TRAINING AND TESTING THE ELITE ATHLETE

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The performance of a top-class athlete can be improved by appropriate training. The fitness training should be closely related to the activities of the athlete during competition. Furthermore, the capacity of the athlete should be known. For that purpose, Yo-Yo tests can be used since they have been shown to be sensitive and to give valid measures of performance in many sports. The fitness training can be divided into aerobic, anaerobic and specific muscle training. Each type of training has a number of subcategories, which allows for a precise execution of the training when the aim of the training is known. A critical factor when training elite athletes is when to do what, i.e. to plan the training. An example of the preparation of the Danish National soccer team for the European Championship 2004 is given in the text with examples of physiological measurements and testing, which also takes individuals' needs into account.

Keywords: aerobic, anaerobic, heart rate, planning fitness training, training categories, Yo-Yo testing

Introduction

Performance of an athlete in top-sport depends on the athlete's technical, tactical, physiological, and psychological/social characteristics (Figure 1). These elements are closely linked to each other, e.g., the technical quality of an athlete may not be utilized if the athlete's tactical knowledge is low. The physical demands in a sport are related to the activities of the athlete. In some sports, continuous exercise is performed with either a very high (e.g., 400-m run) or moderate intensity (e.g., marathon run) during the entire event. In other sports, like soccer and basketball, athletes perform different types of exercise ranging from standing still to maximal running with varying intensity. Under optimal conditions, the demands in sport are closely related to the athlete's physical capacity, which can be divided into the following categories: (i) the ability to perform prolonged exercise (endurance); (ii) the ability to exercise at high intensity; (iii) the ability to sprint; and (iv) the ability to develop a high power output (force) in single actions during competition such as kicking in soccer and jumping in basketball (Figure 1). The performance within these categories is based on the characteristics of the respiratory and cardiovascular system as well as the muscles, combined with the interplay of the nervous system. The muscular system is constituted by a multitude of components, which have important influence on the mechanical and metabolic behavior of the muscle (Figure 1). Muscle morphology and architecture, and myosin isoform composition play a major role in the contractile strength characteristics of the muscle evaluated as maximal isometric, concentric, and eccentric contraction force, maximal rate of force development, and power generation. Glycolytic muscle enzyme levels and ionic transport

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systems are major determinants of anaerobic muscle performance, both when expressed as anaerobic power and capacity. Likewise, mitochondrial enzyme levels and capillary density exert a strong influence on aerobic muscle performance in turn affecting the force development and the maximal power output of human skeletal muscle, while also influencing the endurance performance of the muscle fibers. The respiratory, cardiovascular, and muscle characteristics are determined by genetic factors but they can also be developed by training. A number of environmental factors such as temperature and for outdoor sports, the weather and the surface of

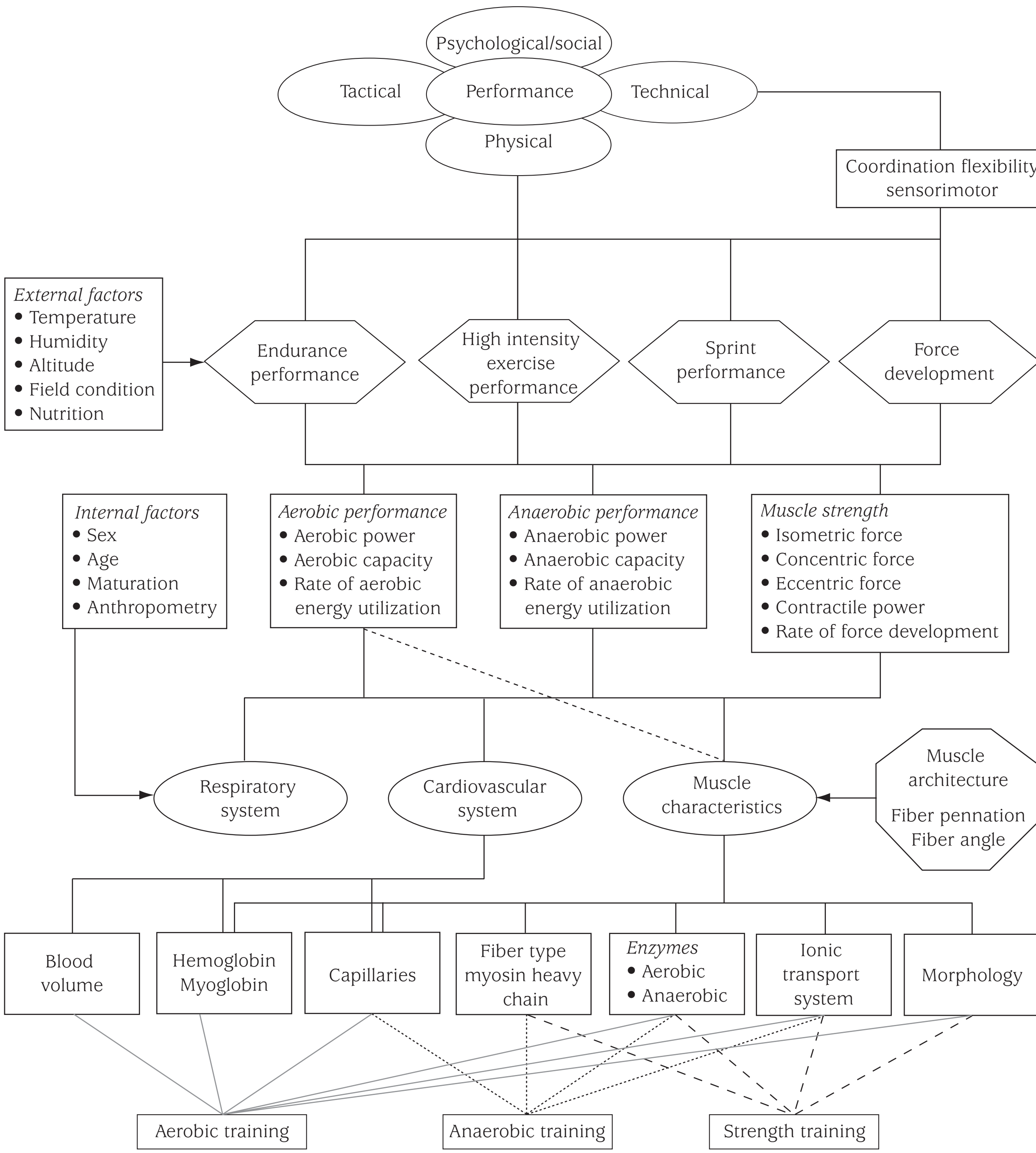

Fig. 1 A holistic model of the determinants of sports performance.

