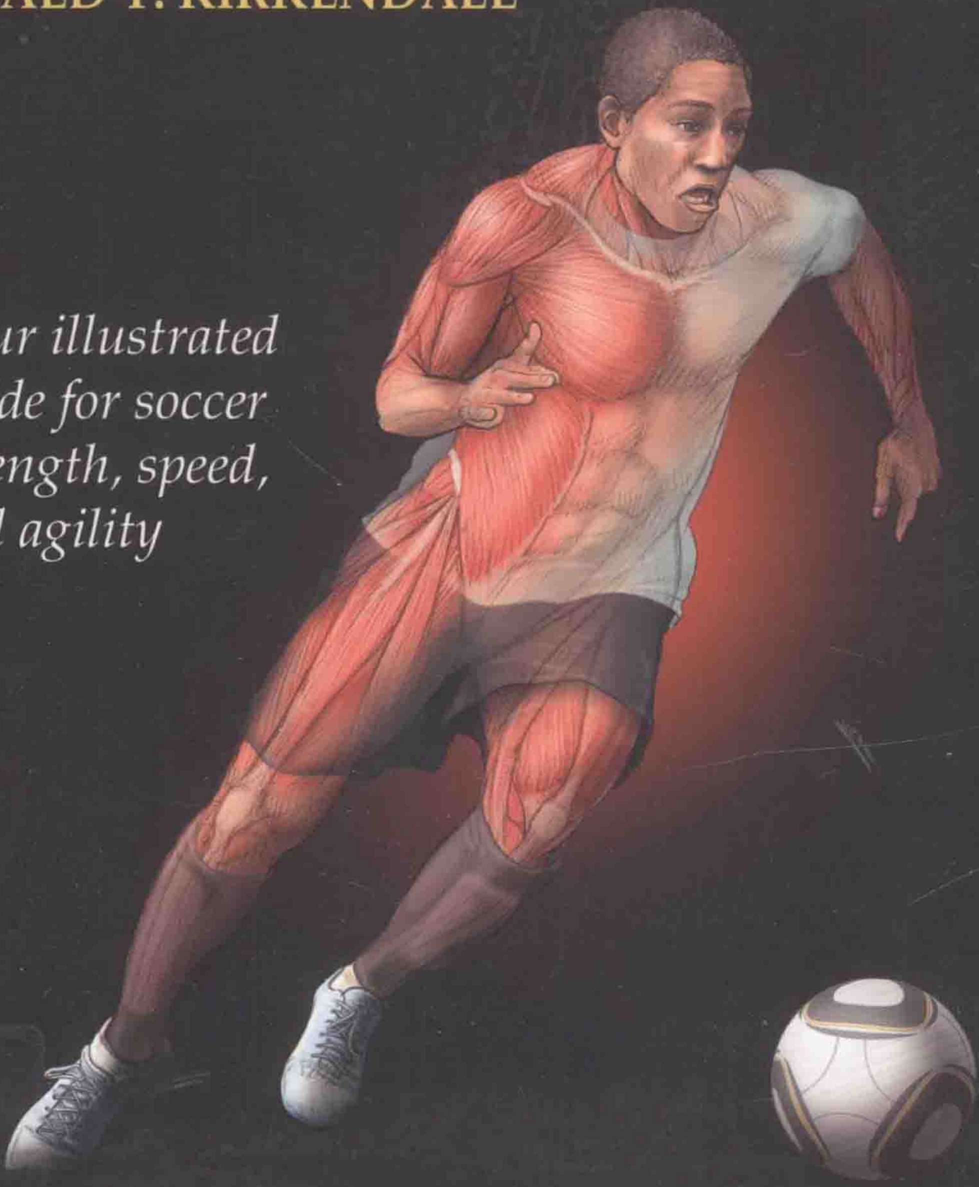
SOCCER Anatomy

DONALD T. KIRKENDALL

Your illustrated guide for soccer strength, speed, and agility



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PREFACE

Pele called it "the beautiful game." The simplicity of his comment about soccer has resonated among fans of the game for decades. The beauty of soccer begins with skill. Beautiful soccer means controlling an impossible ball, such as Dennis Bergkamp's 89th-minute goal in the 1998 FIFA World Cup or Maxi Rodriguez's chest-to-volley strike from the upper corner of the penalty area at the 2006 FIFA World Cup. Soccer's beauty is in the perfectly paced seeing-eye pass threaded through the smallest opening in the defense, which you will see anytime Kaka (Brazil) or Xavi (Spain) is playing. Or a solo dribbling run through the defense such as Diego Maradona's 1v7 run against England in the 1986 FIFA World Cup. Or the long-range cannon shot by Paul Breitner at the 1974 FIFA World Cup.

Then there is tactical brilliance. How about the 25-pass sequence to a goal by Argentina against Serbia in the 2006 FIFA World Cup, or the lightning-fast length-of-the-field counterattack for a goal by the United States against Brazil in the 2009 FIFA Confederations Cup final? Brazil's fourth goal against Italy in the 1970 World Cup is still considered a masterful display of teamwork, skill, and guile.

The objective of soccer is the same as in any other team sport: Score more than the opponent. This simple philosophy is enormously complicated. To be successful, a team must be able to present a physical, technical, tactical, and psychological display that is superior to the opponent's. When these elements work in concert, soccer is indeed a beautiful game. But when one aspect is not in sync with the rest, a team can be masterful and still lose. The British say, "They played well and died in beauty."

Soccer, like baseball, has suffered under some historical inertia: "We've never done that before and won. Why change?" or "I never did that stuff when I played." That attitude is doomed to limit the development of teams and players as the physical and tactical demands of the game advance.

And oh how the game has advanced. For example, the first reports on running distance during a match noted English professionals of the mid 1970s (Everton FC) averaged about 8,500 meters (5.5 miles). Today, most distances average between 10,000 and 14,000 meters (6 and 8.5 miles). There are reports that females, with their smaller hearts, lower hemoglobin levels, and smaller muscle mass, can cover the 6 miles attributed to men. The distance and number of runs at high speed have also increased as the pace of the game has become more ballistic and powerful. To those of us who have followed the game over the years, the pros sure do seem to strike the ball a lot harder now.

