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Competition-Coaching Development (L2C)

Step 1:

Energy Systems

Reference Material
for Dryland Workshop

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1.1 Energy Systems Theory

1.1.1 Introduction to the body's energy systems

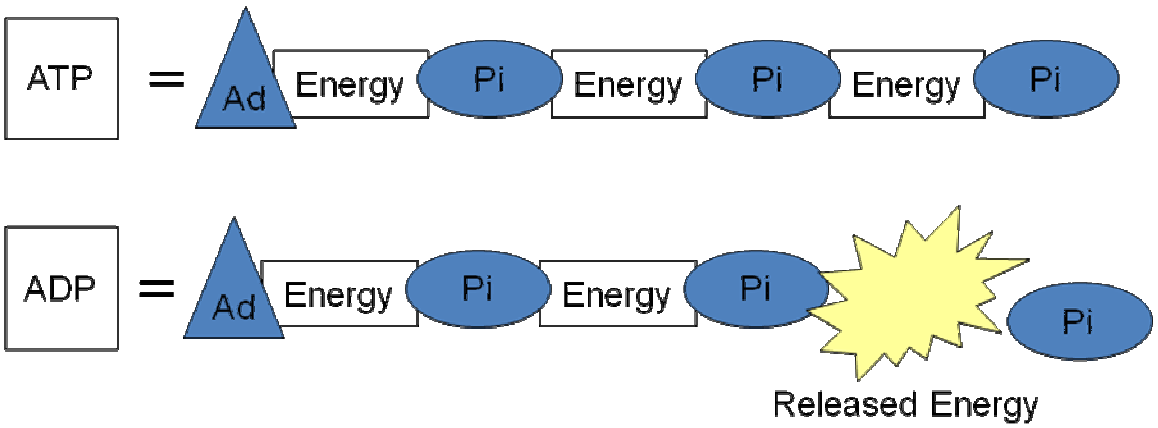
- Different sport situations have different energy demands. For example, in some situations, energy must be supplied very quickly for the muscles to produce high-intensity efforts. In other situations, energy does not have to be provided at such a high rate but must be supplied over a longer period.
- Energy systems are classified as **anaerobic** (oxygen is *not* involved in the reactions that produce energy at the cellular level) or **aerobic** (oxygen *is* involved).
- Three distinct energy systems operate within the body:
  - Anaerobic alactic
  - Anaerobic lactic
  - Aerobic

This energy system…	Has these main features…
Anaerobic Alactic	❑ Oxygen is *not* involved in the reactions that produce energy at the cellular level ❑ Lactic acid is *not* produced in muscle fibres ❑ The body breaks down energy-rich compounds called *phosphagens;* phosphagens include a*denosine triphosphate* (ATP) and c*reatine phosphate* (CP) ❑ The body produces energy very quickly but for only a short time, as muscles contain small amounts of phosphagens
Anaerobic Lactic	❑ Oxygen is *not* involved in the reactions that produce energy at the cellular level ❑ Lactic acid *is* produced in muscle fibres ❑ The body breaks down glucose (sugar) and glycogen (the form in which glucose is stored inside muscle fibres)
Aerobic	❑ Oxygen *is* involved in the reactions that produce energy at the cellular level ❑ The body breaks down muscle glycogen, glucose from the bloodstream, fat stored in muscle fibres and under the skin, and small amounts of amino acids (proteins) ❑ The body produces energy at a slower rate than the anaerobic systems but can do so over a long time

As you know, the body requires energy to perform all of its activities. Free energy is stored in the phosphate bonds of the chemical compound adenosine triphosphate (ATP) until it is needed. Figure 1 illustrates how energy is stored and released using phosphate bonds.

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Figure 1: How energy is stored and released (adapted from Baechle and Earle, 2000)



Several different chemical reactions can be used to generate ATP, some of which occur without the presence of oxygen (anaerobic processes) and some of which require oxygen (aerobic processes). These same processes can also be reversed to release energy from phosphate bonds when the demand exists. For a detailed description of these chemical reactions, refer to the Energy Systems section of the T2T Dryland RM.

The cyclic process of storing and releasing energy is referred to as “energy metabolism”. The metabolic systems of the human body are designed to take fuel (CHO, FAT, PRO) and convert it to ATP so that stored energy is always available when needed. Some ATP is always stored in our muscles and it’s available almost instantly when energy demands increase. Although this ATP can supply energy very quickly (high power), it also runs out very quickly (low capacity). In fact, the human body can only store enough ATP to do about 5 seconds of work. Since the body’s capacity to store ATP is so limited, some fuel sources are stored in various parts of the body, waiting to be mobilized and converted to ATP when energy demands increase.

Sugar (in the form of glycogen) and fat are prime examples of stored fuel sources that can be mobilized into the blood stream and delivered to any location in the body where energy demand is high, such as exercising muscles. When these fuels arrive at the muscle, aerobic and anaerobic processes convert them to ATP, which is then broken down to perform work. Figure 2 summarizes the major energy systems that the body uses to create ATP, the fuel they each require, and the time frames each one operates within.

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Figure 2: Summary of the Major Energy Systems of Human Metabolism

Energy System	Fuel Source(s)	Response Delay*	Time to Peak Power**	Capacity**	Recovery between efforts between sessions
Alactic	Phosphates released from ATP and PC	0 – 1 sec.	0 – 2 sec.	10 – 12 sec.	2' – 3' 24 hrs
Lactic (Fast Glycolysis)	Glucose, then glycogen	~ 2 sec.	20 – 40 sec.	60 - 90 sec.	3' – 7' 48 hrs
Aerobic (Slow Glycolysis)	Glycogen to glucose to Acetyl CoA from pyruvate	>10 sec.$^{+}$	75 – 180 sec.$^{+}$	3 - 6 min.$^{++}$	3' – 6' 48-56 hrs
Aerobic (Fat & Protein)	Trigylcerides & sometimes amino acids (proteins) broken down to Acetyl-CoA	N/A – this is an increasingly important energy source after 75 – 90 minutes of moderate exercise Capacity is several hours when adequate glucose is available to keep aerobic (slow) glycolysis running			56-72 hrs

* Time to ½ peak power
** Approximate values when energy demand is at "full throttle"
$^{+}$ maturity & fitness dependent
$^{++}$ limited by anaerobic processes

1.1.2 Energy Systems Theory & Applications

This section is designed to consolidate the information provided in the Energy Systems sections of the L2T and T2T Dryland Reference Material so that coaches understand the theory in the context of various race efforts in several different sports. The material will also help them to apply their theoretical knowledge by identifying the time frames within which specific energy pathways are most effectively trained.

a) Anaerobic Energy Production

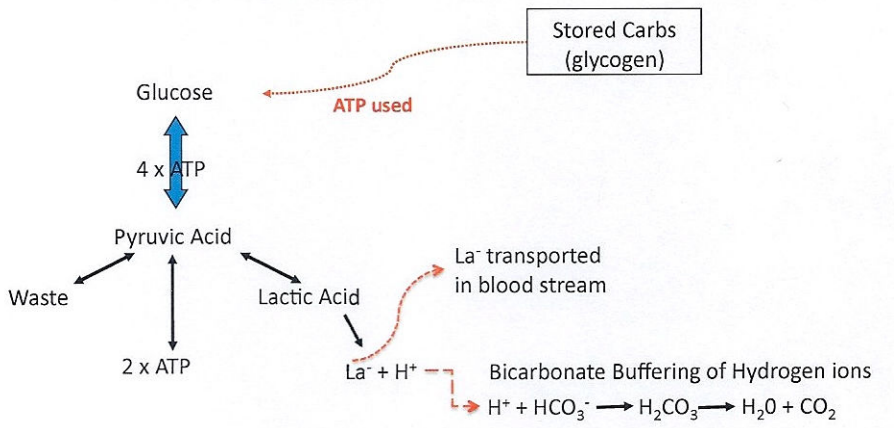
As we've seen in the tables and figures above, the alactic and lactic energy pathways have the ability to produce energy at a very high rate, but their capacity to maintain this level of energy production is quite limited. Figure 2 shows that the alactic system has almost instantaneous power but it's entire reservoir is emptied in 10 to 12 seconds of maximum effort. Similarly, fast glycolysis can reach it's highest rate of energy production (peak power) in about 30 seconds but this rapid rate of energy production is only sustainable during efforts that last less than 60 seconds. This fact suggests that a single exhaustive effort lasting 60 to 90 seconds will empty the reservoir of the fast glycolytic system. This lack of sustainability in fast glycolysis helps to explain Figure 4, which indicates that the aerobic system contributes more than half the total energy for exhaustive efforts lasting longer than 75 seconds.

Perhaps you're wondering what happens to anaerobic energy production if the effort is not an all out sprint to exhaustion. At the L2C stage of development, the capacity of the anaerobic pathways

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is becoming large enough that this is a very relevant question. One factor that helps to moderate the negative effects of lactic energy production is called buffering. This occurs when glycolysis is producing more pyruvic acid than it can convert to pyruvate. At this point, as you remember from the T2T Energy Systems section, lactic acid begins to appear in the muscle, where it dissociates into a lactate molecule (La^-) and a hydrogen molecule (H^+) (see Figure 3). Small amounts of both molecules can be used inside the muscle; the remainder are transported away from the muscle in the blood stream. While the La^- can be used as fuel, the process is slow so only very small amounts are used this way. The H^+ enters into the buffering process, which ultimately creates water (H_2O) and carbon dioxide (CO_2). The CO_2 is exhaled and the water is ultimately lost via perspiration or respiration. During moderate intensity exercise this is an important means of keeping muscle acidity low and extending the limits of predominantly aerobic metabolism.

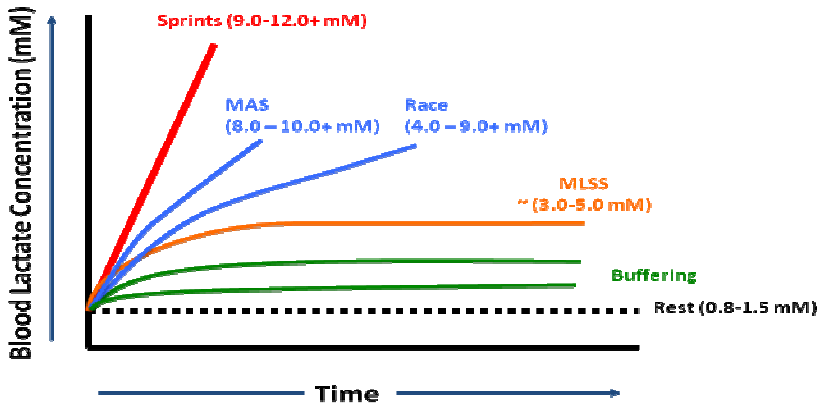
Figure 3: Buffering Hydrogen Ions During Fast Glycolysis



However, when glycolysis is running fast enough that not all H^+ and La^- molecules can be buffered or used in the muscle, these additional hydrogen ions and the associated lactate will need to travel in the blood to other sites in the body where they can be used as fuel or absorbed for disposal. As the energy demand increases, the blood La^- and H^+ concentrations gradually increase as more lactic acid is produced inside the muscle. This process will continue until all the sites in the body have reached their maximum capacity to remove H^+ and La^- from the blood. The exercise intensity at which the maximum rates of all the body's anaerobic waste removal mechanisms are achieved is referred to as Maximum Lactate Steady State (MLSS) because it is the highest rate at which the removal and production of La^- can be equal. At higher intensities, there will be no place for the additional waste products to go and they will begin to accumulate very rapidly. Figure 4 illustrates changes in blood lactate concentration (BLa) that occur during steady paced exercise at different intensities. Each line in Figure 4 represents a single training session, with each session performed at a different steady pace.

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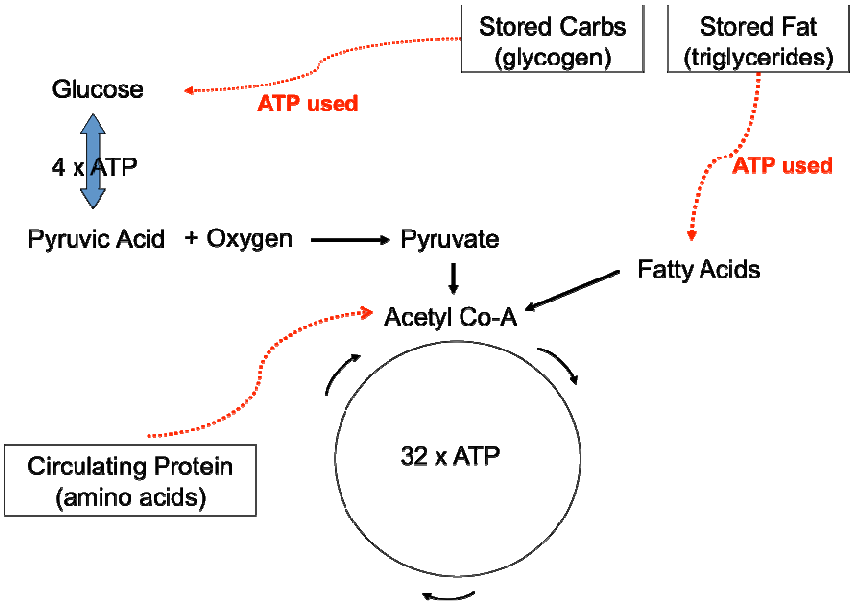
Figure 4: Lactate Accumulation During Steady Paced Exercise



b) Aerobic Energy Production

Recall from the T2T (Dryland) RM, that aerobic energy production begins with slow glycolysis but ends with a cyclic set of reactions called oxidative phosphorylation, which produce large amounts of stored energy in the form of ATP.

Figure 5: How ATP is Generated via Aerobic Pathways



Unlike the anaerobic pathways, aerobic energy production has a very high capacity because few waste products are produced. However, there are so many steps involved in the aerobic processes that their ability to produce energy quickly (eg. their power) is poor.

As a result aerobic pathways are much better suited to providing energy for longer, less intense efforts. Oxidative phosphorylation can continue indefinitely if fuel is continuously supplied. However, the structural limitations of muscles, ligaments and organs will limit exercise after several hours.

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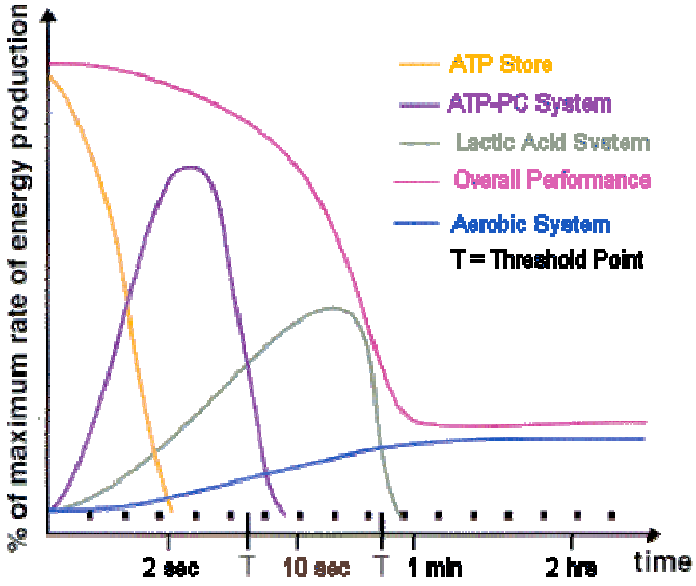
Although the aerobic pathways are not nearly as powerful as the anaerobic pathways, Figure 2 illustrates that the aerobic energy system can reach its maximum power in as few as 75 seconds. However, the intensities that require such a rapid energy supply are also receiving significant resources from the anaerobic pathways. Therefore, maximum aerobic power can only be sustained for 3-6 minutes under these conditions.

Figure 5 illustrates that aerobic pathways provide energy for a wide range of exercise intensities by mobilizing fuel stored throughout the body and by utilizing multiple fuel sources, depending on the rate at which energy is required. It is important to note that triglycerides are a highly efficient fuel source when the exercise intensity is low enough to allow adequate time for stored fat to be converted to triglycerides, transported to the working muscle, and utilized in aerobic processes. Generally, triglycerides can only make a significant contribution to aerobic energy production during exercise at intensities below Aerobic Threshold (AeT).

c) Integration of the Energy Systems

Although the response delay is longer for aerobic processes than for anaerobic processes (see Figure 2), these energy systems all start working as soon as the demand for energy increases. If the work to be done is very intense and explosive (eg. jumping as high as you can or sprinting 40 metres), energy will need to be supplied very quickly by the high power, low capacity alactic and lactic energy systems. These types of activities represent the body's maximum rate of energy production and, therefore, this level of power output cannot be sustained for more than a few seconds. However, the aerobic pathways **are** activated during these activities, despite their inability to make a significant contribution to overall performance. As Figure 6 illustrates, once we approach the capacity of our high power energy systems our overall performance pace drops dramatically; the high capacity of aerobic energy production allows these performances to continue for extended periods of time. Figure 6 also indicates the significant contribution of the aerobic energy systems to overall performance in maximal efforts ranging from 45 seconds (eg. sprinting 200-300 meters) to 2 hours (eg. a 30 km ski race).

Figure 6: Relative Contribution of Major Energy Systems to Maximum Rate of Energy Production in Various Time Frames



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Figure 7 presents a simplified version of the information contained in Figure 6 above. It quantifies the overall contribution of aerobic and anaerobic energy supply to exhaustive efforts of several different lengths.