the competition ground also influence the demands of the athletes.

In some sports it is very important for the athlete to bear a very high physical capacity at least in one of the categories to perform at a top level, e.g., a marathon runner needs a high endurance capacity, but not a well-developed ability to produce a high power output in a single action. In other sports, such as team sports, an athlete may need an all-round fitness level. In such sports, an athlete with a moderate endurance capacity may to some extent compensate this weakness by having good capabilities in other areas relevant to the sport, e.g., a high technical standard or good sprinting ability.

In this article, the cardiovascular and muscular adaptations with regard to training or inactivity are addressed and the various components of fitness training are presented. The value of using field test to evaluate the performance of athletes is also described. Finally, how to prioritize the training of top athletes with a special emphasis on the preparation of the Danish National soccer team for the European Championship 2004 is discussed.

Evaluation of physical performance of an athlete

Competition naturally provides the best test for an athlete, but it is difficult to isolate the various components within the sport and get objective measures of performance. Fitness testing can provide relevant information about specific parts of a sport. Before selecting a test, clear objectives should be defined. The reasons for testing an athlete are outlined below:

- To study the effect of a training program
- To motivate the athletes to train more
- To give an athlete objective feedback
- To make an athlete more aware of the aims of the training
- To evaluate whether an athlete is ready to compete
- To determine the performance level of an athlete during a rehabilitation period
- To plan short- and long-term training programs
- To identify the weaknesses of an athlete

To obtain useful information from a test, it is important that the test is relevant and resembles the conditions of the sport in question. For example, a cycle test is of minor relevance for a swimmer. There are a number of commonly used laboratory tests, which evaluate the various aspects of performance (Figure 1). These include determination of maximum oxygen uptake to evaluate the athletes' ability to take up and utilize oxygen. A Wingate test, which consists of 30 s of maximal cycle exercise, aiming at determining the maximum anaerobic power and ability to maintain a high power output. Strength measurements in which the strength of an isolated muscle group is measured either during isometric, concentric, or eccentric contractions are also used as laboratory tests. Such tests provide general information about the capacity of an athlete and may separate the different performance levels of athletes within a sport. In some sport such general tests can provide information on the requirement of the sport, e.g., to be a top-class cross-country skier a maximum oxygen uptake higher than 80 $mL\,min^{-1}\,kg^{-1}$ is required.

These classical laboratory tests may also be useful for comparisons of performance between various sports. However, to a minor extent, they may only express the performance of the athlete during competition. For example, Figure 2 shows that for 20 top-class soccer players there was no relationship between knee-extensor strength and kick performance, suggesting that the strength of the knee-extensors alone does not determine the final impact on the ball in a

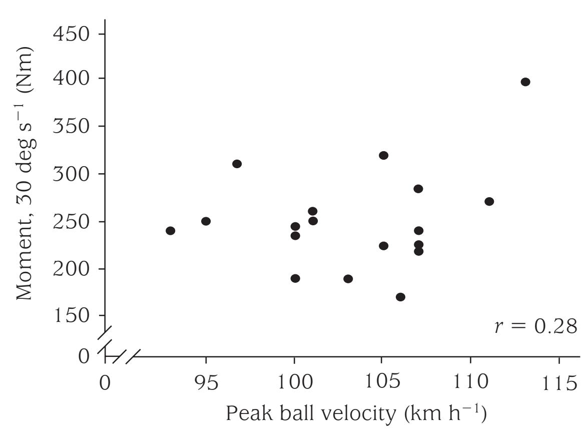

Fig. 2 Individual relationship between kick performance (peak ball velocity) and maximum knee extensor torque (Nm) under isokinetic loading at a velocity of 30 $deg\,s^{-1}$ for elite soccer players.

kick. Strength of other muscle groups, such as the hip muscles, may be important and technical skill is also a predominant factor in the soccer kick, which incorporates a complex series of synergistic muscle movements, involving the antagonistic muscles as well. A test that is more specific to the sport will increase its validity, i.e., the test result reflects the better performance of an athlete. A number of examples of sport-specific tests that are simple to organize is described later in this article. Some of them require special equipment to simulate the activities in the sport while the others only need simple materials.

Rowing is characterized by a certain movement involving body muscles. A rowing ergometer is developed in which it is possible to simulate the movement in the boat. Performance can be evaluated by measuring the total work performed within a given time, e.g., 6 min as in some races, or the time it takes to get exhausted at a given external work rate. To obtain further information about the capacity of the oarsman tested, a number of physiological measurements can be added to the test such as pulmonary oxygen uptake wherein the rate of rise of oxygen uptake in the initial phase of exercise and the peak oxygen uptake during the rowing are determined. Undoubtedly such a test has a high validity.

