) where energy is stored for use by the cell.

ADP created from breakdown of ATP



Adenosine Diphosphate where the last phosphate has been broken from the chain to release energy for work.

Fig. 7 Adenosine Triphosphate converted to Adenosine Diphosphate, so releasing energy.

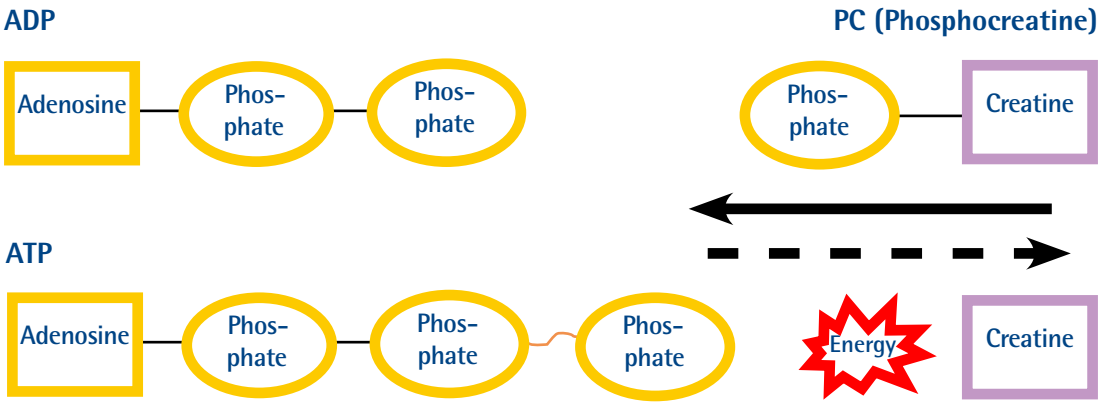
KEY POINT SUMMARY

- Adenosine Triphosphate (ATP) is the petrol for our paddling performance. Carbohydrates, fats and proteins are broken down in the cells of the body to produce the ATP every cell needs. Cells have three systems (two anaerobic and one aerobic) with which to produce ATP. Each of these systems act as 'gears' for energy production. First and second gear, the ATP-PC system and glycolysis (see below), become the dominant fuels relatively quickly, but have a limited duration, whereas the overdrive third gear (aerobic system) is slower to become the main fuel source but can enable activity for long periods of time. Each paddlesport discipline will place different demands on the energy systems.

Cells within the body keep some stores of ATP, for if they did not, every time we wanted to make a movement we would have to delay before the ATP was created. However, this stored ATP (fuel) is limited in its supply, enough for a few seconds work, so very quickly we have to create new supplies of ATP. We have three energy systems that can be used to create ATP from the food we eat to produce the energy we need for paddling. There are two anaerobic energy systems and one aerobic system.

▶ Changing Gear

Anaerobic and aerobic energy production is concerned with creating ATP for the working muscles to allow us to paddle. The simple question is why do we have more than one system, surely if any one of these systems can produce the ATP we need for work then that should be enough? This is not, however, the case. Just as a car has gears so the body needs a variety of systems to produce ATP. Two low gears (1st and 2nd) for power and acceleration along with a high gear (3rd)- overdrive – for efficiency and long journeys. The human 'car' has three gears, 1st and 2nd gear are the anaerobic systems while 3rd gear is the aerobic system. The purpose for all three systems is to create ATP to replace the stores in cells as they are used up when the cell is working.



The bond between the creatine and phosphate (PC) is broken to release the energy required to join the phosphate to the ADP to recreate ATP.

Fig. 8 The Phosphocreatine System

THE ANAEROBIC ENERGY SYSTEMS

The two anaerobic sources of energy production are the phosphocreatine system and glycolysis.

▶ Phosphocreatine System

The most rapid source for creating ATP is the phosphocreatine (PC) system. Each cell stores within the cytoplasm PC which can be used, as shown in Figure 8 above, to recreate ATP for use as a rapidly available short term energy system. Through this reaction phosphocreatine is broken down to release the phosphate to create a third high-energy bond with ADP, forming ATP and leaving creatine. The arrows in Figure 8 show that the reaction is reversible and at times of rest PC will be recreated to be stored in the cytosol of the cytoplasm. Events of up to 10 seconds duration will use this source of energy as the main fuel source.

▶ Glycolysis

The second source of anaerobic energy production is glycolysis. For events lasting longer than 10 seconds and less than one and a half minutes of maximal effort or for a sprint finish this will increasingly become the dominant source for ATP production. As can be seen from Figure 9, glycolysis involves a ten step breakdown of glucose (carbohydrate) to produce Pyruvate and ATP. The breakdown of glucose glycogen (the storage form of glucose. Glucose is stored in the liver and muscles as glycogen – chains of glucose molecules linked together) takes place in the cytoplasm of each cell. It is not important for you as a practising coach to know each of the 10 reactions and so they are not included in Figure 10. The important concept to gather from the figure is that there are many more reactions to produce ATP through glycolysis than through the PC system and it is for this reason that it becomes the second system for energy production. It is, however, faster in producing ATP than the aerobic system.

The end product of glycolysis is pyruvate. If sufficient oxygen is present, i.e. we are paddling below maximum rate and for a period of time over 1½ minutes, the aerobic system can utilise the pyruvate to help produce more ATP (this will be discussed in the next section). However, if a paddlesport discipline requires maximal effort for a short period of time or a sprint at the end of a race there will not be sufficient oxygen to metabolise (use) all the pyruvate. In this anaerobic situation lactic acid, or lactate as it is sometimes called, is formed.