Figure 7: Relative Contribution of Energy Systems During Maximal Exercise (Gastin, 2001)

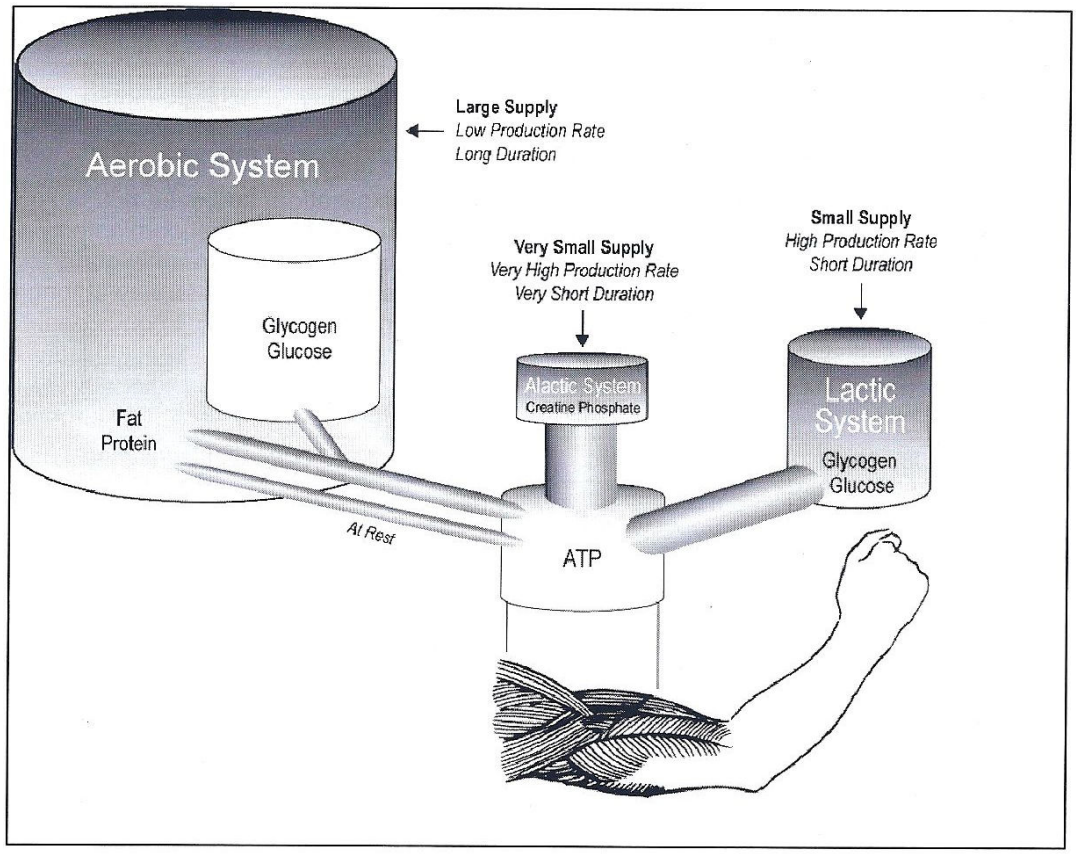
Duration of Exhaustive Exercise (sec)	**% Anaerobic**	**% Aerobic****
10	94	6
15	88	12
20	82	18
30	73	27
45	63	37
60	55	45
75	49	51
90	44	56
120	37	63
180	27	73
240	21	79
** Approximately ± 10% with 95% confidence in the prediction		

Together, these diagrams demonstrate that all energy systems are crucial in determining performance, even for relatively short exhaustive efforts. This is why even sprinters do some aerobic training. The data above has also lead team sport athletes to do more aerobic training, since aerobic pathways contribute at least one quarter of the required energy to power outputs typically required during team games like hockey, basketball and soccer.

Clearly, anaerobic pathways are better for producing energy very quickly, while aerobic energy systems are better suited to longer duration activities where changes in energy demand are less frequent and less drastic. At rest, the aerobic pathways provide almost all the energy required for breathing and maintaining function of the major organs. In fact, triglycerides provide the majority of the Acetyl Co-A required for oxidative phosphorylation during rest; triglycerides provide the most energy per gram of fuel. Since time is not a factor in energy supply at rest, the greatest supply pathway is used, even though it is also the slowest. This example demonstrates a very important point: the body will always choose the most efficient means of producing energy in any given circumstance. One way to think of this is to envision the body's total energy supply as a system of reservoirs and taps, as shown in Figure 8.

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Figure 8: Energy Supply and Demand Schematic (Source: NCCP Comp-Dev Reference Material, Developing Athletic Abilities, p. 11)



The intensity of the effort dictates how wide the ATP tap needs to be opened to supply adequate energy to the muscles. Large pipes can deliver that energy more quickly than skinny ones. In turn, the larger the pipe connected to the tap, the quicker the reservoir of fuel will be drained when the tap is opened up all the way. Certain fuels have a larger storage capacity in the body, thereby generating a larger reservoir to draw on.

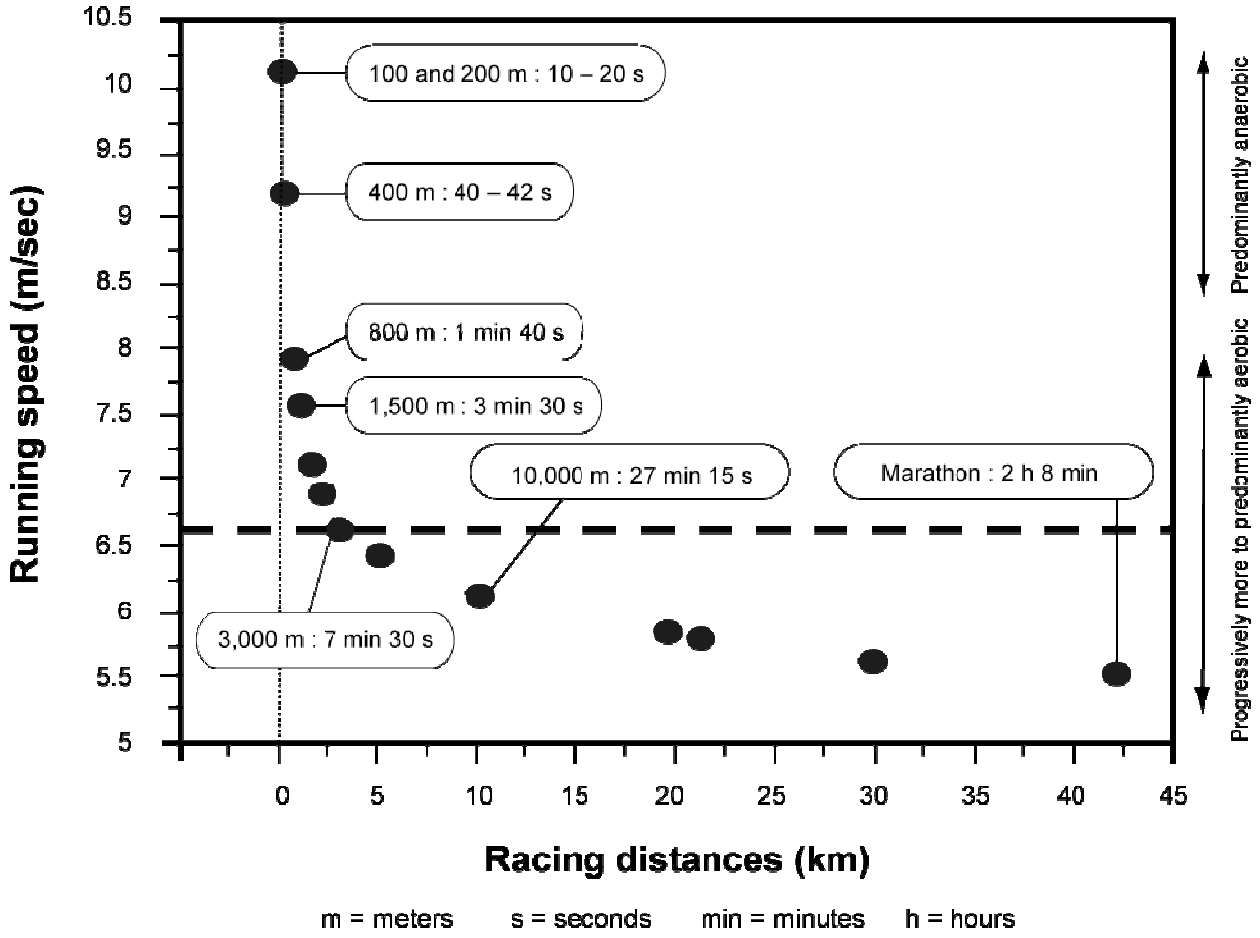
d) Relationship between Intensity and Duration of Effort

The time for which maximum or near-maximum intensity can be sustained reflects the endurance of the primary energy system(s) involved. For example, the powerful anaerobic systems have low capacity and can operate at peak power for only a short time and therefore have very limited endurance; on the other hand, the aerobic system can function at various percentages of its own peak power for fairly long periods of time.

There is an inverse relationship between intensity (power output) and duration of effort: the higher the intensity, the shorter the time for which the effort can be sustained without a decrease in power output. The *power* and *endurance* components of the energy systems can be appreciated by examining the figure below, which shows world-class running performances by male athletes specializing in various distances in athletics.

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Figure 9: *Relationship between Intensity and Duration of Effort*



In figure 9:

- The average running speed sustained over a given distance corresponds to the power output/intensity of the exercise, while the time during which each maximal effort can be sustained indicates the upper limit of the endurance of the energy system(s) that dominates at a specific workload.
- Very high power outputs can be generated during short events, but intensity drops quickly as exercise duration increases.
- The horizontal dotted line corresponds to the average running velocity in the 3,000 m for world-class male runners. This intensity is a good indicator of the peak power of the aerobic system, and it helps to illustrate:
  - The considerable gap between the peak power output of the anaerobic and aerobic systems.
  - The very limited endurance of the high-power anaerobic systems.
  - The ability of the aerobic system to operate for extended periods at intensities that correspond to fairly high percentages of its own peak power. For instance, very well trained endurance athletes can exercise at an intensity corresponding to 100% of the peak power of their aerobic system for approximately 8 minutes and can sustain intensities of 75 to 80% of their MAP for about 90 to 120 minutes.

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e) Racing Examples of Energy Systems Integration

Now that you have a good understanding of the interplay between the different energy systems, let's put all of the above in the context of some familiar examples from different sports. Figure 10 categorizes several different events from running, swimming, cycling and cross country skiing into groups based on their primary energy source. Note that the common denominator amongst the sports is the length of effort. This is due to the fact the capacity of the anaerobic systems limit their contribution to longer event, while the relatively low power of the aerobic pathways limit their ability to provide energy during events lasting less than a minute. This will become a very important point in the next sections, when the focus shifts to effective training methods for the anaerobic and aerobic pathways.

Figure 10: Sport Specific Examples of Predominate Sources and Pathways for Energy Production *(modified from Bompa, 1999, pp. 21 & 23)*

Energy Pathways	Anaerobic Pathways		Aerobic Pathways		
	Alactic	Lactic			
Primary Energy Source	ATP produced without O_2 present		ATP produced in the presence of O_2		
Fuel	ATP & PC stored in muscle	Glycogen & Glucose stored in muscle	Glycogen stored outside muscle & transported there as needed		
			Fats		Protein
Duration	0 s 10 s	40 s 70 s	2' 6'	25' 60'	120' 180'
Sports Events	60 – 100m Run Jumps Throws	200 - 800 m Run 50 – 100m Swim 500 – 1000m Speedskate Cycle Kilo	1500 – 5000m Run 200 - 400m Swim 750 – 1400m XC Ski (Sprinting) Cycle Pursuit	10 km Run 1500m Swim 10 – 15 km XC Ski Cycle 40 km ITT	42 km Run 30 – 50 km XC Ski 60–120 km Cycle RR

In Summary

- All activities derive energy from each of the supply pathways
- Recent research shows that the aerobic system contributes more quickly to all out efforts than has traditionally been thought
- Understanding the time frames associated with the capacity and peak power of each energy system is critical in designing appropriate training sessions

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1.1.3 Training Intensities

This section will introduce and explain the 9 training intensities that make up the L2C Training Zones. The information in the overview is primarily intended to provide theoretical support for the training targets and physiological assessment techniques described in the following sections. As a whole this section should make the physical changes associated with maturation clear and explain the evolution of the training targets (eg. HR, BLA, RPA, etc.) for L2V athletes. Following this section, coaches should be able to create appropriate training session for each intensity, including the work interval, rest interval, total wok, and intensity targets (speed, effort, HR, Bla) and required recovery between training sessions.

During the L2C stage of development, both male and female athletes complete their growth spurt and enter the slow deceleration phase of the growth curve (Phase 5). Although they are still growing, athletes are better able to adapt to new stimuli because physical changes occur more slowly. It is important to remember that, although the outwardly visible physical changes are slowing, there are many physiological changes still occurring inside these athletes' bodies, which also require energy. Therefore, gradual progression of training load and careful monitoring of the athlete's recovery are the most important aspects of the program for the coach to consider. By gradually building their training capacity at a variety of intensities, athletes in this stage of development will develop the ability to fully utilize the potential power and capacity resulting from the growth of their heart, lungs, muscles and bones.

As well, physiological and performance differences between males and females will continue to grow throughout this stage. It is essential that coaches understand and respect these differences so that training program design reflects the diverse needs of athletes at this stage of development.

This is also the stage of development where racing can become a focus for the program. As they pass through the L2C stage of development, young athletes who are motivated to compete should come to think of themselves as "ski racers" and begin to understand the lifestyle requirements of competitive endurance sports.

Because they are training for longer durations at all intensities and because their energy systems are continuing to mature, L2C athletes' training needs become even more specific than during the T2T stage. This in turn must be reflected in the training intensities used for L2C. Figure 10 illustrates the evolution of training intensities from the L2T through the T2W stages of development. It demonstrates that the specificity of the training targets increases as athletes mature physically, improve technically and gain training experience.

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Figure 11: Increased Specificity of Training Intensities from L2T to T2W

L2T	T2T	L2C	T2W	Training Targets
Endurance	Endurance	Endurance	Easy	Easy
			Sub	Sub AeT
		AeT	AeT	AeT
	AnT	Trans	Trans	Sub AnT
Intensity		AnT	AnT	AnT (MLSS A)
	Race	Race		MLSS B
			CS	Critical Speed (CS)
		MAS	MAS	MAS (VO2max)
Sprinting	LAC	LAC	LAC	Lac 1 (1.5' – 2')
				Lac 2 (50" – 70")
				Lac 3 (30" – 45")
	Sprint	Sprint	Sprint	Race Start (15" – 20" long rest)
		Speed	Speed	Pure Speed (2"- 8")

a) Physiological Development at the L2C stage

In the table above, you will note the introduction of four new training zones for L2C, all of which reflect the increased maturity of the energy systems combined with the increased technical capabilities of L2C skiers. You have probably also noticed that the AnT intensity has narrowed somewhat, reflecting the continued maturation of the anaerobic energy systems. In fact, all of the training intensity changes are due primarily to the maturation of the aerobic and anaerobic processes. As buffering capacity begins to develop, a "middle ground" between predominantly aerobic and predominantly anaerobic metabolism begins to develop. The L2C stage of development is the first where a significant range of intensities involve a sustainable mix of aerobic and anaerobic processes. A significant focus of L2C training programs is to increase the sustainability of aerobic processes and anaerobic processes.

As mentioned earlier, athletes' power and capacity improve greatly during their growth spurt. At the L2C stage of development athletes have the structural integrity and metabolic maturity to begin

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increasing their training load. However, there are still several physical changes occurring that, to some extent, dictate the types of training that are most appropriate for this group.

Females, in particular, may have trouble adapting to the changes they experience at this stage of development. Most will be more than 2 years past PHV and, therefore, experiencing fewer performance improvements as a result of growth-related strength and power increases. In addition, they will experience a plateau in hemoglobin and red blood cell development that will make improvements in VO_2max more difficult to achieve. Hormonal changes contribute to body composition changes that generally result in fat mass increasing at greater rate than muscle mass. While all of these changes are not ideal in terms of performance, they are perfectly normal and rather unavoidable. However, the efficiency of the aerobic systems (particularly at Endurance intensities) and the sustainability of the anaerobic intensities can be improved significantly by gradually increasing the duration of training across all aerobic intensities (eg. Endurance to MAS).

Late maturing females may experience more success in competition due to the delay in post-PHV changes described above. Therefore, it is important for coaches to be aware of which females are early or average maturing athletes so that they can be appropriately encouraged and motivated during this sometimes difficult period. Often, the coach will need to help the athlete find motivation to continue training from sources other than competitive success (eg. technical or strength development, social camaraderie, enjoyment of the outdoors).

Males at the L2C stage of development will find continued performance improvement somewhat easier than females. Although their growth is slowing, resulting in smaller muscle mass increases, many of the changes that they experience are beneficial for performance. In males, hemoglobin and red blood cell concentrations tend to increase into their late teens and muscle mass tends to increase well past the end of the L2C stage of development. Males also experience increased rates of fat storage but these are more gradual and less pronounced than in females. Therefore, while VO2max expressed relative to body weight may decrease or plateau during this stage of development, absolute oxygen consumption will continue to increase due to maturation in males at the L2C stage of development.

b) Training Zones L2C stage

The descriptions of each training zone will summarize the energy systems theory. The sections on training priorities and training components will provide practical, developmentally appropriate applications of the energy systems and developmental knowledge discussed to this point.

I. Endurance Training

This intensity was introduced in the L2T stage of development and its purpose remains consistent throughout the developmental years, although the relative intensity of the upper boundary does decrease with maturity. Training at this intensity helps to develop the central cardiovascular mechanisms that deliver oxygen to the muscles. As athletes mature, “long” workouts are lengthened and increasing the sustainability of this intensity is a major focus at this stage of development. For the most experienced L2C athletes, their longest workouts could be up to 3.5 hrs. This kind of extended training also helps the muscles to maintain their efficiency at using the oxygen that is delivered. Athletes in the L2C stage of development typically perform Endurance Training at less than 65% of HR_{max}. Blood lactate values do not exceed 1.0 mM.

II. Aerobic Threshold (AeT)

This intensity is introduced in L2C and represents a specific set of metabolic conditions where slow glycolysis is operating at or very close to the maximum rate that pyruvic acid can be transformed to pyruvate. Exercise above this intensity will result in the production of some lactic acid via fast

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glycolysis. Therefore, this threshold is often referred to as the threshold of predominantly aerobic metabolism. It is the highest intensity at which resting BLa levels can be maintained and represents the most metabolically efficient conditions within the muscle. Blood lactate levels do not increase significantly (eg. not more than 0.5 mM) from resting values during AeT training.

III. Transition Training

Also referred to as the "aerobic-anaerobic transition", the boundaries of this intensity zone are defined by the rate at which lactate accumulates in the blood stream. The Transition Training zone begins when the muscle has reached maximum capacity to buffer the hydrogen ions from lactic acid. At this point, blood lactate concentration rises above resting levels (usually around 1.5 mM), as unbuffered hydrogen ions and their associated lactate molecules are transported away from the muscle for use as fuel or removal. Therefore, during Transition Training blood lactate concentration measures will always be above resting levels and increased training speed will result in linearly proportionate increases in blood lactate (BLa) concentration. The Transition Training zone ends when all of the lactate and hydrogen sinks in the body are almost full. At this point the lactate and hydrogen ions begin to accumulate in the blood with no place else to go. This results in a disproportionate increase in BLa concentration (usually around 3.0 mM in L2C athletes), which signifies that a new intensity zone has been entered.

IV. Anaerobic Threshold Intensity Training (AnT)

Sometimes referred to as Maximum Lactate Steady State (MLSS), training at this intensity improves the muscles' ability to function efficiently in an acidic environment, and also improves their ability to clear lactate and use it as an energy source. As the athlete completes the major growth spurt (post-PHV), the lactic system begins to develop more completely and the capacity to clear lactate improves. For girls, this may happen mid-way through the T2T stage. For boys, it is more likely to occur at the end of T2T or even in the L2C stage of development. Targeted anaerobic threshold (AnT) training becomes possible once the rapid deceleration phase of growth has been established for at least 6 months. As athletes in this phase of growth mature, their anaerobic capacity (the amount of anaerobic work they can do in a single session) naturally increases. Although there are individual differences, anaerobic threshold generally corresponds to about 85% of HRmax in L2C athletes. Most L2C athletes will have BLa concentrations between and 3.0 and 4.0 mM during AnT training. However, late maturers should use the T2T lactate targets until they are at least 6 months past their peak growth rates.