One of the most widely used field test is the Cooper test, where the participants are made to run the longest possible distance in 12 min. Though it is simple to perform, it has the disadvantage that the athletes are required to know how to tactically perform the test to obtain the best test result. It also requires the distance to be least 200 m. Nevertheless, the popularity of the test is probably due to the fact that it is simple and a correlation between performance and $\dot{V}O_{2max}$ has been observed. However, the type of running in the test may only be relevant for track runners and they have anyway the simplest test, namely the competition. Further, the relationship between the test and $\dot{V}O_{2max}$ may not be very useful, since in many sports, such as ball games, $\dot{V}O_{2max}$ is a poor marker of physical performance during competition.

The Yo-Yo tests

The Yo-Yo tests are a number of tests which in an easy way evaluates various aspects of performance. The tests contain running activities that are relevant for many sports. With the tests, the physical capacity is evaluated in a fast and simple manner. Two markers are positioned at a distance of 20 m. A CD is placed in a CD player and the test is performed. The participant runs like a Yo-Yo back and forth between the markers at given speeds that are controlled by the CD. The speed is regularly increased, and the test ends when the individual can no longer maintain the speed. The test result is determined as the distance covered during the test. Using the Yo-Yo tests, it is possible to obtain information about a large number of athletes within a short time, and the tests have higher performance validity during competition than laboratory tests. There are three Yo-Yo tests. In one, called the Yo-Yo endurance test, the participants perform continuous exercise, and in the other two, the participants carry out intermittent exercise, namely the Yo-Yo intermittent endurance test and the Yo-Yo intermittent recovery test. The principles of the Yo-Yo intermittent test are similar to the continuous Yo-Yo tests, except that in the intermittent tests, the athletes have a period of active rest between each of the 2×20-m shuttles. The tests can be used by anyone, irrespective of training status, since each of the three tests has two levels.

The *Yo-Yo endurance test* lasts for 5–15 min and is used for the evaluation of the ability to work continuously for a longer period of time. This test is especially useful for individuals who participate in endurance exercise, such as distance running. The *Yo-Yo intermittent endurance test* lasts for 10–20 min and consists of 5–18 s intervals of running interspersed by regular 5-s rest periods. The test evaluates an individual's ability to repeatedly perform running intervals over a prolonged period of time. The test is especially useful for the athletes who perform interval sports such as tennis, team handball, basketball, and soccer. Figure 3 shows the performance of top-class basketball players. The *Yo-Yo intermittent recovery test* lasts for 2–15 min and focuses on the ability to recover after intense exercise. Between each exercise period (5–15 s) there is a 10-s pause. The test is particularly suitable for sports in which the ability to perform intensive exercise after short recovery periods can be decisive for the outcome of a competition such as badminton, soccer, basketball, ice-hockey, and football. The test is shown to have a high reproducibility, sensitivity, and validity for soccer (Krustrup et al. 2003).

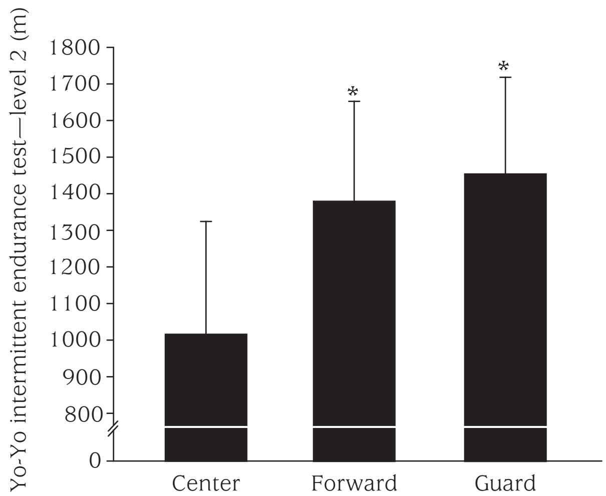

Fig. 3 Yo-Yo intermittent endurance level 2-test performance for elite basketball players at different playing positions. * Significantly better performance for guards and forwards compared to center players (after Oliveira et al. 1998).

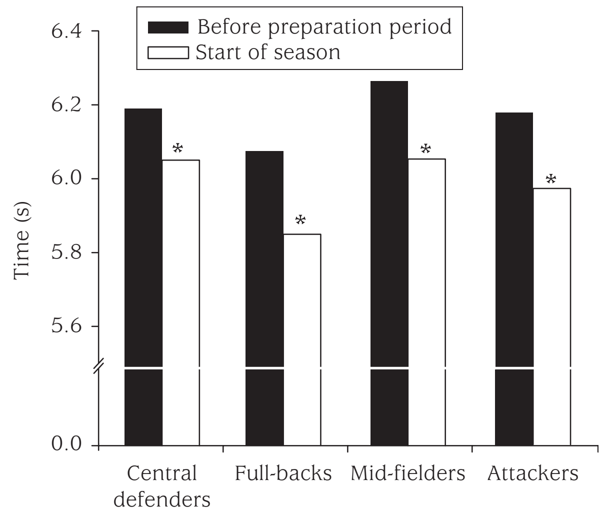

Fig. 5 Repeated sprint performance before and after the pre-seasonal preparation period of elite soccer players at various playing positions. * Significant difference between the test before and after the pre-seasonal preparation period.

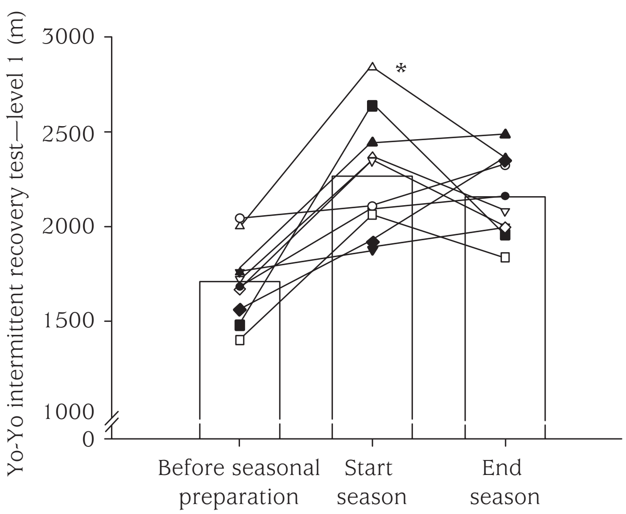

Fig. 4 Yo-Yo intermittent recovery level-1 test performance for 10 elite soccer players before the pre-seasonal preparation, at the start and end of the season. * Significantly better performance at the start of the season compared to before the pre-seasonal preparation.

