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TIME-MOTION ANALYSIS

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Summary

Time-motion analyses are used to indirectly quantify the physical efforts of athletes in training and competition. Information derived from analyses can be used to make objective decisions for structuring the conditioning elements of training and to optimise match preparation. Over recent years, time-motion analysis has grown in popularity, especially at elite levels, mainly due to major advances in computer and video technology and to greater recognition by applied practitioners of its benefits in supplying objective information on physical performance. Indeed, research on physical performance over the last decade has led to the emergence of a comprehensive mass of knowledge on competitive activity profiles across a wide range of sports. While contemporary techniques provide efficient means for the collection and analysis of large amounts of data, scientific validation must have been conducted to ensure information derived from these methods is both accurate and reliable. The number of techniques used to collect data in matches are limited as the rules and regulations in certain sports restrict these approaches and a lack of interchangeability for data derived from different systems suggests the need for a single, internationally accepted ‘gold-standard’ approach. Finally, while the cost of computer and video technology has significantly reduced over the last decade, many of these systems remain expensive and are therefore inaccessible to practitioners at lower levels of the game. Future developments in time-motion analysis are shifting towards the development of miniaturised systems that analyse physical performance data in real-time, allowing objective split-second evaluation and decision making at any moment during performance. The development of intelligent systems is also underway to aid the fitness conditioning process by suggesting pertinent strategies and interventions for optimising training and preparation on the basis of data derived from motion analyses of play.

Introduction

Time-motion analysis has been used extensively since the 1970s to indirectly quantify the physical demands of many sports. Locomotor activities are coded and classified according to the intensity of movements performed by the athlete. Data can be translated into distances covered or the frequency of time spent in a variety of movement activities. The activity profile may be
placed on a time-base so that exercise-to-rest ratios or low-to-high intensity exercise ratios can be calculated to accurately represent the specific demands of the sport and provide objective guidelines for optimising the conditioning elements of training programmes (Reilly, 2007). Indeed, an increased understanding of the specific demands imposed upon sports performers by match-play and training not only provides opportunities for the development of appropriate controlled fitness training regimes but can also inform match-to-match recovery programmes. This may lead to enhanced athletic ability and enable players to maintain high performance levels throughout the duration of games and across the entire season. Information can also be interfaced with physiological measures, such as heart rate, leading to increased opportunities for monitoring the strain and workload inherent to different sports and potentially reducing the risk of injury or ill health (Macleod et al., 2009), especially when recovery between successive matches is short. Finally, motion analysis data can also assist in monitoring the physical progression of players – for example, across age groups or from sub-elite to elite levels of competition.

In this chapter, different techniques commonly used to collect time-motion data in match-play and training are visited. These include manual systems and the computer and video tracking technologies currently employed at elite levels. Examples of published data from the accumulated body of knowledge on physical performance in contemporary competition across many sports are also provided. These include discussion of general characteristics of performance, position-specific demands and the occurrence of fatigue in competition.

### Motion analysis systems and techniques

#### Manual motion analysis

Up until the last two decades or so, manual coding systems were generally employed for the time-motion analysis of athletic performance. Early efforts involved simply tracing soccer player movements on a scaled plan of the playing surface to estimate distances covered and were subject to large inaccuracies. Subsequently, two definitive studies using manual coding techniques to collect data on physical performance in professional soccer were conducted by Bangsbo et al. (1991) and Reilly and Thomas (1976). Reilly and Thomas employed a subjective assessment of distances and exercise intensities recorded manually or onto an audiotape recorder. A learnt map of pitch markings was used in conjunction with visual cues around the pitch boundaries. Bangsbo and colleagues combined analysis of video recordings of soccer player movements in match-play with individual locomotor characteristics pre-established according to runs performed at different exercise intensities. The time for the player to pass pre-markers and known distances was used to quantify the speed for each activity of locomotion. Data collected using these manual methodologies were shown to be reliable and their use in contemporary motion analysis research, notably in soccer, is still frequent (Andersson et al., 2010; Gabbett and Mulvey 2008; Mohr et al., 2008).