V. Race Intensity

This range of intensities develops specific endurance by improving the central factors that contribute to oxygen delivery to the muscles, and by improving the efficiency of the exercising muscle in acidic metabolic conditions. Athletes in the L2C stage of development should work toward sustaining a very high percentage of their maximum heart rate (90-95%) for several minutes (6' – 10'). In this way, Race intensity efforts should become more sustainable and repeatable throughout the L2C stage. Therefore, as technique and power production improve with physical maturity, race intensity efforts should not elicit HR_{max} for prolonged periods of time. BLa concentration will increase continually throughout race intensity efforts. However, depending on the length of the work interval, blood lactate values could be measured as low as 4.5 – 5 mM (during 2-4 min intervals) and they should not exceed 8 - 9 mM.

VI. Maximum Aerobic Speed (MAS) Training

Maximum Aerobic Speed (MAS) is introduced as a distinct training zone in L2C because the aerobic system has reached a level of maturity that allows the maximum power of the system to be systematically trained and, once the rapid deceleration phase has been established, growth has slowed enough that the body can adapt to heavy training loads more quickly. VO_2max improves

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the most by training at this intensity. This training intensity is not systematically introduced into the training environment until PHV has been achieved. For L2C athletes, it should share equal priority with developing anaerobic threshold capacity, but overemphasis and/or inadequate recovery will be detrimental to training adaptation and the maintenance of good technique/power application.

VII. Lactic Sprinting

Lactic sprinting is often referred to as “speed endurance” or “lactate tolerance” training because it improves the muscles’ ability to tolerate extremely acidic conditions. Maximal efforts from 15 to 90 seconds are included in this training intensity, although athletes in the L2C stage will rarely train speed endurance for intervals longer than 60 seconds. Ample recovery is required between repetitions (four to six minutes) and the maintenance of good technique should be the focus of efforts at this intensity. Sprinting efforts are too short and intense for heart rate to be reflective of the energy required. During workouts with repeated sprinting efforts, athletes in the L2C stage of development will usually achieve blood lactate levels in the 8-12 mM range. During repeated sprint efforts, blood lactate does not typically return to resting levels during the recovery interval. Therefore, as the workout progresses, blood lactate concentration at the beginning and end of each interval is usually higher than the previous intervals.

VIII. Alactic Sprinting

As described in the energy systems review, sprint efforts lasting less than 12 seconds do not produce significant amounts of lactic acid. Provided that adequate recovery is given between repetitions (e.g. five to seven minutes of very easy effort or sedentary rest) training sets containing 8-12 second sprints are useful for developing pure speed and power. The focus should be on executing quality technique at maximal power outputs.

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1.2 Testing Energy Systems

1.2.1 Why Testing?

Testing athletic abilities makes it possible to:

- Determine the level of development of athletic abilities or performance factors at a given point in time
- Decide whether this level of development is adequate or should be further developed for optimal performance
- Identify factors that may explain the athlete's level of performance
- Decide what athletic abilities to emphasize in training
- Select the training methods most likely to help athletes' progress
- Set training intensities as precisely and individually as possible for workouts
- Monitor the effectiveness of a sport program, given the direction, magnitude, and rate of change in the development of athletic abilities or performance factors over time

Regular testing and evaluation may also help in the following areas:

- Motivating athletes and giving them an additional incentive to train
- Providing objective points of reference from which to establish training goals
- Helping athletes understand what their training objectives are and why they are doing certain training activities
- Obtaining more data on athletes' physical characteristics and contributing to the development of sport-specific norms
- Guiding athletes into the positions and sports they are best suited for
- Understanding what athletes can achieve in competition, establishing optimum pacing in some types of races, and choosing tactics and strategies to use in competition
- Detecting issues such as incomplete recovery, excessive fatigue, and overtraining

1.2.2 Limitations of Testing

Despite its value, athlete testing should never be viewed as a magical tool for making decisions or predicting performance. Physical testing must *always* be considered in the light of other information the coach has, such as the athlete's skill level and his or her training or competitive experience:

> *It is unwise to attempt to predict performance from any single physiological test or battery of tests, especially in sports where technical, tactical, and psychological components may relegate the physical aspects to a lesser role. Similarly, in the selection of athletes for competition or for teams, physical tests should only augment information which is available on actual performances or field observation.*[1]

[1] Duncan MacDougall, Howard Wenger, Howard Green: Physiological Testing of the High-Performance Athlete (2nd edition), Human Kinetics, Champaign, Illinois, 1991, page 3.

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1.2.3 Types of Tests

The tests used to assess and monitor athletes' physical status fall into three broad categories:

- Lab tests
- Lab-like tests
- Field tests

The table on the next page summarizes key points about these three types of tests.

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Key Points about Lab, Lab-like, and Field Tests

This Type of Test…	Has These Advantages…	And These Disadvantages…
Lab Tests ❑ Done in a controlled lab environment ❑ Often measure variables that are difficult to evaluate in a real sport situation ❑ Example: maximum oxygen uptake determined from the collection of expired gas samples	❑ Measurements are precise, reliable, and objective. ❑ Norms for athletes are often available. ❑ Results are valid for the physical factor measured. ❑ Measurements from lab tests indicate the athlete's training status and show the effects of training programs over time.	❑ May lack specificity, since they are performed away from the playing field. For example, running on a treadmill is not exactly the same as running over ground. And the movement patterns in many sports, such as team sports or sports that take place in a particular environment, may be impossible to mimic in a lab. ❑ Tests require expensive equipment and trained personnel. ❑ There is usually a lab fee for services performed. ❑ It is often necessary to travel to the testing site. ❑ Some tests involve invasive techniques (e.g., blood sampling), which can make athletes apprehensive. Apprehension, in turn, can influence test results. ❑ With certain age groups, it may also be necessary to get parental permission for lab testing.
Lab-like Tests ❑ Measure performance variables in standardized, controlled conditions ❑ Results can be used to *predict* the value of variables that are highly correlated with performance but are usually determined through lab tests ❑ Example: Léger tests	❑ They are inexpensive and relatively easy to perform. ❑ Some tests are very specific to the sport situation. ❑ Some tests provide information that can be used to prescribe training intensities. ❑ Test results can be used to predict or estimate the value of key physical variables.	❑ Test results are not *exact measures* of physical factors. ❑ Few sport-specific tests exist, and normative data are limited.
Field Tests ❑ Conducted where the athlete trains (court, rink, field, track, etc.) ❑ Measure actual sport performance ❑ Example: time to cover 30 metres when sprinting from a standing start	❑ They are simple and easy to administer to large groups. ❑ They are inexpensive. ❑ They measure actual sport performance. ❑ Tests are sport specific. ❑ You can use one of the many tests available or design one from scratch. ❑ Athletes can be tested on an as-needed basis. ❑ You can develop team or age-group norms from them.	❑ Athletes' motivation affects results, tending to make the test less reliable. ❑ Tests do not measure actual physical capacities. Rather, field tests measure performance, which may depend on physical capacity. ❑ Tests may be less precise than lab tests. ❑ Norms seldom exist, because individual coaches often develop field tests for specific situations. And norms that do exist are often specific to a small group of athletes.

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1.2.4 Choosing Effective Tests

Keep the following guidelines in mind when choosing tests for assessing energy systems:

- **Each component tested must be *relevant* to the athlete's sport.** There is little point testing energy systems or variables that are not essential to successful performance.
- **The test should be as *sport specific* as possible.** Tests should mimic performance requirements and require athletes to use the muscle groups and movement patterns of their sport. For example, rowers should be rowing when they're tested, and runners should be running. In sports where it's harder to use existing measurement devices to test the muscle groups and movement patterns used in the sport — in figure skating and gymnastics, for example — use the most specific test available or develop tests that better approximate the sport's performance requirements.
- **Test procedures must be *standardized* so that tests are *repeatable* and their results *reliable*.** Overall, standardization helps to minimize the effects of factors that can influence test results: warm-up procedures, testing environment, weather conditions, testers' skill, etc.
- **Tests must be *valid:* they must really measure *what they are intended to measure*.** For example, the MAP tests described in this document are valid for determining the peak power of the aerobic system, but they are not necessarily good indicators of aerobic endurance.
- **There should be appropriate data to compare results with.** It should be possible to compare results with *normative data*: data from other, larger groups. Normative data must be *appropriate* — i.e., they must apply to athletes of the same sex, of similar age, and of similar developmental level. Comparing test results with inappropriate data can cause results to be misinterpreted. For example, comparing results on the Léger MAP test with norms for the general public might lead coaches to overestimate athletes' fitness. National sport organizations, the literature, and other coaches are all potential sources of normative data.
- **Testing must be conducted at regular intervals, and test results must be properly interpreted and used.** Test results can be used to *monitor the progress of specific athletic abilities*, assess how effective the training program is, and make modifications as needed. The results of certain tests — strength tests, maximal aerobic speed tests, etc. — can also be used to set *training intensities* in workouts.

The coach is ultimately responsible for determining what testing should occur, and when and how it should take place in the training program. It is often a good idea to consult a sport scientist or exercise physiologist for help in implementing or interpreting a physical testing program.

1.2.5 Developing Norms

If there are no norms for the energy systems you want to test, you should develop your own. You can do this by collecting data from your tests and grouping it by athletes' age, sex, competitive level, position of play (where applicable), time of the year, etc. Calculate some basic statistics from each sample, including mean, standard deviation, minimum value, and maximum value.[1]

[1] You can use spreadsheet software such as Microsoft Excel to perform these calculations.

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Compare results within your team or club, and use each athlete as his or her own control when you retest.

Keep records from year to year, and develop your own norms for the competitive level of the sport you are coaching. Where possible, establish linkages between test results and actual performances or specific behaviours you may observe in competition (for instance, the athlete's ability to sustain a fast pace throughout a game).

1.2.6 Testing Tips

Here are some tips to consider when testing athletes.

a) <u>Safety and Consent</u>

- ❑ Always obtain an informed consent form from the athlete or the parents/guardians of young athletes. The form should indicate:
  - What the purpose of the test is
  - How test results will be used
  - What the test involves, what the nature of the test is, and what type of effort is required
- ❑ Before the test, give athletes and their parents/guardians an opportunity to ask any question they have about the test, and answer their questions to the best of your knowledge. It often helps to set up a Q and A session and distribute an information sheet about the test before the session.
- ❑ Ask athletes and their parents/guardians if they want test results to be confidential (i.e., accessible only to them and the coach) or if they'll let others see the results. If they're willing to let others see the results, obtain their signed consent, and list those allowed to see the test results. In general, coaches should keep test results confidential.

b) <u>Safety</u>

- ❑ Athletes who will be doing maximal tests must be in good physical health.
- ❑ If the test involves ergometers,
  - Inspect the equipment before the test
  - Make sure the intensity-setting mechanism is properly calibrated
  - Adjust the equipment for the athlete's size
- ❑ Athletes must wear appropriate clothing, footwear, and protective equipment where appropriate.
- ❑ Athletes should warm up appropriately before the test.
- ❑ **Before** the test, athletes should not:
  - Eat in the 2 hours leading up to the test
  - Drink in the 15 minutes leading up to the test
  - Perform heavy exercise in the 24 hours leading up to the test

c) <u>Test Procedure</u>

- ❑ Ask everyone not directly involved in the test to leave, unless the athlete agrees they can stay.
- ❑ Ask athletes if they want to be encouraged during the test.
- ❑ Get an OK from the athlete that he or she is ready to start the test, and provide a countdown to the start if appropriate.

d) <u>During the Test</u>

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- Encourage athletes to do the best they can, remind them about the nature of the effort to be produced and about previous test results if appropriate
- Ensure that intensity/pace is correct in each stage of the test
- Watch athletes throughout the test, especially if you suspect their fitness level is not optimal, and be ready to intervene if abnormal signs of fatigue or discomfort appear
- Ask athletes with any of the following symptoms to stop as soon as the symptoms appear:
  - Dizziness
  - Chest pain
  - Nausea
  - Mental confusion
  - Any other painful or abnormal symptom

e) <u>After the Test</u>

- Ask athletes to:
  - Remain upright, i.e., not sit or lie down, for about 15 minutes
  - Then do some light dynamic exercise (walking, jogging, cycling, rowing, etc.) for 3 to 5 minutes
  - Finish with a cool-down that is appropriate for the test and intensity of effort they just completed

f) <u>Testing Priorities</u>

- Coaches do not need to test for *all* energy systems, even though most are involved in athletes' performance. Rather, coaches need to set priorities for their testing program by taking into account the resources, time, and experience available, as well as practice and competition schedules.

1.2.7 Physiological Assessment of Training Targets for Cross Country Skiing (L2C stage)

The information in this section is designed to expand on the concepts introduced in the Comp-Intro advanced (T2T) Dryland Reference Materials. It will describe the different types of physiological assessment and discuss appropriate collection, interpretation and application of each type.

a) <u>Constructing Speed/Time Relationships Using Time Trials</u>

<u>Rationale:</u> In general, the purposes of cardiovascular performance testing are to track changes in fitness and to identify specific physiological markers that can be used to design or control training sessions. Time trials are a popular method of tracking fitness changes in almost all endurance sports. Beyond targeting "race pace", the duration of the time trial effort can be strategically selected to facilitate the measurement of valuable physiological markers such as MAS or Speed at AnT. Once estimated, these variables can be used to increase the specificity of intensity training and to assist in prescribing training zones. This is true for many modes of exercise, including running, cycling, swimming and skiing, but the prescription is usually specific to the exercise mode. For example a 5 minute swimming time trial would generate physiological information (i.e. maximum HR) that would not

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necessarily be the same in a running time trial. Therefore, whenever possible, it is best to estimate physiological markers using a sport-specific exercise mode.

Some important factors to consider when conducting time trials are listed below:

- Athletes must be skilled at pacing themselves evenly throughout the effort so that the appropriate energy systems make a balanced contribution to the overall performance
- Environmental conditions (i.e. wind speed and direction, terrain) will influence the results; try to minimize this by using a flat course with the least possible wind influence (loops are best) and record the conditions on test days so that you have a reference point for comparison when you repeat the test(s) in future
- Try to maximize the athletes' performance by ensuring that they are properly rested before the tests, that there is sufficient rest in between tests (at least 2 hrs if more than one time trial is performed on the same day) and that each athlete does his/her best, whatever his/her strength or weakness are.

i. **MAS Time Trial:** One way of identifying physiological markers important to all cross country skiers is to estimate the speed, heart rate and, for more mature athletes, the blood lactate concentration that an athlete can achieve at MAS, the speed associated with VO2max. While not all world class cross country skiers have exceptionally high VO2max values, they all achieve their VO2max at a relatively high speed and they all have an exceptional ability to maintain that speed for several minutes. The speed at VO2max is sometimes called Maximum Aerobic Speed (MAS) and is defined as the steady paced (running or ski) speed that requires VO2max in order to be sustained. Because it is a marker of maximum function of the aerobic energy systems, it is an appropriate benchmark for athletes at all stages of development.

With high performance athletes, MAS is measured using a treadmill (running or ski) and expired gas analysis. However, MAS can also be measured by more practical methods such as a time trial lasting 4 to 7 minutes (running between 1500 and 2000m will be appropriate for most athletes in the L2C stages of development). Within this time frame, MAS is the average speed of the time trial (distance travelled divided by time to complete). By wearing a heart rate monitor, all athletes can measure a maximum HR value during an MAS length time trial. More mature athletes (those who have already experienced Peak Height Velocity) with the available technology could also have blood lactate concentration measured at the end of the time trial to provide a reference point for monitoring future high intensity interval training sessions.
Once MAS has been established, other training intensities usually fall within the ranges indicated in Figure 11, but other time trials can be performed to establish more specific markers. The following tests targeting aerobic or anaerobic energy sources can be done either roller skiing, ski-striding or running.

ii. **Anaerobic threshold (AnT):** Maximum sustainable intensity for 20 to 40 minutes, flat or rolling terrain but ideally continuous intensity. Doing this type of testing in a real competitive situation (as a running or roller-ski race) is ideal to provide a fun/motivating environment that provides other racing related learning experiences.

iii. **Anaerobic Alactic Capacity:** ≤15 sec of all out sprinting (eg. 60-100m running or skiing). Distance covered divided by time will yield an athlete's top speed, especially if a rolling start is used.

iv. **Anaerobic Lactic Capacity:** maximal sustainable intensity for 30 to 60 sec. (only relevant and appropriate for L2C athletes who have completed the rapid deceleration phase of growth) Variations can include repeated sprints with 5 minutes recovery between intervals; see how

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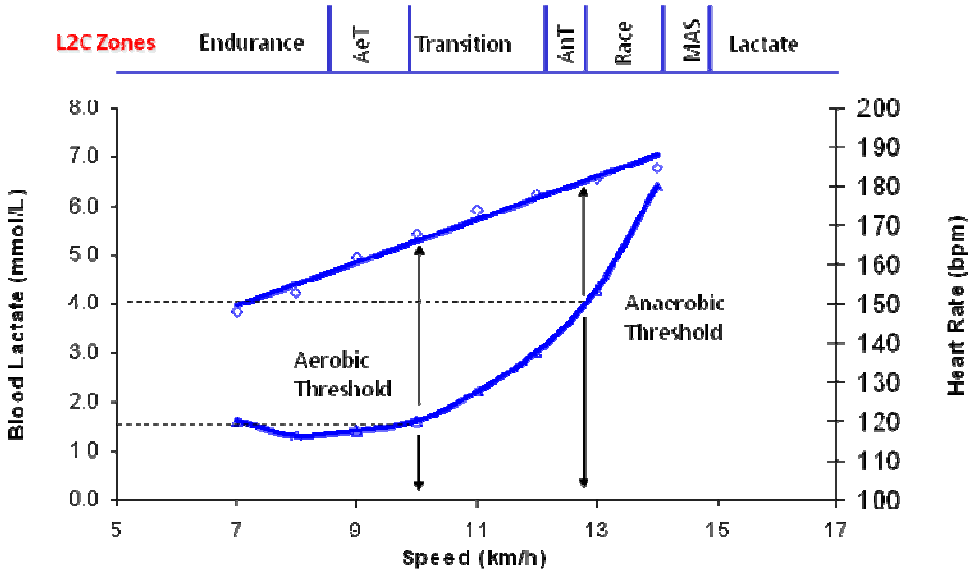
many can be performed before the speed drops. BLa samples can be taken about 3 minutes after a sprint to measure peak BLa.

Note that these tests can also target specific muscle groups or techniques (for example: legs only, double-poling), which would provide more specific information regarding an athlete's strengths and weaknesses.

b) Incremental Exercise Profiles

Physiological profiling tells you about each athlete's physiological strengths & weaknesses relative to their peers or the known requirements of their sport. Ideally, incremental exercise data is gathered one to two times per year for L2C athletes. This testing offers the coach an opportunity to establish accurate and individualized HR and BLa targets for the L2C training zones. Although a full cardiovascular profile (including an incremental or time trial MAS test) may be conducted at the beginning or end of the season, most coaches are already aware of their athletes' biggest weaknesses. Measurement simply provides a means of quantifying the "gap" between the athlete's current and desired capabilities so that training priorities can be established objectively. Assessments related to an athlete's biggest weaknesses can be repeated periodically as a form of monitoring these training targets.

