Metabolic Training for the Soccer Athlete

Soccer is one of the most demanding of all sports. The game is played on one of the largest fields of any sport, for the longest sustained time and with the least amount of breaks. A normal game consists of ninety minutes of virtually non-stop play. Because substitutions are limited and there are no official time-outs players may run up to 5 to 6 miles during the course of a game, often at a high-intensity level. Thus, a player’s fitness level is a crucial factor in sustained athletic performance.

To achieve a high level of fitness for the game of soccer, coaches must know the physical demands imposed upon their players. They must identify important fitness goals and then devise a planned approach to achieve those goals. The challenge facing coaches and players is to develop an optimal level of fitness without neglecting the other aspects of performance like strength, power, speed, and skill. The overall goal of this article is not to improve the skill of the soccer player, but to explore the direct physiological demands on players and create a sport-specific, scientifically based, speed-strength and conditioning program.

A soccer match is characterized by continuous, sub-maximal efforts interspersed with periods of short-term, high intense activity. Players are in constant motion as they contest for loose balls, move to support teammates, interchange positions, and run to
create space or challenge opponents. Running, jumping, sprinting movements in conjunction with sudden changes of speed and direction dominate the play. The intensity of the game ranges between low-level activities like walking, jogging, and cruising and those of high intensity like sprinting. The rhythm of play is constantly changing; a characteristic that separates soccer from other types of endurance sports where the intensity of activity remains relatively stable throughout competition. So, how does one estimate a player’s workload in an effort to develop their aerobic and anaerobic fitness level?

One method of estimating workload is to determine how far a player runs during a game. The total distance covered provides an approximate representation of energy expenditure as well as the overall severity of the exercise. Most studies indicate that field player’s average between 5.6 to 7.5 miles during a typical 90-minute game (3). The total distance covered can be sub-divided into walking, jogging, cruising, sprinting, backward and shuffling movement. Combining results from independent studies (Table 1 Nike Research Review) provides a more complete picture of player movement patterns. Of particular interest is that less than 2% of the distance covered by a field player during a game is with the ball. The vast majority of the effort in playing soccer is through support runs, creating space or challenging opponents.

Table 1. Player Movement Patterns

<table>
<thead>
<tr>
<th></th>
<th>Total (meters)</th>
<th>Standing</th>
<th>Walking</th>
<th>Jogging</th>
<th>Cruising</th>
<th>Sprinting</th>
<th>W/Ball</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (%)</td>
<td>10,000</td>
<td>NA</td>
<td>2600</td>
<td>4900</td>
<td>1700</td>
<td>800</td>
<td>180</td>
</tr>
<tr>
<td>Distance (%)</td>
<td>100</td>
<td>NA</td>
<td>26</td>
<td>49</td>
<td>17</td>
<td>8</td>
<td>&lt; 2</td>
</tr>
</tbody>
</table>


Having analyzed the movement patterns of the soccer player, common sense dictates that you structure your training around the movements, the muscles, metabolic
pathways and energy systems used in soccer in order to develop an effective training program. This is known as specificity of training. Physiological adaptations in response to physical training are highly specific to the nature of the activities and in order to maximize benefits, training should be carefully matched to an athlete’s specific performance needs (1).

The soccer athlete’s ability to perform is based on the ability to gain needed energy. Energy requirements may be short-term or long-term, depending on the activity. Long-term performance requires a great deal of energy from aerobic metabolic sources. Thus, training that enhances the athlete’s ability for various long-term performances at a lower power output are referred to as aerobic (in the presence of oxygen) training or endurance training. In contrast, short-term performance requires energy from anaerobic (in the absence of oxygen) sources. This type of training is called anaerobic training. Because the vast majority of the effort in playing soccer is through support runs, creating space or challenging opponents while over a continuous 90-minute period, the soccer athlete must develop both high levels of aerobic and anaerobic endurance. This can be achieved through what is referred to as metabolic training.

Adenosine triphosphate (ATP) is the compound from which the body derives energy and is generated through both anaerobic and aerobic energy systems. The word aerobic means “in the presence of oxygen.” The energy used for aerobic activity comes from the oxidative system. This oxidative production of adenosine triphosphate (ATP) occurs within special cell organelles called mitochondria, which are interspersed throughout the skeletal muscle tissue. Muscles need a steady supply of energy to continuously produce the force needed during long-term activity. Unlike anaerobic ATP
production, the oxidative system has a tremendous energy yield, so aerobic metabolism is the primary method of energy production during endurance events.