The formation of lactic acid, creating acidity in the working muscles and pain in your muscles when you exercise, for instance in an all-out 1 minute sprint, will limit the duration for which you can continue to exercise at a high intensity. The lactic acid, produced through exercising maximally and using glycolysis to form ATP, causes a rise in acidity in the cells. The enzymes (catalysts) that assist the reactions of glycolysis can only work within a narrow pH range. As lactic acid levels rise and change the pH within the cell, the enzymes are inhibited in their work, impairing our ability to continue to produce ATP through glycolysis and leading to fatigue.

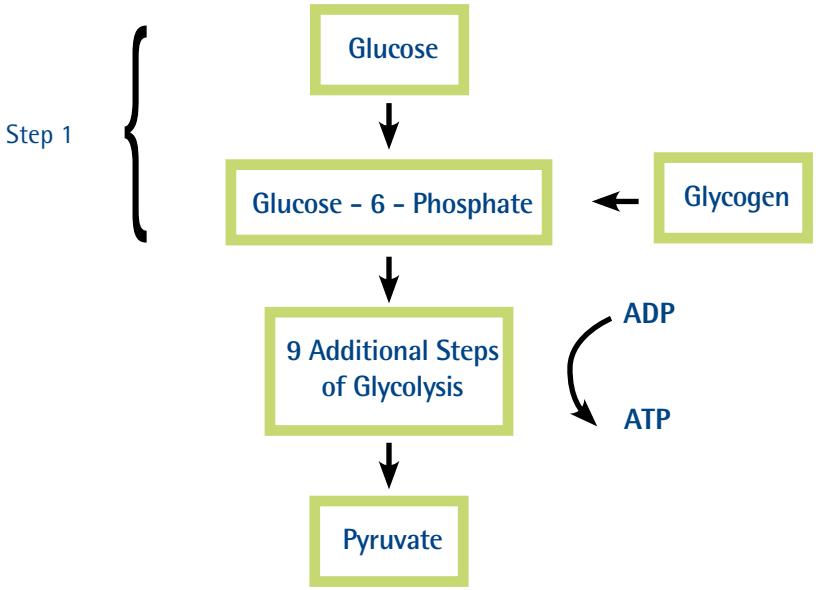


Fig. 9 The Creation of ATP through the Ten Steps of Glycolysis

THE AEROBIC ENERGY SYSTEM

Whereas glycolysis can utilise only carbohydrates, in the form of glucose or glycogen to produce ATP through aerobic metabolism cells can use fats and proteins as well as carbohydrates to produce ATP. The production of ATP within each cell for anaerobic purposes takes place within the cytoplasm of the cell. Aerobic metabolism takes place within the mitochondria (powerhouse) of each cell. Depending on their function each cell can have from a few hundred to several thousand mitochondria. The mechanisms through which fats, proteins and carbohydrates can be, in the presence of oxygen (supplied to each cell from the lungs via the bloodstream), used by cells to create ATP is shown in Figure 10.