Thus, the test is able to pick up changes in performance as shown in Figure 4, where the performance of soccer players at various stages of a preparation period is given. Performance of the *Yo-Yo intermittent recovery test* (level 1) in the pre-season preparation of professional soccer players was improved by 31% with only a minor change in $\dot{V}O_{2max}$.

It is also possible to perform the tests without exhausting the participants. Then the test is stopped after a given time and the heart rate is measured to evaluate the development of the cardiovascular system. The lower the heart rate the higher is the capacity of the individual. Thus, it has been observed that there is a relationship between heart rate after 6 min of the Yo-Yo intermittent endurance test (level 2) and the amount of high-intensity running during intense parts of matches for players in the Danish National Soccer team. Such nonexhaustive tests can be used frequently and is particularly useful for athletes who are in a rehabilitation period.

Repeated sprint test

The ability to be able to run fast and to do repeated sprints can be easily tested by having the athlete to sprint a given distance a number of times separated by a period of recovery that allow a decrease in performance. In relation to the latter aspect Balsom et al. (1992) observed that performance in a 30-m sprint could be maintained when subjects have a recovery period of 120 s between each sprint, but a marked decrease was found when the recovery time was 30 s. This means that in order to evaluate an athlete's ability to recover from intense exercise the rest period between 30-m sprints should be 30 s or shorter. In a test to measure the ability to sprint and at the same time change direction, athletes perform seven sprints each lasting about 7 s, separated by 25-s rest periods. Figure 5 shows how the performance of

25 professional soccer players changed during a preparation period. The significant decrease in the sprint time shows that the test can reveal changes in performance.

Fitness training

In many sports the athletes need a high level of fitness to cope with the physical demands of the competition and to allow for their tactical and technical skills to be utilized throughout the competition. Fitness training in any sport has to be focused on the demands in the sport and in many sports is has to be multifactorial to cover the different aspects of physical performance in the sport. Therefore, the exercise performed should, whenever it is possible, resemble the activities during competition as closely as possible.

It is useful to divide fitness training into a number of components related to the purpose of the training (Figure 6). The terms aerobic and anaerobic training are based on the energy pathway that dominates during the activity periods of the training session. Aerobic and anaerobic training represent exercise intensities below and above the maximum oxygen uptake, respectively. However, in some sport like ball games, in which the ball is used in the fitness training, the exercise intensity for an athlete varies continuously, and some overlap exists between the two categories of training (Bangsbo 2005). The separate components within fitness training are described briefly in the next few paragraphs.

Aerobic training

Aerobic training causes changes in central factors such as the heart and blood volume, which result in a higher maximum oxygen uptake (Ekblom 1969). A significant number of peripheral adaptations also occur with this type of training (Henriksson & Hickner 1996). The training leads to proliferation of capillaries and an elevation of the content of mitochondrial enzymes, as well as the activity of lactate dehydrogenase 1–2 (LDH_{1-2}) isozymes. Further, the mitochondrial volume and the capacity of one of the shuttle systems for NADH are elevated (Schantz & Sjoberg 1985). These changes cause marked alterations in muscle metabolism. The overall effects are an enhanced oxidation of lipids and sparing of glycogen, as well as a lowered lactate production, both at a given and at the same relative workrate (Henriksson & Hickner 1996).

The optimal way to train the central versus the peripheral factors is not the same. Maximum oxygen uptake is most effectively elevated by exercise intensities of 80–100% of $\dot{V}O_{2max}$. For a muscle adaptation to occur, an extended period of training appears to be essential, and therefore, the mean intensity has to be $<80\%$ of $\dot{V}O_{2max}$ once in a while. This does not imply that high-intensity training does not elevate the number of capillaries and mitochondrial volume in the muscles engaged in the training, but the duration of this type of training is often too short to obtain optimal adaptations at a local level.

The dissociation between changes in $\dot{V}O_{2max}$ and muscle adaptation by means of training and detraining

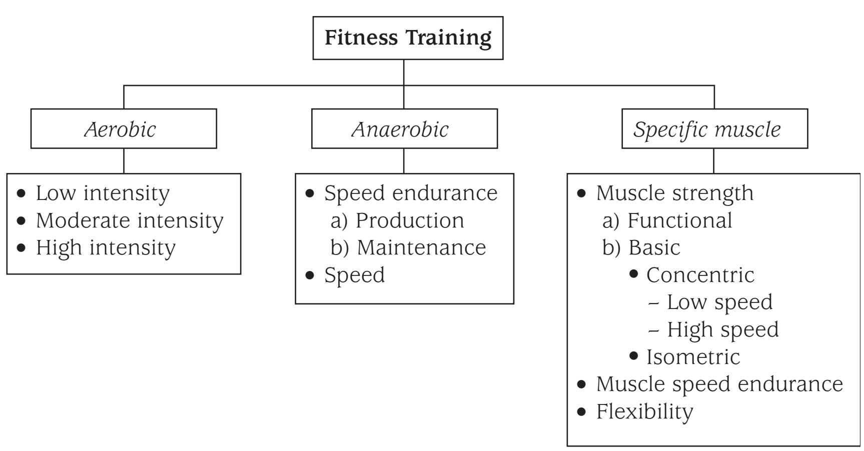

Fig. 6 Components of fitness training.

is illustrated by the results from the two studies. In one study, long-distance runners were kept inactive for 2 weeks (first week with the leg in a cast) which did not result in a change in $\dot{V}O_{2max}$ (Houston et al. 1979). On the other hand, the detraining period led to a 25% decrease in performance in an exhaustive run (from about 18 to 13.5 min) which was associated with a 24% lowering of the activity of succinate dehydrogenase (SDH). In the following 2 weeks of retraining, $\dot{V}O_{2max}$ did not change, whereas performance and SDH were lowered by 10% and 20%, respectively. The level of inactivity does not have to be as extreme as in this study to have a marked effect on performance and muscle respiratory capacity. In another study top-class soccer players abstained from training for 3 weeks (Bangsbo & Mizuno 1988). It was found that $\dot{V}O_{2max}$ was unaltered, whereas performance in a field test was lowered by 8%, and there was a reduction of 20–30% in oxidative enzymes.

