FITNESS IN SOCCER

THE SCIENCE AND PRACTICAL APPLICATION

Jan Van Winckel, Werner Helsen, Kenny McMillan,
David Tenney, Jean-Pierre Meert, Paul Bradley

TABLE OF CONTENTS

3

THE PHYSICAL DEMANDS OF ELITE SOCCER MATCH PLAY

Paul Bradley

3.1 INTRODUCTION

Time-motion analysis is a valuable data-collection technique used to quantify the match performances of elite soccer players (Carling et al., 2008). Interest has substantially grown in this area over the last decade, because it enables sports scientists to identify the current demands placed on players in competition and apply the data to training and testing protocols (Bradley et al., 2011). This has been driven, above all, by the availability of new technologies that help further our knowledge of training and testing modes to optimize soccer performance (Castellano et al., 2011). One such technology regularly used in elite soccer involves semi-automated monitoring through video tracking, using systems from match analysis companies, such as Prozone® and Amisco®, to simultaneously track the movements of all players, the referee and the ball. This chapter therefore aims to detail the factors that impact the physical demands of modern elite soccer with special reference to position, gender, and standard, as well as contextual influences and fatigue.

3.2 ACTIVITY PROFILE

The activity profile of soccer is intermittent, with players regularly alternating between brief bouts of high-intensity exercise and longer periods of low-intensity exercise (Rampinini et al., 2007). During elite matches, players cover 9–14 km of distance in total, with high-intensity exercise accounting for 1–3 km of this (Bangsbo et al., 1991; Bradley et al., 2009; Di Salvo et al., 2009; Mohr et al., 2003). This results in an average intensity of approximately 70% of maximal oxygen uptake and elicits blood lactate concentrations of 4-6 mmol/L (Mohr et al., 2005). However, expressing match intensity as an average value disguises the unique physiological stress induced during intense periods (Glaister, 2005). During these periods, heart rate (HR) can exceed 95% of its maximum, and peak blood lactate concentrations can reach 8-12 mmol/L (Ali and Farrelly, 1991; Bangsbo, 1994). During a typical English Premier League match, players stand still for 6% of the total time. Low-intensity activity represents 85% of the total time, which comprises 59% walking and 26% jogging. High-intensity activity represents 9% of the total time, which is broken down further into 6% running, 2% high-speed running, and 1% sprinting (Figure 3.1).

3.3 POSITIONAL VARIATION

The large differences observed between various playing positions for the energetic and physical performance characteristics of elite players is one of the most robust findings from time-motion analysis studies (Di Salvo et al., 2009; Bradley et al., 2009; Rampinini et al., 2007). When comparing the five most-common positions, it is clear that central and wide midfielders cover more total distance than any other position, with the wide midfielders and fullbacks also displaying superior high-intensity activity profiles (Bradley et al., 2009). The attackers and central defenders consistently show the lowest physical performances during a game (Figure 3.2). These findings have implications for developing position-specific training drills that mimic the characteristics of each position by taking into consideration the unique tactical, technical and physical demands of various positions in the team (Di Salvo et al., 2007). Thus, separate drills for each position can be constructed, either as a rehabilitation tool or for isolated drills. However, conditioning simulation drills in which all positions are worked together in unison with game- and position-specific ball work are much more fruitful in the applied environment due to player enjoyment and coach acceptance.

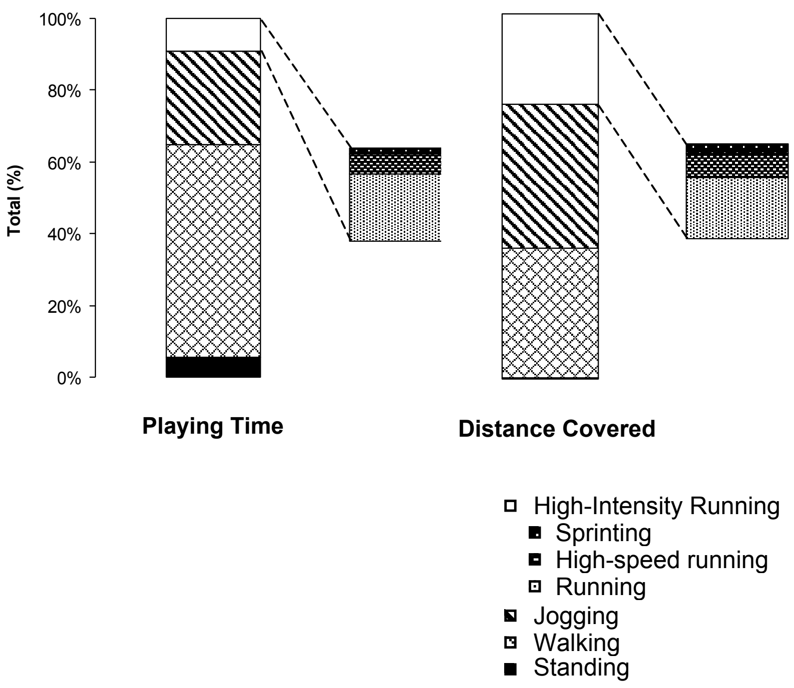


Fig. 3.1: Average values of different activities during English Premier League matches. Values are expressed both as a percent of total playing time and distance covered (Data from Bradley et al., 2009).

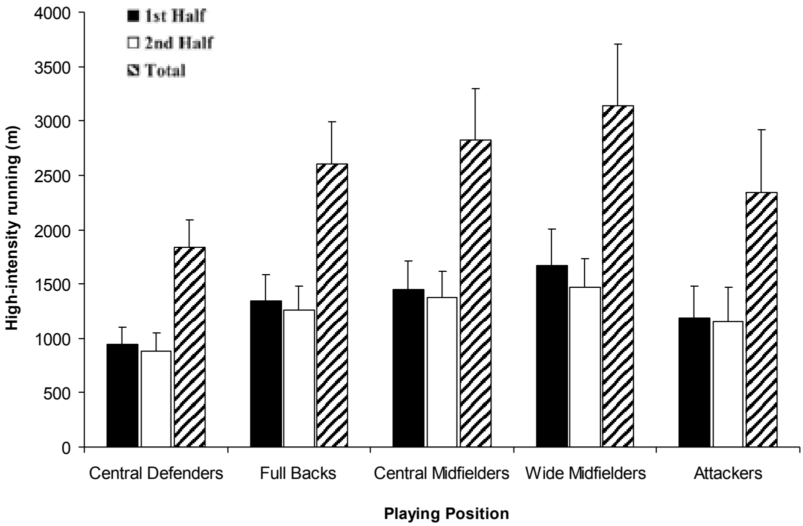


Fig. 3.2: Positional variation in high-intensity running profiles during English Premier League matches (Data from Bradley et al., 2009).

3.4 COMPETITIVE STANDARD

Research has shown players at a higher standard of play to perform more high-intensity running than their peers at lower standards (Bangsbo et al., 1991; Mohr et al., 2008). For instance, Mohr et al. (2003) found that elite Italian League players performed 28% more high-intensity running than sub-elite Danish League peers. Similarly, Ingebrigtsen et al. (2013) reported that distance covered in high-intensity running was 31–38% greater in players in top-ranking Danish teams when compared with middle- and bottom-ranking Danish teams. Based on this data, one would assume that the distances covered at high-intensity increase as we move up the competitive standards, but this is not entirely correct. For instance, studies demonstrate that players cover more total distance and perform more high-intensity running when playing against higher-quality opponents in the same domestic league (Castellano et al., 2011; Di Salvo et al., 2009; Rampinini et al., 2007).

There are also no differences in the activity profiles of international players and those who play in the best domestic European leagues (Bradley et al., 2010). Thus, the relationship between competition standard and physical match performance is more complex than we might initially think. Interestingly, English Premier League players (top tier) cover less distance at high-intensity than Championship (middle tier) and League 1 players (bottom tier) (Figure 3.3). Given there were no real differences in the physical capacity of the players at each tier, it was concluded that this trend was related to the style of play used in the lower tiers, with the Championship and League 1 teams employing a more direct style of play while the Premier League teams used a more possession-based style. This was evidenced by more successful passes in the Premier League and more long passes, headers, clearances and interceptions in the lower tiers (Bradley et al., 2013a). Thus, it seems that tactical variables and style of play have an influence on the distances covered by elite players. It is important to note that while Premier League players cover shorter match distances at high intensity, it does not necessarily mean the overall match demands are markedly different than in the lower tiers, because Premier League players may display superior accelerations or decelerations and lateral movement profiles that are metabolically taxing (Osgnach et al., 2010).

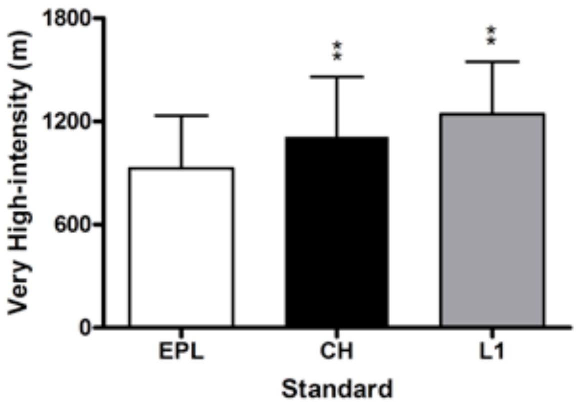


Fig. 3.3: Very high-intensity running profiles in the English Premier League (EPL), Championship (Ch) and League 1 (L1) players. (Data from Bradley et al., 2013a).

3.5 GENDER DIFFERENCES

The relative physiological loadings experienced during matches are similar for both genders, suggesting that the aerobic system is heavily taxed throughout matches, particularly during intense periods (Bangsbo, 1994; Krustrup et al., 2003, 2005, 2006, 2010; Mohr et al., 2004). Female players, however, seem to possess a lower physical capacity than male players across a range of aerobic and anaerobic fitness tests (Bradley et al., 2011, 2012; Mujika et al., 2009). Thus, it is not surprising that studies have reported that high-intensity running in elite female matches is around 30% lower than that of their male counterparts at a similarly competitive standard with similar total distances (Krustrup et al., 2005; Mohr et al., 2008). Recently, Bradley et al. (2013b) analyzed the gender differences in the match performance characteristics for male and female players taking part in the UEFA Champions League. They found that while male players covered just ~2-5% more total distance than female players, they performed ~30-35% more high-intensity running and had a superior technical performance (Table 3.1). This finding illustrates the importance of high-intensity running to the female game and the inferior anaerobic capabilities of female players when compared to elite male players. Practical applications are clear, and this suggests that elite female players may possibly benefit from specific high-intensity aerobic and speed endurance training in the form of small-sided games or generic running drills (Ade et al., 2013).