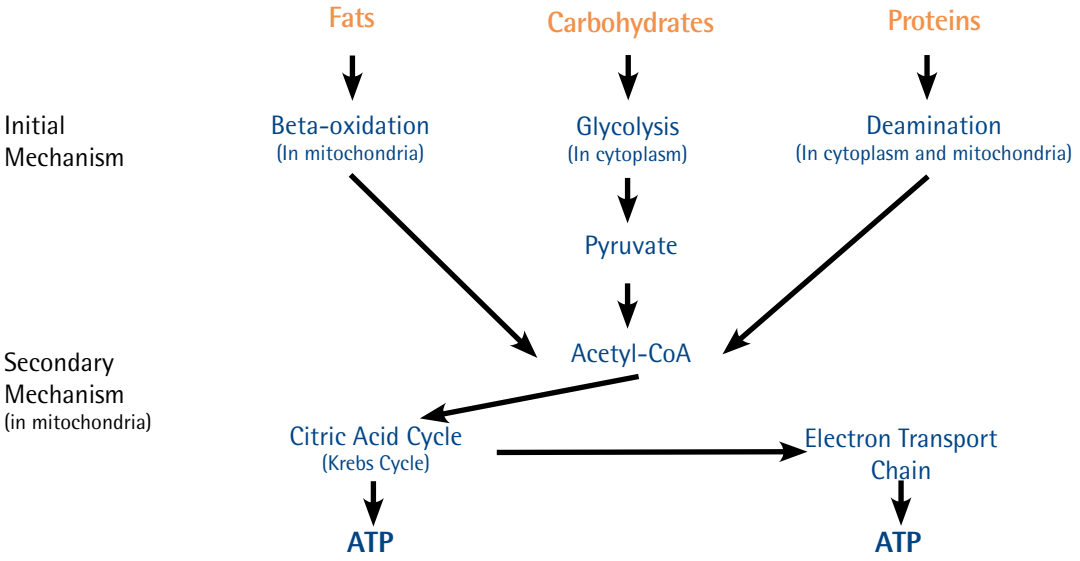


Fig. 10 Breakdown Mechanisms for Aerobic ATP Production

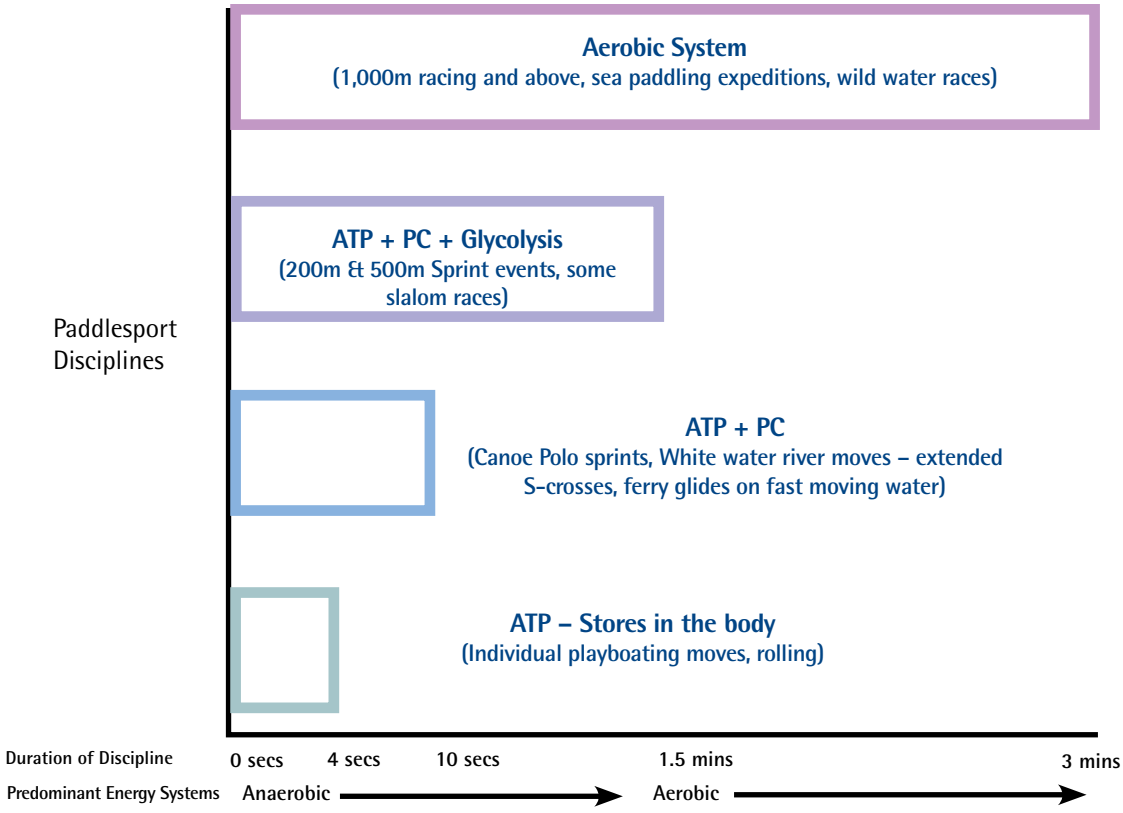


Fig. 11 The Energy Systems for Paddlesport

Even from looking at the steps in the process it is clear why producing ATP from aerobic methods is a slower method for producing energy than using anaerobic mechanisms. Although all three nutrients can be used for energy production it is thought that proteins are responsible for supplying only 10% of our energy needs so the main aerobic fuel sources are fats and carbohydrates. Carbohydrates (glucose or glycogen) are broken down in the cytoplasm through glycolysis, proteins in the cytoplasm and mitochondria through deamination and fats in the mitochondria through oxidation. After this initial breakdown the fate of all three food substances is Acetyl Co-Enzyme A (Figure 10). From Acetyl CoEnzyme A the three nutrients are broken down further through the citric acid cycle (also known as the Krebs Cycle) and the electron transport chain to produce ATP. The largest supply of ATP is available through aerobic metabolism and can provide relatively inexhaustible supplies such as the majority of the energy required to complete marathon paddling races or a day sea paddling.

Figure 11 shows the relationship between the sources of energy production for paddlesport.

MUSCLE FIBRE TYPES

The body is made up of cardiac (heart), smooth (around blood vessels) and skeletal muscle fibres. For energy production in paddlesport, clearly the heart is vital for supplying the oxygen we need, however, we are most concerned with the ability of skeletal muscles to bring about movement. The strength, power and endurance we need for canoeing and kayaking is provided by our skeletal muscles. Just as we have different ways to produce the energy we need for canoesport, there are a variety of muscle cell or fibre types that can be used by our bodies to move our boats around.

Two main distinctions have been made, Type I (slow twitch) and Type II (fast twitch) fibres.

▶ Type 1

Type I fibres have greater aerobic capabilities than Type II fibres. Type I fibres have a higher density of blood vessels supplying oxygen to the fibres, a larger number of mitochondria and increased aerobic enzyme activity (catalysts that enable reactions to take place).

Type 2

Type II fibres have greater anaerobic qualities and are able to generate greater forces than Type I fibres but fatigue more quickly.

Percentages

Each one of us has a slightly different make-up of Type I and Type II fibres and this is what makes us physiologically more suited to some disciplines than others. A paddler with a higher percentage of Type I fibres would be more suited to endurance events, a paddler with a predominance of Type II fibres being more suited to power disciplines. Through training, however, we can affect our fitness and our bodies can make adaptations according to the type of training we undertake. This forms the final part of this discussion of energy systems.

KEY POINT SUMMARY

- We have two main muscle fibre types, Type I and II. Type I are more suited to aerobic activity and Type II are more suited to anaerobic activity. Each of us as paddlers are made up of different proportions of fibre types. If we are made up from more Type I fibres we may be more suited to aerobic disciplines or if Type II fibres predominate we may be more suited to sprint and power type activities.

ADAPTATIONS TO TRAINING

After making decisions about the predominant energy systems for your discipline, the training programme should be based around the specific demands of the activity because the adaptations to training will be highly specific as well.