More recent developments on these early techniques include the Noldus Observer behavioural analysis software and Sportstec’s Trakperformance system. The Observer XT is an event–logging, video-based computer software used for the capture, analysis and presentation of observational data. An early version of this software was used extensively to analyse the wide range of motions, movements and specific playing activities observed in professional soccer (Bloomfield et al., 2004, 2007). Trakperformance enables a single player to be mechanically followed throughout training or competition using a computer pen and tablet on a scaled version of the specific playing field or court. Ground markings and cues around the pitch are used
Time-motion analysis

as reference points for tracking the players. The miniaturised playing field is calibrated so that a
given movement of the mouse or mouse-pen corresponds to the linear distance travelled by the
player. Analysis of soccer match-play has shown this system to be accurate and real-time analysis
is possible, although high levels of operator skill and experience are necessary (Edgecomb and
Norton, 2006).

In general, data capture via manual coding methods is considerably labour-intensive and
time-consuming, and analysis is limited to the analysis of a single player at a time. To a certain
extent, the data collection process is subject to inaccuracies, notably when recording positional
information. Moreover, these techniques do not allow accurate quantification of transitional
changes between running speeds, such as acceleration and deceleration movements (James,
2006). However, manual analysis systems are convenient and relatively cheap, and an experi-
cenced observer can provide reliable and pertinent data sets for dissemination. They are within
reach of standard coaches and can readily provide answers to many of the questions posed on
physical performance, particularly at lower levels of the game. For additional information on the
workings, strengths and limitations of manual coding processes, the reader is referred to Carling
et al. (2005) and Hughes and Franks (2004).

Computerised motion analysis and portable electronic tracking devices

The numerous difficulties encountered in using early manual motion analysis techniques men-
tioned earlier led to the development in the mid-to-late 1990s of computer and video technol-
ologies enabling automatic or semi-automatic tracking of player movements during match-play.
At present, a plethora of time-motion analysis systems exist and a non-exhaustive list of these
technologies is presented in Table 23.1. For additional information on the workings of and
strengths and weaknesses of these and other technologies, the reader is referred to three recent
reviews (Barris and Button, 2008; Carling et al., 2008, 2009). Presently, the scientific legitimacy
of some commercially available tracking systems has not been adequately established, despite the
need to comply with four basic quality control specifications: accuracy, reliability, objectivity
and validity (Drust et al., 2007). The lack of a single test protocol considered the ‘gold standard’
for testing the validity, reliability and objectivity of motion analysis systems may be one rea-
son for this failure (Carling et al., 2008). Nevertheless, two main categories of player tracking
technology currently exist: computerised video-based tracking and portable electronic tracking
devices worn by athletes. Examples of both of these categories are discussed in turn.

Computer and digital video-based analysis

The development of commercial video-based player tracking systems, notably AMISCO Pro
(Sport-Universal, Nice, France) and Prozone 3 (Prozone Sports Ltd, Leeds, UK), initially revo-
lutionised the analysis of physical performance in professional soccer and rugby competition in
the late 1990s. These pioneer systems semi-automatically track the movements of all players
simultaneously on digital video footage obtained from a permanently fixed set of cameras posi-
tioned strategically to cover the entire pitch. This video-based analysis provides an unobtrusive
means of collecting competition-specific information on technical, tactical and physically per-
formance. Analysis is done post-match, but often requires manual intervention to correct errors
by an operator, mainly when interruptions in player tracking occur due to occlusions (Barris
and Button, 2008). Players are frequently lost or cannot be tracked during situations where
multiple players cluster in restricted playing areas (e.g. a scrum or lineout in rugby or a crowd of
soccer players in the penalty area for a corner kick). Results are thus only available 12–24 hours
Table 23.1 Some examples of contemporary systems used for time-motion analysis of sports performance