Figure 12: Relating Incremental Exercise to L2C Training Zones



i. Incremental Lactate Test (Treadmill Protocol)

This test is sub maximal in nature. You will run on a treadmill with the initial speed varying depending on the warm-up heart rate and running performance. The workload will be increased by 0.5mph (or 1 km/h) every 3 minutes while maintaining 1% elevation. After each 3 minute workload a fingertip blood sample will be taken for lactate analysis. The test will be terminated when blood lactate and/or VO_2 indicate that you have exceeded your anaerobic threshold. As the training season progresses, the test will continue until you have completed 2, 3 minute stages above your anaerobic threshold. Your lactate may be greater than 6 mmol/l during the final 3 minute stage. Heart rate will be continuously monitored by a telemetric device.

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Data processing: The relationship between BLa (y axis) and running speed (x axis) is plotted in a y vs x scatter plot as shown in Figure 13. Average HR during the final 30" of each running stage are recorded and plotted on the same y vs x scatter plot.
AeT is selected as the final stage at which a resting BLa was recorded. Once BLa begins to increase above resting levels, the following 2 or three stages should demonstrate a linear increase in BLa, though Figure 12 illustrates that the relationship is not always obviously linear.

AnT is selected as the final stage that conforms to this linear increase. The HR's associated with the AeT and AnT running speeds are selected as the target HR's for constructing training zones.

- ✓ AeT is typically a 10 beat range with the highest HR corresponding to the HR associated with AeT on the BLa curve.
- ✓ AnT is typically a 5 to 10 beat range with the middle HR corresponding to the HR associated with AnT on the BLa curve. Construction of this range depends heavily on the BLa and HR responses above AnT.
- ✓ MAS is typically a 10 beat range with HR_{max} being the highest HR (note that HR_{max} is not always achieved during the MAS test).

Interpretation: Changes in fitness can be observed based on changes in threshold running speeds and associated BLa targets. The rate of accumulation of BLa above AnT also indicates "high end" endurance (i.e. decreased slope of line indicates improved fitness at these intensities). Anaerobic capacity is indirectly indicated by the changes in BLa at thresholds.

ii. Maximal Aerobic Speed (Treadmill Protocol)

This is a maximal incremental running test on a treadmill. Run on a treadmill with the initial speed varying but aiming for a HR ~55 – 60% HR_{max}. Speed will increase 0.5 mph (or 1 km/h) every minute until fatigue (grade constant at 1% throughout). A heart rate monitor will record maximum HR. A finger tip blood sample may be collected immediately post-exercise and 3-5 minutes into recovery to measure BLa.

Protocol Notes: This test is often administered immediately following the Incremental protocol described above. Athletes are given a 10 minute break between tests.
Select the aerobic threshold (AeT) running speed as a starting point if you are doing this test immediately following the Incremental test.

Data processing: Maximum HR, Peak BLa, Recovery BLa and MAS are recorded. MAS is selected as the fastest stage that the athlete was able to complete (45 seconds or more).

Interpretation: Changes in fitness can be observed based on changes in MAS running speed and changes in associated BLa indicate changes in anaerobic capacity. The rate of BLa clearance post-exercise indicates aerobic recovery capacity.

As the racing season approaches, endurance at MAS can be tested by having the athletes run for as long as possible at their MAS speed. They should be able to do this for 3-6 minutes. Their lactate at the end of this test should be similar to that measured at the end of the MAS test. The national team considers the ability to maintain MAS a more important indicator of aerobic performance capacity than measured VO_2max.

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c) Examining Movement Economy

Movement economy has 2 elements, biomechanical efficiency and metabolic efficiency. Cross country skiing, similar to swimming, is a sport where the appropriate application of technique is a key determining factor in movement economy. Regular assessment of all techniques (striding, double poling, one skate, two skate, offset) is essential to the development of L2C athletes. Once again, comparing specific performance measures is the most appropriate way of measuring metabolic efficiency in developing athletes. Some specific examples are listed below.

- Tracking changes on a technical checklist in combination with "speed reserve" (the difference in average speed between two time trials)
    - 15" sprint (all out; distance covered) compared to 1 km time trial
    - 3 km time trial compared to 10 km time trial
    - 10km time trial speed as a % of MAS

The percentage of MAS that can be sustained without continuous accumulation of anaerobic waste products, is a primary determinant of performance speed in endurance events. For L2C athletes who have not yet reached international competitive standards, the average speed in a 10 km time trial is representative of this speed (considered the AnT Training Zone). Therefore, tracking the relationship between AnT Speed and MAS can be a valuable means of monitoring improvements in athletes whose growth has slowed considerably. Females, in particular, can focus on improving movement economy at the L2C stage through a combination of improved technique, increased duration of long slow distance sessions and increased ability to sustain AnT Speed.

d) Monitoring Recovery

Monitoring allows coaches to individualize training targets and track changes (both development and training related) over time. These assessments allow coaches to track athletes' physical development as well as their fitness. Submax monitoring assessments are ideally performed every 3 to 6 weeks, and weekly to daily for resting heart rate and Rusko tests (see below). The athlete should be in a consistently recovered state (eg. following a rest week) when assessments are performed.

i. Standardized Submaximal Exercise

Perform 4, 3 minute continuous workloads below the athlete's measured anaerobic threshold while they are wearing a HR monitor. The first running speed will be slower than aerobic threshold speed. Each subsequent running speed should increase by an equal amount (eg. 1.2 km/h increments). Immediately following the 4^{th} stage, walk at a standard, pre-determined speed for 2 minutes. The average HR during the final 30 seconds to 1 minute of each stage should be recorded. The HR at the end of the first minute of walking should also be recorded.

Data processing: The relationship between HR (y axis) and running speed (x axis) is plotted in a y vs x scatter plot. The slope and fit of the resulting straight line are tracked along with predicted y intercept and speed at max HR.

Interpretation: Changes in fitness can be observed over the course of the training season but, in the short term, the tracked data demonstrates changes in exercise tolerance due to training load or other fatigue inducing factors. The slope of the line may increase with fatigue related to intensity training or decrease with more volume-related fatigue. Fitness or maturation related changes are generally observed if the entire line moves down and to the right, suggesting improved efficiency.

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ii. Resting HR or Rusko Test

This is a resting heart rate test designed to help quantify recovery from training. Record heart rate using a HR monitor for 10 minutes, first thing in the morning. After you wake up and attach the monitor to your chest, lay flat on your back and wait briefly for your heart rate to stabilize and then record the values for 8 minutes. Then stand up straight and continue to record the heart rate for 2 minutes.

Data processing: Record the average HR during the final 2 minutes of lying, the peak HR after standing, and the average HR during the final 30 seconds of standing. Calculate the difference between peak and standing HR's. Also calculate the difference between lying and standing HR's. To simplify matters, tracking only the lying portion can be helpful.

Interpretation: Individual "normal ranges" should be established for all tracked data. Although responses are highly individualized, there are some general guidelines.
Increases in lying HR of 7-10+ bpm indicate decreased tolerance for training load. Small differences between peak and standing HR, as well as large differences between lying and standing HR indicate decreased ability to recover from a stressor. The HR response to standing will vary depending on the body's ability to regulate changes in blood pressure on a beat to beat basis.

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1.3 Training Methods- The Basics

1.3.1 What is Training?

Effective training in sport:

- Is a planned and organized undertaking that involves a cyclical process of analysis/assessment, forecasting, prescription, implementation, and control
- Is based on an understanding of the demands of the tasks athletes perform in competition, as well as athletes' background, current status, and coaching context (Competition – Development, for example)
- Aims at producing both general and specific adaptations or learning that will enhance performance
- Applies proven principles
- Uses methods that target specific athletic abilities and may cause significant short-term fatigue
- Alternates overload and recovery throughout the training program (weekly, daily, and in individual sessions)

1.3.2 Training Principles

Effective training is built on the principles described in the table below.

This Principle…	Has these implications for the design of training activities…
Adaptation	Over time, the body gets used to training activities; it adapts and improves less as the same activities continue to be performed
Individualization	The response to training, in terms of both the rate and magnitude of the adaptation, varies greatly from athlete to athlete The training load must be a function of the individual athlete's current work capacity
Interference	Under certain conditions, a training load used to develop one athletic ability may negatively affect the performance capacity of another athletic ability
Maintenance	Once an adaptation has occurred, its regression can be prevented, even if training volume and frequency are reduced, as long as intensity and specificity stay at the level that created the adaptation in the first place
Non-uniformity	Adaptations do not always occur in a linear and predictable fashion; in fact, they are usually rapid and more noticeable at the beginning of a program, but they usually *plateau* after several weeks or months of training When athletes are less fit, it is possible to achieve significant fitness gains with a variety of training stimuli; but as fitness increases, the training stimulus must become more specific to produce the desired training effect
Overload	For adaptation to occur, an appropriate stimulus, or training load, must be applied The training load must represent a challenge for the athlete, and it must create some fatigue and a temporary decrease in the athlete's

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	performance
Progression	Overloading must be progressive; e.g., athletes must move from easy to more difficult activities, from simple to complex activities
Purpose	Training activities must be planned with specific training or learning effects in mind The purpose determines the best activities, methods, and conditions to use in training Athletes must have a clear purpose in mind when they perform a task
Recovery	Adaptations that follow the application of a training load take place only if the body can recover from the training load and the resulting fatigue
Reversibility	Adaptations may regress if there isn't an appropriate training stimulus
Specificity	Adaptations are specific to the training load applied, the muscle groups involved, and the energy systems used
Variation	To have maximum effect, the training stimulus must be varied from time to time, even though the target athletic ability or energy system remains the same.

1.3.3 The Development and Maintenance of athletic abilities (Energy systems)

When training energy systems, the intended outcome can be *development* or *maintenance*. Some key considerations about each are outlined in the table below.

Intended Outcome	Training Considerations
Development: The aim is to improve the current level of the athletic ability	**Time:** More time must be spent on the training of a particular athletic ability when the goal is development than when the goal is maintenance.
	Rate of improvement: For a given athletic ability, the rate of improvement is usually fairly rapid and more noticeable during the first few weeks or months of a program or when the athlete's training background is limited. After a while, however, a lot of training may be necessary to obtain relatively small gains in performance.
	Training response: Some people following a training program for a particular athletic ability may improve a lot or very quickly, and others may improve less or more slowly. The training response to specific programs and training methods seems to be genetically determined.
	Training background: The athlete's training background is a key factor to take into account when developing athletic abilities. There must be an appropriate progression in the training methods used, in the training load in each session, and in training frequency; otherwise, injuries will occur.
	Maximum development: Top performance in some sports may require that some athletic abilities be developed to the highest possible level, i.e., to the limit of the athlete's genetic potential. This can take several years.
	Optimum development: In many sports, there is very little to be gained by developing athletic abilities beyond a certain point. Normative data from tests of successful athletes provide insights into the optimum level of development for a given athletic ability. The optimum level of

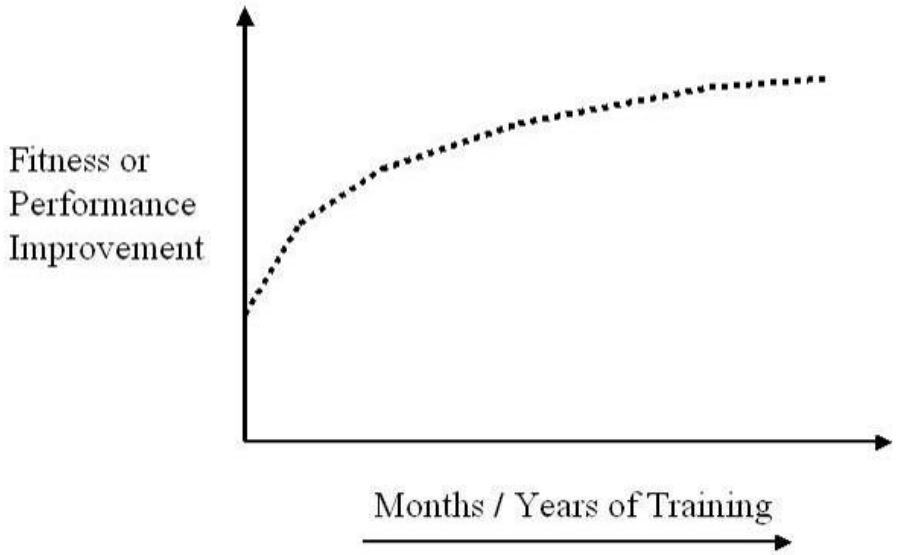
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	development is often below the athlete's genetic potential.
	Secondary training effects: Given the interplay that exists among the energy systems during exercise, some secondary training effects may result from the use of methods whose primary focus is the development of a particular athletic ability. Possible secondary training effects are noted in some tables in this document.
Maintenance: Once an athletic ability is sufficiently developed, the aim is to retain that level and prevent it from regressing	**Intensity:** Intensity should not be decreased when the goal is maintaining a given level of development for an athletic ability.
	Volume and frequency: The level of development for an athletic ability can be maintained even if session or weekly training volume and frequency are less than that required to develop the given ability.

1.3.4 Potential for Improvement

At the beginning of a training program, physical abilities generally improve fairly rapidly, **especially if the initial level is low**. Then the rate of improvement slows down and a plateau may be reached; from that point on, continued improvement usually requires a lot of specific training.

Figure 13: potential for improvement



After several years of systematic training, it may become practically impossible to further improve certain physical athletic abilities. The primary goal of training then becomes the *maintenance* and *refinement* of very subtle performance factors.

The table below summarizes the rate and magnitude of training gains that can be expected in the athletic abilities.

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Key Performance Variables		Average Percentage Improvement in Initial Values
Maximum Speed	Speed, speed of movement	≈ 10 - 15 %
	Peak power of the anaerobic alactic system	15 % in 15 weeks (Range: 5 - 45%)
Speed-endurance	Endurance of the anaerobic alactic system	20 % in 15 weeks (Range: 5 - 65%)
	Peak power of the anaerobic lactic system	12 - 15 % in 6 weeks 20 - 25 % in 15 weeks (Range: 5 - 75%)
	Endurance of the anaerobic lactic system	30 - 35 % in 15 weeks (Range: 10 - 75%)
Aerobic Stamina	VO_2 max	8 - 10% in 6 to 8 weeks ≈ 25 % in 24 months
	Mechanical efficiency, economy of motion	Highly variable: large improvements in sports that have significant technical requirements (swimming; cross-country skiing), less in others (cycling; running) ≈ 8 - 10% over 5 to 8 years in cycling
	Aerobic endurance, sub-maximal intensities	Very high > 50 - 100% over several years in some cases
Maximum Strength		Very high > 50 - 100% over several years in some cases
Strength-endurance		Very high > 50 - 100% over several years in some cases
Flexibility		Significant improvements in 8 to 12 weeks

1.3.5 Types of Training

Three main training approaches are considered in this section: *Continuous Training* (CT), *Interval or Intermittent Training* (IT), and *Fartlek*. Some key points about each are presented in the table below.

Type of Training	Key Points
Continuous Training (CT)	❑ CT consists of sustained efforts with no pauses ❑ Intensity generally stays fairly constant throughout the session ❑ For cyclical sports, intensity is generally below or similar to that in competition ❑ CT is relevant mainly for training aerobic endurance

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Interval or Intermittent Training (IT)	❑ IT involves alternating periods of effort and recovery in a planned manner ❑ The efforts are called *repetitions*, and they're usually grouped in sets; e.g., 5 standing starts over a distance of 40 metres, each followed by a 60-second active recovery interval, represents one set of five repetitions ❑ IT programs usually specify the following: • Number of sets of training to be performed • Number of repetitions or work periods in each set • Intensity: the workload at which each repetition or work period is to be performed • Type of recovery between repetitions/work periods and sets • Duration of the recovery interval between repetitions/work periods and sets ❑ Varying the number of repetitions/work periods, the duration and intensity of the repetitions/work periods, as well as the type and duration of recovery makes it possible to target specific athletic abilities and to focus on the power or the endurance of a particular energy system ❑ In general, there should be 3 or 4 sets when the total number of reps is 15 or more; 2 sets when there are 8 to 15 reps, and one set if there are 6 or fewer reps ❑ IT offers many possibilities for the development or maintenance of speed, speed-endurance, and aerobic stamina; many training methods used in the development of strength, strength-endurance, and speed-strength are also a form of IT
Fartlek	❑ Fartlek means *speed play* in Swedish ❑ Fartlek involves continuous training where efforts at low or moderate intensity alternate with efforts at much higher intensity ❑ Unlike IT, there is no set pattern for how efforts alternate, and the duration and sequence of each effort can vary greatly from session to session ❑ Fartlek can be used as a somewhat hard continuous session in many cyclical sports at any stage of the season ❑ Fartlek can contribute to the development or maintenance of speed-endurance and aerobic stamina

Work:Rest Ratio

Many IT programs explicitly specify a work:rest ratio — W:R. This refers to the ratio of the duration of the periods of effort to the duration of the recovery that follows. For example, a W:R of 1:5 means that the recovery is five times longer than the effort, so if the effort lasts 10 seconds, the recovery should last 50 seconds.

1.3.6 Key Training Variables

- ❑ Coaches manipulate a number of variables when they design training programs for their athletes. The sample training methods presented in this document all describe training in terms of training variables that apply to the athletic ability being trained.
- ❑ Three training variables, intensity, frequency, and progressions, merit special attention and are discussed below.
- ❑ These three key training variables are closely linked to the training principles just discussed. For example, the variables frequency and intensity are embedded in the principle of recovery.

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a) Intensity

- Working at the right intensity is critical. Regardless of the type of training, the optimal development of athletic abilities and their subsets requires that athletes work at critical thresholds, or intensities. Coaches therefore need to know how to estimate exercise intensity as precisely as possible and how to correctly apply exercise intensity.
- Exercise intensity must be based on each athlete's capabilities. Training loads must be prescribed in a manner that is consistent with the *Individualization* principle. In other words, they must take into account each athlete's capabilities at a given point in time. For instance, a particular intensity (e.g., running at 16 km/h for a certain period of time to improve aerobic endurance) may represent an adequate training stimulus for some athletes, but it may be too low or too high for others.
- While it may not always be possible for athletes to exercise at *precisely* the required intensity, training activities should take place within a certain range (e.g., 3% to 5%) of the required intensity, and deviations from those ranges should be kept to a minimum.
- When setting intensity for a given mode of exercise (running, swimming, cycling, etc.) the values used must be drawn from data obtained in the same mode of exercise. For example, maximum heart-rate values obtained in swimming should not be used as a point of reference when setting intensities in running.

b) Frequency

- *Frequency* refers to the number of times a particular athletic ability is trained in a given period, usually one week
- The frequency chosen depends on the ability trained, the athlete's training status, the athlete's ability to recover, and the training load
- As a general rule, training frequency must be higher when the goal is to develop or improve the level of an athletic ability than when the goal is to maintain an athletic ability at a given level

c) Progressions

- To promote optimal adaptation, avoid excessive fatigue, and reduce the risk of injury, workloads should be increased progressively.
- It is relatively easy to prescribe an effective workload if data are available about the athlete's fitness level and his or her ability to handle certain types of workouts.
- When such information is not available, the coach must exercise good judgement and proceed carefully by trial and error.
- When establishing an initial training progression for the use of Interval Training (IT) and resistance training, err on the safe side initially and exercise judgement throughout:
    - Start with the *lowest* intensity proposed.
    - Keep the overall volume of work in terms of sets and repetitions/work periods per set at the initial intensity until the athlete can perform the work required without undue stress.
    - When the athlete can perform the work required without undue stress, progressively increase the number of sets until the athlete can perform the highest number of sets recommended for the protocol in question without undue stress.
    - Progressively increase the number of repetitions per set until the athlete can perform the maximum total recommended volume for the protocol without undue stress.
    - Ask the athlete to stop if he or she seems to be under undue stress.