But the benefits of soccer extend beyond the competitive game. Emerging evidence shows that regular participation in soccer by adults is as effective as traditional aerobic exercise such as jogging for general health and for treating certain chronic conditions. For example, people with hypertension can see reductions in blood pressure similar to that seen in joggers. Blood fats can be reduced. Increased insulin sensitivity means those with type 2 diabetes and metabolic syndrome should see benefits. Regular soccer helps people, youths or adults, who are attempting to lose weight. A host of benefits are possible, all from playing an enjoyable game. An interesting sidenote is that when those studies were concluded, a lot of joggers just quit, but soccer players looked at each other and said, "Great. Can we go play now?"

The game is not as embedded in American culture as it is in other countries. Around the world, families, neighbors, and friends play the game whenever they can. In the United States, this neverending exposure to soccer is not as evident, so upon joining a team, an American child does not possess the beginnings of a skill set obtained from free play with family and friends. The coach may well be the child's only exposure to the game, requiring almost all coaching to be focused on the ball, which may neglect some basic motor skills and supplementary aspects of fitness.

In particular, the soccer community—and not just in the United States—has viewed supplemental strength training with skepticism. In addition, soccer players tend to view any running that is longer than the length of a field as unnecessary, and they avoid training that does not involve the ball. But give them a ball and they will run all day. The problem is many coaches apply the principle of specificity of training too literally ("if you want to be a better soccer player, play soccer") and end up denying players training benefits that are proven to improve physical performance and prevent injury.

This book is about supplemental strength training for soccer. When developed properly, increased strength will allow players to run faster, resist challenges, be stronger in the tackle, jump higher, avoid fatigue, and prevent injury. Most soccer players have a negative attitude toward strength training because it is done in a weight room and does not involve the ball. These attitudes were taken into consideration when the exercises in this book were selected. Many can be done on the field during routine training, and some involve the ball.

When a player or coach does favor some strength training, the primary focus is usually the legs. But as any strength and conditioning specialist will tell you, a balance must be struck up and down the body because the body is a link of segments, chains if you will, and the most prepared player will have addressed each link of the chain, not just an isolated link or two. Furthermore, those same specialists will say that while one group of muscles may be important within a sport, to address that group alone and neglect the opposite group of muscles will result in an imbalance around that movement or joint. Imbalances are known to raise the risk of injury. It has been known for years that strong quadriceps and weak hamstrings increase the risk of knee injury, but it is also known that athletes with a history of hamstring injury not only have weak hamstrings but also have poor function in the gluteal muscles. Weak hamstrings are also implicated in low back issues.

Many readers will review these exercises and select those that address specific weaknesses. The exercises in *Soccer Anatomy* are good choices to supplement traditional soccer training, but the concepts continue to evolve. These exercises are a good place to begin. With a regular program that uses systematic progression, players will improve aspects of fitness important for competitive play—aspects not addressed in traditional ball-oriented training. Players who want to keep playing and stay healthy with as few injuries as possible need to include some strength training. Players who neglect the strength element of training but want to move up to the next level will be in for a shock when they discover how far behind they are and realize just how much catching up is necessary. Should these exercises be considered the definitive list? Of course they shouldn't. Will conditioning professionals offer alternatives? Of course they will. But this is a good starting point with options for the coach and player.

The unique aspect of *Soccer Anatomy* isn't the supplemental exercises, as many other resources can provide suggestions. *Soccer Anatomy* takes you inside each exercise to show you which muscles are involved and how they contribute to proper execution of the exercise and to success on the field. The anatomical illustrations that accompany the exercises are color coded to indicate the primary and secondary muscles featured in each exercise and movement.

Primary muscles   Secondary muscles

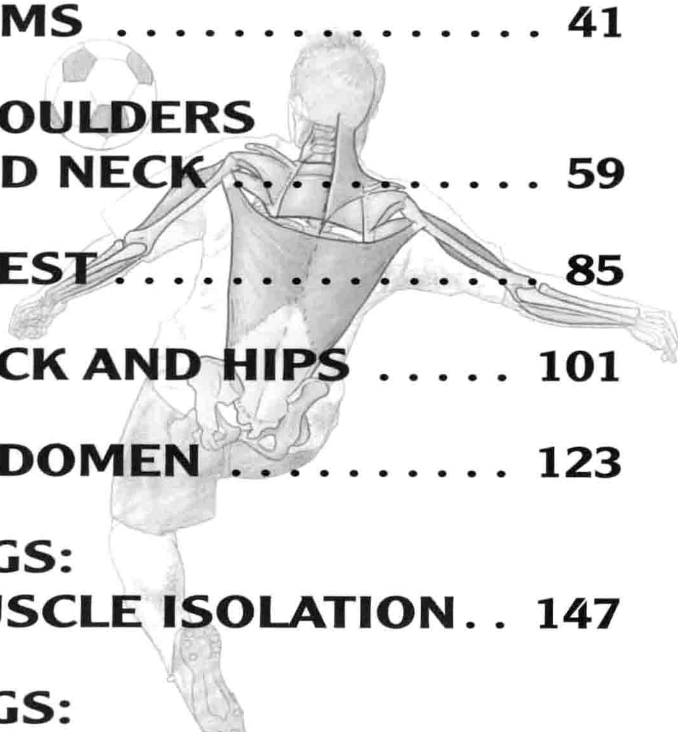
Use this information to improve your skill, build your strength and endurance, and stay on the pitch. Choose exercises that are appropriate for your age, gender, experience, and training goals. Even young athletes can benefit from resistance training. In preadolescent athletes, strength improvements come mostly from increasing training volume by adding repetitions and sets while using modest resistance (e.g., two or three sets of 12 to 15 repetitions on two or three nonconsecutive days per week). Excellent exercise choices for preadolescents are those that use body weight for resistance.