Adaptations To Aerobic (Endurance) Training

Endurance training such as longer distance paddling sessions or interval work will bring about a number of changes to the body that will enhance aerobic performance including:

- Increase in size and number of mitochondria.
- Increased blood flow round the body (the heart, also a muscle, will increase in size through training thus improving the ability of the heart to pump blood to the muscles that need it).
- Increased ability to use fats as a fuel source (we have relatively unlimited stores in our bodies) thus sparing glycogen stores which are limited.
- Increased lactate removal from the blood to enable a canoeist to paddle at higher intensity of exercise with the same level of lactate.

Adaptations To Anaerobic (Strength And Power) Training

If a paddler follows an anaerobic programme this will have a number of positive effects on their anaerobic capabilities including:


16

Photo 16 Endurance training

- Increased anaerobic stores such as ATP, PC, glycogen stores and strength of muscles.
- Increased ability to produce lactate and sustain high levels of lactate before ceasing exercise.
- Increased activity and stores of enzymes involved in anaerobic energy production.

In Summary

In summary, the energy systems are concerned with producing ATP, the fuel for paddling and exercise. To start any movement or activity we have stores of ATP


17

Photo 17 Strength and power training

that are quickly used up so we have 3 gears or systems for creating ATP and continuing movement. The first two anaerobic systems (ATP-PC and glycolysis) are relatively fast in being able to supply energy, but have a limited duration as a main fuel source. The third aerobic system is slower to initiate due to the number and nature of reactions required for the system to get 'up to speed' but is a long-term fuel source for producing the ATP we need to paddle. As paddlers we need to analyse our discipline to identify the predominant energy system(s), and then our training can be based around maximising the efficiency of the systems through the adaptations identified above. Without the knowledge in this section it is very difficult to accurately develop training for any canoesport discipline.

STRENGTH TRAINING AND CONDITIONING

So far we have discussed the components of fitness that might apply to any particular canoesport discipline, general principles for designing a training programme, how to divide up a training year to peak for an event and how to evaluate the success of the programme. Having done this, and with knowledge of the energy systems, the next step is to examine the range of strength (also called resistance or weight) training and conditioning exercises that can form the basis of a training programme for a paddler. This section will provide the specific training suggestions that can help you to address physiological improvements in performance.

STRENGTH TRAINING

There are a great number of gyms and sports centres in Britain now where you can undertake a resistance training programme. If you lack power or muscular endurance in your paddling, resistance training can help to address this. Strength or resistance training can be carried out using free weights or machine weights or a combination of both. With this range of equipment there are numerous exercises that can be performed for each muscle group working in isolation or in functional groups. Carrying out a preacher curl would be an example of working a muscle in isolation – the biceps muscle – whereas a power clean, a very popular exercise for athletes, works large groups of muscle in co-ordinated movement pattern and is, as mentioned above, much more specific to sporting performance. For canoe and kayak sport we work our muscles to a large extent in functional groups - several muscle groups working together - to bring about propulsion in our boats. Therefore, following the specificity principle we should try to match this in the weight training programmes we follow to improve our strength, power or muscular endurance.

Resistance training can be used to bring about a variety of results through manipulating the weight, repetitions and sets carried out for each particular exercise. Table 4 provides details of the variation in reps and sets that would be required for each particular outcome. The weight for each exercise should be decided by experimenting with the weights until you find a load at which in the last set you can just complete the repetitions required. Start with lower weights and build up; after you have been to the gym for a short period you will be able to find the appropriate weight quite quickly – do not sacrifice technique for extra weight. The 2 for 2 rule could then be used to make decisions about increasing training loads as your body makes adaptations to training. An instructor at a local gym should know all of these exercises and would be able to provide you with further advice on choice of exercises and technique.

KEY POINT SUMMARY

- Strength training programmes can be designed to develop a wide range of muscular goals including pure muscular strength, power, muscle size and endurance. The repetitions, sets and weight can be manipulated to bring about desired results.

Outcome	Strength/Power	Strength	Hypertrophy	Muscular Endurance
Repetition Range	1 - 3	5 - 8	8 - 12	15+
Sets	3 - 5	2 - 4	2 - 4	3
Rest Between Sets	3 - 5 mins	1 - 3 mins	1 - 3 mins	1 min

Table 4 Possible Training Units Within a Periodised Programme

Body Part	Exercise	Equipment
Shoulders	Lateral Raise	Dumbells or Machine
	Shoulder Press	Barbell, Dumbells or Machine
	Deltoid Raise	Dumbells
	Upright Row	Barbell
	Lower Arm Abduction/Adduction	Cable Pulley
Legs	Back Squat	Olympic Bar
	Front Squat	Olympic Bar
Upper Back	Seated Row	Cable Pulley or Machine
	Lat Pulldown	Machine
	Bent Arm Pullover	Barbell or Machine
	Dumbell Row	Dumbells
Lower Back	Back Extension	Machine or Floor Exercise
Chest	Fly Curls	Dumbells
	Pec Deck	Machine
	Bench Press	Barbell or Machine
	Incline Press	Barbell or Machine
Tricep Press	Tricep Press	Machine
	Tricep Extension	Machine
	Bicep Curl	Barbell, Dumbells or Machine
	Wrist Curls/Raises	Barbell
Abdominals	Abdominal Curls	Machine, Floor or Physio Ball
	V-ups	Floor
	Chinnies	Floor
	Hanging or Dip Machine Leg Raise	Hanging from pull-up bar or dip
	Hip Crunch	Floor with Medicine Ball
	Hip Rotator	Floor with Medicine Ball
Combination Exercises	Power Cleans	Olympic Bar
	Deadlift	Olympic Bar
	Bent-over Row	Olympic Bar

Table 5 Suggested Resistance Training Exercises for Paddlesport

A Range Of Exercises

There are a wide range of exercises that can be usefully undertaken in a general fitness programme for kayak and canoesport and these are listed in Table 5. The number of exercises in a session would be between 8-12 and those selected should be those that you believe are the most specific to your discipline. In terms of specificity it is clear that the major element of paddlesport is upper body dominant, however the low back, abdominals and legs are important as assistor muscles, and weaknesses in these aspects of your development can impact negatively on your performance.