The recovery processes from intense exercise are related both to the oxidative potential and to the number of capillaries in the muscles (Tesch & Wright 1983). Thus, aerobic training not only improves endurance performance of an athlete, but also appears to influence an athlete's ability to repeatedly perform to maximal efforts. The overall aim of aerobic training is to increase the work-rate during competition, and also in ball games to minimize a decrease in technical performance as well as lapses in concentration induced by fatigue towards the end of a game. The specific aims of aerobic training are as follows:

- To improve the capacity of the cardiovascular system to transport oxygen. Thus, a larger percentage of the energy required for intense exercise can be supplied aerobically, allowing an athlete to work at higher exercise intensity for prolonged periods of time
- To improve the capacity of muscles specifically used in the sport to utilize oxygen and to oxidize fat during prolonged periods of exercise. Thereby, the limited store of muscle glycogen is spared and an athlete can exercise at a higher intensity towards the end of a competition
- To improve the ability to recover after a period of high-intensity exercise in team sports. As a result, an athlete requires less time to recover before being able to perform in a subsequent period of high-intensity exercise

Components of aerobic training

Aerobic training can be divided into three overlapping components: aerobic low-intensity training ($Aerobic_{LI}$), aerobic moderate-intensity training ($Aerobic_{MO}$), and aerobic high-intensity training ($Aerobic_{HI}$; Figure 6). Table 1 shows the principles behind the various categories of aerobic training, which take into account that in some sports the training may be performed as a game, and thus, the heart rate of the athlete may frequently alternate during the training.

During $Aerobic_{LI}$ the athletes perform light physical activities, such as jogging and low-intensity games. This type of training may be carried out the day after a competition or the day after a hard training session to help the athlete to return to a normal physical state. $Aerobic_{LI}$ may also be used to avoid the athletes from getting into a condition known as "overtraining" in periods involving frequent training sessions and a busy competitive schedule.

The main purpose of $Aerobic_{MO}$ is to elevate the capillarization and the oxidative potential in the muscle (peripheral factors). Thus, the functional significance is an optimization of the substrate utilization and thereby an improvement in endurance capacity. The main aim of $Aerobic_{HI}$ is to improve central factors such as the pump capacity of the heart, which is closely related to $\dot{V}O_{2max}$. These improvements increase an athlete's capability to exercise repeatedly at high intensities for prolonged periods of time. Figure 7 shows the changes in heart rate for two soccer players performing aerobic high-intensity training in a soccer drill called pendulum (Bangsbo 2005).

Table 1. Principles of aerobic training

Aerobic training	Heart rate			
	Mean		Range	
Low intensity	65*	130†	50–80*	100–160†
Moderate intensity	80*	160†	65–90*	130–180†
High intensity	90*	180†	80–100*	160–200†

* Measurement in $\%HR_{max}$ (maximal heart rate).
†Measurement in beats min^{-1}, if $HR_{max} = 200$ beats min^{-1}.

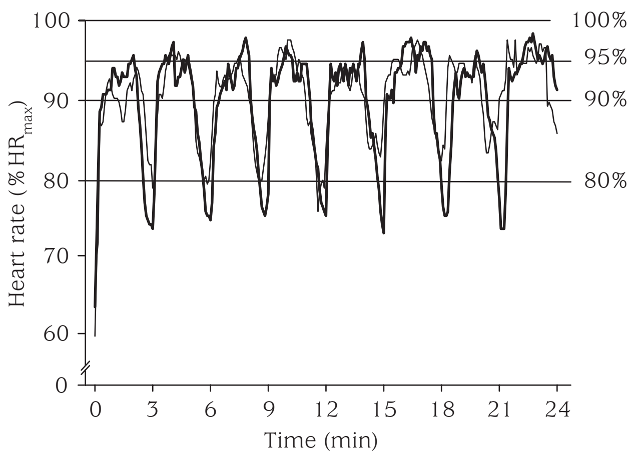

Fig. 7 Heart rate in percentage of individual maximal heart rate (HR_{max}) for two players during an aerobic high-intensity soccer drill called "Pendulum". The maximal heart rates of the players were 185 and 206 beats min^{-1}.

Anaerobic training

In a number of sports an athlete performs activities that require rapid development of force such as sprinting, quickly changing direction or jumping, which are associated with a high rate of creatine phosphate (CP) utilization. Also in many sports, the lactate-producing energy system (glycolysis) is highly stimulated during periods of competition. Therefore, the capacity to perform high-intensity exercise, and in many sports repeated intense exercise, may specifically have to be trained. This can be achieved through anaerobic training.