Resistance training, like any physical training, has inherent risks. As athletes mature, they are better able to process, follow, and adhere to directions that minimize injury risk. In general, when an external resistance such as a barbell or dumbbell is lifted, the set is performed to muscle failure. Exercises that use body weight as resistance usually have a set number of repetitions as a goal, although sometimes muscle failure occurs before the goal is reached. Depending on the training goal, the load must be individualized and age appropriate. Once you can perform the desired repetitions in a set without reaching muscle failure, increase the resistance by 5 to 10 percent.

Training goals will influence the workout program. Improving local muscle endurance requires high volume (sets of 20 to 25 repetitions) and low intensity. Hypertrophy training acts as the entry point to higher-quality training and requires 10 to 20 repetitions per set and low to moderate intensity. In basic strength training, the intensity is high (80 to 90 percent of capacity), but the volume is low (2 to 5 repetitions per set). Power training, which usually includes explosive movements, requires a higher intensity (90 to 95 percent of capacity) and a low volume (2 to 5 repetitions per set). In general, soccer players should focus on higher-volume exercises of low to moderate intensity, performed twice a week during the season with a focus on maintenance. Save strength and power gains for the off-season.

Safety is key when working out in a weight room. Always work with a spotter. Use safety collars on weights. Lift with your legs, not your back, when picking up weight plates. Drink fluids regularly, and use correct posture and form. Dress properly, and be careful not to drop weights. Consider keeping a workout journal to track your progress. Listen to your body, and don't work through joint pain or unusual muscle pain. See a physician who specializes in sports medicine. If you want to recruit help in the weight room, consult a certified strength and conditioning specialist (CSCS certification) or certified personal trainer (CPT certification).

CONTENTS



CHAPTER 1 THE SOCCER PLAYER IN MOTION

Unlike individual sports such as golf, dance, swimming, cycling, and running in which the individual athlete largely dictates her own performance, soccer is a team sport. A team sport adds the dimensions of direct opponents, teammates, a ball, and rules regarding fouls and conduct that are applied during a constantly changing environment of individual, small group, and large group offensive and defensive tactics. A team sport such as soccer requires a range of complexity and intensity and physical and mental preparation beyond what is seen in many individual sports.

Preparation for competition in a team sport involves skill acquisition, tactical development, mental preparation, and physical training. Soccer demands its players to prepare nearly all aspects of physical fitness. As a result, a well-trained soccer player typically is pretty good in all aspects of fitness if not especially outstanding in any one aspect (in many cases, agility). A sprinter must have speed. A marathoner must have endurance. A weightlifter must have strength. Unlike these sports, soccer does not require a player to excel in any one area of fitness to be successful. This explains part of soccer's appeal—anyone can play.

This chapter focuses on the physical demands of soccer, but inherent in any discussion of the physical work required is the inclusion of some basic tactics. Tactics and fitness are intimately related. To know the players, one must know the game. Is a team's tactical performance the result of the players' fitness levels? Or does a higher fitness level allow the team to execute a broader vision of the game? That's soccer's version of the chicken or the egg question.

The Sport of Soccer

At its most basic level, soccer appears to be a game of nonstop motion. The adult game consists of two 45-minute periods that are played with a running clock. (In leagues with younger players, the duration of each half is shorter.) There is no allowance in the rules for the clock to stop. Although the clock runs continuously, the ball is not in play for the full 90 minutes. In general, the ball is in play for only 65 to 70 minutes. All those seconds when the ball is out of play—after a goal, before a corner, during an injury, when a player is singled out by the referee, and so on—add up. If the referee believes these circumstances are shortening the game, additional time, called stoppage time, may be added to the end of each half. One of the charms of the game is that the only person who knows the actual game time is the referee. Note: Some leagues, such as the National Collegiate Athletic Association (NCAA) and many high school leagues, control match time from the sideline and do allow the referee to stop the clock.

Since the game is not continuous, neither is the running of each player. People who study the movement of soccer describe several distinct actions: standing, walking, jogging, cruising, and sprinting. Cruising is defined as running with manifest purpose and effort, which is faster than a jog but slower than a sprint. The speeds above jogging are sometimes further defined as high-intensity running and very high-intensity running, which are further combined with jumping, sideways running, diagonal running, and backward running. A soccer player will execute nearly 1,000 distinct actions during a match. For the player, action changes every four to six seconds. When the running pattern is viewed like this, the game is no longer considered to be continuous activity simply because of a running clock. Instead, soccer is a hybrid of many actions, speeds, and changes of direction. Because the action changes frequently, it is not surprising that soccer players consistently score extremely high on agility.

Successful soccer is about how each team uses space. Soccer tactics can be summarized in a simple concept: When on offense, make the field as big as possible; when on defense, make the field as small as possible.

Ball Movement

The objective of soccer is the same as in any other team sport: Score more than the opponent. On average, 1.5 to 2 goals are scored per match. When counted over many matches, shooting success is pretty low. The overall shots-to-goals ratio is typically 10-to-1. At the 2008 Euro Championship, the average number of passes by a team was 324 per match. Because of the nature of the sport, ball possession changes constantly. Over 90 minutes, a team will have about 240 separate ball possessions. That averages to about 11 seconds per possession. (Remember, your team does not have possession for the full 90 minutes; the other team has possession, too.)

A ball possession can be brief with no completed passes or a long string of completed passes before possession is lost because of poor skill, an intercepted pass, a tackle, a ball lost out of play, or a goal. When plotted over thousands of matches, about 40 percent of all possessions have no completed passes, and 80 to 90 percent of possessions involve four players and three passes or less (figure 1.1). This explains why so many small-sided training activities are 4v4; it is the essence of the game.

If your team gains possession close to your opponent's goal, the number of players and passes will be less. This is an important concept. Forcing your opponent to make a mistake near its own goal puts your team at a distinct advantage. In soccer, goals often are the result of an opponent's mistake instead of a long string of passes by the attacking team. Strange as it sounds, high-pressure defense in the opponent's defensive end is an important offensive tactic. Because soccer is a hybrid of running speeds and directions, it also is a hybrid of possession and quick strike strategies.