Ordering The Exercises

Having selected the exercises for a programme, there are a number of ways that exercises can be ordered depending upon the outcomes desired. For maximal strength and power gain, exercises can be carried out

from largest to smallest muscle groups (for example bench press before tricep extension), or changing from upper body to lower body exercises (for example Lat Pulldown to Squat to Pec Deck) where maximising rest is important. For hypertrophy and muscular endurance training you could consider moving from small to large muscles groups (tricep extension before bench press) or completing all exercises for one body part before moving on to the next. Weight training exercises can also be linked in with matched plyometric exercises (see below) in 'complex' training that can also impact upon the power or endurance capacity of muscles. An example of this would be bench press being matched with clap press-ups - a strength exercise to pre-load the system followed by a plyometric power exercise.

By altering the order of exercises or splitting routines into separate body parts it is possible for us to train in the gym up to six days per week. However, this degree of weight training specialisation would be more appropriate to sports where the physical domain is larger than the skill component. This is not the case for paddlesport and, as such, a maximum of three weight training sessions per week would allow a more appropriate focus on skill development.

▶ Alternatives

As well as weight training there are a number of alternative forms of resistance training that might prove beneficial to paddlesport. One of the most important of these is, as mentioned above, plyometrics which can be used in conjunction with the above. In the reading list below the book by Chu (Power & Strength) has a very good focus on plyometric exercises and how they can be linked in with strength exercises to form complex training programmes. Plyometric exercises use pre-tensioning of muscles to increase force generation and research has shown that they can help with power development, especially when linked in with weight training exercises. Yoga and pilates both offer forms of training that can help with core strength and mobility for paddling and could be considered as part of your resistance training programme. Finally, circuit training, a form of training that combines strength and conditioning can provide an efficient form of training for canoesport. The key with all aspects of resistance and conditioning training is not to lose your focus on the most important aspects of your paddling. It would be very easy to have yoga, pilates, weight training and conditioning sessions dominating your training. Paddlesport is skill dominant and as such, for most times in our development, paddling should be at the centre of our training.

CONDITIONING TRAINING

Conditioning training involves anaerobic and aerobic training sessions that are specific to the demands of your canoe or kayak discipline. Table 6 provides details of the various forms of conditioning that can be undertaken as part of your training programme.

▶ Measuring Effort

For sprint training and short duration interval training the method for measuring each of the efforts is how close you are to your maximum. For longer duration intervals and all other forms of training in Table 6 it is possible to use heart rate as an indicator of effort. The development of heart rate monitors has made it relatively easy and inexpensive to monitor your training effort. The more exact you can be with monitoring your training the more accurately you can evaluate the success of your training programme. In working out heart rate training zones a simple way to do this is to take your age away from 220 beats per minute, (your approximate heart rate maximum at birth which decreases by about one beat per year), so if you were 20 your heart rate maximum would be 200 beats per minute. From this basis you can then work out your training zone for each type of training.

▶ Specificity

The majority of the conditioning training for paddlesport can and should be carried out in-boat, however, it is worth thinking about rowing machines and cycling as two possible additional forms of training that could add variety to your programme. Rowing machines, such as the Concept II rower, are available in many gyms and have a more similar muscle pattern usage than any other gym equipment for developing aerobic and anaerobic fitness. Cycling, as an almost perfect opposite to paddlesport has a crossover in that it will provide general cardiovascular improvements but also contributes well to the development of core stability, an important aspect for paddlesport and a feature of pilates sessions. Cycling power comes from the legs, with the upper body and abdominals working as fixators, whereas in paddlesport the power comes from the upper body with the legs and abdominals as fixators.

KEY POINT SUMMARY

- Conditioning training programmes can be designed with a great deal of variety. One of the most versatile forms of conditioning training is interval work where the repetitions, sets and intervals can be varied to meet many training goals.

Type of Training	System Trained	Intensity	Repetition	Sets	Duration of Repetitions
Sprint Training	Anaerobic	90 - 100% of maximum effort	5 - 10	1 - 5	5 - 30 secs
Interval Training	Anaerobic/ Aerobic	85 - 100% of maximum effort/heart rate	3 - 10	1 - 3	30 secs - 2 mins
Medium Paced Continuous Training	Aerobic	70 - 80% of maximum heart rate	1 - 3	1	3 - 10 mins
Fast Paced Continuous Training	Aerobic	80 - 90% of maximum heart rate	1 - 3	1	1 - 5 mins
Fartlek* or Speedplay	Aerobic	70 - 85% of heart rate maximum	1	1	40 - 60 mins
Long Slow Distance Training	Aerobic	50 - 70% of heart rate maximum	1	1	40 - 60 mins or more

Table 6 Anaerobic and Aerobic Training Programmes

INJURY PREVENTION AND REHABILITATION

A carefully planned and balanced resistance training programme can be a central part of injury prevention and rehabilitation for a canoeist. A key part of injury prevention is about keeping a balance between muscle groups around the main joints. Canoeing and kayaking, as 'pulling from the shoulder activities', place a heavy load on the muscles around the shoulder. To avoid muscle imbalances, do weight training and conditioning exercises that develop the 'pushing' muscles around the shoulder. Having suitable rest and recovery periods between training and a good basic diet can also help with avoiding both overtraining illnesses and injuries. Finally, the use of warm-ups and cool-downs have, through research, been shown to help with injury prevention.