<table>
<thead>
<tr>
<th>Company/Institution</th>
<th>Country</th>
<th>System</th>
<th>Web site</th>
<th>Further reading</th>
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<td>University of Campinas</td>
<td>Brazil</td>
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<td>Sagit/Squash</td>
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<td>Australia</td>
<td>Minimax</td>
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<td>LPM Soccer 3D</td>
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<td>PAL Technologies Ltd</td>
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<td>Bloomfield et al. (2007)</td>
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post-competition. However, independent testing of movement data produced by the Prozone system has shown high levels of accuracy, reliability and validity (Di Salvo et al., 2009), thereby reassuring applied practitioners and academics of the scientific legitimacy of the system.

Recently, passive technologies such as Tracab (Tracab AB, Stockholm, Sweden) and Venatrack (Venatrack Ltd, Slough, UK) are providing information in real-time on competitive play through improvements in mathematical algorithms especially developed for movement tracking. The advantage of real-time analysis is the availability of objective performance-related data upon which coaching staff can base their half-time ‘team talk’ and make immediate decisions on tactical changes and/or substitutions over the course of a match. The video-tracking processes developed by Tracab AB are reportedly based on state-of-the-art image-processing technology and enhanced mathematical algorithms for guiding missiles in the military industry (see www.tracab.com). Venatrack monitors player movements on video at a frequency of 25 measures per second, with accuracy rates for player identification operating at 98 per cent and player position tracking at 98 per cent (Redwood-Brown et al., 2012). A further development is the Spinsight K2 Camera System (Spinsight, Edinburgh, UK). This portable system reportedly provides real-time player tracking using a portable camera configuration with three video images being merged into one to provide a panoramic view of the match (see www.spinsight.com).

Portable electronic tracking devices

In recent times, Global Positioning Systems (GPS) have impacted on the measurement of physical performance in daily training and competition (Coutts and Duffield, 2010). GPS have also been applied to detect fatigue in matches, identify periods of most intense play and identify activity profiles by position, competition level and sport (Aughey, 2011). Indeed, there is a growing body of knowledge examining the use of GPS for analysis in numerous sports, notably Australian rules football (Brewer et al., 2010), cricket (Petersen et al., 2011b), field hockey (Macutkiewicz and Sunderland, 2011), golf (Hayes et al., 2009), rugby league (Waldron et al., 2011) and union (Coughlan et al., 2011), skiing (Brodie et al., 2008), tennis (Duffield et al., 2010) and soccer (Buchheit et al., 2010). GPS receivers estimate their position on earth by triangulating their position based on the receive time for signals sent from satellites orbiting the earth. The units are worn in a harness on the athlete’s back to avoid hindrance and to reduce interference with play. They are used to capture data on distances run and movement speeds and are also interfaced to provide physiological information on exercise intensity via heart-rate measures (see www.gpsports.com and www.catapultsports.com). The latest versions of these systems transmit live data to a laptop via wireless connection, enabling immediate analysis, evaluation and feedback. In addition, integrated tri-axis accelerometers can be used to record information on the frequency and intensity of accelerations and impacts, such as tackles and collisions. These events can be identified and incorporated in the analysis to provide an overall index of the physical stresses placed on the player.

While these systems are regularly used in friendly matches and youth competitions, they are generally limited in many sports to measuring and controlling work intensity in training as
performers are equipped with electronic material which may be forbidden at professional and senior international level. The accuracy of GPS is influenced by several variables: the number of satellites and their geometrical arrangement relative to each other and the receiver, and the topography of the playing area surroundings. Large buildings notably can affect signal reception. In addition, despite the increased sampling rate of more recent models (>10 Hz), the efficacy of GPS technology to accurately and reliably quantify critical high-speed movements, accelerations and changes in direction at speed over short distances is still questionable at the time of writing this chapter (Jennings et al., 2010). Similarly, contrasting evidence exists on whether the same GPS device should be used by the same player in order to avoid possible inter-unit measurement error (Castellano et al., 2011; Duffield et al., 2010).