Anaerobic training results in an increase in the activity of creatine kinase and glycolytic enzymes. Such an increase implies that a certain change in an activator results in a higher rate of energy production of the anaerobic pathways. Intense training does not appear to influence the total creatine phosphate pool, but it allows the muscle glycogen concentration to be elevated, which is of importance for performance during repeated high-intensity exercise (Reilly & Bangsbo 1998). The capacity of the muscles to release and neutralize H^+ (buffer capacity) is also increased after a period of anaerobic training (Juel et al. 2004; Pilegaard et al. 1999). This will lead to a lower reduction in pH for a similar amount of lactate produced during high-intensity exercise. Therefore, the inhibitory effects of H^+ within the muscle cell are smaller, which may be one of the reasons for a better performance in high-intensity tests after a period of anaerobic training. Another important effect of anaerobic training is an increased activity of the muscle Na^+/K^+ pumps resulting in a reduced net loss of potassium from the contracting muscles during exercise, which may also lead to increased performance (Nielsen et al. 2004).

The overall aim of anaerobic training is to increase an athlete's potential to perform high-intensity exercise. The specific aims of anaerobic training are summarized as follows.

- To improve the ability to act quickly and to produce power rapidly. Thus, an athlete reduces the time required to react and elevates the performance of sprinting.
- To improve the capacity to produce power and energy continuously via the anaerobic energy-producing pathways. Thereby, an athlete elevates the ability to perform high-intensity exercise for a longer period of time.
- To improve the ability to recover after a period of high-intensity exercise, which is particularly important in ball games. As a result, an athlete requires less time before being able to perform maximally in a subsequent period of exercise, and in ball games the athlete will, therefore, be able to perform high-intensity exercise more frequently during a match.

Components of anaerobic training

Anaerobic training can be divided into speed training and speed endurance training (Figure 6). The aim of speed training is to improve an athlete's ability to act quickly in situations where speed is essential. Speed endurance training can be separated into two categories: production training and maintenance training. The purpose of production training is to improve the ability to perform maximally for a relatively shorter period of time, whereas the aim of maintenance training is to increase the ability to sustain exercise at a high intensity. Table 2 shows the principles of the various categories of anaerobic training.

Anaerobic training must be performed based on an interval principle. During speed training, the athletes should perform maximally for a shorter period of time (<10 s). The periods between the exercise bouts should be long enough for the muscles to recover to near-resting conditions, to enable an athlete to perform maximally in a subsequent exercise bout. In many sports, speed is not

Table 2. Principles of anaerobic training

Anaerobic training	Exercise(s)	Rest(s)	Intensity*	Repetitions
Speed	2–5	>50	Maximal	5–20
	5–10	>100	Maximal	2–10
Speed endurance production	20–90	>5 times exercise duration	Very high	2–10
Speed endurance maintenance	20–90	<3 times exercise duration	High–very high	2–10

*Maximal, very high and high intensity corresponds to 100%, 70–100% and 45–70% of maximal intensity, respectively.

merely dependent on physical factors. It also involves rapid decision making, which must then be translated into quick movements. Therefore, in ball games speed training should mainly be performed with a ball. Speed drills can be designed to promote an athlete's ability to sense and predict situations, and the ability to decide on the opponents' responses in advance.

By speed endurance training the creatine kinase and glycolytic pathways are highly stimulated. The exercise intensity should be almost maximal to elicit major adaptations in the enzymes associated with anaerobic metabolism. In production training the duration of the exercise bouts should be relatively short (20–40 s), and the rest periods in between the exercise bouts should be comparatively long (2–4 min) in order to maintain a very high intensity during the exercise periods throughout an interval training session. In maintenance training the exercise periods should be 30–90 s and the duration of the rest periods should be one- to three-fold longer than the exercise periods, to allow athletes to become progressively fatigued. The adaptations caused by speed endurance training are mostly localized to the exercising muscles. Thus, it is important that an athlete performs movements in a manner similar to during competition, e.g., an oarsman should train in the boat or on a rowing ergometer. In ball games this can be obtained by performing high-intensity games or drills with a ball.

Specific muscle training

Specific muscle training involved training of muscles in isolated movements. The aim of this type of training is to increase the performance of a muscle to a higher level than can be attained just by participating in the sport. Specific muscle training can be divided into muscle strength, muscle speed endurance, and flexibility training (Figure 6). The effect of this form of training is specific to the muscle groups that are engaged, and the adaptation within the muscle is limited to the kind of training performed. A brief description of muscle strength training is given below. Further information about strength training as well as an overview of muscle endurance and flexibility training can be obtained elsewhere (Blomfield & Wilson 1998; Bangsbo 1994).

Strength training

In many sports there are activities that are forceful and explosive, e.g., high-jumping, hiding in boxing, and turning in ice hockey. The power output during such activities is related to the strength of the muscles involved in the movements. Thus, it is beneficial for an athlete in such sports to have a high level of muscular strength, which can be obtained by strength training.

Strength training can result in hypertrophy of the muscle, partly through an enlargement of muscle fibers. In addition, training with high resistance can change the fiber-type distribution in the direction of fast twitch fibers (Aagaard & Bangsbo 2005; Andersen et al. 1994). There is also a neuromotor effect of strength training and a part of the increase in muscle strength can be attributed to changes in the nervous system. Improvements in muscular strength during isolated movements seem closely related to training speeds. However, significant increase in force development at very high speeds (10–18 rad s^{-1}) have also been observed with slow-speed high-resistance training (Aagaard et al. 1994).

One essential function of the muscles is to protect and stabilise joints of the skeletal system. Hence, strength training is of importance also in preventing injuries as well as re-occurrence of injuries. A prolonged period of inactivity, e.g., during recovery from an injury, will considerably weaken the muscle. Thus, before an athlete returns to training after an injury, a period of strength training is needed. The length of time required to regain strength depends on the duration of the inactivity period but generally several months are needed. For a group of soccer players observed 2 years after a knee operation, it was found that the average strength of the quadriceps muscle of the injured leg was only 75% of the strength in the other leg (Ekstrand 1982).