See also 'Functional Stability' Chapters 18 and 20, and 'Achieving Correct Posture for Paddling Kayak' in Chapter 18.

▶ Professional Help

For rehabilitation purposes the use of a physiotherapist or similar medical professional can help with specific recovery strategies. In addition, they can provide specific resistance training exercises that can be used during the later stages of injury recovery to assist with strengthening the muscles around joints. An example of this is the lower arm abduction and adduction exercises from Table 5 that can be incorporated into a resistance training programme and can assist in both rehabilitation from, and prevention of, shoulder impingement injuries.

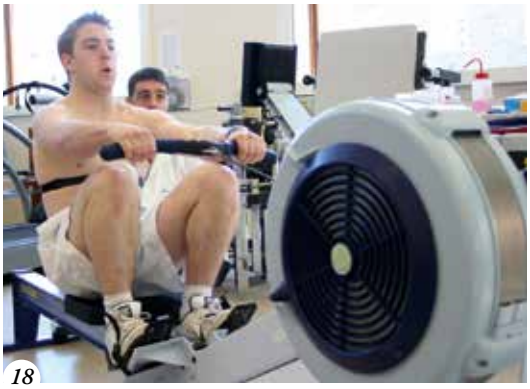

18

Photo 18 A heart monitor used for conditioning training.

19

Photo 19 Strengthening the 'pushing' muscles to avoid muscle imbalance.

WARM-UP AND COOL-DOWN

Aspects that should be considered as part of skill, strength training, and conditioning sessions are the start and end of the training. Research tells us that both warm-up and cool-down can improve performance, help avoid injury and promote recovery. The following points should be considered with regard to warm-up and cool-down:

Warm-ups should consist of a pulse/heart rate raiser and mobilising exercises.

Cool-downs should consist of gradual pulse lowering activities and stretching or flexibility exercises.

Improved flexibility, within healthy limits, has been shown to be beneficial to performance and a lack of mobility can limit skill development. In other words, hypermobility (too much flexibility) and hypomobility (too little flexibility) of a joint can lead to injury and have a detrimental effect on performance.

Specifically, research has shown us that warm-ups can improve:

- Blood flow to muscles and muscle temperature. Sudden bouts of strenuous exercise without warm-up have been shown to lead to abnormal heart performance through inadequate oxygen supply to the heart muscle.
- Oxygen utilisation and the functioning of the energy systems including reducing lactic acid build up.
- Nerve transmission.
- Psychological readiness for the activity by focusing the mind and body on the session ahead.
- Performance during the first minutes of strenuous exercise.

Warm-ups should be specific to the activity to be undertaken, so where possible should include in-boat activities and paddling related pulse raisers and mobilising exercises.

Pulse-raising activities can move from general to discipline-specific activities and can be completed entirely within your boat.

Mobility exercises involve developing intensities of range of movement activities around the key joints to be used for the discipline, such as trunk rotation and shoulder rotation.

Cool-downs have been shown to have an impact on:

KEY POINT SUMMARY

- An appropriate sequence for a paddlesport warm-up would begin with a *pulse raiser* and then light *mobilising* exercises ***before*** the lifting of any boats. Once on the water a secondary boat-specific *pulse raiser* and *mobilising* exercises can be carried out. All *flexibility* exercises should be carried out at the end of the session.

- Reducing delayed onset of muscle soreness (DOMS) that is often felt 1-2 days after strenuous training sessions.
- Stretching to improve flexibility has been shown to be most effective for warm muscles. Stretching carried out during the cool-down is the most beneficial for reducing DOMS and improving flexibility.

A gradual lowering of heart rate and activity levels at the end of a session can assist with removal of waste products from working muscles.

There are a number of forms of stretching that can be undertaken during a cool-down. Two that could be usefully undertaken for paddlesport flexibility are static stretches, held in a comfortable position for 3 x 30 seconds, and proprioceptive neuromuscular facilitation (PNF) which is discussed further in the texts within the reading list. Proprioceptive neuromuscular facilitation involves stretching with a partner whereby a partner assists you to hold a stretch then, as you relax, take your body a little further into the stretch. This is a very useful stretching technique but it requires skill and care in execution to avoid over-stretching and injury.

Flexibility exercises for paddlesport should focus on the shoulder, trunk rotation, flexion and extension, lateral flexion and extension, and hip flexion.

KEY POINT SUMMARY

- Warm-ups are now frequently used as part of a training session for paddlers. The most appropriate are those that closely match the demands of the discipline and can be carried out in-boat. Cool-downs are less frequently carried out at the end of a paddling session, but can have a very positive impact upon recovery from training. The end of the session can also usefully include flexibility exercises. **See also Appendix A.**

GROWTH AND DEVELOPMENT

The purpose of this chapter is to discuss paddler development from a long-term context rather than to think of it as session-by-session planning process. With such a starting point it is important to briefly look at the implications of growth and development on our paddling. If we start paddling at a young age or coach younger canoeists, what are the differences between these athletes and adults - are there some fundamental differences that we need to take into account? The short answer to this, not surprisingly, is yes. The individualisation principle of training is a key concept for all paddlers including younger canoeists. Children are not simply mini-adults and we must take notice of differences between them and adults, and between males and females.