The development of electronic tracking systems using small lightweight transponders worn by players provides alternative opportunities for real-time movement data acquisition and analysis. Systems such as the Local Positioning Measurement monitoring system (LPM) collect information on the movements and positions of every player and the ball up to several hundred times per second. Independent research has shown that the LPM system produces highly accurate position and speed data in static and dynamic conditions (Frencken et al., 2010). The LPM system also permits the collection of heart-rate responses to exercise. However, usage is again generally restricted to training, friendly matches and youth competitions played on a single training pitch equipped with the system. Alternatively, it is worthwhile noting that time-motion information on physical performance can be captured at a relatively lower cost to GPS and/or electronic transponders using small accelerometer-based physical activity devices strapped to the athlete’s ankle. For example, simple step activity monitors have been used to monitor and record the number of steps over set time intervals and subsequently determine the duration and intensity of work bouts performed in soccer match-play (Orendurff et al., 2010).

**Competitive activity profiles: general characteristics and position-specific demands**

Within any evidence-based performance framework for sport, and especially at elite levels, knowledge of the physical requirements of play is necessary to aid in the design and application of optimal fitness training strategies in preparation for contemporary competition. Over the last four decades, motion analysis has helped identify the physical performance demands and fitness requirements for competition across many sports. It has aided in determining physical activity profiles across the playing positions respective to many sports, as well as in referees. Information from motion analysis enables objective and realistic decisions to be made for structuring the physical conditioning elements of training programmes. Questions commonly asked by coaching and conditioning personnel about the physical performance of their athletes in competition and training include:

- What are the general contemporary physical characteristics and position-specific demands in my sport?
- Can my players respond to these requirements and the demands directly imposed on them by opposition in competition?
- Are my players contributing physically to all aspects of the game: defence, attack, build-up play?
- Is physical performance in my players consistent throughout games and over the course of the season and have the demands of play evolved over recent seasons?
- Are competitive physical demands adequately replicated in the training we perform?
Irrespective of the sport, the overall work contribution in field sports can be expressed as the total distance covered in a game, since this feature generally determines the energy expenditure irrespective of the speed of movement (Reilly, 2007). Motion analyses have shown that the total distance run in competition varies greatly in relation to the sport. Elite junior male Australian rules footballers are shown to run up to 17 km (Veale et al., 2007), whereas elite senior field hockey players cover around 7 km (Edgecomb and Norton, 2006) per match. Outfield male professional soccer players run on average 8–12 km (Reilly, 2007). In one-day cricket, a fast bowler has been shown to run approximately 16 km over the course of a match (Petersen et al., 2009). In some sports, longitudinal measures of the total distance run have enabled analysis of the evolution of physical activity profiles over seasons. The overall physical demands in professional soccer (Carling et al., 2008) and Australian rules football (Wisbey et al., 2010) match-play notably have increased. In turn, this information has had important consequences for contemporary fitness training strategies.

In time-motion analyses of athletic performance, the total distance covered is generally broken down into discrete movement activities. These activities are coded according to their intensity, which is determined by the speed of actions. Choice of speed thresholds is often arbitrary among practitioners and sports science personnel and some examples of default speed zones for time-motion analysis of sports performance in match-play and training are presented in Table 23.2. Alternatively, speed thresholds used to categorise and quantify physical efforts can also be tailored in relation to the individual physiological capacity of the player (Abt and Lovell, 2009). Club personnel might want to evaluate the frequency of the types of movement or the time spent or distance covered in each category of movement. Traditionally, categories used are classed as standing, walking, jogging, cruising (striding) and sprinting.