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1.4 Energy Systems Training Targets for the L2C stage in Nordic Skiing

The increased specificity of L2C Training Zones is reflected in the target heart rate, RPE and blood lactate ranges shown in Figure 14. The four new training zones necessitate narrower target ranges within each of the nine zones. These targets reflect the increased range of ski speeds that more mature and experienced athletes are capable of producing as well as the need for increased awareness and control of training effort. As training volume increases, one of the most important skills a young athlete learns is to keep each training session within the target training zone.

Figure 14 also describes approximate training speeds and durations that are appropriate for L2C athletes in each training zone. Although many athletes' training speeds may not correspond exactly to the percentages of MAS listed below, they are a good general reference especially if the coach is concerned that the athlete may be regularly training at intensities that are higher than intended. Any training session can be treated like a time trial in the sense that an average speed for the session can be calculated if the training time (excluding long drink breaks and equipment changes) and the distance covered are known. Obviously, terrain will influence these calculations but, over time, coaches can get a good general idea of the average speeds that correspond to training in each zone. If these speeds are 10% or more faster than the targets, it's likely that the athlete is performing Endurance or AeT training too quickly.

Likewise, the target durations are guidelines for the **maximum** length of a training session at the L2C stage of development. For example, an Endurance session of 210 minutes (3.5 hours) is only appropriate for the most advanced L2C athletes and this will happen less than 5 times in an entire training year. In contrast, an entry level L2C athlete may only perform a handful of sessions longer than 120 minutes (2 hours) during summer training.

Figure 14: Physiological, Speed and Time Training Targets MAS for L2C Athletes

Energy System	L2C Training Zone (for YTP)	L2C Training Zone (detailed)	HR Range (% HRmax)*	% of HR reserve[1] (HRR) + rest HR (RHR) NB: prefered method	RPE Range (Borg Scale)	Blood Lactate[2]	% of MAS	Sustainable Time
Aerobic	ZONE 1	Endurance	< ~ 65%	<~60-65% HRR + RHR	7 – 9	1	<~60-65%	90' - 180'
		Aerobic Threshold (AeT)	~ 65 – 75%	~ 65-75% HRR + RHR	9 – 11	1.0 - 1.5	~ 65-75%	60' - 90'
	ZONE 2	Transition	~ 70 – 85%	~ 75% - 80% HRR + RHR	11 – 13	1.5 - 3.5	~ 75% - 80%	45' - 75'
	ZONE 3	Anaerobic Threshold (AnT)	~ 85 – 90%	~ 80% - 90% HRR + RHR	13 – 15	~ 3.0 - 4.5	~ 80% - 90%	30' - 45'
	ZONE 4	Race pace	90 – 95%	~ 85% - 95% HRR + RHR	15 – 17	~ 4.0 - 9.0	~ 85% - 95%	10' - 25'
		Maximal Aerobic Speed (MAS)	95 – 100%	~ 95% - 100% HRR + RHR	17 – 19	~ 8.0 - 10.0	100%	3' - 6'

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Anaerobic Lactic	**SPRINT**	**Lactic Sprinting (LAC)**	N/A	N/A	18 – 20	~ 9.0 - 12.0	110% - 135%	0.5' - 2'
Anaerobic Alactic		**Alactic Sprinting**	N/A	N/A	20	N/A	N/A	8 to 15 sec
	SPEED	**Pure Speed**	N/A	N/A	20	N/A	> 140%	2 to 8 sec

[1]Heart Rate Reserve (HRR) corresponds to MaxHR - Resting HR
[2]lactate references are only appropriate for athletes who are 18-24 months past PHV; lactate guidelines are based on steady paced efforts and assume athlete has warmed-up to at least the level of intensity that will be required during the workout
[3]CT = Continuous Training

*Karvonen method or incremental exercise measures recommended to replace these targets when possible

Due to differences in maturity and genetics, there are considerable individual differences in the heart rates associated with each training zone at this stage of development. While the ranges above offer a "ball park" estimate for each training zone, additional testing is recommended to determine individualized HR targets for training purposes. If incremental treadmill testing is not available, the Karvonen method can be used to estimate target HR's that correspond to any percentage of MAS.

For example

Athlete A has a maximum HR of 205 bpm and a resting HR of 55 bpm. Athlete B has a maximum HR of 190 and a resting HR of 52 bpm. To exercise at an intensity of approximately 80% MAS, the following Heart Rate Reserve formula can be used to calculate target HR's.
% MAS = (HR during exercise – Resting HR)/(Max HR – Resting HR)
Rearrange to solve for HR during exercise:
HR during exercise = [% MAS x (Max HR – Resting HR)] + Resting HR

	Athlete A	Athlete B
Max HR	205	
Resting HR (lying down)	55	
HR Reserve (Max HR – Resting HR)	205 – 55 = 150	
HR during exercise (target HR)	[0.8 x 150] + 55 = 175 bpm	

Try this yourself with Athlete B (hint: target HR = 162 bpm)

In Summary

- The switch to L2C Training Zones is appropriate only AFTER the growth spurt has ended; 6 months post-PHV at the earliest
- Improving the ability to sustain Endurance, AnT and MAS are top priorities for all L2C athletes; strength development is also a priority for males, while females focus on the more complex task of improving Lactic Sprinting power
- Understanding the developmental progression of the energy systems and the situations in which each is best suited to provide energy is crucial in designing an appropriately periodized training program.

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Training Zones with Workout Examples

Energy System	L2C Training Zone (for YTP)	L2C Training Zone (detailed)	% of HR reserve[1] (HRR) + rest HR (RHR) NB: prefered method	Blood Lactate[2]	% of MAS	typical interval length	recommended W:R	recommended total work per session	example of easier workout	example of harder workout
Aerobic	ZONE 1	Endurance	<~60-65% HRR + RHR	1	<~60-65%	continuous	n/a	30 min to 3 hrs	CT[3] for 30 to 60 min.	CT for 1,5 hrs to 3 hrs
		Aerobic Threshold (AeT)	~ 65-75% HRR + RHR	1.0 - 1.5	~ 65-75%	continuous	n/a	30 min to 1.5 hrs	CT for 15 min. to 45 min.	CT for 60 min. to 1,5 hrs
	ZONE 2	Transition	~ 75% - 80% HRR + RHR	1.5 - 3.5	~ 75% - 80%	continuous	n/a	20-60 min	CT for 10 min. to 20 min.	CT for 45 min. to 60 min.
	ZONE 3	Anaerobic Threshold (AnT)	~ 80% - 90% HRR + RHR	~ 3.0 - 4.5	~ 80% - 90%	4-6 min or 10-20 min	4-5:1 or 2-3:1	15-30 min	4 x (5 min. effort / 1 min. rest)	2 x (15 min. effort / 5 min. rest)
	ZONE 4	Race pace	~ 85% - 95% HRR + RHR	~ 4.0 - 9.0	~ 85% - 95%	continuous or 2-5 min.	n/a or 1.5-2:1	10-20 min	4 x (3 min. effort / 2 min. rest)	CT for 20 min.
		Maximal Aerobic Speed (MAS)	~ 95% - 100% HRR + RHR	~ 8.0 - 10.0	100%	20-60 sec or 1-3 min	1:1-1.5 or 1:1-2.5	5-12 min	10 x (30 sec. effort / 45 sec. rest)	4 x (3 min. effort / 4 min. rest)
Anaerobic Lactic	SPRINT	Lactic Sprinting (LAC)	N/A	~ 9.0 - 12.0	110% - 135%	20-45 sec	1:6-9	1.5-4 min	5 x (20 sec. effort /3 min. rest)	5 x (45 sec. effort / 5 min. rest)
Anaerobic Alactic		Alactic Sprinting	N/A	N/A	> 140%	10-15 sec	rest 2 to 4 min between reps and 7-10 minutes between sets	1-2 min	6 x (10 sec. effort / 3 min. rest)	2 sets of 4 x (10 sec. effort / 3 min. rest); 10 min. between sets
	SPEED	Pure Speed	N/A	N/A	> 140%	2-8 sec	rest 2 to 4 min between reps and 5-7 minutes between sets	30-60 sec	6 x (5 sec. effort / 3 min. rest)	2 sets of 4 x (5 sec. effort / 2 min rest); 5 min. between sets

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Annexes

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Annex A: Interpreting test results

General Considerations

- Monitoring performance involves having a planned approach to testing and effectively using test results.
- To be of use for monitoring purposes, testing must occur regularly and at appropriate times throughout the sport program.
- Tests must be appropriate for the training period in which they are administered. For instance, a large battery of tests is appropriate before each major training phase of the program, but only a few key tests should be run at the end of specific training cycles.
- Tests of performance, such as sprint times or the time it takes to complete a circuit of exercises, can be used quite frequently within programs, for instance, once a week or once every two weeks.
- While test results can motivate athletes, it's important not to let poor test results distract or discourage athletes.
- For monitoring purposes, coaches should keep records of their athletes' performances and test results.

Key Terminology about Normative Data

The terms *mean*, *standard deviation*, and *percentile* are often used in the presentation of normative data. Knowing how these terms are defined is essential to using such data effectively. Here's what these terms mean:

- **Mean:** The mean represents the general characteristic of a sample. It is the average of all the observations reported, and it is calculated by adding all the results and dividing the total by the number of observations.
- **Standard Deviation:** The standard deviation refers to how the data are distributed around the mean. About 68% of all observations are within one standard deviation of the mean (plus or minus), about 95.5% are within two standard deviations (plus or minus), and 99.75% are within three standard deviations (plus or minus).
- **Percentile:** The percentile refers to the percentage of observations that are below a certain point of reference. For instance, when a result is described as being in the 90th percentile, it means that 90% of the results are lower; in other words, this value and all above it are in the top 10%.

Points to Consider when Interpreting Test Results

The table below outlines key points to consider when analyzing the results of tests of physical abilities.

When Interpreting…		
Test results when the test is conducted	**How test results may evolve over time**	**How variables evolve relative to one another**
Consider…		
❑ What the data actually show,	❑ Whether there have been	❑ Whether each variable

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for example:[2] • Overall pattern of the plotted data • Highest/peak value • Average value • Time to reach certain values • Fatigue rate, i.e., the degree to which power output declines in the test and the points at which marked decreases occur	significant changes in the athlete's morphology (weight gain or loss, growth) or in the equipment used from test to test ❑ Whether testing conditions were the same as in previous tests ❑ Whether the same test administrator performed all tests after the first and if not, whether the later test administrators were experienced	seems to be improving over time ❑ Whether one or more variables stops improving and if so, when in the season this happens
❑ Whether it's better to express results in absolute terms (e.g., higher is better) or in relative terms (e.g., data are adjusted to account for individual differences like body weight)	❑ What the desirable direction of results is over time: up or down? ❑ When the current measurement is being taken and whether development is adequate for that time in the season	❑ What is happening to the athletic ability or variable most likely to affect performance ❑ How test results and actual sport performances (or certain behaviours in competition) are related
❑ Whether testing conditions were controlled and standardized and what equipment was used	❑ How the result compares to the previous score and when the previous test was conducted	
❑ How results compare to normative data for athletes of the same age, sex, sport, and position	❑ How the result compares to the athlete's personal best in this test and when the best score was achieved	❑ What training was done when results were improving versus what was done in the lead-up to when the results for one or more variables stopped improving
❑ Whether performance would improve if results for the tested variable improved	❑ Whether there is noticeable progress or whether performance is plateauing	
❑ Whether the point of reference for designing training intensities for a particular athletic ability needs to be reset	❑ Whether fatigue affected test results (what kind of training and how much training took place in the months/weeks before testing)	❑ How much work is needed to achieve a given training response and when that response will become noticeable
❑ What the athlete's health, fatigue, hydration, and nutritional status was at the time of the test	❑ Whether to develop the athletic ability or the variable tested maximally or to an optimal level	❑ Whether the program is implemented as planned and if not: • What areas had significant gaps between planned and implemented activities • What testing data and performance-related trends were associated with those gaps
❑ How test results and actual sport performances (or certain behaviours in competition) are related	❑ Whether the variable being tested can still improve significantly with training or whether the theoretical ceiling of development has been reached ❑ Whether the training priority from now on should be maintenance or development ❑ How test results and actual sport performances (or certain behaviours in competition) are related	

[2] This applies to tests where several values are recorded, such as all-out running efforts where split times are taken every 50m.

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Examples of How to Interpret Test Results

This section presents and interprets the hypothetical results for seven different tests. These examples are presented only as a general guide to the kinds of results certain tests yield and the type of analysis Competition – Development coaches should be capable of.

Example 1: Maximal Aerobic Power in a Team Sport

Background

- Athlete A is a national-level male soccer player whose maximal aerobic speed (MAS), determined from the 400-m Léger MAP test, is 19 km/h. Given his MAS, the player's VO_2 max can be estimated to be approximately 67 ml/kg/min. The mean score for the team on this test is 16.5 km/h (about 58 ml/kg/min), and this is comparable to the values reported for other teams in the league. Two months ago, Athletes A's result on the MAS test was 20.5 km/h, and his weight has not changed since then.

Analysis

- One possible (but incorrect) reaction would be that the drop in Athlete A's MAS is of little importance because his MAS is so much higher than that of his teammates and other players.
- A better response would be concern that Athlete A's MAS has dropped by about 7%. Performance in soccer, especially in the latter stages of the game, depends on the ability to recover between short bursts of activity and avoid notable drops in the ability to work at high intensities during long sequences of intense play. The decline in MAS may indicate that the current training program is inappropriate for training (or maintaining) this component of aerobic stamina in this athlete and should be re-examined. It could also be that Athlete A is not following his training program as he should. Another possibility is that his health or nutritional status has suffered since the first test; in this case, medical attention may be warranted.

Example 2: Maximal Aerobic Power in a Sport where Body Weight is Supported

Background

- Athlete B is a 74 kg male rower with a VO_2 max on a rowing ergometer of 70 ml/kg/min. He has been training very hard for the past 4 years, doing a lot of interval training to improve his MAP, and he wants to make the national team.

Analysis

- A VO_2 max of 70 ml/kg/min is very high for a rower and is comparable to those of successful international oarsmen. The issue with Athlete B's results, however, is that because the boat supports the body weight in rowing, **absolute** power output is more crucial to performance than **relative** power output.
- Expressed in absolute terms, Athlete B's VO_2 max is approximately 5.18 litres per minute (L/min), compared to values in excess of 6.0 L/min for most successful heavyweight oarsmen. Since 70 ml/kg/min is probably quite close to the upper limit of Athlete B's physiological training potential, given the training he has done over the past few years, it is unlikely that he will increase his absolute aerobic power output to international standards, even with more intensive training. Since Athlete B is unlikely to become a successful heavyweight oarsman, one solution would be to compete in the lightweight division.

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Example 3: Maximal Aerobic Power and Endurance in Distance Running

Background

- Athlete C is a male 10,000 m runner with 3 years of national experience. Laboratory tests indicate that each year his VO_2 max reaches 72 ml/kg/min in the competitive season. This is corroborated by his results on the Léger MAP test on a 400-m track, where his MAS is 20.5 km/h. His results on an aerobic endurance test show that he can sustain 90% of his MAP for over 30 minutes. He trains hard, mostly through continuous training, and his training mileage approaches 150 km per week in his Preparation Period. He has never won a major competition.

Analysis

- VO_2 max values for top 10,000 m runners are usually in the 80-85 ml/kg/min range. At 72 ml/kg/min, Athlete C may have reached his physiological limit, or his training preparation may not be as effective as it could be. However, his endurance appears to be excellent, as few individuals can sustain 90% of their MAP for as long as he does (see Annex D).
- Doing large volumes of training at race pace or slower is an effective way to train aerobic endurance, but it does not stress the body enough to promote significant increases in MAP. Higher intensity interval training at paces requiring 95-105% of maximal aerobic speed are more effective at increasing MAP.
- Since Athlete C has a good level of endurance and has focused mostly on this type of training in the past, it is possible that increasing the proportion of training time devoted to higher intensity interval work may significantly improve MAP and that race performances may also improve. Athlete C may also consider moving up to distances longer than the 10,000 m, where he might be at less of a disadvantage, given the level of his MAP.

Example 4: Effects of Training on Submaximal Heart-Rate Response

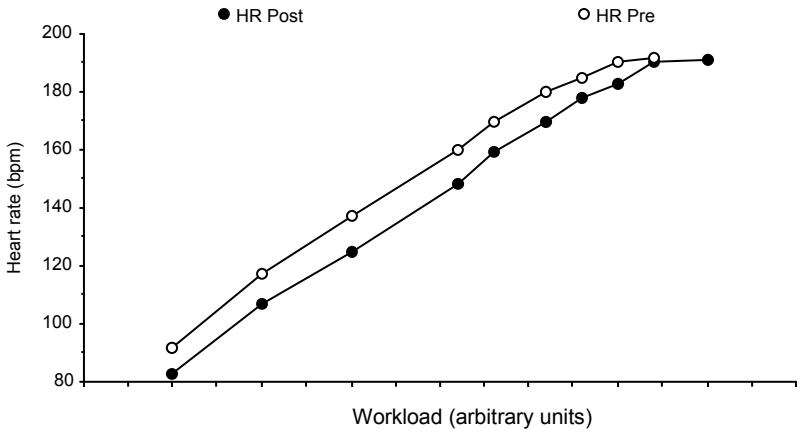
Background

- Athlete D is a female tennis player who has completed 8 weeks of general preparation featuring both continuous and intermittent aerobic training. Her score on the Léger shuttle-run test has improved by 10%, and her heart-rate response to submaximal exercise has decreased by several beats per minute. Her maximum heart rate has not changed.

Analysis

- Improvements in MAP in the order of 8 to 10% can be observed after 8 to 10 weeks of training, particularly if the program features interval training at high percentages of the athlete's MAP (95 - 100%). Given standard exercise conditions, HR at submaximal work outputs is also usually lower as a result of training. Simple field tests using HR response can therefore be used to assess general fitness improvements. In such tests, the athlete is his or her own control, and performances and HR responses from different testing sessions are compared.
- On a graph, the relationship between HR and work intensity should be expected to shift to the right as a result of training. The figure below shows HR before (HR Pre) and after (HR Post) for the same absolute workload.

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- A lower resting HR and faster HR recovery are also common outcomes of aerobic training. It is normal for maximal heart rate NOT to change with training.

Example 5: Anaerobic Energy Production in a Sport where a High MAP is Critical

Background

- Athlete E is a 19-year old female heavyweight rower who wants to make the national team in the near future. In previous trials, she showed great promise. During a 90-second maximum effort test on a rowing ergometer to assess her anaerobic work capacity, she averaged a power output of 295 watts. This is equivalent to 3.9 W per kg of body weight. The average for the national team in such a test is 340 W, or 4.6 W per kg. An analysis of her training program reveals that she trained mainly for aerobic stamina (endurance and MAP) over the past 18 months or so. Athlete E's MAP is comparable to that of national team members. Rowing races last for only a few minutes.