The overall aim of muscle strength training is to develop an athlete's muscular make-up. The specific aims of muscle strength training are:

- To increase muscle power output during explosive activities such as jumping and accelerating
- To prevent injuries
- To regain strength after an injury

Components of strength training

Strength training can be divided into functional strength training and basic strength training (Figure 6). In functional strength training, movements related to the sport are used. The training can consist of activities in which typical movements are performed under conditions that are physically more stressful than normal. During basic strength training muscle groups are trained in isolated movements. For this training different types of conventional strength training machines and free weights can be used, but the body weight may also be used as resistance. Strength training should be carried out in a manner that resembles activities and movements specific to the sport. Based on the separate muscle actions the basic strength training can be divided into isometric, concentric and eccentric muscle strength training (Figure 6). Common to the different types of strength training is that the exercise should be performed with a maximum effort. After each repetition an athlete should rest a few seconds to allow for a higher force production in the

Table 3. Training schedule for two 9-day periods (phases 1 and 2) for the Danish National Soccer team before EURO 2004

Day	Phase 1		Phase 2	
	Morning	Afternoon	Morning	Afternoon
1	Yo-Yo IE2 test Technical/tactical training	Aerobic_{HI} training (6 × 2 min) Play—20 min	Yo-Yo IE2 test Technical/tactical training	Speed training Technical/tactical training Play—20 min
2	Free	Technical/tactical training	Free	Aerobic_{HI} training (6 × 2 min) Technical/tactical training Play—20 min
3	Technical/tactical training	Speed training Technical/tactical training Speed endurance maintenance training	Technical/tactical training	Speed training Technical/tactical training
4	Free	Technical/tactical training Play—30 min	Group C: Speed endurance Production training	Friendly game (evening)
5	Free	Speed training Aerobic_{HI} training (8 × 2 min) Play—20 min	Free (traveling)	Free (traveling)
6	Free	Technical/tactical training Group C: Aerobic_{HI} training (6 × 2 min)	Aerobic_{MI} (3 × 5 min) Play—30 min	Free
7	Free	Friendly game	Technical/tactical training	Speed training Technical/tactical training Speed endurance production training
8	Free	Group A: Recovery training Group B: Speed training Play—30 min	Free	Technical/tactical training
9	Free	Aerobic_{HI} training (8 × 2 min) Play—20 min	Yo-Yo IE2 test Technical/tactical training	Speed training Technical/tactical training Play—20 min

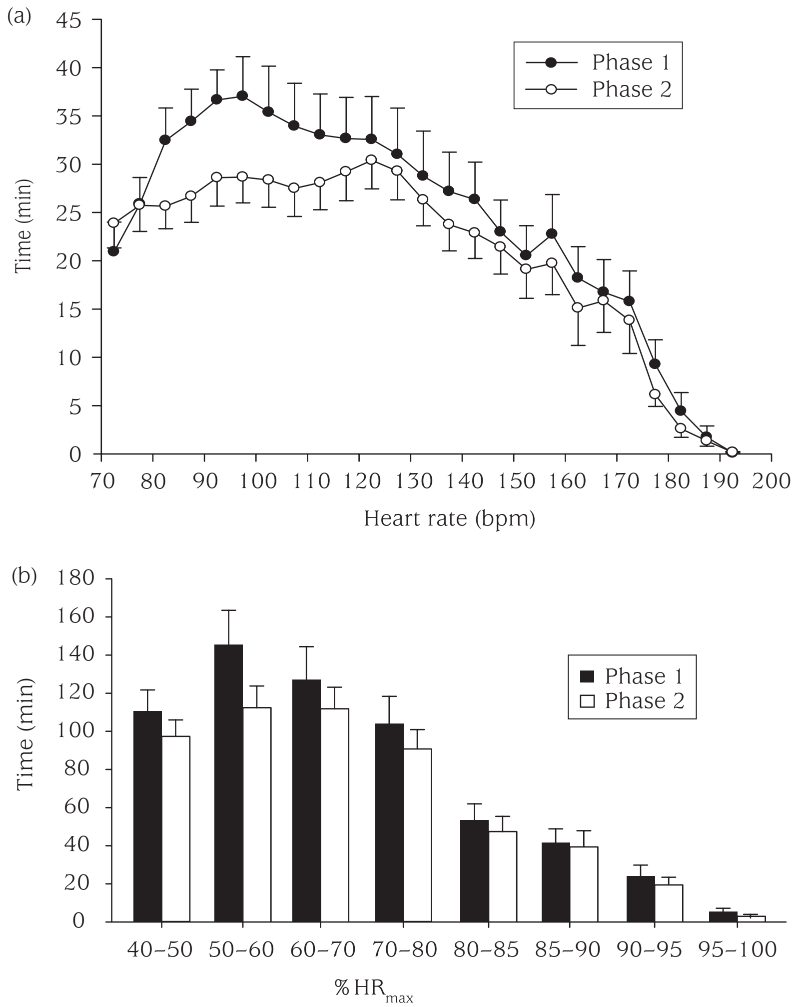

Fig. 8 Heart-rate distribution during two 9-day preparation periods (phases 1 and 2) for the Danish National team soccer squad before the European Championship 2004. The values are expressed as mean ± SEM in: (a) beats min^{-1}; and (b) % HR_{max}.

subsequent muscle contraction. The number of repetitions in a set should not exceed 15. During each training session two to four sets should be performed with each muscle group, and rest periods between sets should be longer than 4 min. During this time the athletes can exercise with other muscle groups. Several principles can be used in strength training (Ritzdorf 1998).

Planning fitness training

The time course of adaptations in the various tissues should be taken into account when planning fitness training. A change in heart size is rather slow, and there is a need for training over a longer period of time (years) to improve the pump capacity of the heart significantly (Blomqvist & Saltin 1983). Blood volume changes more quickly than the heart size, but this adaptation is optimal first after a dimensional development of the cardiovascular system has occurred. The content of oxidative enzymes in a tissue and the degree of capillarization of skeletal muscle change more rapidly than the volume of a tissue, e.g., the heart, but months of regular training are needed to obtain considerable increase in muscle capillaries and oxidative enzymes. On the other hand, a reduction in these parameters can occur with a time constant of weeks. The changes in glycolytic enzymes are rapid and they can be markedly elevated within a month of appropriate training (Reilly & Bangsbo 1998).