In terms of anaerobic metabolism, it consists of two different energy sources, phosphocreatine system and glycolytic system. In addition to ATP, your cells have another high-energy phosphate molecule that stores energy. This molecule is phosphocreatine (PC). With this system, as energy is released from ATP by the splitting of a phosphate group, your cells can prevent ATP depletion by reducing PC, providing more energy from ATP. This process is rapid and can be accomplished without any special structures within the cell. Although it can occur in the presence of oxygen, this process does not require oxygen, so the ATP-PC system is said to be anaerobic. During the first few seconds of intense muscular activity, such as sprinting for a loose ball, ATP is maintained at a relatively constant level, but the PC level declines steadily as the compound is used to replenish the depleted ATP. Thus, the capacity to maintain ATP levels with the energy from PC is limited. Your ATP and PC stores can sustain your muscles’ energy needs for only 3 to 15 seconds during an all-out sprint. Beyond that point, the muscles must rely on other processes for ATP formation---otherwise known as the glycolytic and oxidative system.

The other anaerobic metabolism is glycolysis. The glycolytic energy system is essentially the breakdown of glucose to pyruvate acid and the conversion of this intermediate, in the absence of oxygen, to lactic acid. If it is converted into lactic acid it is then considered anaerobic metabolism. Carbohydrates pass through the glycolytic cycle of reactions and either end up being used in aerobic metabolism or anaerobic metabolism, thus, the term’s aerobic and anaerobic glycolysis.
The interplay of energy systems is quite dramatic. In Figure 2 the interplay of different metabolic systems with exercise duration is shown. Again, understanding the metabolic demands of exercise helps in developing training programs to meet the acute or immediate energy needs of a sport (1). Lastly, all energy systems, whether aerobic or anaerobic, are engaged upon the initiation of physical activity. It is the magnitude and relative proportion of the energy contribution from each source that differs and can dramatically change moment to moment depending upon demands of the sport (1). After exploring the movement patterns of the soccer athlete and a brief summarization of the different energy metabolisms, common sense would tell us the primary metabolic demands of soccer fall heavily on the ATP-PC system while oxidative energy system and anaerobic glycolysis (ATP-LA) is only moderate.

**Figure 2. Relationship between energy delivery systems and exercise duration.**

How much your aerobic capacity improves is determined, in part, by how many calories you expend during each training bout and how much work you accomplish over a period of a week (5). Many athletes and coaches believe this means gain in aerobic endurance will be proportional to the volume of training. If training volume were the
most important stimulus for muscular adaptations, individuals who expend the most energy during training should have the highest $V_{O_2\text{ Max}}$ values (5). But this is not the case.

The amount of improvement attainable with endurance training seems to have an upper limit. Athletes who train with progressively greater work loads eventually reach a maximal level of improvement beyond which additional increases in training volume won’t improve endurance or $V_{O_2\text{ Max}}$ (1994). Some athletes try and perform more physical work by training twice per/day, doubling their normal training volume. If an athlete is already expending 1,000 kcal/day in training, a second training session is unlikely to produce additional benefits (5).

The degree of adaptations to endurance training depends not solely on training volume, but also on training intensity. Muscular adaptations are specific to both the speed and duration of effort performed during training (5). Runners, cyclists and swimmers who incorporate intermittent, high-intensity bouts of exercise into their training regimen show more improvements in performance than those who perform only long, slow, low-intensity training bouts. Long-distance, low-intensity training doesn’t develop the neurological patterns of muscle fiber recruitment and the high rate energy production required for maximal endurance performance (5).

High-intensity speed training can include either intermittent exercise intervals or continuous exercise at a near competition pace. Although it has been used for many years, most athletes use interval training mainly to improve their anaerobic capacity. But this training format can also be used to develop the aerobic system. Repeated fast-paced bouts that allow short rest intervals between bouts achieve the same aerobic benefits as long high-intensity continuous exercise (5). With interval training, short to moderate
periods of work is alternated with short to moderate periods of rest or reduced activity (1). For example a female soccer player may run a 40 yard sprint in 5.3 seconds and then recover for 14-15 seconds before sprinting another 40 yards. Some guidelines for interval training are presented in Table 2. The table provides an estimated percentage figure on the amount of time to be spent on various types of metabolic training for a variety of sports.