Analysis

- Anaerobic power and capacity can be expressed in absolute units (watts) or relative to body weight (watts per kg). As with MAP, when weight is supported externally, as it is in rowing, absolute power output is a more meaningful measure. By contrast, when work must be done against gravity, as is the case in running, relative power output is more important.
- While performance in rowing is limited primarily by aerobic energy delivery, there is also a significant contribution from the anaerobic systems (approximately 20% of total energy during a race). Any increase in the anaerobic systems' ability to supply energy therefore probably leads to improved performance. In rowing, this would certainly be the case if the anaerobic lactic system was developed to a higher degree.
- That Athlete E's relative score (W per kg) is considerably less than the normative data for the national team and that she has not done much specific training to develop her anaerobic energy systems suggests that there is important potential for improvement in this area. It would therefore be advisable for her to increase the proportion of her training time devoted to training the anaerobic systems in general and the power and endurance of the lactic system in particular.
- Athlete E should seek to increase her strength and speed-strength, as improvements in these areas are also known to have positive effects on the anaerobic energy systems. Given the somewhat limited potential of females for hypertrophy and the fact that body

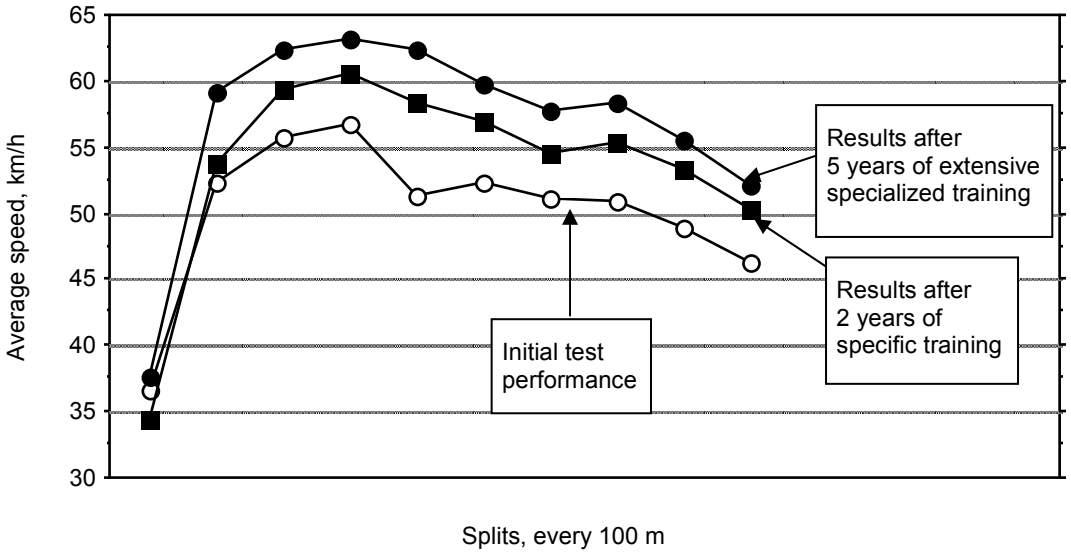
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weight is supported in rowing, any increase in body mass resulting from resistance-training programs should not be a problem.

Example 6: Power Output as a Function of Time in an All-out Effort

The figure below shows the theoretical improvements of a cyclist, Athlete F, over a five-year period in acceleration, peak velocity, and speed-endurance. The cyclist performed all-out tests over 1 km. He started from a standing position (speed = 0), tried to reach peak velocity as quickly as possible, and tried to maintain peak velocity for as long as possible thereafter.

High anaerobic power and capacity are obviously essential to achieving a good performance in this type of test, but MAP power is also important to a certain degree, since the effort lasts between 60 and 70s.



Here are some key points about the data in the figure:

- The speed during the first segment of the test (acceleration phase, since the initial speed is 0) is an indication of the power of the alactic system: the greater the power, the higher the speed measured at the first marker will be, assuming there are no significant differences in the athlete's mass from one test to another.
- The speed reached at the second marker is an indication of the capacity of the alactic system and of the athlete's speed. At this point in the effort, the contribution of the lactic system becomes increasingly important. Significant improvement in that area occurred between tests 1 and 3.
- The average speed achieved between markers 3 and 5 is a good reflection of both the power and the capacity of the lactic system. During this segment of the test, (i) the higher the speed, the higher the peak power of the anaerobic lactic system and (ii) the more constant the speed, the greater the anaerobic lactic capacity. The marked drop in speed between markers 4 and 5 in test 1 indicates that the anaerobic lactic system had lower endurance at that time.
- From about the 6th marker on, the contribution of the aerobic system becomes increasingly significant. The capacity of the anaerobic lactic system and the power of the aerobic system both determine the speed sustained in the second half of the test.
- Speed decreases in the last 200 m in all three tests. From a physiological point of view, this could be explained by the shift that is occurring between the anaerobic and the aerobic

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energy systems in terms of dominance. Indeed, at this stage of the test, the aerobic system, whose peak power is lower, is supplying more and more energy. Therefore, in addition to significant increases in the amount of energy supplied by the anaerobic systems from one test to the next, these data suggest MAP has improved.

Example 7: Performance Improvements over Time

Background

- Athlete G is 17 years old, and he is new to a sport where speed-endurance, strength, and aerobic stamina are all important for successful performance. The sport also involves a lot of running. Athlete G is just starting to train seriously for his sport, and he had not done much fitness training before. During the past three months, he has been training each athletic ability 2 to 3 times a week, and he has been tested 4 times. His scores on a 1-RM squat test, the Léger 20-m shuttle run, and the 30-s Wingate test on a bicycle ergometer are shown below.

Test	Score 1	Score 2	Score 3	Score 4
1-RM squat*	100 kg	112 kg	120 kg	130 kg
Léger 20-m shuttle run	Stage 10 (13 km/h) ***14.5 km/h***	Stage 10 (13 km/h) ***14.5 km/h***	Stage 11 (13.5 km/h) ***15.3 km/h***	Stage 11 (13.5 km/h) ***15.3 km/h***
30-s Wingate test (bicycle ergometer)	10.0 watts/kg	11.0 watts/kg	12.0 watts/kg	11.2 watts/kg

* This test may not be appropriate, given the athlete's age and training background. For the purposes of this example, assume that it is.

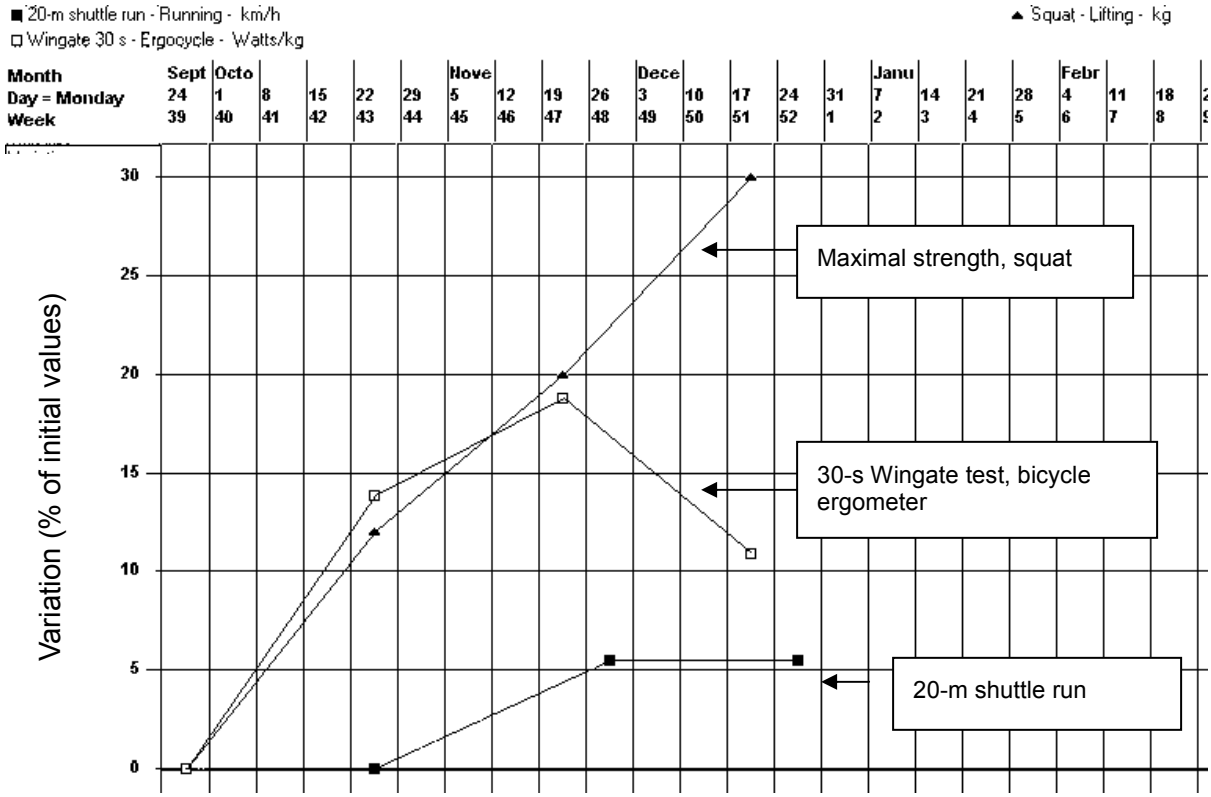
Analysis

- To interpret the results of the Léger 20-m shuttle test, first convert the number of stages completed into actual running speed. The converted values are shown in bold italics in the table above.
- Although not essential, organizing the data as shown below makes it possible to access key pieces of information about each variable at a glance.

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Title	20-m Shuttle Run – Running – km/h	Squat – Lifting – kg	Wingate 30 s – Ergocycle – Watts/kg
Initial value	14.50 Week of 24-09-2007	100.00 Week of 24-09-2007	10.10 Week of 24-09-2007
Final value	15.30 Week of 24-12-2007	130.00 Week of 17-12-2007	11.20 Week of 17-12-2007
Difference (final – initial)	+0.80 (+5.52%)	+30.00 (+30.00%)	+1.10 (+10.89%)
Minimum value	14.50 Week of 24-09-2007	100.00 Week of 24-09-2007	10.10 Week of 24-09-2007
Maximum value	15.30 Week of 26-11-2007	130.00 Week of 17-12-2007	12.00 Week of 19-11-2007
Difference (max – min)	+0.80 (+5.52%)	+30.00 (+30.00%)	+1.90 (+18.81%)
Average value	14.90	115.50	11.20
Standard deviation	0.46	12.69	0.80
Number of observations	4	4	4
Duration of period of analysis (weeks)	14	13	13

- It would also be useful to:
  - Assess the rate at which the results for each test progress.
  - Observe general trends in how the variables tested change relative to one another. Recording test results in a graph, as shown below, helps make these trends clear. Because the tests may have different units of measurement, express results as percentage improvements (for example, (Score 2 – Score 1)/Score 1*100) to ensure a meaningful interpretation.



  - Consider the specific types of training done by the athlete on a weekly basis to see if there is a relationship between the methods and loading parameters used and the resulting adaptations.

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- While the above results are fictitious, the following analysis points to certain factors that should be considered in a case like this:
  - Because Athlete G is relatively young, is new to his sport, and has done very little physical training, significant and fast improvements are to be expected in all performance areas tested in the initial phase of his program.
  - Athlete G's performance in the squat test improves steadily throughout the period, and his strength gains are rapid and important. This may suggest a strong predisposition to this type of training. Given the results, the strength program he follows also seems appropriate, and the other training being done concurrently does not seem to negatively affect his ability to progress.
  - However, Athlete G's response to aerobic training is very different, and his improvements after 3 months of training are quite small. This could be due to several factors, including a limited genetic potential for performance in aerobic activities, a slow response to this type of training, or the use of inappropriate training methods for improving MAP in his program. Indeed MAP, not aerobic endurance, is the variable tested by the 20-m shuttle test; if Athlete G did a lot of continuous training at low to moderate intensities, he probably improved his endurance, not his MAP. If Athlete G gained weight and muscle mass as a result of his strength training, it might have contributed to the poor results on the MAP test; however, the latter is unlikely to have been the primary cause of the poor response to aerobic training.
  - Since Athlete G's sport involves running, testing the power of the anaerobic lactic system on a bicycle ergometer is not very specific. Despite this lack of specificity, his performances in the 30-s lactic power test show interesting improvements in only two months, again indicating good training potential. The decline observed between the 3rd and the 4th testing sessions could simply be due to having a bad day when the testing occurred, since this type of effort requires a lot of motivation, and the results can be affected by fatigue from previous training days. However, these results may also indicate a need to adjust the training program for speed-endurance or reflect the fatigue that occurs when someone with a limited training background trains several athletic abilities concurrently. In this case, it might be advisable to plan for adequate recovery within the program and to verify that the athlete's health and nutritional status are adequate.
  - Because Athlete G seems to respond well to strength and speed-endurance training but not as well to aerobic training, it might be useful to do more thorough physiological testing in a lab. This may lead the athlete to switch to a sport whose demands are mainly in the areas of strength and anaerobic energy production.

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Annex B: Limitations of Using Heart Rate to Quantify Aerobic Training Loads

Using target heart rate (HR) to quantify aerobic training loads may allow coaches to individualize the training stimulus and to adjust training as fitness improves. However, the relationship between HR and work intensity is not perfect. Some of the limitations of using HR to set aerobic training intensities are outlined below.

If this happens…	It has these implications when HR is used to estimate exercise intensity…
In some subjects, HR may reach a plateau *before* MAP or VO_2 max	Any formula using max HR values will *underestimate* the intensity the athlete is working at; e.g., the athlete may think he or she is working at 80% of MAP but may actually be working at 70 or 75% of MAP. For a detailed example of how target HR may be affected by the athlete's actual max HR, see page 71.
HR tends to increase with exercise duration even if intensity doesn't change; this is normal, and it is called *cardiac drift*	Because cardiac drift is caused largely by the loss of fluid through sweating and by other cardiovascular adjustments that occur during exercise to help regulate body temperature, HR values tend to become less precise measures of aerobic intensity when: ❑ exercise is prolonged ❑ it's hot or humid (higher sweating rate) ❑ clothing or other equipment insulates the body ❑ the athlete is dehydrated Under these conditions, HR may *overestimate* the intensity the athlete is working at relative to his or her MAP.
HR during submaximal exercise is higher at altitude than at sea level	Target HRs associated with sea-level workouts may not be valid targets for the same workouts at altitude.
HR usually increases with psychological stress; however, in some cases, it may decrease	HR may *overestimate* or *underestimate* actual intensity relative to MAP, and it can be difficult to determine which response is being observed. However, the chances are greater that psychological stress increases HR at a given submaximal workload, and so overestimation is more likely.
It takes a few seconds for HR to adjust to a given workload; whether athletes reach the HR approximating the desired percentage of MAP therefore depends on the length of the work interval	HR is not a valid measure of intensity: ❑ In IT sessions with short, high-intensity work intervals ❑ In intervals performed at intensities greater than 100% of MAP In these cases, target speeds or split times should be used to estimate intensity, not HR.

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Annex C: Measuring Heart Rate

General Considerations

Heart rate (HR) is one of the key physiological parameters used by athletes and coaches to estimate the relative intensity of exercise. This practice is based on the well-known relationship between HR and work output: the higher the intensity of an effort, the higher the heart rate (up to a point), as the heart must pump more blood to deliver oxygen to the active muscles. This relationship is generally linear throughout a large portion of the aerobic work range.

HR fluctuations can provide direct feedback about changes in the relative intensity of the exercise. HR response also provides information that makes it possible to individualize some types of aerobic training. HR can also be used as a point of reference to assess fitness improvements: training causes cardiovascular adaptations that allow the heart to pump more blood at each contraction, and HR at a given submaximal workload is generally lower than before.

Widely available and affordable lightweight, portable HR monitors have made it easy to accurately measure athletes' HR in a variety of sport-specific exercise conditions. This technology has become popular with coaches because of its potential for quantifying training loads and monitoring athletes. The small size, ease of use, and light weight of such monitors makes it possible to record HR accurately over extended periods during training or competition without interfering with performance. The compatibility of HR monitors with computers and the availability of specialized software also make it possible to rapidly and easily perform sophisticated analyses of HR data. This allows coaches to obtain valuable information on the demands of their sport and on the overall level of stress athletes experience as they perform certain tasks.

The relationship between HR and work intensity is not necessarily perfect. For a discussion of the limitations of using HR to set and monitor training intensities, see Annex B.

Determining Maximum Heart Rate

The first step in using HR to set training intensities or to monitor the effects of training is to determine the athlete's maximum HR (max HR). The four most common methods for doing this are:

(1) 220 minus age and similar formulas

(2) Continuous progressive maximal tests

(3) Discontinuous progressive maximal tests

(4) Repeated maximum efforts

220 Minus Age and Similar Formulas

Max HR is genetically determined. In able-bodied 20-year-olds, max HR is usually 195 - 200 bpm regardless of sex. It then declines gradually by about 10 bpm per decade. This has led to the development of the simple and well-known 220 minus age formula to estimate max HR. However, these values represent averages, and important variations among individuals (e.g., ± 10 bpm or more) can be observed in any age group. For instance, the max HR of a 25-year-old female could be similar to that of a 50-year-old man, and differences of 20 bpm or more can be observed within the same age group.

Another method based on age is:

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- Max HR = 209 – 0.587 x (age in years).

The intent of this formula is to correct some of the errors in the 220 minus age formula. However, the margin of error remains quite high compared to direct measurements.

Because of their limited precision, these formulas should not be used to determine max HR in athletes. Rather, max HR should be determined individually and in exercise-specific conditions using one of the three methods described below.

Note: Each of the three methods described below assumes that the athlete has access to an HR monitor. If this is not the case, the athlete's pulse should be recorded at either radial (thumb side of the wrist) or carotid (junction of the head and neck) sites over a 10-second period **immediately** after the work bout. Recording over longer periods is not recommended because recovery will have begun by then, and max HR may be underestimated. If the count is between two heart beats at the end of the 10-second period, add 0.5 to the count. For instance, if the count is between 33 and 34 at the end of 10 seconds, use 33.5 beats as the count, and estimate max HR as 33.5 x 6 = 201 bpm.

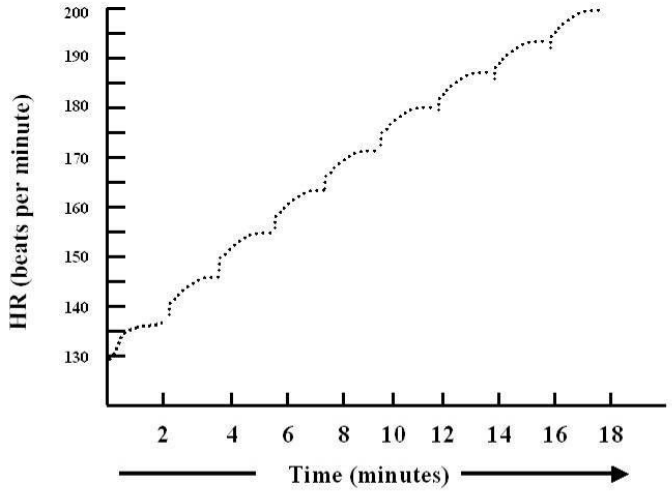
Note: The mode of exercise and the position of the body during the effort may affect max HR. Max HR tends to be **higher** when more or larger muscle groups are involved (e.g., running versus cycling versus swimming; exercising with the legs versus the arms), **lower** when body position is horizontal or inclined as opposed to vertical.