Growth refers to increases in size both of the body as a whole and of individual components, such as the heart which increases by between 10-20 times in size between birth and adulthood. Development refers to the gaining of skills and behaviours for life such as social, emotional and sporting learning and progress. Maturation, a term often associated with growth and development, refers to progress towards the mature biological functioning of the body. This section examines these differences before the implications of these differences are brought together in Chapter 10 Coaching Young People.

MEASUREMENT OF AGE IN GROWTH AND DEVELOPMENT

There are many different ways in which age can be assessed. Traditionally for teaching and coaching we group by chronological age (years, months, days), however, the biological age (developmental stage) of the group may show a wide variation. Through the pubertal years adolescents can differ biologically by as much as 8 years, i.e. a 13 year old could developmentally be more like a 9 year old, and his friend more like a 16 year old. Research tells us that while we follow a similar pattern of development from birth to adulthood, the timing and extent of changes is highly individual, in addition, girls tend to mature physically about 2-2½ years before boys. As coaches we must attempt to take these differences into account when working with groups.

Photo 20 They may be the same biological age but are at very different stages of growth and development.

HEIGHT AND WEIGHT

Two of the most widely studied and easily recorded measures of progress to maturity are height and weight. There are a variety of points at which height and weight measures in childhood can be used as predictors of adult values, for instance on average 50% of adult height is reached at the age of two years old. From birth to puberty weight gain is constant and similar for males and females. During puberty there is a significant rise in weight for boys and girls. For males this rise is mainly in muscle mass, for females it results from an increase in bone mass, fat mass and muscle mass.

PHV And PWV

A measure of great interest for physiologists and coaches working with young athletes, found by keeping longitudinal (long-term) records of height and weight, is the individual's peak height and weight velocities (PHV and PWV respectively). That is the periods in growth where height and weight gain are at their maximum rates. For each of us there are two peaks in height and weight velocities, the first between birth and two years of age, the second during puberty. The start of the second increase in height gain starts before puberty with PHV occurring at about 12 years for girls and 14 years old for boys. For girls PWV is reached on average at the same time as PHV (12 years old) while for boys it is reached after PHV (14½ years old). Research indicates that knowledge of the timing of PHV in particular, for an individual is an important indicator for long-term paddlesport development. PHV gives us a reference point for the design of optimal training programmes, as the body grows critical periods of trainability occur that can be maximised. Children usually grow at about 5-6 cm/year before puberty, this increases to about 9-10 cm/year during the growth spurt, which lasts anything from 1.5-5 years. (Menarche occurs in girls approximately 6

to 18 months after PHV. Girls rarely grow more than 5 cm after the menarche has occurred.)

KEY POINT SUMMARY

- Peak height and peak weight velocities are critical stages in development for each paddler. Monitoring height/weight changes on a regular basis for younger paddlers can enable a coach to time when to introduce new aspects of training.

▶ Measuring PHV

The best way to identify the growth spurt is to take accurate height measurements:

- Use a reliable tape measure.
- Take measurements at the same time everyday.
- Measure height without shoes and socks.
- Stand with heels flat and together and legs straight.
- Stand with heels, buttocks and scapulae against a flat wall.
- Keep eyes looking straight ahead.
- The arms should be hanging loosely at the sides with the palms facing the thighs with the shoulders relaxed.
- The paddler is asked to breathe in and stand tall.
- Height is measured, with a level rule, from the top of the head, to the nearest mm.

Photo 21 Measuring PHV **21**

In order to ensure the growth spurt is recorded these measurements should be taken monthly from age 9-10 for girls and 11-12 for boys. This is perhaps earlier than necessary, but avoids the danger of missing the initial growth acceleration.

KEY POINTS

- Before the growth spurt children should focus their sporting activity on learning sport skills in varied environments.
- During the growth spurt accelerated adaptation of the aerobic system occurs, and flexibility is important to help the growing body remain flexible and injury free.
- For girls, the optimal time for strength development comes at the onset of menarche.
- For boys, the optimal time for strength development comes 12-18 months after PHV.

It is also important to realise that during this time hormonal and emotional changes are taking place as well as physical development. These are discussed in an article titled "Characteristics of Physical, Mental/Cognitive and Emotional Development" by Istvan Balyi. This is available on www.bcu.org.uk by following the LTPD link. This discusses the basic characteristics, general consequences and implications for coaching of Physical, Mental/Cognitive and Emotional Development from childhood to early adulthood.

MOTOR DEVELOPMENT

A major part of childhood is spent learning basic movement patterns and skills such as walking, running, jumping, hopping, skipping, throwing, kicking, catching and striking. These movement patterns are the foundations for developed sport-specific skills learned in later life. Research has shown that a rounded and fulfilled motor development in childhood is vital to future sporting performance. Skills that are not developed during this vital stage are not compensated for later in life and will leave deficits in global motor performance that can impact on sports performance. Researchers are indicating that for successful long-term development a paddler and his/her coach should address these core motor movement patterns at the appropriate stages in development. Gender differences in these basic motor abilities are most clearly evident for throwing and striking and may reflect societal differences in programmes for boys and girls. This is certainly a concern for the paddler, as there are much smaller differences between common movement patterns such as running, hopping, skipping and jumping.

THE IMPLICATIONS OF GROWTH AND LTPD

As the body develops from childhood, through adolescence, into adulthood the physiological systems undergo a number of changes.

To summarise:

• The pre-adolescents (approximately under 12s, ± 2 years) should focus on quality skill development and do not need to 'train' the physiological systems other than through general sporting activity. Development of flexibility, agility, balance and co-ordination should be at the heart of all sessions. Children in this age group are good aerobic machines and find the low intensity environment preferable with equipment and activities that are sized appropriately to the strength and size of the child. The LTPD Skill and Speed Development Windows of Opportunity apply during this age range.