Table 2. Guidelines for Interval Training

<table>
<thead>
<tr>
<th>Energy system mainly involved</th>
<th>Interval sprint training</th>
<th>Interval mid-distance training</th>
<th>Interval distance training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate</td>
<td>10-30 s</td>
<td>30-120 s</td>
<td>120-300 s</td>
</tr>
<tr>
<td>Glycolytic</td>
<td>30-90 s</td>
<td>60-240 s</td>
<td>120-310 s</td>
</tr>
<tr>
<td>Oxidative</td>
<td>1:3</td>
<td>1:2</td>
<td>1:1</td>
</tr>
<tr>
<td>Load:recovery</td>
<td>25-30 s</td>
<td>10-20 s</td>
<td>3-5</td>
</tr>
</tbody>
</table>

Reprinted from Essentials of Strength Training and Conditioning (1994)

High-intensity continuous training, on the other hand, is performed at work intensities that represent 85% to 95% of the athletes’ maximal heart rate. For example, a soccer player may run 1 mile at 180 beats per minute (bpm). High-intensity continuous training is very effective for training endurance in athletes without requiring high work levels that are stressful and uncomfortable (5). Unfortunately, the demands of such a training program are extraordinary, particularly when extended over weeks and months. Slower paced variations should be introduced periodically, such as once or twice a week, to give the athlete some relief from exhaustive, high-intensity, continuous training (5).

The increase in the aerobic capacity of skeletal muscle that occurs after endurance training is expressed in both fast- and slow-twitch muscle fibers. Slow-twitch fibers (ST) have an inherently higher aerobic capacity than fast-twitch fibers and are preferentially
recruited during endurance activities. However, if the intensity is sufficient, such as in running repeated 200-meter intervals, fast twitch fibers (FT) also make a significant contribution to the effort. Under such capacity the aerobic capacity of the athlete increases with training (5). Thus, creating a power-endurance athlete.

Furthermore, recent research with animals has shown that fiber-type conversion is actually possible under conditions of cross-innervation, where FT motor unit is innervated by a ST motor neuron, or vice versa (5). Also, chronic stimulation of FT motor units with low frequency nerve stimulation transforms FT motor units into ST motor units within a matter of weeks (4). Muscle fiber types in rats have changed in response to 15 weeks of high-intensity treadmill training, resulting in an increase in ST and FT fibers and a decrease in FTa fiber (2). The transition of fibers from FTa to FTa and FTa to ST was confirmed by several different histochemical techniques (5). Of what significance are these studies? If you want to be a quick and explosive athlete, you must train quick and explosive.

Not all of the mechanisms that are responsible for improving muscular strength and endurance are fully understood. Nevertheless, this article is an attempt to identify and explore the adaptations occurring within the muscles and in the energy systems themselves that accompany aerobic and anaerobic training and how these types of training can improve athletic performance. In closing, the following is a recap of the metabolic adaptations to training:

• Aerobic training leads to the improved peripheral blood flow and an enhanced capacity of the muscle fibers to generate greater amounts of ATP.
• Anaerobic training leads to increased muscular strength and greater tolerance for acid-base imbalances during highly intense effort.
• The ideal training regimen for endurance athletes should be a caloric expenditure of about 4,000 to 6,000 kcal/week. There seems to be little benefit beyond this level.
• The primary metabolic demands of soccer fall heavily on the ATP-PC system while oxidative energy system and anaerobic glycolysis (ATP-lactic acid) is only moderate.
• Physiological adaptations in response to physical training are highly specific to the nature of the activities. In order to maximize benefits, training should be carefully matched to an athlete’s specific performance needs.
• Intensity is a critical factor in improving performance. Adaptations are specific to the speed and duration of training bouts, so those who perform at higher intensities must train at higher intensities.
• Aerobic interval training involves repeated bouts of high-intensity performance separated by brief rest periods. This training, although traditionally considered only anaerobic, generates aerobic benefits because the rest period is so brief that full recovery can’t occur, thus the aerobic system is stressed.
• Continuous training is done as one prolonged bout of exercise, but needs to be periodized due to its extraordinary stresses on the body.

Included is a twelve-week off-season soccer speed-conditioning program. This type of metabolic training does not allow full recovery between bouts of work and is generally done during the middle to later part of the off-season preparatory phase. As the pre-season approaches, interval training consists of longer rest intervals to accommodate near-maximal intensity intervals and smaller volume in total conditioning.

Resources