Physical/Technical Indicators	Male Players			Female Players		
	First	Second	Total	First	Second	Total
High intensity (m)	1049	1063	2112	854	718	1571
Time possession (s)	33.8	35.8	69.6	34.6	31.9	66.5
Total balls lost (No.)	7.5	5.1	12.6	9.2	8.2	17.4
Successful passes (%)	78.1	80.1	79.4	72.0	70.4	71.5

Table 3.1: Gender differences in physical and technical indicators for elite players in the UEFA Champions League (data from Bradley et al., 2013b).

3.6 MATCH-TO-MATCH VARIABILITY AND STABILITY

When players' match performances are analyzed across a season, it is very evident that substantial differences exist between games. Mohr et al. (2003) reported that the high-intensity running distances of elite players differed by approximately 10% between successive matches but it differed by 25% between different stages of the season using the coefficient of variation as the variability measure. Gregson et al. (2010) also found that English Premier League players' high-intensity and sprint profiles differed by 16–30% from one match to the next. The technical profiles of players seem to also illustrate similar differences, with the total number of passes for English Premier League players differing by approximately 30-50% from match to match (Bush et al., unpublished observation). This makes it very difficult for sports scientists to evaluate the impact of various technical, tactical and physical training interventions because of limited consistency in the performance measures. Substantial match-to-match variability is less likely to be caused by changes in physical capacity, because this does not differ substantially in the short term, but it could also possibly be due to technical, tactical and contextual factors.

3.7 CONTEXTUAL AND TACTICAL FACTORS

Research examining contextual factors—such as match status (i.e., win, lose or draw), location (i.e., home or away), level of opposition (i.e., top, middle or bottom) and match half—demonstrates these have a real impact on the activity profiles of elite players (Lago et al., 2012; Catellano et al., 2011). For instance, Castellano et al. (2011) found the distance covered when the ball was in play (effective playing-time distance) in various movement categories to be greater when playing at home rather than away, as well as when the opposition team was losing and of a higher competitive level. Other contextual factors, such as score line but not match importance, also seem to be important factors in dictating physical performance. Bradley and Noakes (2013) observed that elite players covered similar high-intensity running distances in matches with differing score lines, but position-specific trends indicated that central defenders performed 17% less high-intensity running and attackers 15% more during matches that were decisively won when compared to matches that were lost. However, high-intensity running distances were com-

6

HIGH-INTENSITY INTERVAL TRAINING (WITH SPECIAL REFERENCE TO SMALL SIDED GAME PLAY)

Kenny McMillan, Jan Van Winckel, Guido Seerden, Werner Helsen

6.1 INTRODUCTION TO HIGH-INTENSITY INTERVAL TRAINING (HIIT)

Interval training can be defined as a single or repeated interval of sport-specific exercise with no additional resistance (Paton and Hopkins, 2004), while high-intensity training refers to exercise performed above the second ventilatory threshold (Seiler and Kjerland, 2006). Because training at high intensity puts a high strain on the player, high-intensity training can be organized through interval training. Interval training at high intensities (i.e., just below or around VO_{2max}) improves endurance performance through improvements in all of the three components of the aerobic system: VO_{2max}, anaerobic threshold, and running economy.

HIIT (High-Intensity Interval Training) may consist of high-intensity workloads (> 85% VO_{2max}) executed for a short duration (between 30 seconds and 4 minutes) interspersed with recovery times in between each exercise bout (usually in a 1:1, 1:2 or 2:1 ratio). HIIT can be traced back to as long ago as 1912, when the Finnish Olympic long-distance runner Hannes Kolehmainen was reported to be using interval training in his workouts (Billat, 2001). Several years later in the 1930s, the German professor Dr. Woldemar Gerschler further developed interval training at the University of Freiburg. Gerschler teamed up with cardiologist Dr. Herbert Reindel, and together they developed a training system consisting of running intense but short distances followed by brief recovery "intervals" (Sears, 2001). Gerschler did not allow a runner to begin the next repetition until the HR had returned to 120bpm (Jenkins, 2005).

Today, HIIT is regarded as one of the most effective means of improving the physical performance of athletes (Buchheit and Laursen, 2013a). Indeed, in already well-trained athletes, the supplementation of high-intensity training on top of an already high training volume seems to be extremely effective (Laursen, 2011; Laursen and Jenkins, 2002). Various studies have shown the significant effects of HIIT in as little as 2–3 weeks (Acton-Jacobs et al., 2013; Bogdanis et al., 2013; Buchan et al., 2013; Tjonna et al., 2013; Boyd et al., 2013). Scientific research on the optimum length of high-intensity intervals is equivocal, although positive results have been found with various interval lengths ranging from 30 seconds up to 4 minutes (Little et al., 2010; Esfarjani and Laursen, 2007; Laursen et al., 2002; Billat et al., 2000; Smith et al., 1999). With regards to the training intensity, scientific research demonstrates that sub-maximal (i.e., 90–95% VO_{2max}) (Zuniga et al., 2011) or maximal intensities (100% VO_{2max}) (Bishop et al., 2011) elicit the greatest adaptations. In their review on HIIT, Buchheit and Laursen (2013a) suggest that maximal or close to maximal intensities are the most effective at increasing aerobic capacity because they stress the oxygen transport system the most, activate more and larger motor units of muscle fibers, and are performed at near maximal cardiac output. While there is evidence that there are still benefits to be gained from HIIT training programs using lower intensities (Boyd et al., 2013), the most profound benefits are realized at higher intensities (Acton-Jacobs et al., 2013; Boyd et al., 2013; Cicioni-Kolsky et al., 2013; Moholdt et al., 2013).

When examining the effect of training intensity distribution on aerobic fitness variables in elite soccer players, Castagna et al. (2011) reported that even though almost two-thirds of players' training time was spent at low intensities, only the time spent at high intensity (90% of HR_{max}) was related to changes in aerobic fitness. Impellizzeri et al. (2005) reported similar findings and demonstrated a significant correlation between time spent in high-intensity zones and changes in oxygen uptake at lactate threshold. These results highlight the effectiveness of high-intensity training in soccer. It is believed that an optimal stimulus to elicit both maximal cardiovascular and peripheral adaptations is one where athletes spend at least several minutes per session in their "red zone," which generally means reaching at least 90% VO_{2max} (Buchheit & Laursen, 2013b). High-intensity training that raises the HR to above 90% of HR_{max} should constitute at least 7–8% of the total weekly training plan for elite soccer players during preseason and in-season (Castagna et al., 2013).

6.2 HIIT EFFECTS ON CARDIOVASCULAR AND MUSCULAR ADAPTATIONS

The cardiovascular and muscular adaptations to HIIT are summarized in the table below.

Effects of High Intensity Interval Training
Cardiovascular adaptations
• Increased cardiac muscle capillary density • Lowered HR at similar pre-training work levels • Increase cardiac efficiency and the maximal mitochondrial capacity of the heart (Hafstad et al., 2011). • Increased stroke volume (Helgerud et al., 2007) • Lower blood lactate levels for a given work intensity • Increased left ventricle volume and increased contractibility (Slordahl et al., 2004) • Increase in VO_{2max} (Daussin et al., 2008)
Muscular adaptations
• Increased transcription and biogenesis of mitochondria in the skeletal muscle cells of highly trained athletes (Acton-Jacobs et al., 2013) • Increase in mitochondria (number and size) (Gibala, 2009) • Increase in maximal activities of mitochondrial enzymes in skeletal muscle (Kubekeli et al., 2002; Laursen and Jenkins, 2002) • Increased proportion of Type IIa fibers (Billat, 2001) • Optimized oxidative phosphorylation • Increase in oxidative enzymes (Burgomaster et al., 2008) • Activation of PGC-1α via AMPK pathways • Increase in fat oxidative capacity (Talanian et al., 2007) • Increase in GLUT4 and glycogen

Table 6.1: Overview of the effects of HIIT

6.3 LACTATE FORMATION DURING HIIT

During oxygen-independent glycolysis, glucose/glycogen molecules are processed and broken down inside the muscle cells. Each molecule of glucose is broken down to deliver ATP, and two molecules of lactic acid are produced (a proton and lactate). Many coaches still believe that lactate is a metabolic dead-end only formed under anaerobic conditions, with lactate playing the role of the toxic by-product. This oxygen-independent glycolysis works continuously (even during rest) and not only when sufficient oxygen is unavailable (Brooks, 1986). All energy systems are, to a greater or lesser extent, active all the time, and their contributions depend on the energy requirements and therefore the intensity and duration of exercise.

The level of lactate found in the blood and muscles is the **difference between lactate produced and lactate processed**. At some point of increasing intensity, lactate production will become higher than lactate clearance. In the past, this was referred to as the anaerobic threshold or the Onset of Blood Lactate Accumulation (OBLA). We use the term lactate threshold in this book. This lactate threshold is determined not just by lactate production but also by the ability of muscle cells to remove and process lactate. If lactate levels accumulate, as may happen during HIIT, glycolysis is inhibited and the muscle fiber fatigues due to the protons associated with lactate ions.

6.4 LACTATE CLEARANCE DURING HIIT

Lactate can be cleared via two mechanisms. It can be metabolized back to pyruvate and processed in the muscle cell by oxidative phosphorylation, which is an oxygen-dependent process. On the other hand, lactate can leave the muscle cell through the cell membrane. It may then be absorbed and utilized in oxidative metabolism by other muscle cells within the same muscle, or it may leave the muscle and enter the circulation system.

Once in the circulation, lactate can be:

- Transported to other skeletal muscles where it can be stored
- Used by the heart for oxidative energy production
- Transported from the peripheral tissues to the liver by means of the Cori Cycle, where it is then reformed into pyruvate through the reverse reaction using lactate dehydrogenase
- Transported to the brain for oxidative energy production.

The lactate shuttle, which describes the movement of lactate intracellularly and intercellularly (cell to cell), was hypothesized by Dr George Brooks in the 1980s. This theory states that lactate produced at sites with high rates of glycolysis and glycogenolysis can be shuttled to adjacent or remote sites, including the heart and other skeletal muscles, where the lactate can be used as a gluconeogenic precursor or substrate for oxidation (Brooks, 2009). During HIIT, fast-twitch fibers begin producing lactate at high rates. Because fast-twitch fibers are not built well for oxidative phosphorylation, lactate is emitted and subsequently picked up by slow-twitch fibers, which are better equipped for oxidative phosphorylation, or the circulatory system may carry it to the heart, the liver, the brain or less active muscles.