In the English Premier League, about 80 percent of any individual player's possessions are only one touch (a redirect) or two touches (control and pass), with no dribbling. Also in the English Premier League, about 70 percent of goals come from one-touch shots, and

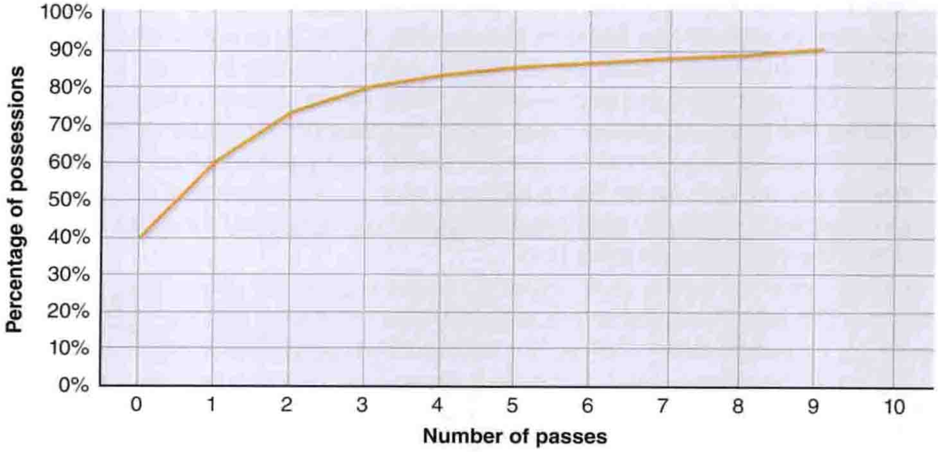


Figure 1.1 Number of passes per possession.

about two-thirds come from open play. The remaining come from restarts—fouls, corners, and penalty kicks (PKs). Combine these stats with the number of passes, and it becomes obvious that soccer is a passing game, not a dribbling game. The less dribbling and the faster passes are played, the faster the game overall.

Physical Demands on the Soccer Player

Many years ago, I asked someone how far a player runs in a soccer match and was told 10 miles. I did the math—10 miles in 90 minutes was 9 minutes per mile; this is doable. But a typical field is 110 yards (100 m) long, and 10 miles is 16,000 meters. That would mean I would have to run the length of the field 145 times at a constant 9-minute-per-mile pace to accumulate 10 miles; this is not likely.

Tracking a player's running distance isn't easy. People have used a paper and pencil coding system (at matches or while watching video replays), step counters, a GPS, and more. No matter what the method, getting the data is labor intensive and time consuming. Those who study the physical demands of soccer generally agree that the average running distance in adult male professional soccer is between 6 and 8.5 miles (9,700 to 13,700 m). Adult female professional soccer players run about 5 miles (8,000 m), but there are reports of female midfielders covering the 6 miles (9,700 m) males run. The total distance decreases in younger players, who play a slower and shorter game.

Since soccer is played at many different paces, the distance is divided according to speed. The general observation is that one-half to two-thirds of the game is played at the slower, more aerobic paces of walking and jogging. The rest is at higher, more anaerobic paces plus sideways and backward running. In addition, distances vary by position. Central attacking and holding midfielders cover the most distance followed by wing midfielders and defenders, strikers, and finally central defenders. Some call the slower paces *positional intensities* (get to the right place on the field) and the faster paces *strategic intensities* (make something happen).

Matches may be won or lost by a strategically timed sprint, so many select teams look carefully for fast, skilled, and tactically savvy players, understanding that endurance can be improved by training. In general, sprints in soccer are 10 to 30 yards (9 to 27 m) long and happen every 45 to 90 seconds. The overall distance an adult male professional player covers at a sprint is 800 to 1,000 yards (730 to 910 m), although in 10- to 30-yard (9 to 27 m) chunks. Hard runs (cruising) happen every 30 to 60 seconds. The time between these hard runs is spent walking, jogging, or standing.

The physiological load on a player when running at any speed is increased by about 15 percent when the player is dribbling a ball. Therefore, one simple way to increase the intensity of any activity is for players to dribble. Small-sided games (4v4 or smaller) that increase the number of ball-contact opportunities usually are more intense than games played in larger groups (8v8 or more) during which ball contact is less frequent and players have more opportunities to stand and walk.

Physiological Demands on the Soccer Player

Many attempts have been made to describe the physiological demands on the soccer player. A basic factor to observe is heart rate during a match. When a person goes for a jog, his heart rate increases rapidly and then settles to a plateau that stays fairly constant throughout the run. When this happens, oxygen demand is being met by oxygen supply. When the jogger stops, the heart rate slows rapidly to a new low recovery plateau that is still above resting heart rate until it finally returns to the resting level. The corresponding oxygen consumption is shown in figure 1.2 (page 4).

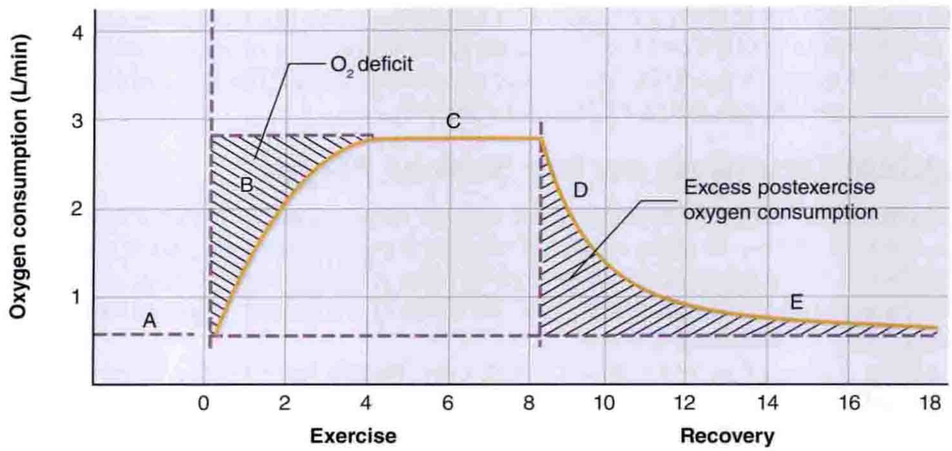


Figure 1.2 Oxygen consumption during exercise and recovery.