To give an example of the priorities and the amount of training within the different aspects of training in a top sport, the program of the preparation of the Danish National soccer team for the European Championship 2004 will be described. After the season the players had 1–2 weeks of holiday before they started preparing for the Championship. The preparation period lasted 18 days, which can be divided into two periods: 23rd May to 1st June (phase I) and 2nd June to 11th June (phase II). In each period the team played one match. The various elements of each training session are described in Table 3. The players were wearing heart-rate monitors during every training session allowing for an evaluation of the loading of each player during both phases of preparation. It should, however, be emphasized that the heart-rate measurements do not give a clear picture of the amount of anaerobic work performed during a training session. Figure 8 shows the distribution of the time in the different heart zones for the whole team. It is clear that the amount of work leading to a high heart rate was the same in the two phases, and that the total amount of training was reduced in the second phase. This is in accordance with more studies showing that performance can be maintained and improved by reducing the amount of low-intensity training and keeping a sufficient amount of high-intensity training (Mujika 1998; Shepley et al. 1992). It should be mentioned that the team seemed to have been well prepared, since they were able to qualify to the quarterfinals at the expense of Italy and Bulgaria.

The players were tested by the Yo-Yo intermittent endurance test (level 2) twice during the season as well as before and after phase I of the preparation period. It was clear that performance, measured as the

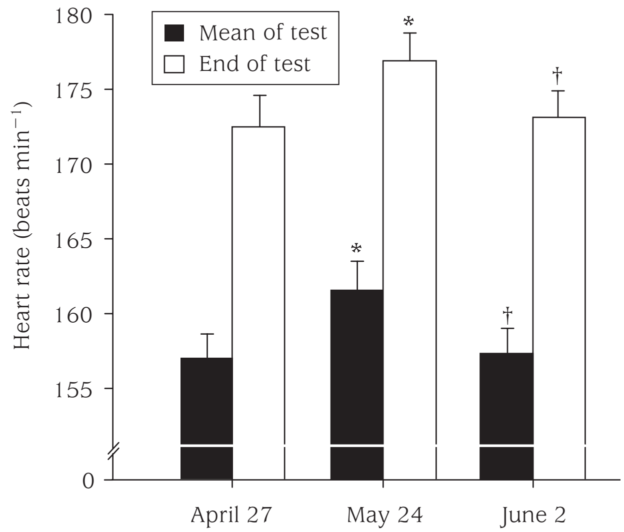

Fig. 9 Mean and end heart rate values of 18 players of the Danish National team soccer squad during a sub-maximal Yo-Yo intermittent endurance level 2-test performed 46, 19, and 10 days prior to the start of the European Championship 2004. * Significantly higher heart rate during the test performed on May 24 compared to April 27. † Significantly lower heart rate during the test performed on June 2 compared to May 24.

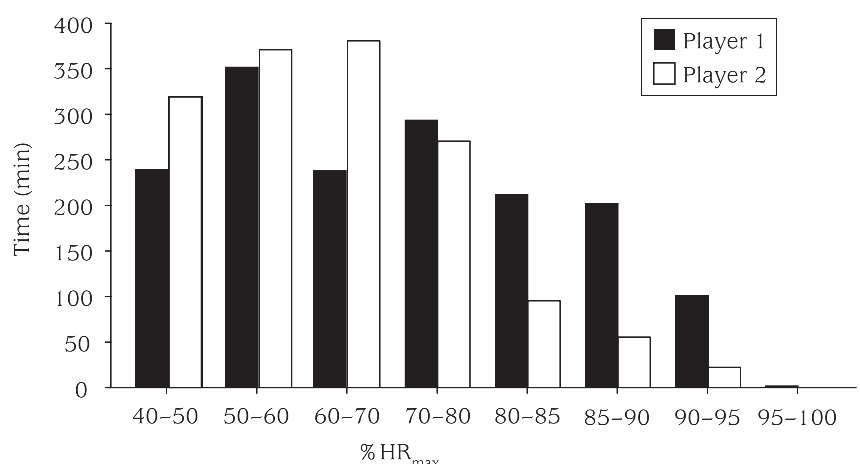

Fig. 10 Heart rate distribution of two players in the Danish National team soccer squad during an 18-day training period (sum of phases 1 and 2) before the European Championship 2004.

heart-rate response, was lower when they started the preparation period which by training during the first 10 days had reached the level of the season (Figure 9). This allowed the coaches to reduce the total amount of training in phase II of the preparation.

It should be emphasized that there were large individual differences in time where the players were in the high heart-rate zones (Figure 10). These variations were due to individual programs and large differences between players in the amount of high-intensity work performed during the tactical training. Therefore, it is essential to carefully evaluate the physical loading of the players also during training that are not having the specific aim of being in fitness training.

Conclusion

With appropriate training, performance of an athlete can be increased and the risk of injury can be reduced. To design an efficient training program it is important to be aware of the physical demands of the sport, the capacity of the athlete which can be determined by various tests, and the different components of fitness training. Aerobic training increases the ability to exercise at an overall higher intensity during competition, and minimizes a decrease in technical performance induced by fatigue. Anaerobic training elevates an athlete's potential to perform high-intensity exercise. Muscle strength training, combined with technical training, improves an athlete's power output during explosive activities in a match. Planning of fitness training is essential in top-class sport, and an example of the preparation of the Danish National Soccer team for the European Championship 2004 combined with physiological measurements and testing is provided taken into account individual needs.

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