6.4.1 Monocarboxylate transporters (MCTs) and HIIT

Monocarboxylate transporters (MCTs) are proton-linked plasma membrane transporters that carry molecules having one carboxylate group (monocarboxylates), such as lactate and pyruvate, across biological membranes.

In the literature, at least 14 MCTs have been identified, although MCT1 and MCT4 seem to be most relevant to lactate and pyruvate transportation within cardiac and skeletal muscle (Bonen, 2001). MCT1 and MCT4 have been identified as H^+/lactate symporters capable of mediating the bidirectional transport of lactic acid across the plasma membrane (Halestrap and Meredith, 2004).

MCT1 is the most important MCT for endurance athletes because it is the key lactate mover in muscle cells. Slow-twitch muscle fibers in particular have relatively large amounts of MCT1 in their membranes. The presence of large quantities of MCT1 in slow-twitch fibers and cardiac muscle cells demonstrates that MCT1 is probably responsible for clearing lactate to cells that are better equipped for oxidative phosphorylation.

Unlike MCT1, MCT4 is more common to fast-twitch muscle fibers, suggesting that MCT4 is better equipped to transport lactate out of the muscle cell. Exercise training can increase the expression of both MCT1 and MCT4 in muscle cells, and this effect is related to the intensity of training. MCT4, like other glycolytic enzymes, is up-regulated by hypoxia. This adaptive response allows the increased lactic acid produced during hypoxia to be rapidly cleared from the cell (Ullah et al., 2006).

Although the research into MCTs is still in its infancy, it can already be concluded that lactate processing can be improved through appropriate training. To improve lactate clearance and processing in soccer players, training at fluctuating high intensities (i.e., HIIT) is necessary. During soccer-specific HIIT for example, lactate is produced, and during recovery intervals, the body is trained to efficiently utilize and clear the lactate. Therefore, HIIT is important to improve MCT concentrations, lactate processing, lactate clearance, the lactate threshold, and performance capacity.

6.5 HIGH-INTENSITY INTERVAL TRAINING VERSUS LOW-INTENSITY CONTINUOUS TRAINING

Both HIIT and low-intensity continuous training are important in improving aerobic fitness. The main goal of interval conditioning is to induce a greater training stimulus at intensities higher than what would be tolerated in a single bout of continuous exercise (Wenger and Bell, 1986). Continuous low-intensity training recruits predominantly slow-twitch motor units, while HIIT will recruit additional fast-twitch motor units for relatively short durations (Enoka and Duch, 2008). The cardiovascular adaptations that occur with HIIT are similar, and in some cases superior, to those that occur with continuous endurance training (Helgerud et al., 2007; Wisløff, Ellingsen and Kemi, 2009). Moreover, HIIT can often produce a broad range of physiological effects in less time than high-volume low-intensity continuous exercise (Londeree, 1997; Daussin et al., 2008; Psilander et al., 2010). This may be because the time course for performance improvement with increases in training volume may not occur as rapidly as when using acute increases in high-intensity training (Laursen et al., 2002; Laursen, 2011).

However, some important physiological adaptations occur in response to low-intensity continuous training that are not observed with HIIT (Laursen, 2011). For instance, Ingham et al. (2008) demonstrated that a low-intensity continuous training group improved their speeds at lactate threshold to a greater extent than the mixed-intensity training group. It is often purported that these periods of relatively low intensity and high training volumes may provide the "aerobic base" needed to facilitate the specific adaptations that occur in response to HIIT (Laursen, 2011). The periodization of continuous extensive soccer drills (e.g., 2 x 15 minutes of 9 v 9 play at an intensity of 70-75% of HR_{max}) and higher intensity "intensive" drills (e.g., 6 x 4 minutes of 4 v 4 small sided game play play) throughout the soccer season is discussed in Chapters 14 to 18.

8

FITNESS TESTING

*Jan Van Winckel, Kenny McMillan, Jean-Pierre Meert,
Balder Berckmans, Werner Helsen*

8.1 INTRODUCTION

Monitoring the physical abilities critical to soccer performance allows sports scientists and coaches to gain valuable information that can be subsequently used effectively to optimize training and recovery. However, in complex sports like soccer, the ability to isolate and evaluate specific physical abilities can be problematic. The physiological and mechanical demands of soccer require players to be proficient in numerous aspects of fitness, such as aerobic and anaerobic power, muscle strength, flexibility, speed, agility and quickness (Reilly and Doran, 2003). These physical demands can vary according to playing position, players' individual abilities, and the tactical guidelines imposed by the coach (Reilly, 2003). Ultimately, match analysis of physical performance (e.g., distance covered) only provides the coaching staff with a one-dimensional perspective, because players do not always maximally exert their physical capacities during match play due to factors such as tactics, score, and opposition standard. In this regard, research into elite match play has found the work rate to be associated with that of the opposing team, as well as their competitive level (Rampinini, 2007).

The main purpose of fitness tests is to build a physical profile of the player or squad. There are also other reasons for periodic fitness tests, such as being able to objectively assess the impact of training interventions (e.g., determine if the players' physical abilities have improved over the season), as well as to inform the coaches and sports scientists when a player is ready to return to training and, more importantly, to competition following an injury.

8.2 CRITERIA

Fitness testing for soccer players should meet the following criteria:

- They must be objective: A test's results must be reproducible from day to day and from one rater to the next, thus minimizing any subjective interpretation. This gives the best chance of observing sensitive changes in fitness over the season (improvements and decrements).
- It must be specific: A test must be specific to soccer and therefore assess physical parameters important to performance (e.g., utilize similar movements, muscle groups, and energy systems).
- It must be valid: A test must actually measure what it professes to measure.
- A test should not require technical competence because of the learning effect being too great. For example, if speed is being measured, it should be measured without the ball, because the player's technical skill will influence the result of the test.
- It must be comprehensible: A test must be as simple as possible to minimize learning effects and maintain reproducibility.
- It must be standardized in terms of administration, organization and environmental factors. Ideally, tests should be conducted at the same time of day, the same day in the microcycle, and after a similar amount of load or recovery. Even the presence of parents or encouragement from the staff can affect the test result.
- It must respect necessary recovery between tests. Coaches should be guided by the time needed for replenishment of metabolic substrates when considering the recovery time between tests. Coaches should taper for at least 48 hours before conducting a test in order to reduce the effect of accumulated fatigue and allow players to be tested in an optimal physical condition (Viru and Viru, 2001).
- It must be reliable. Intra-rater reliability is the degree of agreement among multiple repetitions of a diagnostic test performed by a single rater. Inter-rater reliability is the degree of agreement among different raters. A statistical measure of inter-rater reliability is Cohen's Kappa, which ranges in general from 0 to 1.0. Larger numbers mean better reliability, and values approaching zero suggest that any agreement can be attributed to chance alone. As a rule of thumb, Kappa values from 0.40 to 0.59 are considered moderate, 0.60 to 0.79 are considered substantial, and 0.80 and greater are believed to be outstanding (Landis and Koch, 1977).
- It must follow a logical order between consecutive tests. The National Strength and Conditioning Association (NSCA) (Harman, 2008) suggests the following order: resting and non-fatiguing tests first (e.g., resting heart rate (HRr), body composition, flexibility, and jump tests), followed by tests for agility, power and strength; sprints; local muscular endurance; and anaerobic and aerobic capacity.
- Preferably, a test should measure isolated physical abilities (e.g., not speed and endurance together). A test that measures too many factors at once does not provide useful information to the coaches and sports scientists as to why the player performs well or not. It is therefore difficult to set up a specific individualized program.

8.3 WHY MEASURE?

Measuring physical ability is important for both players and coaching staff for a number of reasons.

8.3.1 For the players

- Testing provides feedback about the training process. This gives players a clear understanding of their personal development.
- Reference data. Tests give an indication of a player's strengths and weaknesses, with the results providing reference data for an individualized training program. This makes it possible to outline a performance profile for each player.
- Tests convey information about the player's state of fitness. Playing soccer at a high level is a strain on the body (overload principle), and this can result in overload injuries. Tests can enable overtraining to be detected.
- A testing program is an educational process, helping the player to understand the objectives of the training program.
- Regular testing increases the player's motivation. Being more aware of one's own possibilities will encourage the player to conscientiously follow the training program.

8.3.2 For the coach

- Setting positions. Based on the test results, the coach can designate players to playing positions where their physical abilities are best suited to match demands. For example, a player with a good acceleration and high peak running speed may be more suited to playing as a winger.
- The test results enable the coach to create a team profile. This may give the coach a better insight into the strengths and weaknesses of his team. As an example, speed tests can give the coach an idea of the speed of his defenders, and this information can then be used to advise the defensive line on how high up the field they should initiate pressure.
- Reference data. Test results are good indicators for the rehabilitation process. Match fitness can be checked based on earlier results.
- Testing data can provide coaching staff with objective feedback on the effectiveness of a training program and enable the evaluation and adjustment of the training schedule in order to optimize results.

8.4 TEST ENVIRONMENT

The test environment and conditions must be consistent and standardized for the testing data to be interpreted correctly. For example, if an initial fitness test is conducted on the pitch in a warm environment, but the following test is carried out in an indoor air-conditioned facility with a hard-floor surface, the two tests will produce differing results.

Always note the conditions in order to simplify the analysis of the results:

- Time (The time of day can influence the result.)
- Equipment used (Is the time measured electronically or manually?)
- Periodization phase
- Training sessions 48 hours prior to the beginning of the test
- The order of the different tests
- Noise pollution
- Temperature and humidity
- Number of hours of sleep
- Emotional state of the athlete
- Medication
- Caffeine and other beverages
- Time and contents of the last meal
- Test environment
- Knowledge of the test (Is there a possible learning effect? Is the test "user friendly"?)
- Accuracy (such as the unit of time, distances, etc.)
- Warming up (Was there enough time to warm up?)
- People present (Try to keep the number of people present as low as possible to minimize outside influence.)
- Players' motivation (Is the player motivated for this type of test?
- Encouragement (Do not allow encouragement or incentives, because these can affect the test results.)

As a general rule, testing should be conducted under neutral conditions. This means a good surface and a moderate temperature with no other environmental factors that could influence results, such as humidity, rain, and so on.

8.5 THE TERMS "TO BE" AND "AS IS"

These two terms are used in sporting circles to determine the demands of the sport and measure the current status. In other words, "to be" is an analysis of the sport and the physical abilities required, while "as is" represents the current state of the player for each of these abilities. For example, "to be" could be that a winger has to run 1,000m at high intensity during a match. The "as is" is then determined by looking at how many meters the player actually ran. For instance, if the player only ran an average of 800m during matches, the difference between "to be" and "as is" is then 200m. This implies that the player has to work on his fitness to make up the difference between the two values.