In a soccer player, a remarkably similar pattern emerges, and average heart rates are reported (figure 1.3). When the time scale is expanded, however, the pattern is quite different and reflects the intermittent nature of the game. The heart rate is rarely very steady during a match. Brief, rapid increases in response to faster runs are followed by rapid drops in heart rate during recovery periods (figure 1.4). Most reports show the typical heart rate range of a competitive adult soccer player is 150 to 170 beats per minute, with periods at or above 180 beats per minute. Most players work at 75 to 80 percent of capacity. Based on common interpretations of exercise heart rate, soccer is considered an aerobic exercise.

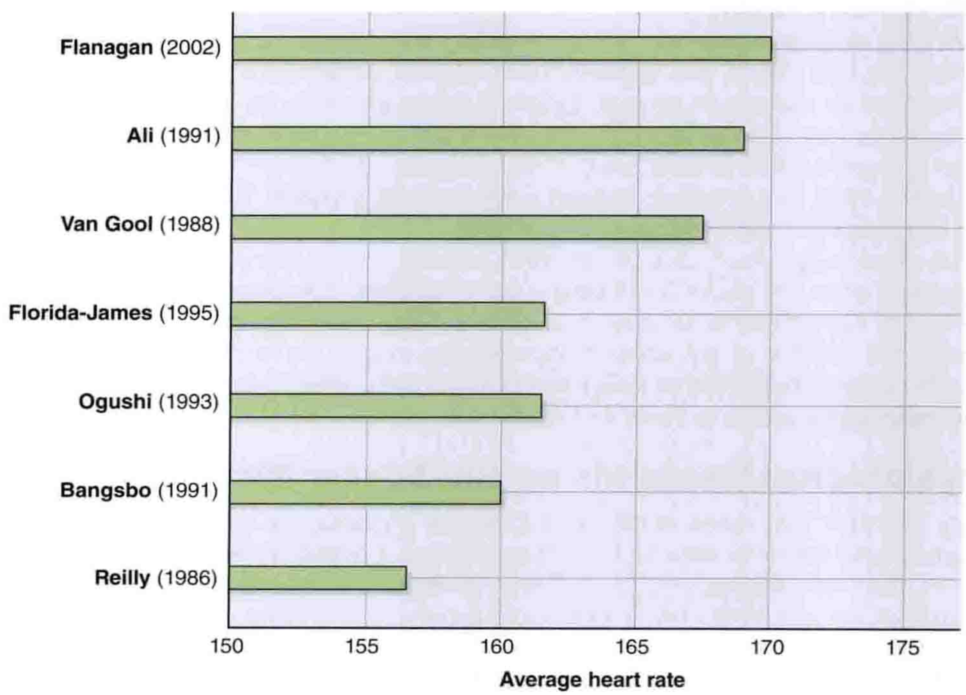


Figure 1.3 Average match heart rate reported by seven research studies.

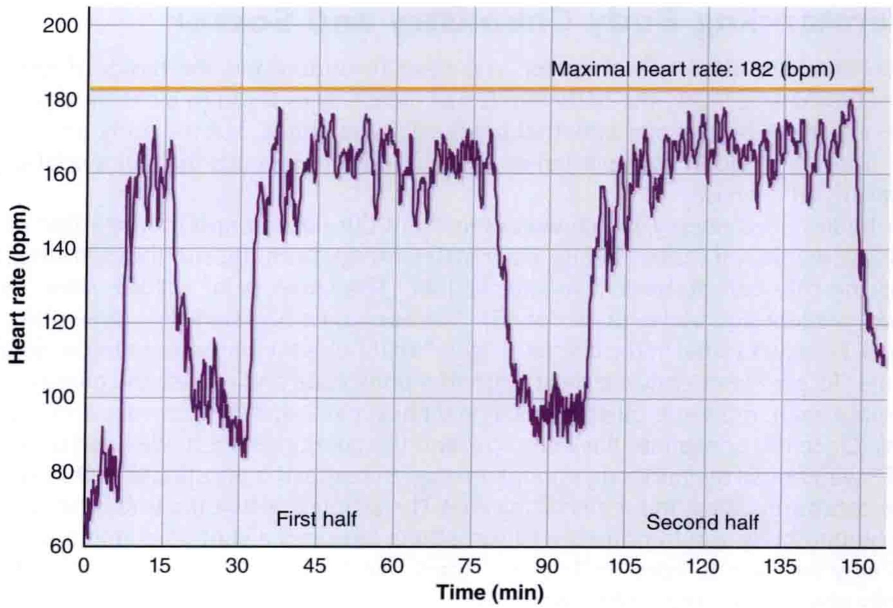


Figure 1.4 Heart rate fluctuations during a soccer match.
Courtesy of Dr. Peter Krustrup.

When the body works intensely, lactic acid is produced. Lactic acid is a product of anaerobic metabolism. Its buildup is perceived as pain (burn) in the exercising muscles, but lactic acid is rapidly removed during recovery. The resting level of lactic acid is around 1 unit. High levels for most people are 6 to 10 units. Anaerobic athletes such as wrestlers and rowers can produce lactic acid levels well into their teens or even 20s. Soccer does not require that kind of anaerobic challenge. Most reports show an elevated level of lactic acid during a match (figure 1.5), but it is hardly overwhelming considering the spectrum seen in sports. Lactic acid values are based on the time between the last intense run and when the blood is drawn. Most researchers sample blood at a fixed time (as seen in figure 1.5). If it has been a while since the last hard run, the blood sample could show a low level of lactic acid. A key physiological feature of a well-trained soccer player is the ability to recover quickly after each hard run, so it is not surprising that lactic acid values in soccer players seem to be low. Soccer players are able to get rid of lactic acid quickly because soccer training has taught their bodies to recover very quickly.