Continuous Progressive Maximal Tests

HR values measured at the end of progressive maximal tests such as those described earlier in this section for MAP are simple, valid, reliable ways of determining max HR. In this type of test, exercise intensity is increased progressively in a step-wise fashion over several minutes until the athlete reaches exhaustion.

Alternatively, the athlete exercises for a few minutes in sport-specific conditions at an HR of 120 to 140 beats per minute (bpm). HR is then increased by 8 to 10 bpm, and the new intensity is maintained for about 2 minutes. Similar step-wise increments are repeated until the athlete is exhausted or HR plateaus despite an increase in intensity; this should occur in 12 to 16 minutes.

During this type of effort, HR increases gradually after intensity is increased, rather than abruptly, as the figure below shows.

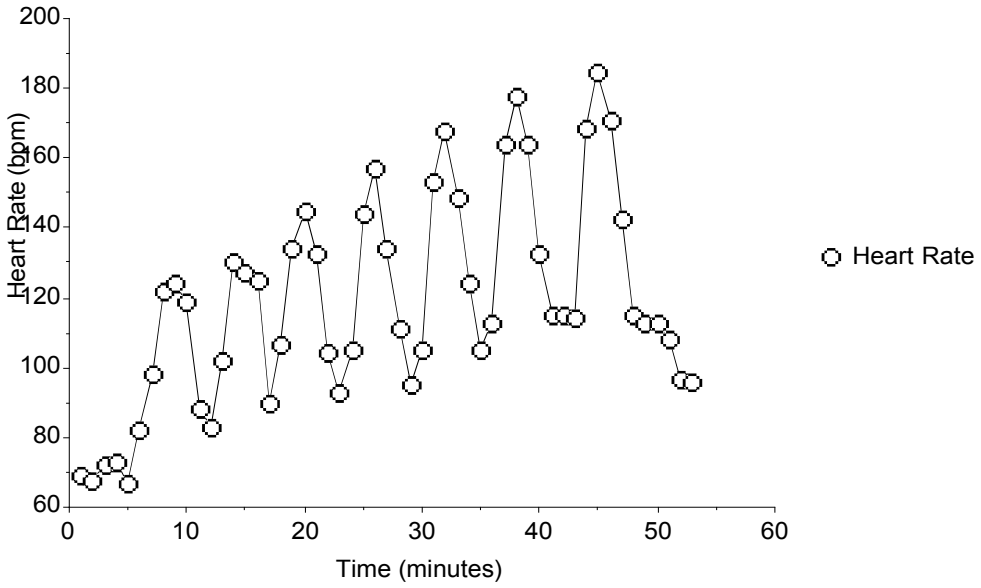


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In addition to HR, mode of exercise, exercise conditions, environmental conditions during the test, and speed or power output at each stage (if applicable) should be recorded for future comparison. The test should be repeated at least twice within a short time period to ensure that the values obtained represent the athlete's actual max HR.

Discontinuous Progressive Maximal Tests

In these tests, the athlete recovers partially between high-intensity exercise bouts. The figure below shows the HR response of an elite cyclist during a discontinuous progressive maximal field test. Although these tests are valid ways of determining max HR, they are time-consuming tests.



Repeated Maximum Efforts

Another method of determining max HR consists of performing a thorough warm-up and then doing 6 to 8 30-second repeats at near-maximum effort with 20- to 30-second pauses between each repetition.

Because it takes some time for the cardiovascular and metabolic systems to adjust once exercise has begun, a single maximum effort initiated from rest and lasting 1 or 2 minutes should not be used to assess max HR. Although it is possible for athletes to reach maximum or near-maximum HR in all-out efforts of short duration, a high level of motivation and arousal is required. As a result, the reproducibility of the data may be affected.

Determining HR during Exercise

If an HR monitor is used, HR values are provided in real time during exercise and associated with a specific time. It is therefore easy to see HR information for a particular moment, throughout a session, or for a specified period of time. However, if no HR monitor is available, the athlete must learn how to determine HR during exercise.

For continuous exercise, HR can be taken either any time throughout the workout or at predetermined times. Where necessary, values can be recorded for later analysis.

For intermittent or interval work, HR should be taken immediately after each repetition.

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Pulse rate recorded manually during exercise should be taken over a 10-second period, using the procedure outlined in the note above.

Determining HR at Rest

Some HR formulas require knowing the athlete's resting HR. Resting HR can be obtained by recording HR during sleep with an HR monitor or by recording HR manually after waking up.

In the latter case, HR *should not* be taken immediately after the alarm has rung or after getting out of bed, as HR is likely to be higher than during sleep. Instead, the athlete should:

- Stay in bed and relax for a few minutes while taking deep, slow, controlled breaths.
- Avoid any brisk movement.
- Take his or her HR over a 15-second period at a radial (thumb-side of the wrist) or carotid (junction of the head and neck) site. If the count is between two heart beats at the end of the 15-second period, add 0.5 to the count.
- Multiply the count by 4 to get resting HR in bpm. For instance, if there are 12.5 beats in a 15-second period, resting HR is estimated at 50 bpm (12.5 x 4 = 50).

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Annex D: Estimated Time to Exhaustion during a Continuous Effort at Various Intensities

The table below indicates the time to exhaustion during continuous efforts at various percentages of MAP. Data are provided for individuals with high, moderate, and low endurance levels. While the data are particularly relevant for running, they can serve as a general point of reference for other forms of exercise. However, the data may not be relevant for non-endurance sports, especially at intensities of 90% and more of MAP.

If athletes train at this percentage of MAP…	And have this level of endurance…	They will become exhausted in… (min)
100	High	8 +
	Moderate	6 - 7
	Low	< 6
95	High	14
	Moderate	12
	Low	< 10
90	High	25 +
	Moderate	20 - 22
	Low	< 18
85	High	60 +
	Moderate	45 - 50
	Low	< 35
80	High	120
	Moderate	75
	Low	< 60
75	High	200 +
	Moderate	120
	Low	< 75
70	High	240 +
	Moderate	180
	Low	< 90
60	High	300 +
	Moderate	200
	Low	< 150

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Annex E: Guidelines for the Training of Athletic Abilities by Athletes' Age

Athletic Abilities		Developmental Age in Years														
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Aerobic Power (intense, short efforts of 2-10 min)	F	☹	☹	☹	☹	☹				☺	☺	☺	☺			
	M	☹	☹	☹	☹	☹	☹				☺	☺	☺			
Aerobic Endurance (long efforts)	F	☹	☹	☹	☹		☺	☺	☺	☺						
	M	☹	☹	☹	☹	☹		☺	☺	☺	☺					
Speed-Endurance	F	☹	☹	☹	☹	☹			☺	☺	☺					
	M	☹	☹	☹	☹	☹	☹			☺	☺	☺				
Strength-Endurance	F	☹	☹	☹			☺	☺	☺	☺	☺	☺				
	M	☹	☹	☹			☺	☺	☺	☺	☺	☺	☺			
Maximum Strength	F	☹	☹	☹	☹	☹	☹	☹			☺	☺	☺			
	M	☹	☹	☹	☹	☹	☹	☹	☹	☹		☺	☺	☺	☺	
Speed-Strength (muscular power)	F	☹	☹	☹	☹	☹	☹	☹	☹			☺	☺	☺		
	M	☹	☹	☹	☹	☹	☹	☹	☹				☺	☺	☺	
Flexibility	F	☺	☺	☺	☺	☺										
	M	☺	☺	☺	☺	☺										
Speed (efforts of 8 seconds or less)	F	☺	☺	☺			☺	☺	☺	☺						
	M		☺	☺	☺				☺	☺	☺	☺				
Speed (fast cadence of movement, short efforts)	F	☺	☺	☺												
	M	☺	☺	☺												
Agility/Balance/ Coordination	F	☺	☺	☺	☺	☺										
	M	☺	☺	☺	☺	☺										
Basic Techniques	F			☺	☺	☺	☺	☺								
	M				☺	☺	☺	☺	☺							
More Advanced Techniques	M F							F	FM	☺	☺	☺	☺			
Tactics and Decision-making	F	☹	☹	☹					☺							
	M	☹	☹	☹					☺							

Legend: ☹ Should be avoided ☺ Optimal training age ☐ Not a priority
▒ In moderation ■ As needed by the sport
F Female M Male

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Annex F: Order of Activities in the Main Part of the Practice

Practices often feature several activities aimed at developing a variety of abilities.

Paying attention to the **order** in which activities take place in the main part of the practice may increase the probability of achieving the desired goal. Here are a few general guidelines about the optimal order of activities.

Early in the Main Part of the Practice…

Athletes are not tired, so try to plan for:

- Activities to acquire **new** techniques, skills, or motor patterns
- Activities that develop or require coordination or balance
- Activities that develop or require speed

Then Consider…

- Activities to develop or require speed-endurance
- Activities that develop or require strength
- Activities that develop or require strength-endurance

Later in the Main Part of the Practice…

Athletes may be tired, so try to plan for:

- Activities to consolidate skills already acquired
- Activities that develop or require aerobic endurance
- Activities to develop flexibility

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ANNEX G: Training Methods — Guidelines and Examples

- This section presents guidelines for training each of the athletic abilities, as well as examples of training methods for each athletic ability.
- Training methods and examples are presented in terms of a number of training variables, including intensity, frequency, and progressions (see page 35 for a discussion of these three key training variables).

Choosing Training Methods

- For any athletic ability, choose training methods that are consistent with:
  - Athletes' training objectives
  - The demands of their sport
  - Athletes' stage of growth and development
  - Athletes' training background
  - Athletes' injury history
  - Athletes' individual strengths and weaknesses
  - The time of the year the training is occurring
  - The training environment

1- Training for Speed

Key Words

- Short efforts
- All-out or near all-out intensity
- Long recovery: W:R = 1:12 - 15
- Highly sport-specific movements

Guidelines

Variable	Must be …
Type of training	Based on intervals
Activities/ movements	Dynamic and highly sport-specific A lot like the movements for which an increase in speed is desired
Intensity	Performed at maximum or near-maximum speed
Duration	Relatively short (less than 5 - 8 seconds), for speed to remain high
Number of repetitions	Relatively low overall; 10 - 16 is the norm, as speed tends to decrease with more reps because of fatigue; a few more reps can be performed if efforts are really short
Recovery between repetitions	Long enough to allow CP stores to return to a high level in the active muscles; W:R = 1:12 - 15 ; this allows the athlete to perform subsequent repetitions at high

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Variable	Must be …
	speed with no major decrease in power output
Recovery between sets	Long, to allow a good replenishment of CP stores A *pause* for 3 to 10 minutes between sets; this results in a more complete recovery and forces the correct energy system to function
Type of recovery	*Very light activity* involving the muscles used during the work interval (e.g., a slow walk after sprinting)
Position in training session	At the beginning of the main part of the training session, when athletes are not yet tired
Safety considerations	Performed after a thorough warm-up to avoid injury
Position in training program	Scheduled when the athlete is not too tired from previous training sessions Preceded by several weeks of other forms of preparatory training (strength-endurance, strength, aerobic stamina)

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Examples of Training Methods for Speed of Locomotion[3]

This Variable…	Should be …	
Type of training	Interval training	
Activities/movements	• As sport-specific as possible • Progressive acceleration before initiating the effort OR • Accelerations performed from a standing start OR • Sudden acceleration when changing direction	
Intensity of each repetition	95% or more of maximum speed for the type of activity involved (running, cycling, swimming, skating; etc.)	
Duration of each repetition*	3 - 5 s or a distance suitable for the type of activity	6 – 10 s or a distance suitable for the type of activity
Number of repetitions per set	4 - 6 +	3 - 5 +
Number of sets	2 - 4	2 - 3
Total number of repetitions	8 - 24	6 - 15
Duration of recovery between repetitions	45 - 75 s	75 - 120 s
Type of recovery between repetitions	Active, very low-intensity recovery, followed by passive recovery for 20 - 30 s before the next effort	
Recovery between sets	Active, low-intensity recovery for 5 to 8 minutes, followed by passive recovery for about 1 minute	
Stop if…	Speed of movement or quality of execution decreases	
Total time (repetitions and recovery)**	15 to 58 minutes	16 to 50 minutes
Frequency***		
❑ For development	2 - 3 X per week, for 4 to 12 weeks	
❑ For maintenance	1 X per week	
For significant improvements in…	4 - 6 weeks	
Dominant energy system(s)	Anaerobic alactic (power component)	
Other training effects, including degree	Coordination, agility Anaerobic alactic system (endurance component) and speed-strength: moderate	

* Excluding the progressive acceleration phase ** Excluding warm-up and cool-down

*** If the ability has high importance in the athlete's sport, use the highest weekly frequency, and apply a progression that enables athletes to complete the maximum volume suggested for each session. This may take several weeks. If the ability has moderate importance in the athlete's sport, start with the lowest weekly frequency, and apply a progression that enables the athlete to complete the minimum volume suggested for each session. This may take several weeks. If there is enough time during practices, try to do more work. If the ability has low importance in the athlete's sport and there isn't enough time to include it in your program, encourage athletes to participate in different sport activities outside your program or during the off-season. This will help them achieve a balanced athletic development.

[3] *Speed of locomotion* refers to covering a given distance as fast as possible, e.g., a sprint in running.

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Examples of Training Methods for Speed of Movement[4]

This Variable…	Should be…
Type of training	Interval training with long pauses
Activities/movements	Ultra-specific sport movements performed against low or no resistance Use of lighter implements or exercise conditions that reduce resistance to movement (e.g., very small gear ratio in cycling)
Intensity	As fast as possible
Duration of each repetition	Less than 1 s for single-action movements About 5 s for cyclical movements
Number of repetitions per set	4 - 5
Number of sets	2 - 4
Total number of repetitions	8 - 20
Duration of recovery between repetition	20 to 30 times longer than the effort
Type of recovery between repetitions	Active, very low-intensity recovery, followed by passive recovery for 20 - 30 s
Recovery between sets	Active, low-intensity recovery for 2 - 3 minutes
Stop if…	Quality of execution or speed of movement decreases
Total time (repetitions and recovery)*	5 to 16 minutes (excluding warm-up and cool-down)
Frequency**	
❑ Development	2 - 3 X per week
❑ Maintenance	1 X per week
Significant improvement in…	4 - 6 weeks
Dominant energy system(s)	Alactic (power component)
Other training effects, including degree	Coordination, agility Speed-strength: moderate

* Excluding warm-up and cool-down

** If the ability has high importance in the athlete's sport, use the highest weekly frequency, and apply a progression that enables athletes to complete the maximum volume suggested for each session. This may take several weeks. If the ability has moderate importance in the athlete's sport, start with the lowest weekly frequency, and apply a progression that enables the athlete to complete the minimum volume suggested for each session. This may take several weeks. If there is enough time during practices, try to do more work. If the ability has low importance in the athlete's sport and there isn't enough time to include it in your program, encourage athletes to participate in different sport activities outside your program or during the off-season. This will help them achieve a balanced athletic development.

[4] *Speed of movement* refers to performing a sport-specific movement as fast as possible without necessarily moving the body, e.g., throwing a ball or moving a racquet in a tennis serve.

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Other Considerations for Speed Training

- Speed training must *not* be viewed as a general conditioning session where more is better and work is harder when recovery is short. Rather, speed training must always be seen as quality work, and recovery between efforts must be long enough to preserve proper technique. This will ensure that the proper adaptations take place at the neuromuscular and energy-systems levels.
- Neural factors play a key role in speed. Athletes can further activate the central nervous system in sprint-type efforts lasting a few seconds by rapidly moving the body parts responsible for moving the body (2 or 3 vertical jumps in running, rapid movements with the arms in swimming, etc.) 30 seconds or so before the actual sprints.
- Performance in speed activities is affected by other athletic abilities such as strength, speed-strength, coordination, and agility.
- During the few seconds of passive recovery that precede the effort, the athlete should concentrate and prepare psychologically to perform at maximum speed while maintaining good technique (mental imagery).
- Maintaining good technique is essential to the development of inter- and intra-muscular coordination. Speed exercises should be interrupted if technique starts to deteriorate. During a speed-training session, coaches must pay attention to the speed or times athletes are achieving *and* to the athlete's technique.
- Progression can be applied by increasing total volume: by adding repetitions within sets, by adding a set, or by increasing intensity. Recovery periods must *not* be reduced when the primary training effect desired is greater speed.
- Whether and how to increase volume depends on the goals of the training program and the athlete's response to speed training. If the athlete can perform the minimal number of reps and sets prescribed in the previous tables without a decrease in speed and quality of execution and without feeling undue fatigue, volume can be increased. Volume can be increased every 2 or 3 weeks thereafter.
- Given the relatively important contribution of the aerobic system in most short-duration cyclical events (see page **Error! Bookmark not defined.**), preparation for speed events should include *some form* of aerobic conditioning.
- Heredity seems critical with regard to speed; the potential for improvement is relatively limited (in the order of 10 - 15%).

More Advanced Methods

- Maximum limb velocity can be increased by adapting training conditions to reduce the resistance that must be overcome during certain movements.
    - In running, cycling, and cross-country skiing, a slightly downward-sloping surface may be used for sprinting; in activities involving throwing or swinging motions, lighter equipment may be used.
    - When air resistance is important (e.g., in cycling, speed skating, and sprinting), athletes may benefit from working with a strong tailwind, at altitude, or behind a motorized vehicle.
    - When an inclined surface is used in running, the eccentric component of the movement will be high, and damage to muscle fibre damage can therefore be more severe than on a flat surface. This can lead to delayed onset muscle soreness in the

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days that follow, which can impair performance. Also, there may be a greater degree of stretching in the antagonist muscles such as the hamstrings. *The slope of the surface should therefore be low (1 to 3%), and the athlete should be in excellent specific physical condition when this type of method is used.* Careful attention should also be paid to the warm-up before the exercise and to the development of flexibility in agonist and antagonist muscle groups in the weeks leading up to the use of such methods. This approach should accordingly be used with caution (not more than once a week), and it should be avoided near important competitions.