8.6 TESTS

Different tests that can be used to determine the team's current status ("as is") are described below. We now describe examples of muscular endurance, power, sprint, repeated sprint, agility and endurance tests that can provide useful information on the fitness status of soccer players.

8.6.1 Muscular endurance tests

Introduction

Augustsson et al. (2009) demonstrated that males performed significantly more push-ups than females and had 44% greater upper-body strength endurance. They also stated that females who trained upper-body strength were more likely to avoid injury. Kennedy et al. (2012) confirmed this when they suggested that athletes with limited upper-extremity endurance, as demonstrated by low push-up performance, were more likely to be injured.

Warm up

The standardized warm up for muscular endurance tests should be:

- Five minutes jogging followed by a dynamic activation of the deep musculature.

Push-up or press-up test

- **Aim**: The push-up test is used to evaluate upper-body endurance, specifically the pectoralis major, anterior deltoids, and triceps (Hoffman, 2006).
- **Protocol**: Many variations on push-up tests exist, such as the duration of the test, the placement of the hands, how far to go down, and so on. The push-up test is conducted with a normal hand and foot support position, and the body and legs are in a straight line with the feet slightly apart. The player lowers the body until there is a 90-degree angle at the elbows and then returns to the starting position. The back must be straight at all times, and the player has to continue the upward movement until his arms are fully extended.
- **Result**: The number of repetitions are counted until exhaustion or until the player is unable to maintain the proper technique over two consecutive repetitions. No pause is allowed at elbow extension, and a self-selected tempo should be maintained throughout the test.

Some other tests exist, such as timed tests like the two-minute army push-up test and the one-minute navy push-up test, as well as tempo tests where the push-ups are performed to the rhythm of a beep or metronome. The push-ups are performed at a rate of one push up every 3s in the cadence push-up test as part of the FitnessGram and the President's Challenge Fitness Award.

Push-up test				
	Min.	**Max.**	**Stdev.**	**Avg**
Elite U16	19.00 ABS	46.00 ABS	7.71	28.40 ABS
Elite U17	21.00 ABS	50.00 ABS	7.35	31.14 ABS
Elite U19	21.00 ABS	75.00 ABS	9.81	37.82 ABS
Elite U21	20.00 ABS	61.00 ABS	11.70	39.04 ABS
Elite First team	22.00 ABS	76.00 ABS	13.45	48.17 ABS

Table 8.1: Reference data based on tests at different top clubs (TopSportsLab).

11

TRAINING CONTINUUM

*Jan Van Winckel, Werner Helsen, Jean-Pierre Meert,
Kenny McMillan, Paul Bradley*

11.1 INTRODUCTION

In the preceding chapters, we described and defined various physical abilities, such as speed and endurance, as well as physical parameters, such as volume and intensity. We also outlined different methods that can be used to calculate training load. In this chapter, we aim to provide an overview of the different effects of training. There is a lack of clarity regarding the different terms in the existing literature, with the concepts of overtraining, overreaching and overload being used interchangeably. For example, the term "overtraining syndrome" is used regularly in soccer jargon, yet this state rarely occurs in soccer. Declines in performance can also be due to other life stressors, so the term "underperformance syndrome" is sometimes used (Budgett et al., 2000).

Successful training must involve overload, but it must also avoid the combination of excessive overload and inadequate recovery. Athletes can experience short-term performance decrements without severe psychological or other lasting negative symptoms. This Acute Fatigue (AF) or Functional Overreaching (FOR) will eventually lead to an improvement in performance after adequate recovery. When athletes do not sufficiently respect the balance between loading and unloading, Non-Functional Overreaching (NFOR) can occur. The distinction between NFOR and the Overtraining Syndrome (OTS) is very difficult and depends on the clinical outcome and exclusion diagnosis (Meeusen et al., 2013).

Process	Training (overload) →			
Outcome	Acute fatigue (AF)	Functional overreaching (short-term OR)	Non-Functional overreaching (extreme OR)	Overtraining syndrome (OTS)
Recovery	Day(s)	Days - weeks	Weeks - months	Months - …
Performance	Increase	Temporary performance decrement	Stagnation decrease	Decrease
Example	Acute fatigue after a day with two training sessions	Overreaching after a pre-season training camp	Continued excessive training load after a training camp with inadequate recovery	Several months with stressful competition, stressful team environment, excessive load and inadequate recovery

Table 11.1: The different stages that differentiate normal training from OR (functional and non-functional OR) and the OTS. (Meeusen et al., 2013)

11.2 DIFFERENT STAGES OF THE TRAINING CONTINUUM

11.2.1 Detraining

Undertraining or detraining involves a load that is insufficient to maintain or stimulate positive adaptation. Many terms—such as tapering, active recovery and unloading—are also used interchangeably in relation to detraining or undertraining.
Set out below is an overview of the most widely used terms:

1. **Active recovery or unloading** allows both the training volume and intensity to drop. Active recovery is used to recover from match load or successive heavy training loads.

2. **Taper**: The highest level of performance follows on from a period of tapering. Tapering is defined by Mujika et al. (2003) as a progressive, nonlinear reduction of training load over a particular period in order to reduce psychological and physiological stress and therefore optimize performance. Tapering differs from unloading in the sense that although the volume and frequency decrease, the intensity remains the same (80–100%). This process is very individual, but the best results are typically seen after a recovery period of 7–14 days, which is not possible in the calendar of professional soccer. In soccer, tapering strategies are imposed in every microcycle for the days preceding a match and during the last phase of preseason, just before the start of the season.

3. **Detraining**: The term "detraining" is used when a player's performance level drops. The detraining effect will appear, for example, a few weeks into the off-season, when players' fitness levels begin falling rapidly.

The reduction in aerobic endurance is significantly greater than for other motor abilities, such as strength, power and flexibility. In a study conducted by Saltin (1968), five people were kept in bed for 20 days. Their VO_{2max} fell by 25%. This drop can be mainly attributed to a decline in the heart's performance that occurs, in particular, during the first 12 days of detraining.

The physiological effects of 2–4 weeks detraining:

- VO_{2max}: - 5–10%
- resting and submaximal exercise HR: + 5–10%
- blood volume: - 5–10%
- stroke volume: - 6–12%
- cardiac output: reduced
- flexibility (suppleness): reduced
- lactate threshold: reduced
- muscle glycogen stores: - 15–30%
- aerobic enzyme activity: reduced

Physiological adaptations lost over a particular period need more time to recover than it takes to detrain them. Fourteen days of detraining is sufficient to induce a significant decrease in VO_{2max}, but it takes considerably longer than two weeks to return to the same baseline levels. The mechanisms of physical deconditioning are many, but it seems that hypovolemia (a decrease in volume of blood plasma), decreases in the activity of oxidative enzymes, and lower muscle glycogen stores are the first factors responsible for a decrement in performance (Oliviera et al., 2008).

11.2.1.1 Effects of training parameters

As highlighted above, detraining is a consequence of reduced frequency, intensity and/or volume. An overview of the effects of a reduction in these three factors is set out below:

1. **Reduction in frequency**: If training is reduced from six sessions to three sessions, while the volume and intensity are maintained, there is no substantial detraining effect.
2. **Reduction in intensity**: If the training intensity is reduced by 50%, performance will be diminished significantly.
3. **Reduction in volume**: Even if the total volume is reduced by 50%, the detraining effect can be limited.

This shows that a reduction in intensity, in particular, induces a detraining effect.

Reference	Days of inactivity	Percentage
Houston, Bentzen, & Larsen, (1979)	15	−4 % VO_{2max}
Martin et al. (1986)	40	−20 % VO_{2max}
Houmard, Hortobagyl, & Johns (1992)	14	−5 % VO_{2max}
Coyle et al. (1984)	21	−8 % Cardiac Output
Chi et al. (1983)	21	−64 % activity aerobic enzymes
Costill et al. (1985)	7	−20 % Glycogen store

Table 11.2: Overview of detraining effects

11.2.2 Retaining (maintenance)

A retaining or maintenance load is used when further positive adaptation and/or overload are contraindicated, but maintenance of physical capacity is desired. Soccer training for 60–70 minutes at 60–70% intensity is a good example of maintenance training for professional players. Although strategies to maintain stable performance throughout the season are key to a successful season, retaining loads are rarely investigated by scientific research.

11.2.3 Acute fatigue

Overload training disturbs players' homeostasis and results in acute fatigue, followed by an improvement in performance. (Soccer example: two consecutive intensive training sessions). Intensified training is commonly employed by coaches in an attempt to enhance performance. Subsequently, the player may experience acute feelings of fatigue and decreases in performance because of a single intense training session or an intense training period. The resultant acute fatigue can be followed, after an adequate rest period, by a positive adaptation or improvement in performance, and this is the foundation of effective training programs (Meeusen et al., 2013). The sequence of training and the interrelationship between training and recovery are crucial factors in achieving the desired training response.

The term overtraining is often used in soccer. In this book, the term "overtraining" is used as a "verb" to refer to a process of intensified training that possibly results in short-term overreaching (functional OR), extreme overreaching (non-functional OR), or OTS, depending on the appropriate balance between loading and unloading cycles (Halson and Jeukendrup, 2004).

11.2.4 Functional overreaching (FOR) or short-term OR

When training continues and fatigue accumulates, or when coaches purposely use a short period (e.g., a training camp) to increase training load (fatigue accumulation), players can experience short-term performance decrements without severe psychological or long-term negative symptoms. This functional OR (or short-term OR) will ultimately lead to an improvement in performance after adequate recovery (supercompensation effect). (Soccer example: A seven-day training camp followed by 3–4 days of adequate recovery.)

Overreaching is an integral part of successful training regimes, and it can be analyzed using a multidisciplinary approach involving physiological and psychometric data. Overreaching is often utilized by coaches during a typical training cycle to enhance performance. Intensified training can result in decreased performance, but when appropriate periods of recovery are provided, a "supercompensation" effect may occur, with the player unveiling (because of reduced levels of fatigue) an enhanced performance. This process is often used during "training camps," and it will lead to a temporary performance decrement that is followed by improved performance. In this situation, the physiological responses will compensate for the training-related stress (Steinacker et al., 2004). This form of short-term "Overreaching" can also be called "Functional Overreaching."