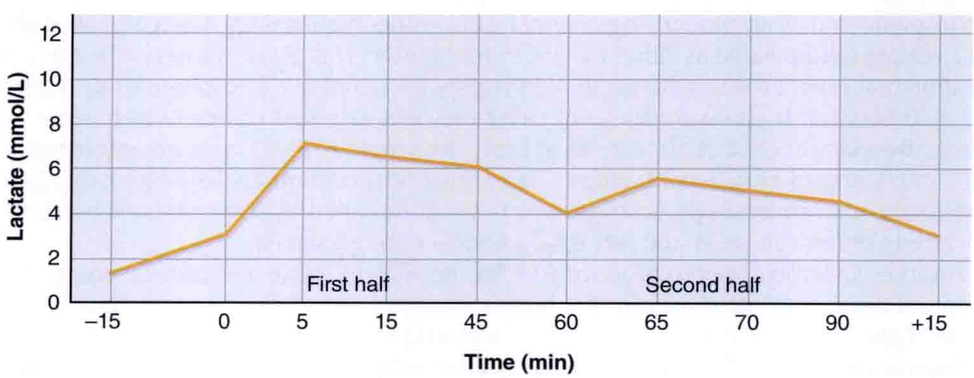


Figure 1.5 Lactic acid levels during a soccer match.
Courtesy of Dr. Peter Krustrup.

Understanding Body Chemistry and Soccer

To understand the demands of soccer, you need to understand the basics of energy. To perform mechanical work, the body needs fuel, which goes through a chemical process to provide energy. A car has one tank that holds one type of fuel, but the body has a number of fuel options found in multiple tanks. Fuel preference depends on fuel availability and the intensity of exercise.

Our bodies need energy, which we obtain from the sun through the ingestion of food. Technically we do not make energy; we transfer energy from the sun through food to the cells so the cells can perform their specific jobs. The currency of cellular work, exercise included, is adenosine triphosphate, or ATP. The adenosine backbone has three phosphates attached. Energy is stored in the chemical "glue" that holds the phosphates to the adenosine molecule. To get the energy, we must strip off a phosphate and release the energy, leaving a two-phosphate molecule called adenosine diphosphate, or ADP. Enzymes accelerate this process. Once the phosphate has been split and the energy released, we need to replenish our ATP warehouse by gathering enough energy to reattach a phosphate to that ADP. The body is constantly using and replenishing ATP. The estimate is that the total amount of ATP in the human body would probably fill something between a shot glass and a juice glass. This is why we have to keep refilling our stores. We are never completely at rest because the body always uses and replenishes ATP.

Released energy is used for many tasks. During exercise, energy is used primarily for muscle contraction, an enormously complex mechanism. The mechanical work of a muscle functions much like a ratchet. Each turn of the ratchet requires energy from a chemical source. Each turn uses energy, so the ratchet needs more energy to keep going.

Only about 40 percent of the energy available is actually used for cellular work, such as muscle contraction. The remainder is released as heat. The rapid breakdown of ATP during exercise to power all those ratchets heats the body. This heat needs to be dissipated so we do not overheat.

Anaerobic Metabolism

The word *anaerobic* means "in the absence of oxygen." We have two ways to produce energy anaerobically. One is simply to break down ATP and release the energy. If more ATP is needed, the body can take two ADPs and slide a phosphate and its energy from one ADP to the other to make a new ATP, turning the donor ADP into adenosine monophosphate, or AMP. Both processes are incredibly fast, but they drain the supply of available ATP almost as quickly. If there were any activity that ran this way exclusively, we would run out of fuel quickly, causing contraction to cease.

Once an ATP has been used, it must be replenished. The body does this by transferring a phosphate and its accompanying energy from another high-energy molecule called phosphocreatine (abbreviated as either PC or CP) to the ADP. This gives us a new ATP and a free creatine that must be resupplied with high energy for bonding a phosphate to be ready for the next transfer. If you were to sprint using only this as a fuel source (which never happens), the sprint might last 10 seconds at best. The simple ATP–PC cycle goes nonstop with each ratcheting of muscle contraction. There must be a continuous feeding of energy and phosphate to keep the cycle running, which is accomplished by the metabolic breakdown of carbohydrates (glucose) and fats (triglycerides) during exercise.

Another anaerobic way to produce ATP for the ATP–PC cycle and provide energy is the chemical breakdown of glycogen, the body's storage form of glucose. Glycogen is a long chain of glucose molecules stored in many places in the body. For our purposes, we will focus on muscle glycogen as the source. Glucose is a six-carbon molecule that is broken down into two three-carbon units. In the process, enough energy is generated to reattach a phosphate to an ADP molecule and make ATP. Actually, four ATP are produced, but the process needs two ATP to run, so the breakdown of a glucose molecule nets two ATP—not much. Because the process has a far greater source of fuel (muscle glycogen) than our juice glass of ATP, it can continue for a longer time, just not as fast and at the cost of lactic acid accumulation. When lactic acid, a product that causes a burning pain in the muscles, is produced faster than the body can get rid of it, the local tissue chemistry is altered. To prevent injury to the muscle cell, the metabolic process is slowed. This is one aspect of fatigue. If you were to sprint using only the anaerobic breakdown of glucose as fuel (again, this never happens), the estimate is that the sprint might last about 45 seconds before the chemical effects of lactic acid would cause the cells to shut down in an attempt to prevent cell damage.