• Adolescents (approximately 12-14 year olds) become able to withstand a higher intensity of exercise, their aerobic system is continuing to develop and their ability to tolerate lactic acid accumulation is improving. Adolescents should avoid working in the 20-120 second range as this puts excessive stress on their underdeveloped anaerobic system. They are particularly responsive to aerobic and short speed work during this age. Strength training can be started using light weights and focusing on high quality movements. The LTPD Speed and Aerobic Development Windows of Opportunity apply during this age range.

• As adolescents' physical development slows down they become able to withstand higher levels of intensity especially in the 20-120 second range, and can cope with higher strength demands both in the gym and on the water. The LTPD Strength Development Window of Opportunity applies during this age range.

See Chapter 10 'Coaching Young People' and for more details.

See Chapter 1 'Coaching' for an introduction to LTPD.

AEROBIC DEVELOPMENT

As our heart and lungs - our respiratory and circulatory systems - improve with development so does our aerobic capacity. With smaller hearts and lungs children can transport lower levels of oxygen to their working muscles when paddling, however, as they grow this ability continues to develop. The maximal oxygen uptake of children in absolute terms is lower than adults, but when expressed in terms of body weight is similar to adult levels. The differences in aerobic performance between adults and children are related to economy of effort - adults are more efficient than children. This difference in economy for paddling ability is related to limb length and co-ordination. With longer limbs and more efficient movement patterns adults use less oxygen at all sub-maximal levels when compared with children. The greatest improvements on aerobic development coincide with the PHV for boys and girls. The absolute $\dot{V}0_{2max}$ is higher on average for boys than girls before and after PHV.

ANAEROBIC DEVELOPMENT

Children have a lesser ability to generate energy from glycolysis – they are essentially aerobic machines with lower abilities to work maximally anaerobically. That is not to say that they do not work anaerobically; lots of activities that children take part in - games and pastimes - involve short burst anaerobic activity. Each child's ability to produce energy anaerobically increases linearly with age. Before puberty boys and girls tend to have similar anaerobic abilities. Children have a lesser ability to produce a key enzyme for glycolysis, phosphofructokinase, which is thought to be a significant reason for their lower anaerobic abilities as shown through a lower ability to produce lactate. In addition children have a smaller muscle mass than adults and lower stores of ATP in their muscles and these will contribute to lower anaerobic abilities.

STRENGTH DEVELOPMENT

Strength improves, not surprisingly, with increases in muscle mass, maximising in females by about 20 and for males by 20-30 years of age. The hormonal changes we experience through puberty will bring about significant increases in strength for males but have a lesser effect for females who continue with linear increases in strength that are related to muscle mass increases. Prior to puberty strength differences between boys and girls are small, but males become stronger than females from puberty onwards. The greatest gains in strength occur after the PHV and are linked with increases in muscle mass and hormonal changes.

IN CONCLUSION

Whatever the age you enter paddlesport, or the level at which you wish to take part, adopting a long-term approach to planning your development will help your progress. Using this chapter to unlock the physical aspects of your planning can help you to improve your overall paddling performance.

For discipline specific examples and further exploration of many of the issues in this chapter read Chapters 18 and 20.

Photo 22 Enjoying paddlesport

FURTHER READING

Essentials of Strength Training and Conditioning, Baechle, T.R. and Earle, R.W. (2000). Human Kinetics: Champaign, IL. ISBN 0-7360-0089-5.

Theory and Methodology of Training, Bompa, T.O. (1994). Kendall/Hunt: Dubuque, Iowa. ISBN 0-7872-3371-4.

Explosive Power and Strength, Chu, D.A. (1996). Human Kinetics: Champaign, IL. ISBN 0-87322-643-7.

Training in Sport, Elliott, B., (Ed). (1998). John Wiley & Sons: Chichester. ISBN 0-471-97870-1

Advanced Fitness Assessment and Exercise Prescription, Heyward, V.H. (1998). Human Kinetics: Champaign, IL. ISBN 0-7360-4016-1.

Physiological Aspects of Sport Training and Performance, Hoffman, J. (2002). Human Kinetics: Champaign, IL. ISBN 0-7360-3424-2.

Physiological Assessment of Human Fitness, Maud, P.J. & Foster, C. (1995). Human Kinetics:Champaign, IL. ISBN 0-87322-776-X.

Exercise Physiology: Energy, Nutrition and Human Performance, McArdle, W.D. Katch, F.I. & Katch, V.L. (2001). Lea & Febiger. ISBN 0-7817-2544-5.

Physiology of Sport and Exercise, Wilmore, J.H. & Costill, D.L. (1999). Human Kinetics: Champaign, IL. ISBN 0-7360-4489-2.

The Food Guide Pyramid, Leaflet No. 572. U.S. Department of Agriculture. (1992). U.S. Government Printing Office

NICK DRAPER

Nick is a keen kayaker and canoeist having taken part in trips on rivers and lakes all over Britain. In addition, he has paddled rivers in Europe, New Zealand and South Africa. His favourite aspect of paddling is running new rivers in kayak or canoe. Nick is a Senior Lecturer at the Centre for Adventure Science Research within the School of Physical Education at the University of Chichester where he teaches physiology. Before joining the University of Chichester he was Performance Planner for the Great Britain Judo Team and was Team Manager for Judo at the Sydney 2000 Olympic Games. His research interests include the effects of environmental and exercise demands on performance in paddlesport and mountaineering.