11.2.5 Dysfunctional or Non-Functional Overreaching (NFOR)

When coaches do not sufficiently respect the balance between training and recovery, NFOR (extreme OR) may occur. At this stage, the first signs and symptoms of prolonged training distress are performance decrements, psychological disturbance, decreased vigor, increased fatigue, and hormonal disturbances. Players will often require weeks or months to recover. An example in soccer would be when a team plays competitive games twice a week for six consecutive weeks without respecting adequate recovery between games. Dysfunctional overreaching is the point along the training continuum when functional overreaching results in more persistent decreases in performance (Moore and Fry, 2007).

11.2.6 Overtraining syndrome (OTS)

Although this term is frequently used, overtraining rarely occurs in soccer. OTS occurs mainly in individual athletes (especially endurance athletes) and is the consequence of an excessive training load over a prolonged period. In most cases, OTS will occur in combination with other stressors, such as psychological, immunological, social, and so on. The confusion surrounding OTS is complicated by the fact that the clinical features are non-specific, anecdotal, and numerous (Meeusen et al., 2013).

The distinction between NFOR and OTS is very difficult, because a player will often display the same clinical, hormonal, and psychological signs and symptoms. A key phrase in the recognition of OTS might be the "prolonged maladaptation" of several biological, neurochemical, and hormonal regulation mechanisms (Meeusen et al., 2013). Recovery from overtraining syndrome can take months (Kreider et al, 1998).

In a study by Morgan et al. (1988), 12 male swimmers were assessed prior to, during, and after increasing their workloads from 4,000m to 9,000m at 94% VO_{2max} over a ten-day period. Swimmers completed a POMS (profile of mood status), muscle soreness scale, and 24-hour history each morning before starting the first of two daily training sessions. Seven swimmers successfully completed the required training regimen, but three others had difficultly completing the training requirements, and these athletes had significantly higher levels of POMS mood disturbance. Many of the physiological and psychological responses tended to stabilize after the first five days of exposure to the training stress. Three other swimmers were so severely affected by the training that they had to be dropped from the study. In those swimmers, the psychological changes were very marked.

13

FATIGUE MANAGEMENT

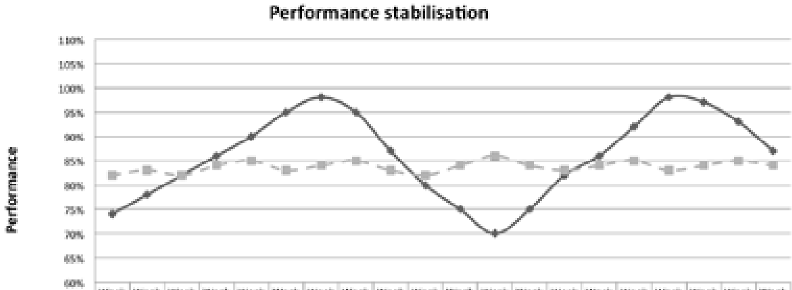
*Jan Van Winckel, Werner Helsen, Kenny McMillan, John Fitzpatrick,
Ester Lowette, Kyle Woodruff, Paul Bradley, David Tenney*

13.1 INTRODUCTION

In the preceding chapter, we considered the causes and effects of fatigue. We also discussed the various ways of countering fatigue. In this chapter, we will discuss the concept of "fatigue management," which involves monitoring, manipulating, and adjusting fatigue. Professional players are expected to compete in 60–70 high-level matches per year. Therefore, it is virtually impossible to peak by means of classic peaking strategies, as there will be a loss of consistent performance in the preceding and ensuing weeks. It is up to the coaching staff to keep the team at a maximal stable level for an entire season. This process is referred to as performance stabilization.

13.2 PERFORMANCE STABILIZATION

At the very top level, performance stabilization can be considered at least as important as performance enhancement. It is a challenge for every soccer coach to keep the players at an appropriate level (around 85% of peak physical capacity) for the entire season, although periods with higher performance levels can be strategically planned during the season.



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20
Individual sports	74%	78%	82%	86%	90%	95%	98%	95%	87%	80%	75%	70%	75%	82%	86%	92%	98%	97%	93%	87%
Team sports	82%	83%	82%	84%	85%	83%	84%	85%	83%	82%	84%	86%	84%	83%	84%	85%	83%	84%	85%	84%

Fig. 13.1: Example of a buildup in an individual sport (e.g., marathon or cycle racing) as opposed to performance level in soccer.

To maintain this constant high level, a clear strategy has to be developed to manage and manipulate a player's fatigue. We refer to this as fatigue management.

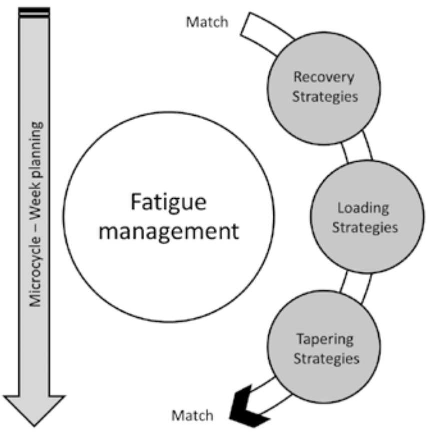


Fig. 13.2: Representation of the fatigue management strategies in a microcycle

13.3 FATIGUE MANAGEMENT

As we already mentioned in the preceding chapters, performance preparedness results from the interplay between the body's long-term fitness increase, which is stimulated by training, and the opposing short-term aftereffects of fatigue, also caused by training (Siff and Verkhoshansky, 1999). Specifically, it reflects the readiness of an athlete to participate in an enhanced level of training and/or excel in competition (Zatsiorsky, 1995). Fatigue is the degree to which training or match-induced stress masks the capacity to display fitness. The higher the accumulated fatigue levels, the greater the inability to utilize the increased fitness levels. This does not imply that fitness levels have decreased but rather that they are simply masked by match- or training-induced fatigue. This also implies that, within physiologically acceptable levels, the greater the increase in accumulated fatigue induced by training stress, the greater the potential to increase fitness levels once the player has the opportunity to recover from the stress and fatigue imposed by training or matches. Fatigue levels should accumulate at various times of a training program to create overload and elicit adaptation. Training is nothing more than systematically disrupting homeostasis and permitting higher levels of performance to occur. Fatigue need to be managed at two levels:

1. **Within a mesocycle:**
   - Within a mesocycle, a certain specific load is imposed in each microcycle in order to generate specific fatigue, causing the body to make a specific adaptation.
   - Within each mesocycle, an unloading period (a lowering of volume and/or intensity) is applied to allow fatigue to decline and let supercompensation take place. The term "regeneration" is used at times to refer to periods of extended recovery within a long-term training plan (Hackney, 1999).

2. **Within a microcycle:**
   - Recovery strategies to reduce the fatigue induced by matches as fast as possible.
   - Loading strategies in order to create specific acute fatigue to elicit adaptation.
   - Tapering strategies to allow fatigue to decline and consequently increase preparedness for an upcoming match.

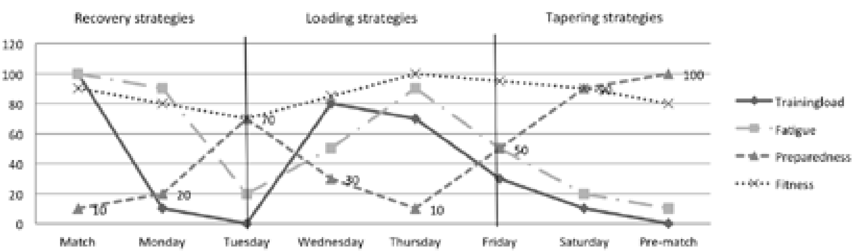


Fig. 13.3: Fatigue management within a microcycle composed of three phases

1. **Phase 1:** Recovery strategies
   The objective in this phase is to eliminate fatigue induced by the game as rapidly and as thoroughly as possible. The training load is reduced, and recovery strategies are applied. Preparedness will decrease due to excessive fatigue, but fitness levels remain high due to the match load.
2. **Phase 2:** Loading strategies
   In the second phase of fatigue management, the training load is high in order to create accumulated fatigue and overload. In this phase, the load is adapted to the physical periodization. Preparedness declines due to accumulated fatigue, whereas specific fitness increases.
3. **Phase 3:** Tapering strategies
   In this phase of the microcycle, the main objective is to enhance the players' preparedness as much as possible. This is done by lowering the training load via reducing the volume while keeping the intensity sufficiently high (80%).

13.4 RECOVERY STRATEGIES

Fatigue occurs in various forms, namely physiological, psychological, neural and hormonal. A good recovery strategy has to tackle these different forms of fatigue. Moreover, Gould and Dieffenbach (2002) demonstrated that failure to adequately recover from the stress of training induces a state of overtraining and burnout. The term under-recovery is often used in this regard. Under-recovery predisposes players to overtraining injuries during a congested fixture period where players are required to compete repeatedly within a short period (e.g., two games a week) (Dupont et al., 2010). Professional soccer players are exposed to demanding competition schedules and can be easily exposed to 70 games in a single competitive season (King and Duffield, 2009). Playing competitive soccer involves eccentric work, particularly during competition, resulting in varying levels of exercise-induced muscle damage (EIMD). This EIMD is characterized by delayed-onset muscle soreness (DOMS) (Impellizzeri et al., 2008), decreased muscle function (Jakeman et al., 2009), impaired performance (Reilly and Ekblom, 2005), and increased perceived fatigue (Twist and Eston, 2009). Many biochemical and tissue repair processes take place after a match, and the body needs rest to recover completely for the next game or training session. Although the recovery process is initiated automatically, it can be assisted by appropriate recovery strategies. The capacity to recover from training and competition is therefore an important determinant in soccer performance (Kellmann, 2002; Odetoyinbo et al., 2009).

Athletes attempt to recover from training and competition as quickly as possible, so their performances in the subsequent training session or game are not compromised by muscle soreness or reductions in physical abilities. According to Peterson (2005), "The concept of effective, regular, and varied recovery activities has become part of the language of today's smart, professional athlete." Recovery can be defined as an inter- and intra-individual multidisciplinary (physiological and psychological) process to restore the initial performance level. This definition implies that recovery is much more than just rest - it is a strategy that should be adapted according to the type, intensity and volume of the previous training cycle (Steinacker and Lehmann, 2002).

Recovery can be defined on different levels:

1. Within a training session or match: The amount of time between exercises (training session) or high-intensity efforts (match)
2. Within the microcycle: the amount of time between sessions on a daily basis
3. Within the mesocycle: the amount of time between longer cycles or periods of training
4. Within the year planning: the amount of time during the off-season and mid-season breaks.