Aerobic Metabolism

The aerobic breakdown of glucose proceeds through the process just described with one twist. In the presence of oxygen, lactic acid is not produced. Instead, the predecessor of lactic acid moves into a circular cycle that spins off carbon dioxide (those six carbons from the original glucose molecule need to go somewhere) and a number of compounds that carry hydrogen (those six carbons of the glucose molecule have hydrogen attached, and they too need to be dealt with). These hydrogen-containing compounds go through a process that transfers the hydrogen down a series of steps to the final acceptor, oxygen. Each oxygen molecule accepts two hydrogen molecules, producing water. During this transfer of hydrogen, enough energy is captured to transfer to an ADP, secure a phosphate, and replenish spent ATP. Depending on the details, the complete metabolism of a single glucose molecule produces 35 to 40 ATP.

But glucose, a carbohydrate, is not the only substance metabolized aerobically. Fat is a rich fuel source for energy. While glucose is a six-carbon molecule, a triglyceride has a glycerol head (with its three carbons and associated hydrogen) and three fatty acid chains, any of which can be less than 10 to 20 or more carbons in length. In fat metabolism, each fatty acid chain is cut up into two-carbon segments that each follow an aerobic path similar to the one taken by glucose to produce energy. Remember that a glucose molecule is split in half, and each half goes through the energy production process. A triglyceride, on the other hand, is far larger because of its three long fatty acid chains. If each of the three chains has 18 carbons and the process proceeds in two-carbon units (and do not forget the glycerol head), well, you can see the aerobic breakdown of a triglyceride produces far more ATP than does glucose, perhaps by a factor of 10 or more, with the same easily eliminated products of carbon dioxide and water. The problem is that fat metabolism is the slowest process.

We also can produce energy from the aerobic metabolism of proteins, but the amount of energy we get from proteins during exercise is pretty small. Most people tend to ignore the energy contributions of proteins to exercise.

The end products of the aerobic metabolism of carbohydrate and fat are water and carbon dioxide, both easily eliminated, especially when compared to lactic acid. In terms of the time needed to produce ATP, the aerobic breakdown of glucose and fat takes longer than the anaerobic metabolism of glucose and far longer than the ATP–PC cycle. Although speed of production is not its strong point, aerobic metabolism has the capability to produce energy for exercise for an indefinite period of time because everyone has an ample supply of fat.

Energy During Exercise

The interaction of all these metabolic processes can be complicated. At no time is any one of the metabolic processes or sources of fuel supplying 100 percent of the energy needed for exercise. The intensity and duration of the exercise dictates the predominant energy process and fuel. Intensity and duration of exercise are inversely related: The longer the exercise, the lower the intensity; shorter work is more intense. You could not run a marathon at your 100-meter pace, and you would not want to run a 100-meter race at your marathon pace.

Figure 1.6 helps explain this interaction. The X-axis is exercise time, and the Y-axis is the percentage of energy supplied by the various fuel sources. For exercise of very short duration, such as a 40-meter sprint, the primary fuel source is stored ATP and phosphocreatine, but a small portion of energy comes from anaerobic and aerobic metabolism of glucose. As the duration of exercise increases, up to around four minutes, the primary source of energy comes from anaerobic metabolism of glucose, but some energy comes from other pathways. Exercise that lasts four minutes or more is fueled primarily by aerobic metabolism of glucose and fat, with a progressively smaller fraction of energy coming from the other processes.

The amount of energy available from stored ATP and phosphocreatine is very small. The amount of energy from stored carbohydrate is greater but still limited. The amount of available fuel from fat is essentially unlimited. The fat that is stored within the muscle, that surrounds the organs, and that lies under the skin is far more than anyone would need for exercise. But remember, it takes time to obtain fuel from fat. It is estimated that if fat were the sole source of fuel for running, you could run at only about 50 percent of capacity—a walk or slow jog at best. Muscle glycogen also is a limited fuel source. Someone who runs out of glycogen will slow down because the main source of fuel is now from fat. Most people run out of muscle glycogen in the fibers recruited for exercise in about 90 minutes. Soccer players can therefore run out of glycogen during a match. To compensate, soccer players should follow the dietary recommendations to increase muscle glycogen that individual-sport athletes have wisely adopted. A combination of training and high carbohydrate intake allows the muscle to pack in more glycogen, allowing the player to go further into the match before running out.

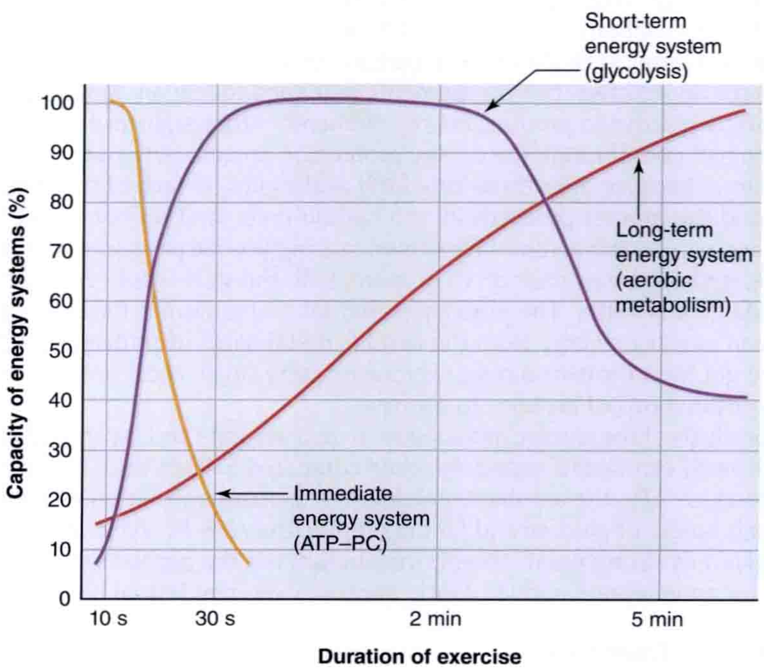


Figure 1.6 Relationship of exercise duration and energy systems.