2 - Training for Speed-endurance

Key Words

- Below maximal speed, but above maximal aerobic speed
- Repetitions in the range of 10 - 75 s
- Long recovery; length affects the dominant energy system
- Sport-specific movements
- Highly demanding

Guidelines

Variable	Must be …
Type of training	Based on intervals
Activities/ movements	Dynamic and highly sport-specific A lot like the movements for which an increase in speed-endurance is desired
Intensity	Below maximum speed, but above maximum aerobic speed
Duration	Variable, between 10 and 75 s or so, depending on the primary energy system and component (power or endurance) targeted
Number of repetitions	Variable, between 6 and 24 or so, depending on the primary energy system and component (power or endurance) targeted; fewer reps for longer efforts
Recovery between repetitions	W:R of 1:8 to 1:12 for short efforts (10 to 15 s) W:R of 1:6 to 1:8 for moderate and long efforts (20 to 75 s)
Recovery between sets	Long, in the range of 6 to 8 minutes
Type of recovery	*Very light* activity involving the muscles used during the work interval (e.g., a slow walk after sprinting)
Position in training session	Early in the main part of the training session, when athletes are not yet tired
Safety considerations	Performed after a thorough warm-up to avoid injury
Position in training program	Preceded by several weeks of other forms of preparatory training (strength-endurance, strength, aerobic stamina)

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Examples of Training Methods for Speed-Endurance

This Variable…	For Short Efforts, Should Be …	For Intermediate Efforts, Should Be …	For Long Efforts, Should Be …
Type of training	Interval	Interval	Interval
Activities/movements	As sport-specific as possible	As sport-specific as possible	As sport-specific as possible
Target intensity	All-out or near all-out ≈ 95% of the maximum speed associated with 1 rep*	Controlled, paced, in between maximal speed and maximum aerobic speed (MAS) 92%-95 % of the maximum speed associated with 1 rep	Paced, above MAS (110 to 115% of MAS in running, or 92% - 95% of the maximum speed associated with 1 rep)
Duration of each repetition	10 s: W:R = 1:12 15 s: W:R = 1:8	20 s: W:R = 1:6 30 - 45 s: W:R = 1:6 to 1:8	60 - 75 s 90 s (1 set only)
Number of repetitions per set**	4 - 6	3 - 5	4 - 5
Number of sets	3 - 4	2 - 3	1 - 2
Total number of repetitions	12 - 24	6 - 15	4 - 10; maximum of ≈ 12 minutes of effort
Duration of recovery between repetitions***	1 min 30 s - 2 min	1 min 30 s - 4 min	6 min
Type of recovery between repetition	Active, very low intensity	Active, very low intensity	Active, very low intensity
Recovery between sets	Active, low-intensity recovery for ≈ 6 minutes	Active, low-intensity recovery for ≈ 10 minutes	Active, low-intensity recovery for ≈ 10 minutes
Stop if…	Athlete can no longer maintain a high speed	Athlete can no longer maintain the target speed	Athlete can no longer maintain a high speed
Total time (repetitions and recovery)	34 - 70 minutes	28 - 90 minutes	38 - 80 minutes
Frequency******			
❑ For development	2 X per week	2 - 3 X per week	2 X per week
❑ For maintenance	1 - 2 sets, 1 X per week	1 - 2 sets, 1 X per week	1 set, 1 X per week
For significant improvements in…	4 - 6 weeks	4 - 6 weeks	4 - 6 weeks
Dominant energy system(s)	Anaerobic alactic (capacity component)	Anaerobic lactic (power component)	Anaerobic lactic (endurance component)

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This Variable…	For Short Efforts, Should Be …	For Intermediate Efforts, Should Be …	For Long Efforts, Should Be …
Other training effects, including degree	Anaerobic alactic and lactic energy systems (power component); coordination; agility	Anaerobic lactic energy system (endurance component); anaerobic alactic (capacity component); coordination; agility	Anaerobic lactic energy system (power component)

* Set a target distance such that the athlete can work all-out for the work interval chosen

** The higher number of repetitions per set should be for shorter efforts

*** Longer recovery may be needed for efforts closer to all-out intensity for the duration considered

**** If the ability has high importance in the athlete's sport, use the highest weekly frequency, and apply a progression that enables athletes to complete the maximum volume suggested for each session. This may take several weeks. If the ability has moderate importance in the athlete's sport, start with the lowest weekly frequency, and apply a progression that enables the athlete to complete the minimum volume suggested for each session. This may take several weeks. If there is enough time during practices, try to do more work. If the ability has low importance in the athlete's sport and there isn't enough time to include it in your program, encourage athletes to participate in different sport activities outside your program or during the off-season. This will help them achieve a balanced athletic development.

Setting Intensity for Speed-endurance Workouts

For the development of speed-endurance, intensities must be set *between the values for maximum speed and maximum aerobic speed (MAS)*. To adjust such intensities appropriately, given (1) the exercise durations for which the anaerobic energy systems can contribute and (2) the demanding nature of the efforts that must be produced, follow these steps:

- Select a distance corresponding to approximately what the athlete should cover, given the duration selected for the work interval (e.g., 400 m for running efforts lasting 50 to 60 s).
- Have the athlete perform *one maximal effort* over that distance.
- If the time achieved by the athlete over the chosen distance is roughly the intended one, set the distance as an appropriate work interval for speed-endurance work. If not, use a somewhat shorter distance (10 to 15% shorter or as needed) for the work intervals, and repeat the previous step after 10 to 15 minutes of recovery.
- Calculate the *speed corresponding to one maximal repetition over the distance*: Speed (m/s) = Distance (m)/Time (s).
- Set the *target training speed*. Depending on the length of the work intervals, the athlete should aim to produce efforts at 92% to 95% of the speed determined above.
- Determine *target times for the selected work intervals:* Target Time (s) = Distance (m)/Target Training Speed (m/s)

Example: Work intervals of 60 s are to be performed. During the maximal effort, time over 400 m is 61 seconds. The *speed corresponding to one maximal repetition over the distance* is therefore 400 m/61 s = 6.56 m/s. A *target training speed* set at 95% of this value would equal 6.23 m/s. The *target times for the selected work intervals of 400 m* would be 64.2 seconds.

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Other Considerations

- The systematic development of speed-endurance before puberty is NOT recommended.
- Speed-endurance can be developed in sport-specific situations (e.g., team, racquet sports) by designing drills that require athletes to perform various types of technical tasks at high intensity and alternating the periods of effort with active recovery at much lower intensity in accordance with the guidelines in the table above.
- Given the importance of the aerobic system in most events where speed-endurance is an important athletic ability (see Section 1), *some form* of aerobic conditioning and resistance training should precede the use of specific methods designed to improve speed-endurance.
- In cyclical sports, the high-intensity bouts performed during fartlek may contribute to the development or maintenance of speed-endurance; the actual training effect will be determined by the intensity and length of the efforts, as well as their number. Given the random nature of the efforts produced, bouts lasting between 30 and 90 seconds at intensities well above maximal aerobic speed may represent a good stimulus for improving speed-endurance and the power or endurance components of the anaerobic lactic system.

3- Training for Aerobic Stamina

Key Words

- IT at 95 to 105% of MAP for effective MAP training
- IT at 80 to 90% of MAP for quality aerobic endurance training
- CT at 75 to 85% of MAP for quality aerobic endurance training
- CT at 60 to 70% of MAP for general aerobic endurance and conditioning training

Guidelines

Variable	Must be …
Type of training	Variable, depending on whether the power (MAP) or the endurance component is being trained. IT is the most efficient approach for MAP; IT, CT, or fartlek can all be used for aerobic endurance training.
Activities/ movements	Dynamic and sport-specific; should at least involve the same muscle groups as those primarily responsible for locomotion in the sport.
Intensity	Variable, depending on whether the power (MAP) or the endurance component is being trained. IT intensities in the range of: • 95 to 105% of MAP are optimal for MAP training • 80 to 90% of MAP are optimal for aerobic endurance training CT intensities in the range of: • 75 to 85% of MAP are optimal for aerobic endurance training • 60 to 70% of MAP can be used for aerobic endurance training
Duration	Variable, depending on whether the power (MAP) or the endurance component is being trained. When training for:

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Variable	Must be …
	• MAP, IT work efforts can range from a few seconds to 3 minutes or so • Aerobic endurance, IT work efforts can range from 90 s to 6 minutes or more • Aerobic endurance, CT, or fartlek sessions can last between 20 minutes and 3 hours or more
Number of repetitions	CT: One repetition. IT: Variable, depending on intensity and work interval. Can range from about 4 to 30 or so; fewer reps for longer efforts.
Recovery between reps	Not applicable for CT. Active for IT, with the length depending on the duration of the effort; in general, W:R ranges from 2:1 to 1:2 or so.
Position in training session	Should *not* take place before activities aimed at training motor abilities, sport-specific skills, speed, and speed-endurance, as well as most forms of resistance training.
Safety considerations	Ensure proper hydration throughout CT or IT sessions, particularly when exercising in hot and humid conditions. Carbohydrate should be ingested every 20 minutes or so during continuous efforts lasting 90 minutes or more.
Position in sport program	Aerobic endurance before MAP; some aerobic stamina training should take place before emphasizing speed and speed-endurance, with the exact nature of the training for aerobic stamina (type, frequency, volume, etc.) depending on the athlete's sport or position.
Programming considerations	Increase duration first, *then* intensity **Development**: 2 – 3 X per week **Significant improvements** in 6 – 8 weeks **Maintenance:** 1 X per week

Setting Workout Intensities for Aerobic Stamina

The most accurate measure of work intensities in training for aerobic stamina is *percentage of maximum aerobic power (MAP)*. Three methods of estimating percentage of MAP are discussed below:

- Percentage of maximum aerobic speed (MAS)
- Percentage of MAP expressed in watts
- Heart-rate reserve, or the Karvonen formula

Of the three, the method based on heart rate is the *least* accurate.

Percentage of MAS

This method applies to running. Because energy expenditure and speed have an almost perfect linear relationship in running, it is easy to determine the submaximal training speeds corresponding to a given percentage of MAP once maximal aerobic speed (MAS) is known. Such estimates are also very accurate.

The two Léger MAP tests are very useful tools for setting training intensities for a wide range of IT and CT aerobic workouts.

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For instance, if MAS is 20 km/h, a target training speed of 12 km/h corresponds to about 60% of MAP, a target training speed of 15 km/h to 75% of MAP, a target training speed of 18 km/h to 90% of MAP, etc. Once the target training speed is established, the target time for covering a specific distance can be calculated from this formula:

Target Time = Distance/Target Training Speed

Note: *When using the 20-m shuttle run to estimate MAP, the value obtained for MAS must be adjusted to reflect training intensities under normal running conditions.*

Percentage of MAP Expressed in Watts

This method applies to training on ergometers or bicycles.

Energy expenditure and intensity expressed in watts have an almost perfect linear relationship. Once the wattage corresponding to MAP is known from a test conducted on an ergometer or on a bicycle equipped with the appropriate measurement devices, it is easy to determine the wattage corresponding to a given percentage of MAP, and the estimates are quite accurate.

For instance, if MAP is reached at an intensity of 300 watts, 180 watts is 60% of MAP, 240 watts is 80% of MAP, 270 watts is 90% of MAP, etc.

Heart-rate Reserve, or the Karvonen Formula

Because the relationship between HR and work intensity is somewhat linear, HR is frequently used to estimate the percentage of his or her MAP that an athlete is working at.

While HR has certain limitations as a measure of aerobic intensity (see Annex B), it is a useful guide to exercise intensity. This is especially true if HR is used with other methods (e.g., percentage of MAP in watts) or for activities where the relationship between energy cost and speed is not as linear as in running.

Of the various approaches to using HR to estimate the intensity of aerobic workouts, the most accurate is the heart-rate reserve method; it is also called the Karvonen formula. Three HR measurements are needed to calculate HR reserve:

- Max HR
- Resting HR
- HR during exercise

The HR reserve formula is:

Percentage of MAP = (HR during exercise – Resting HR)/(Max HR – Resting HR)

Note: Annex C of this document describes in detail the methods for measuring max HR, resting HR, and HR during exercise.

Example

Athlete A has a maximum HR of 205 bpm and a resting HR of 55. Athlete B has a maximum HR of 190 and a resting HR of 52 bpm. To exercise at an intensity of approximately 80% of MAP, the target HRs should be 175 for Athlete A and 162 bpm for Athlete B.

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For Athlete A:

0.8 = (x – 55)/(205 – 55), where x represents the target HR (unknown at this point)

0.8 = (x – 55)/150

150*0.8 = x – 55

120 = x – 55

175 = x

The target heart rate for Athlete A is 175 bpm.

For Athlete B:

0.8 = (x – 52)/(190 – 52), where x represents the target heart rate (unknown at this point)

0.8 = (x – 52)/138

138*0.8 = x – 52

110 = x – 52

162 = x

The target heart rate for Athlete B is 162 bpm.

When using this formula, coaches are advised to target a *HR range* rather than a *specific value.* For instance, if the objective is to train at about 80% of MAP, Athlete B in the example above could exercise anywhere between 158 and 166 bpm. If the intent is to perform at a relatively constant workload throughout the session, the target range should be increased by 5 to 8 bpm after an hour or so to reflect the rise in HR resulting from dehydration and increased core temperature. Similarly, target HR may need to be adjusted to take into account the type of clothing worn and environmental conditions (see Annex B for more details).

Continuous Training for Aerobic Stamina

For many coaches and athletes, continuous training (CT) is *THE* form of training that comes to mind when the objective is to train aerobic stamina. However, the actual training effects of CT may vary significantly, depending on the intensity and the duration of the workout, as well as the athlete's specialization.

Here are a few key points about CT:

- At low to moderate intensities, the subset of aerobic stamina most likely to be improved or maintained through CT is aerobic endurance, *not MAP*; for CT to affect MAP, the athlete's aerobic fitness must be fairly low.
- At intensities above 80-85% of MAP, CT may lead to improvements in MAP, especially if the athlete's sport *does not* have very high aerobic demands. However, the best way to improve MAP is to do IT at intensities ranging between 95 and 105% of MAP.
- When using CT, the best training effects on aerobic endurance come from workouts performed at intensities higher than 70-75% of MAP.
- Athletes can sustain low-intensity CT (60-65% or less of MAP) for very long periods (up to several hours in the case of endurance athletes), especially if they consume adequate amounts of carbohydrate and water.

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- In well-trained endurance athletes, muscle glycogen stores should not decrease markedly during low-intensity CT, because the rate of glycogen use by the muscles is not very high, and a large proportion of the energy needed comes from fat.
- At intensities of approximately 75% or more of MAP, glycogen is the primary energy source for the working muscles, and the rate of use increases as the effort gets more intense; in most athletes, glycogen stores are greatly diminished after 75 to 90 minutes of exercise at such intensities.
- Low-intensity CT (60-65% or less of MAP) of short to moderate duration can serve as light training sessions, particularly during the Competition Period or the Specific Preparation Phase

Progression in the Use of IT for Aerobic Stamina

Once you have determined that the athlete is capable of completing IT workouts without undue stress (see Section 3), you may want to consider the types of progression that can be used in an IT program for aerobic stamina.

Type of Progression	Possible Progressions	Rationale
Progression in **intensity**	❑ Progress from endurance to MAP ❑ When working on endurance, start with sessions of lower intensity, e.g., 80% of MAP, and increase intensity to 85%, then 90% ❑ When working on power, start with sessions at 95% of MAP, and increase to 100%, then 105%, then 110% of MAP	❑ Allows metabolic, technical/motor, articuloskeletal, and psychological adaptations to occur at lower intensities first, before moving on to the stress of higher intensities
Progression in **duration**	❑ From shorter to longer sessions, regardless of the intensity of the workout	❑ Prepares the athlete to complete progressively longer training sessions
Progression from **quantity** to **quality**	❑ Use sessions with a high number of repetitions but shorter work intervals at the start of the training program, and then progress to longer work intervals but fewer repetitions ❑ This approach can be used for MAP and aerobic endurance, regardless of the intensity of the workouts	❑ Emphasizes total work time at targeted intensities earlier in the program ❑ Progressively increases the ability to sustain longer and longer repetitions before recovering

Fartlek for Aerobic Stamina

Fartlek is a form of training characterized by continuous exercise where the intensity and duration of efforts can be quite variable but there is no set pattern to the change in intensity, as there is in IT. Depending on the intensity and duration of efforts, a fartlek session can contribute to the development of both the aerobic *and* the anaerobic lactic energy systems.

Fartlek can be used as a hard session at any stage of the season, especially during the Specific Preparation Phase and the Pre-competition Phase.

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Here's an example of a group fartlek session in cycling on a circuit that is 5 to 8 km long and includes a good hill:

- Perform a 15-to-20-minute warm-up at 60 - 65% of MAP while inspecting the circuit.
- Lap 1 of the circuit:
  - Ride at a constant pace and at moderate intensity (70 - 75% of MAP) for a few km, then speed up and cycle as hard as possible over 2 or 3 km; then recover actively at 60% or so of MAP for a few minutes before reaching the hill.
  - Start the climb at a good pace, then accelerate suddenly to near-maximal intensity in the middle of the hill, and continue the intense effort for the 2 or 3 km after the hill.
  - Complete the rest of the circuit at a constant speed that corresponds to 70 - 75% of MAP.
- Lap 2 of the circuit:
  - Cycle the circuit at moderate speed, sprinting on the hill and maintaining the effort on the flat for 300 or 400 m; then recover at low speed for several minutes for the rest of the lap.
- Lap 3 of the circuit:
  - Cycle the circuit as quickly as possible, with riders taking turns setting the pace for 30 to 45 seconds; the athlete who leads rides at his or her own pace, and all riders sprint to an imaginary finish at the end of the lap.
- Finish with a cool-down period of several minutes.

Other Considerations

- Aerobic endurance can be looked as:
  - The ability to sustain a high relative power output for a given period of time (for instance, an athlete capable of sustaining 80% of his or her MAP for 1 hour has greater endurance than another who can sustain only 75% of MAP for1 hour)

  OR
  - The ability to maintain a given percentage of MAP for the longest possible time (for instance, an athlete capable of sustaining 100% of his or her MAP for 8 minutes has a greater endurance than another who can sustain the same workload for only 6 minutes)
- An athlete's aerobic endurance is *independent of the level of his or her MAP*. Therefore, athletes with a very high MAP may or may not have a lot of endurance, and athletes with a low MAP may have extremely high endurance.
- A number of factors can affect aerobic endurance:
  - Fuel supply (glycogen stores in the muscles, as well as the ability to spare glycogen by mobilizing and using fat)
  - Hydration status
  - Capacity to dissipate heat
  - Availability of glucose to maintain blood sugar level (glycemia) during exercise

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- Economy of motion (i.e., spending less energy at a given intensity because of superior technique)
- Motivation and psychological factors

- MAP and endurance both play key roles in endurance events in cyclical sports:
  - For short events (time ≤ 15 minutes), MAP is by far the most important determinant of performance
  - Even for longer events, such as marathon running, MAP remains an important determinant of performance, but other factors such as running economy (technical efficiency) and endurance also play a key role
  - Athletes with very high endurance and a high but not exceptionally high MAP can still perform well, particularly in events lasting three hours or more
- Interval or intermittent training for aerobic stamina training:
  - Usually makes it possible to do a higher volume of high-intensity work during a training session than would be possible with CT
  - Can be considered more specific than CT for many sports (team sports, racquet sports, combative sports, etc.)
  - May benefit athletes prone to injury when they do high volumes of CT work
- In non-cyclical sports (e.g., team sports, racquet sports), aerobic stamina can be developed in sport-specific situations through drills that require athletes to perform various technical tasks at high intensity for 30 seconds to 2 minutes with a W:R of 1:1 or 2:1, repeated for a total of 12 to 15 minutes at high intensity. These types of intermittent efforts should allow athletes to maintain relatively high intensity throughout, which can be effective in improving MAP. Athletes can also simulate game-like situations by playing non-stop for 5 to 10 minutes. Coaches should have extra balls, pucks, etc., on hand to minimize recovery periods if the ball or puck goes out of play.

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