13.4.1 Recovery between high-intensity efforts

Krustrup et al. (2006) and Mohr et al. (2010) demonstrated that the ability to perform repeated bouts of high intensity, an important physical ability in soccer, is reduced toward the end of soccer games. Some research has demonstrated a positive effect of active recovery on performance in repeated sprints and on the speed of lactate removal (Bogdanis et al., 1996). This contradicts recent research that postulates that active recovery adversely affects performance, decreases the speed of replenishment of phosphocreatine, and increases fatigue (Dupont et al., 2003; Dupont et al., 2004; Spencer et al., 2006; Jougla et al., 2010). On the other hand, passive recovery induces a faster re-oxygenation of myoglobin (Dupont et al., 2004). In conclusion, it seems better to recover passively between intensive bouts during a match, but the recommendation that players should walk or stand still during and following bouts of repeated sprinting needs to be coordinated with tactical windows of opportunity.

13.4.2 Recovery post-match

Several studies have demonstrated that it takes more than 72 hours to reach pre-match values for physical performance and normalize muscle damage and inflammation (Andersson et al., 2008).

The magnitude of match-induced fatigue, extrinsic factors (e.g., match result, quality of the opponent, match location, playing surface, environmental conditions) and/or intrinsic factors (e.g., training status, age, sex, muscle fiber typology), could influence the time course of recovery (Nédélec et al. 2012).

Several post-match recovery interventions have been suggested to enhance performance (Barnett, 2006). These recovery strategies are broadly classified into two categories (Bompa, 1999): active and passive recovery. Active recovery strategies include cycling, jogging, aqua-jogging, and deep-water running, followed by stretching exercises. These interventions are regularly used after training sessions and matches in professional soccer (Dabedo et al., 2004). In particular, when matches are played on a weekly or twice-weekly basis, focus is placed on accelerating the recovery and consequently the regeneration processes. This commences immediately after the match by using nutritional strategies to replenish glycogen stores and drinking water or carbohydrate beverages to restore fluid balance. With the next competitive match 3–7 days away, a recovery training session is often planned the next day as well. It is still unclear whether immediate post-match recovery offers additional benefits when compared to a traditional next-day recovery. A cool down after a tough training session often feels good, and the psychological relief of some

14

PERIODIZATION IN SOCCER

Jan Van Winckel, Kenny McMillan, Carlo Buzzichelli, David Tenney, Paul Bradley

Periodization is a planned/programmed distribution or variation in training methods and means on a cyclic or periodic basis. As highlighted in the previous chapter, an important aim of periodization in elite soccer is **fatigue management**. Periodization for soccer entails organizing the season in a structured manner to ensure the level of performance is kept as consistently high as possible (performance stabilization) throughout the season. To achieve this, periods of loading, unloading (recovery), and tapering (for the most important competition(s) of the year) have to be sensibly arranged. Periodization refers to the planned alternation of loading and unloading (fatigue management), the structured sequence of which physical ability (i.e., strength, speed, endurance) to develop, and the division of the annual plan into distinct periods.

14.1 HISTORY OF PERIODIZATION

The Ancient Greeks used very elementary plans to prepare for the Olympic Games. The legendary Milo of Croton (6th Century BC), winner of six Olympic Games, was one of the first to use a primitive form of periodization by varying his training load during his training program. Milo began his training most days by lifting a calf, and as the animal grew bigger, the lifting load increased, consequently improving his performance. At the end of his training process, he was able to carry the animal around the Olympic stadium. Galen (129–200 AD) was a Roman physician, surgeon and philosopher (Nutton, 1973). At the age of 28, he returned to Pergamon in Italy as a physician to the gladiators and became one of the first to write about periodization. He believed that various types of exercise needed to be blended in order to improve performance. He divided exercises into three categories: without "hostile" movement, such as weightlifting; quick exercises, such as ball games; and exercises with a "hostile" nature, which we now refer to as plyometric exercises. It was not until the run-up to the Olympic Games in Helsinki (1952) that the experience of the Russian coaches became the impetus for the methodological principles of training systems. Researchers emphasized that the competition schedule had to be integrated into the overall system and that "active rest" was very important. The former Eastern Bloc, especially the Soviet Union, believed in a multi-year development preparation period, and the coaches there delayed the specialization phase of the sport for longer. This was in contrast to Western coaches who implemented specialization much earlier and without any thorough multilateral development. In the Soviet Union, as well as in other Eastern Bloc countries, a clear sports program existed to train children from elementary school level up to the elite level. In this way, they monitored and controlled all the factors. Dr. Verkhoshansky himself went so far as to say that periodization was based on the principles of communism. In the West, it was impossible to adopt the same training approach, because the culture did not permit such a thing. East Germany could obviously not be left behind, and in 1956, the German High School for Physical Culture was established in Leipzig. With the Cold War as the catalyst, sport became the flagship of various countries. State support was more the rule than the exception. However, the medal also had a darker side. "Sport for all" was an empty concept, because East Germany selected children at a young age and only invested in the very strongest. Two distinct trends then emerged from 1970 onwards: The West invested time and energy in the different areas of sport—such as school sports, health and rehabilitation—while in the East, the emphasis continued to be focused on the elite. It was in this race for better performances that periodization models surfaced. In the 1970s, many scientists, mainly Eastern European, published a large number of important works on periodization and the training process, such as Arosiev and Kalinin (1971), Djatschkov (1974), Zatsiorsky (1972), Matvejev (1974, 1981), Kusnezov (1972), Harre (1974), Vorobiev (1974) and Tschiene (1977). Matvejev, the father of periodization (1964), has not always received the recognition he deserves. Vice-President of Sport Kolessov stated in 1991 (Sovietsky sport, 1991) that the "outdated" system of Professor Matvejev should not be pursued anymore.

The origins of soccer science lie in the former Soviet Union. The Russians were the first to practice soccer science in a structured way, with Valeriy Lobanovskyi playing an important role in developing the knowledge and know-how and intertwining soccer and sport science. Lobanovskyi used statistics and data as a means of gaining competitive advantage in sport more than two decades before the foundation of specialized companies such as TopSportsLab®, Amisco, and ProZone. Lobanovskyi started as the coach of Dneproprtovsk (1969–1973), recruiting Anatoly Zelentsov, a statistician who was at the time the *Dean* of the Dneproprtovsk Institute of Physical Science. Soccer became for them a system of 22 elements (two sub-systems of 11 elements) moving within a defined area (the pitch) and depending on a series of restrictions (the laws of the game). They had the players perform tests and then analyzed the results via a computer. Lobanovskyi even went so far as to let Zelentsov and his computer system make the selection for the European Championships in 1988. The coach, who died in 2002, surprised friend and foe alike by playing scientific "total football" with Dynamo Kyiv (1984–1990) long before Rinus Michels embodied "total" football in the Netherlands. He created a system that evaluated every action in a match. A group of scientists noted each successful and unsuccessful action relating to passes, tackles, shots and dribbles. These data were then analyzed by a computer, enabling each player to be evaluated for "intensity, activity, error rate and effectiveness."

14.2 TYPES OF PERIODIZATION

Periodization improves performance through various mechanisms:

1. A planned, progressive overload favoring positive morpho-functional adaptations through planned alternation of loading and unloading
2. Avoiding reaching critical levels of fatigue and overtraining (Morton, 1997)
3. Tapering at the right moment to reach peak condition

14.3 SEASON PLANNING

There are different ways of preparing players for a game or season. There is the "ad hoc" approach (deciding from day to day), the intuitive approach (based on the "best practice" of the coach), and structured periodization. There are definite gaps in the current knowledge because periodization theory is based largely on empirical evidence, related research (e.g., overtraining), and a few mesocycle-length variation studies. Most of these involved experimental periods no longer than two to three months and/or subjects with limited training experience, whereas no actual multiple mesocycle or integrated studies (e.g., combined strength/power and speed/endurance training) on advanced athletes have been published in English (Plisk and Stone, 2003). Moreover, most of the scientific research published is in the domain of strength training, and it is not easy to translate these findings to team sport settings. For example, training parameters such as volume and intensity in strength training are completely different compared to training parameters in soccer. We have compiled a classification system below that should enable soccer coaches to better understand the mechanisms of periodization. This format, which has not been used anywhere else, attempts to a reach a consensus with regard to the terms used in the research literature. We have deliberately used all the terms used in publications in order to make it easier to find more information via search engines and/or publications.

14.3.1 Season-planning components

Periodization can be considered a process of structuring training into phases to maximize athletes' chances of achieving peak performance and therefore their competitive goals (Bompa, 1999). Accordingly, periodized training programs are typically structured into macrocycles, mesocycles, and microcycles that progress from extensive to intensive workloads, as well as from general to special tasks (Plisk and Stone, 2003). Before discussing the types of periodization, we first give an overview of the yearly planning components below. There is a chance you will find other definitions in the literature, but those used here are the most widely supported and accepted.

1. **Multi-year plan or megacycle.** For athletes, this is often a four-year (or Olympic) cycle. In soccer, this cycle is used for younger players in academies, where long-term objectives can be set using models such as the Long-Term Athlete Development (LTAD) model designed by Dr. Balyi (Ford et al., 2011).
2. **Annual plan (Bompa)/Annual Macrocycle (Soviets)**. According to most models, the annual plan comprises three macrocycles: the preparation phase, the competition phase, and the transition phase. The preparation phase is normally divided up again into general and specific preparation, and the competition phase is split into a pre-phase and a competition phase.
3. **Phase (Bompa)/Macrocycle (Soviets).** The term "macro" comes from the Greek word "makros," meaning "big." The term "cycle" refers to something that is constantly repeated. It defines the general direction of the training process in a certain period (general or specific preparatory, pre-competitive or competitive, transitory).
4. **Macrocycle (Bompa)/Mesocycle (Soviets)**. A macrocycle (Bompa) or mesocycle (soviets) is a period of 2–5 weeks that specifies the direction of the training process for each of its components (i.e., physical strength, speed, endurance, and technical/tactical). In this timeframe, one to three loading microcycles are followed by one or two unloading microcycles (thus reducing intensity and/or volume, but usually just volume). It is particularly during these periods of reduced load that progress can fully manifest itself.
5. **Microcycle** (from match to match or week to week). The term "micro" comes from the Greek word "mikros," meaning small. This microcycle runs from match to match in most cases, although it can be longer in the preparation phase and shorter in the competition period.
6. **Daily planning:**
   - Warm up
   - Central section
   - Rehabilitation and progression training
   - Cooling down

In this book, we use the terms macrocycle (for preseason, in-season, off-season, etc.), mesocycle (2–5 weeks in length) and microcycle (from match to match).