Application to Soccer

Let's get back to the game. Remember, soccer is a game of numerous short sprints and episodes of high-intensity anaerobic work separated by periods of low-intensity aerobic recovery in preparation for the next bout of high-intensity work. During a sprint, shot, jump, tackle, or cut, some ATP is spent and some glucose is used to power the muscles for the hard work. Then the player recovers during a lower-intensity phase of play (walking, jogging, standing) during which ATP is replenished and lactic acid is removed. (Lactic acid is metabolized aerobically, which is one reason you breathe hard after slowing down or stopping.) This prepares the muscles for the next bout of hard work.

How long before the player is ready to work hard again depends on how quickly ATP is replenished, how much lactic acid is removed, and how a few other electrochemical processes connected with contraction are completed. What you need to understand is that the important parts of the game—the parts that define who wins, those high-intensity runs—are fueled primarily by anaerobic means, and the recovery periods are accomplished aerobically.

Recovery is an aerobic event. This is something most coaches and players either forget or ignore. The higher the player's aerobic capacity, the faster she will recover and the more frequently she can work hard, going deeper into the match before tiring. A player with poor aerobic fitness will take longer to recover from a sprint before again being able to use that blazing speed, and chances are each successive sprint will be shorter and slower. Research shows that training-induced improvements in speed are not nearly as great as training-induced improvements in endurance. That is why speed is such a highly valued trait in a soccer player, because the coach knows endurance can be improved more easily than speed. Coaches look for fast players who can improve their endurance instead of players who can run all day but need to improve speed. Yet the modern game is not about raw speed. It is about how fast a player recovers to use the speed she has over and over.

Some studies can nearly rank the final standings of a league's clubs according to each team's aerobic capacity. Aerobic capacity for rapid recovery is that important. Coaches are very adept at designing training sessions to improve endurance and the ability to recover. To raise intensity, they use short small-sided games on a small field, with restrictions to force play (for example, multiple two-minute games with limited recovery between each game; 4v4 or fewer for more ball contacts; or games in a penalty area or smaller marked area to force quick decisions, with restrictions such as overlapping every pass with a sprint). The smaller sides mean less downtime, so the body has to learn to adapt for fast recovery from the temporary fatigue induced by each sprint. For endurance, activities usually involve more players in a larger space, with restrictions that force a more constant pace of play for a longer period of time (for example, a 15- to 20-minute drill or games of 8v8 or more, in a three-quarter or full field, with restrictions such as all players in the attacking zone before a shot). A player with higher aerobic fitness can recover more quickly than an unfit player. The fit player gets to a new position faster and is ready for higher-intensity work well before the unfit player.

Jogging at a constant pace around a field or a park will improve jogging ability, but it won't train the body to do what is necessary to recover in a start–stop game. When jogging, you recover once—at the end. In soccer, recovery happens repeatedly. A well-trained soccer player will be able to keep the heads of each ratchet in the muscle well supplied with ATP to keep the ATP–PC process running and delay the influence of lactic acid on local muscle fatigue. Players who are unable to rapidly replenish the ATP for that ATP–PC cycle will be standing around waiting while other players are running past.

Muscle Fiber Recruitment

You may have heard of fast-twitch and slow-twitch muscle fibers. We are all blessed with a mosaic of muscle fibers with unique characteristics that make us supremely adaptable to a multitude of activities. Basically, the big fast-twitch fibers produce a lot of tension very quickly but can't keep producing this amount of tension for many contractions. The smaller slow-twitch fibers produce less tension at a slower rate but can keep contracting repeatedly. Think back to the description of energy, and apply that to the concept of fiber type. Fast-twitch fibers produce most of their energy anaerobically (for a rapid production of tension), while slow-twitch fibers produce most of their energy aerobically (for repeated contractions). The distribution of fast-twitch and slow-twitch fibers is, for the most part, fixed by genetics. Although some people might reason that a soccer player should have more of one type than the other, most studies show a soccer player has about a 50:50 ratio. Remember, soccer is the game of the masses, so it makes sense that no genetically predetermined factor, such as a high percentage of slow-twitch fibers in a marathoner or height in basketball, is a requirement to play the game.

Female Players

Much of the worldwide growth in soccer is due to the increased participation of women. Although the rules are the same, there are subtle tactical differences between the men's and the women's games that may not be evident to casual fans. The general pattern of work is similar but at a lower running volume and pace, although some female midfielders cover the 6 miles (9,700 m) male players do. Women have physiological differences such as a lower engine capacity. This lower capacity of females is the result of less muscle mass, smaller hearts, less total blood volume, and less hemoglobin. A female playing a match of the same duration and field size as a male and running the same distance as a male will have to play the game at a higher intensity. It isn't unusual for adult female professional players to exhibit heart rates above those of their male counterparts. They work hard.

Female athletes have other issues that can cause health problems. The female athlete triad is the interaction of disordered eating, menstrual dysfunction, and reduced bone density. Some female athletes choose not to eat appropriately, which can lead to a disruption of normal hormonal balance evident in menstrual problems. A disruption of normal hormonal balance, especially of estrogen, can reduce bone density. The repeated impact of physical training can then lead to stress fractures, mostly in the lower extremities. Because the triad begins with reduced calorie intake and possibly disordered eating, ensuring females are consuming adequate calories is imperative for maintaining normal menstrual function and healthy bones.

Females also need to ingest appropriate amounts of iron and calcium. Even athletes on a vegetarian diet can get plenty of these minerals with proper food selection. The Fédération Internationale de Football Association (FIFA) has produced an excellent booklet on the female player; see the additional resources on page 207.

Nutrition and Hydration

Our fuel for exercise comes from the food we eat. We all have plenty of fat, but carbohydrate storage capacity is limited, meaning we have to refuel carbohydrates frequently. For you to be a player in motion, you need to be well fueled, and that comes from carbohydrates. FIFA has an excellent booklet on nutrition specifically written for the nonscientific audience. See the additional resources on page 207.

Dehydration is a problem in soccer. The length of the game, the intensity of the running, the elements, and the lack of planned stoppages all contribute to players not getting neces-