14.4 TYPES OF PERIODIZATION

In this section, we will see how different periodization models can be distinguished. We do this on the basis of four types of classifications:

1. Volume and Intensity
   Periodization models that vary intensity and volume.
2. Physical abilities
   Models that vary the basic characteristics (physical abilities) of the sport being trained (e.g., aerobic fitness, speed, etc.).
3. Workload
   Models that vary in workload.
4. Integrated
   Multidisciplinary models.

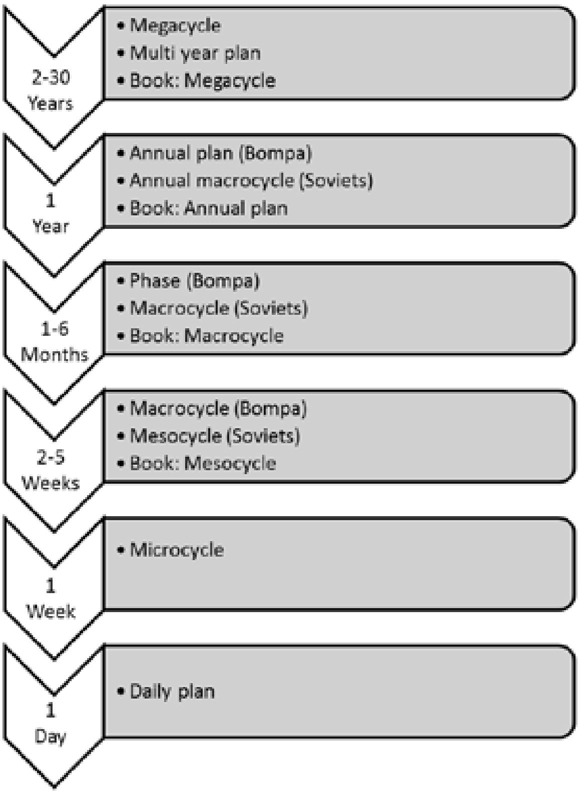


Fig. 14.1: Overview of the different phases of a periodization model.

16

MACROCYCLE: PRESEASON

Jan Van Winckel, Werner Helsen, Kenny McMillan, Paul Bradley

16.1 INTRODUCTION

In the previous chapters, we talked about the importance of "fatigue management" and "performance stabilization" throughout the competitive in-season period. In this chapter, we take a closer look at the preseason macrocycle. The preseason training period is traditionally the period when players complete the most physical work, enabling them to cope with the physiological demands of the competitive season (Bangsbo, 1994). Tae-Seok et al. (2011) examined the physiological loads of programmed "preseason" and "in-season" training in professional soccer players. They concluded that the average physiological loads were higher in preseason than in in-season, and a greater proportion of time was spent exercising at 80–100% of maximum heart rate. During preseason, coaches usually focus on rebuilding fitness (retraining). Adjustments in load are a direct attempt to deliver a training stimulus to promote specific training adaptations (Tae-Seok Jeong et al., 2011). This contrasts with the goals of training sessions during the competitive season, where emphasis is mainly on maintaining the physical abilities developed during preseason (Bangsbo et al., 2006). During preseason, the training load can be as high as one or two daily training sessions (90–120 minutes per session) for five days a week (Impellizzeri et al., 2006). Overall, the aerobic capacity of team sport players (e.g., basketball, rugby league and soccer) has been shown to increase throughout the preseason and decrease during the competitive season when using a classical team sport conditioning approach (Stone and Kilding, 2009). Thus, the focus of preseason is usually centered on long-term improvement of physical abilities. For elite teams unfortunately, the emphasis during preseason is increasingly placed on commercial activities, or games are planned to meet sponsorship requirements. Although this may be lucrative in the short term, it could detrimentally affect performance in the longer term.

16.2 PRESEASON TRAINING PRINCIPLES

We highlight below some important training principles, which should be taken into consideration when setting up a training plan for the preseason macrocycle.

16.2.1 Aerobic fitness

Aerobic fitness is the keystone on which all further training builds upon. For this reason, aerobic fitness has to be given sufficient attention before other physical abilities can be trained. In an interesting study, Magarey et al. (2013) examined the relationship between preseason fitness testing and injury in elite junior Australian football players. Players with lower levels of aerobic endurance (in a 20m multi-stage shuttle run) were at greater risk of shin/ankle/foot region injuries. The researchers suggest that this is possibly due to the fact that these players are subject to higher levels of fatigue at a comparative workload.

16.2.2 Off-season

Professional players should maintain aerobic fitness during the off-season to reduce the detraining effect. McMillan et al. (2005) found that aerobic endurance performance increased significantly between the start of the preseason training period and the early weeks of the competitive playing season. They suggested that this may be because players return to preseason training in a detrained state after a summer intermission of several weeks. Bangsbo (1994) found, in contrast with Impellizeri et al. (2006), no change in VO_{2max} after a preseason training period in professional soccer players, although the speed at 3 mmol/L blood lactate concentration increased significantly. Impellizeri et al. (2006) suggest that the absence of improvement in VO_{2max}, as found by Bangsbo, could be due to the shorter summer break of 2-3 weeks that is typical of professional soccer teams (compared to the longer detraining period for the junior players used in Bangsbo's study). Amigo et al. (1998) studied the effects of weeks of rest on three groups of adolescent soccer players who had undergone systematic training for the previous 11 months. The researchers found a detraining effect: a decrease in the cross-sectional area of type I and type II fibers and a significant decrement in the activities of aerobic enzymes. Bangsbo and Mizuno (1988) found that a relatively short-term training intermission was not enough to cause a significant decrease in VO_{2max}, but muscle oxidative enzymes did decrease quickly. They suggest that for these two reasons, the level of physical activity needs to be kept reasonably high during a detraining period to ensure that the mitochondrial enzymatic activity of the players will be as high as it was before the off-season period.

16.2.3 Physiological load / Mechanical load

With the arrival of GPS devices, the understanding of the mechanical load imposed on players has increased enormously. Joints and muscles are subjected to a significant load when changing direction (five times the body weight or higher), which is why it is best to limit the number of impact training sessions in a microcycle. One of the main goals of preseason training is to improve various physical abilities, and this can be achieved by increasing the physiological load on players while limiting the mechanical load, thus decreasing the chance of injury. However, it is also important during preseason to prepare players for the demands of match play. By monitoring mechanical load during matches using GPS, reference values can be created. Training can then be tailored to ensure players are able to meet their mechanical demands (e.g., number of sprints performed, acceleration and decelerations, the number of high intensity efforts, etc.).

16.2.4 Respect recovery

If your club does not have appropriate facilities to allow players to rest and recover between two training exercises or sessions, it is advisable to avoid two impact-training sessions per day.

Examples:

- **2 x 75 minute training sessions:**
  - Warm up = 2 x 30 minutes
  - Active learning time = 2 x 45 minutes
  - Recovery before the next training session: a maximum of four hours after first training session and 16–17 hours after second training session.

- **1 x 120 minute training session:**
  - Warm up = 1 x 30 minutes
  - Active learning time = 1 x 90 minutes
  - Recovery before the next training session: 24 hours
  - When training twice a day, alternative training (cross-training principle) can also be included in the program. Running, aqua-jogging or cycling can also be used to improve aerobic fitness and create overload without the risk of injury.

16.2.5 Match load / Training load

Training should be as match specific as possible. The match itself is therefore good training in principle. After a hard training session, however, the body needs time to recover and transform the training work into improved performance, so do not plan any tough training sessions too soon before a match.

A match is one of the most difficult types of activity to monitor. Not all players will be active for the entire match, and some players will be used as substitutes. It is therefore necessary to closely monitor matches so that all the players receive the same training load. An extra training session the day after a match is not sufficient. The load imposed by a match is often difficult to mimic, and players who are not used regularly will have difficulties coping with the demands of match-play..

16.2.6 Workload management

As we already read in the earlier chapters, it is important to manage and manipulate fatigue (fatigue management). This can be done based on objective parameters given by heart rate monitors and GPS devices, but it can also be based on subjective parameters.

During the preseason period, it is important to closely follow the balance between load and load tolerance. This can be done by monitoring the status of players using a simple questionnaire that can be displayed in the changing room (Fig. 16.1). There are also software applications available now for smartphones and computers that can be used by players to record their status.

	Session RPI scale 10	Session RPMF scale 20	Overtraining scale
	RPI Scale 10 What best reflects the intensity of the training? 0: Rest 1: Very, very low intensity 2: Very low intensity 3: Moderately intensive 4: Somewhat intensive 5: Intensive 6: 7: Very intensive 8: 9: Maximal intensity	How fatigued are your leg muscles? 0: No fatigue at al 1: 2: 3: 4: 5: Legs feel slightly heavy 6: 10: Legs feel fatigued 15: Legs feel heavy 20: Training is impossible	Overtraining scale 6 What best reflects your feeling? 0: No pain/fatigue at all 1: Muscle pain/fatigue in the morning after waking up 2: Muscle pain/fatigue in between exercises 3: Muscle pain/fatigue at the start of the warm up, but the pain/fatigue fades during warming up 4: Muscle pain/fatigue at the start of the training, the muscle pain/fatigue fades during training 5: Muscle pain/fatigue is constantly present during the training session 6: Training is no longer possible.
Player 1			
Player 2			
Player 3			

Fig. 16.1: Sheet that can be used to monitor subjective fatigue. (RPI - Rate of Perceived Intensity; RPMF - Rate of Perceived Muscle Fatigue)

As training adaptations are only possible when an overload is created which results in some fatigue accumulation, a player will often feel muscle soreness at the start of the next training session in the preseason phase. Training sessions in soccer are normally completed by the entire team, but because the fitness levels of players can vary significantly, some players will train hard while others undergo a lighter training session. In order to make sufficient progress for all players, it is therefore important to properly monitor the overload process. One of the golden rules is that a maximum of 25% of the players may be in overtraining scale phase 3 during preseason.

16.2.7 Variation / Monotony

The greatest progress is made when there is sufficient variation in the training. Variation also ensures that injuries are prevented. If monotony (the lack of variation in load or intensity) is too high, the likelihood of injury increases.

16.2.8 Finish the training session with an extensive exercise or cool down

You often see training sessions ending with an intensive exercise. This gives the coach and players the impression that a satisfactory, intensive training session has been completed. It is important, however, to finish the training session with a cool down. By gently working the major muscle groups, rest products such as lactate are actively processed. A cool down also allows body and muscle temperature, heart rate, and blood pressure to gradually return to resting levels. Due to the increase in muscle temperature, the cooling down period is a perfect time to stretch and increase or maintain joint range of movement and flexibility.

16.2.9 Unloading week

It is best to incorporate an unloading period of five to eight days into the preseason phase if possible. This allows dissipation of any accumulated fatigue arising from the first few weeks of preseason training, and also provides time for players to recover from minor injuries. The unloading period is best planned in the third or fourth week. This period also allows the staff to analyze data from heart rate monitors and GPS devices and consequently adjust the training plan and set new individual goals.

16.2.10 Periodization of tests

All too often, physical tests are scheduled during the first week. This is not ideal as players often arrive in a detrained state and are physically unprepared for intensive tests. It may be better, for example, not to carry out any speed or agility tests during the first week of preseason. Instead, the ideal time to conduct these tests is in the fifth phase (intensity phase) of preseason. On the other hand, submaximal aerobic tests can be scheduled in the first microcycle, but maximal tests should be avoided in the first few days.

16.2.11 Individual periodization in off-season

Each player needs a minimum of two to three weeks of relative rest after a stressful (both physically and mentally) season. This means that players returning from international duty must also be given the same time to sufficiently rest and process the physical and neural fatigue. If this break is not respected, it will have consequences for the remainder of the season.

16.2.12 Foreign players

Foreign players often want to stay in their home countries for as long as possible, often returning to the club a day or just a few days before the first training session. This compromises the quality of their training sessions in the first week of preseason, and it could lead to overtraining because of insufficient recovery from "travel fatigue" (Reilly et al. 1997). Ensure that players report for preseason training fresh and free from jet-lag, because this will allow time for the players to settle in and cope with the demands of preseason training.

18
MICROCYCLE: WEEK PLANNING

Werner Helsen, Jan Van Winckel, Paul Bradley, Kenny McMillan

18.1 INTRODUCTION

As was already mentioned in the previous chapters, weekly planning in soccer is entirely focused on preparing for the forthcoming match. At the beginning of each week, the emphasis is placed on recovering from the fatigue accrued during the previous match, while at the end of the microcycle, different tapering strategies are applied in order to optimally prepare players for their next match. Only training sessions at least 48 hours prior to, or after, a match can be used to physically overload the players.

18.2 STRUCTURE OF A TRAINING SESSION

A training session consists of the following parts:

1. Pre-activation or functional strength training
2. Warm up:
   - cardiovascular stimulus:
     - increase oxygen uptake
     - increase heart rate
     - activate the transportation of oxygen to the active muscles
   - dynamic stretching
   - speed: ATP-CP system and activate lactate removal (longer exertion with sufficient rest)
3. Technical/tactical training
4. Small-sided games (SSGs)
5. Progression phase: In this phase, work is done for each player individually based on a strength-weakness analysis; this can be technical (e.g., shooting, passing, receiving, etc.), tactical (e.g., line defense), mental, and physical (e.g., repeated sprint ability, speed, etc.)
6. Recovery phase:
   - cooling down
   - restoration of fluid balance
   - replenishment of energy substrates

7. Prevention phase:
Prevention exercises are done in close collaboration with the sports science and medical staff:

- increase active and dynamic flexibility (e.g., static, active, PNF method)
- eliminate muscular maladaptations
- restore muscular balances
- increase proprioception
- increase core strength
- increase core balance
- increase core endurance
- other forms of injury prevention

18.3 PRE-ACTIVATION

The warm up of all the different muscle groups (pre-activation) can be initiated in the dressing room or a specially designated room, such as a gym or fitness room if available, and it should focus particularly on the deep musculature. It is not always easy to properly warm up these muscle groups in cold-weather conditions. The deep musculature serves as anchor points for the other muscle groups, so they must be well prepared.

18.4 WARM UP

According to Bishop (2003), warm-up techniques can be broadly classified into two major categories: (i) passive warm up or (ii) active warm up. Passive warm up involves raising muscle temperature (Tm) or core temperature (Tc) by some external means (e.g., hot showers or baths, saunas, diathermy, and heating pads). Active warm up involves exercise and is likely to induce greater metabolic and cardiovascular changes than passive warm up. Active warm up is probably the most widely used warm-up technique. During the warm up, a player prepares various systems (cardiovascular, neural, pulmonary and muscular) for the load they will be subjected to in the game. An active warm up increases the total oxygen uptake and guarantees faster lactate elimination during training or a match. A passive warm up, such as a hot bath, does not generate these effects. It is insufficient to merely warm the muscles to the right temperature. All the systems that are linked to oxygen transportation and consumption need to be activated before starting a match or training session. Burnley et al. (2002) concluded that the VO_2 response to heavy exercise can be significantly altered by both sustained high-intensity submaximal exercise and short-duration sprint exercise. In contrast, passive warming elevated muscle temperature but had no effect on the VO_2 response.

Referring to the beneficial effects of increased temperatures on muscle extensibility, two studies by Shellock and Prentice (1985) and Strickler et al. (1990) both suggest that a warm-up phase and dynamic stretching should always precede training to prevent stretching-induced injury. According to Shellock and Prentice (1985), most of the physiological effects of a warm up are temperature dependent. Mechanical efficiency of the muscle contraction is close to 20%, while most of the energy produced (70-80%) is thermal energy. Heat production by contracting muscles increases in the first minutes of the exercise (Krustrup et al., 2001). Most of the heat produced during the first seconds of exercise seems to accumulate in the contracting muscle, but after those first minutes, most of the produced heat is transported to the inner core by the blood or lymph drainage (Gonzales-Alonso et al., 2000). An increased body temperature increases the amount of oxygen available in the working tissues, therefore helping oxygen to dissociate from hemoglobin and myoglobin. Moreover, an increase in muscle temperature reduces the time needed to reach the peak torque and the half-relaxation time of an electrically evoked twitch (Davies and Young, 1985; Segal et al., 1986).

The main aim of a warm up is to prepare the body for optimal performance. Warm-up strategies are planned by coaching staff who rely on previous trial-and-error experiences (Bishop, 2003). A typical warm up in soccer consists of 30–40 minutes of moderate- to high-intensity activities (Mohr et al., 2004). This contrasts with research suggesting that 5–10 minutes at 40-70% of VO_{2max} is sufficient to improve performance (Bishop, 2003). However, coaches should take care and ensure that performance itself is not jeopardized by increasing pre-competition fatigue, decreasing blood glucose levels and muscle glycogen stores, and prematurely elevating core temperature (Gregson et al., 2005). During the transition from rest to exercise, the body increases the oxygen supply to the muscles through the complex orchestration of pulmonary, cardiovascular and muscular processes.

18.4.1 Effects of warming up

A thorough warm-up has the following effects:

- The muscle temperature increases (39°C).
- Depending on the intensity and duration of the warm up, short-term performance is likely to be improved if the recovery interval allows phosphocreatine (PCr) stores to be significantly restored (Bishop, 2003).
- The stroke volume of the heart, and the cardiac output increases.
- Local vasodilation redistributes blood from the viscera to the working muscles. This redistribution of blood flow allows increased nutrient and oxygen delivery and improves the efficiency of waste product removal.
- The rise in temperature triggers enzyme activity, which increases the metabolism in the body, resulting in more energy being available for the muscles.
- The quantity of oxygen-rich blood to the muscles increases, improving the metabolism in the muscles.
- A warm up longer than ten minutes can impair long-term performance by decreasing muscle glycogen content (Gollnick et al., 1973) and/or decreasing heat-storage capacity (Gregson et al., 2002).
- It is thought that the compliant muscle can be stretched further after warming up (Safran et al., 1988).
- Nerve conduction velocity increases, with the impulses reaching the muscles, tendons and ligaments faster.
- Improved coordination.
- Positive influence on the contraction and reflex times of the muscles.
- The range of movement of the joints increases.
- The muscles are better prepared for extreme movements with a high range of motion.
- The risk of injury is reduced (Olsen et al., 2005). Grooms et al. (2013) investigated the effects of a soccer-specific warm-up program (F-MARC 11+) on lower extremity injury incidence in male collegiate soccer players. They concluded that the F-MARC 11+ program reduced overall risk and severity of lower extremity injury when compared with controls in collegiate-aged male soccer athletes.
- Higher rate of force development and therefore a decrease in time to peak torque.
- Higher half-relaxation time.

However, a warm up can also have negative effects, such as:

- The glycogen reserves diminish:
  The substrates (muscle glycogen, blood glucose) will be used during the warm up. An excessively long warm up can therefore have a negative influence on performance. A warm up of 15-20 minutes is sufficient (depending on the outside temperature).
- The body temperature could rise to dangerous levels (hyperthermia):
  In hot weather conditions, the body temperature can rise too high and affect performance. At a body temperature above the critical temperature of approximately 40°C, the body will limit performance in an attempt to prevent over-

heating. Research has demonstrated that a hot and humid climate reduced short-sprint performance (Maxwell et al., 1999) and sprint time in a 90-minute soccer-specific protocol (Morris et al., 1998, 2000), as well as during an intermittent-sprint protocol on a bike (Noakes et al., 2001).

- Muscular performance diminishes through extended static stretching. For example, the 20m-sprint performance of rugby union players decreased after static stretching (Fletcher and Jones, 2004).

18.4.2 Post-activation potentiation phenomenon

Another physiological mechanism that helps clarify the increase in performance following a dynamic warm up is a phenomenon called post-activation potentiation (PAP). Following a short bout of high-intensity exercise (preload stimulus), the muscle is in both a fatigued and a potentiated state (referred to as post-activation potentiation). Consequently, subsequent muscle performance depends on the balance between these two factors (Kilduff et al., 2007). PAP refers to an increased power output following a specific stimulus (Robbings, 2005). For example, following a bout of dynamic exercise, the muscles show a clear enhancement in the rate of force development, such as jumping height. This period of improvement has been demonstrated to last between 5 and 20 minutes (Chiu et al., 2003). It seems that the majority of the enhancement is achieved in fast-twitch fibers (French et al., 2003). Kilduff et al. (2007) concluded that muscle performance in rugby (e.g., power) can be enhanced following a bout of heavy exercise (preload stimulus) in both the upper and the lower body in cases where adequate recovery (of 8–12 minutes) is given between the preload stimulus and performance. Till and Cooke (2009) found no significant group PAP effect on sprint and jump performance after both dynamic and isometric maximum voluntary contractions (MVCs) when compared with a control warm-up protocol. However, the large variation in individual responses (-7.1% to +8.2%) may suggest that PAP should be considered on an individual basis.