In soccer, these categories of movement have been extended to include other activities such as skipping and shuffling (Bloomfield et al., 2004). Additional game-related activities must also be taken into account in the analysis which contribute to overall energy expenditure. These include alterations in pace, unorthodox running modes (backwards and sideways movement) and rapid changes in direction. In Australian rules football, more than half of all sprints performed in competitive matches involved at least one change of direction, mostly within the 0–90 degrees arc and left or right (Dawson et al., 2004). Contemporary Global Positioning Systems provide a means to quantify, in a single index, the amount of stress placed upon a player from actions such as accelerations, decelerations, changes of direction and impacts (McLellan et al., 2011). Other game-related activities include challenging for possession and the execution

<table>
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<tr>
<th>System</th>
<th>Variable 1</th>
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<td>11.1–14.0</td>
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<td>7.4–14.5</td>
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<td>7.6–10.0</td>
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of game-specific skills with the ball. While a common feature of many sports is that only a small percentage of the total distance covered by players is in individual possession of the ball, analyses in professional soccer have shown that the majority (34.3 per cent) of the distance covered was performed at high speeds (>19.1 km.hour⁻¹) (Carling, 2010).

In most sports in which time-motion analyses are employed, activities at lower levels of intensity tend to dominate physical activity profiles. Indeed, in a recent detailed review of time-motion analyses in team sport events, it was shown that sprint-type activities generally constitute 1–10 per cent of the total distance covered (Girard et al., 2011). Research by Spencer et al. (2004) on international field hockey players reported that the large majority of the total game time was spent in the low-intensity motions of walking, jogging and standing (46.5±8.1, 40.5±7.0 and 7.4±0.9 per cent, respectively). In comparison, the proportions of time spent in striding and sprinting were 4.1±1.1 and 1.5±0.6 per cent, respectively. Junior elite basketball players covered 7558±575 m per game, of which 1743±317, 1619±280 and 2477±339 m was performed at high, moderate and low intensities, respectively (Ben Abdelkrim et al., 2010b). Data from Petersen et al. (2010) for an elite fast bowler playing in international Twenty20 cricket competition showed that around 9 per cent of movement was performed at high intensities (sprinting and striding).

In an earlier related review of literature, Spencer (2005) concluded that the mean distance and duration of sprinting actions in team sports was between 10–20 m and 2–3 s, respectively. Only on rare occasions do team sport players attain maximal speed in competition, and acceleration capacity over short distances is probably more important. High-intensity activity is often unpredictable and intense efforts sometimes follow each other after a short recovery period, resulting in dense phases of work. In general, intense efforts interspersed with brief recoveries (<60 s) are common during the majority of team and racket sports (Bishop et al., 2011). Analyses of physical performance over short periods in professional soccer match-play also show that players transiently perform substantially higher amounts of high-intensity running than the game average (Carling and Dupont, 2011). Gabbett and Mulvey (2008) found that international female players performed repeated-sprint bouts (defined in their study as a minimum of three consecutive sprints, with recovery of less than 21 s between actions) approximately five times per game and that recovery between sprint efforts was generally active in nature (~93 per cent of the time). In intermittent-type sports, the capacity of players to perform high-intensity work repeatedly is therefore essential. Indeed, Krustrup et al. (2005) have reported a strong correlation between performance in a field test of intermittent recovery and competitive sprint activity in elite female soccer players.

Information on the frequency of repeated high-intensity efforts and time spent in recovery between discrete intense bouts of exercise is pertinent for designing high-intensity conditioning programmes. Data from motion analyses can also be used to a certain extent to determine the effects of physical conditioning interventions on work activity profiles in match-play. Work by Impellizzeri et al. (2006) in youth soccer players demonstrated significant improvements in high-intensity running performance during actual match-play after a period of aerobic interval training. However, there is a lack of information across elite sports on whether fitness training regimens in general provide a sufficient training stimulus to simulate the high-intensity needs specific to competition. While a study in cricket (Petersen et al., 2011a) has shown this to be the case, the same trend was not observed in elite soccer (Gabbett and Mulvey, 2008) or field hockey (Gabbett, 2010).

Work activity profiles can vary across geographical locations and playing standards. For example, substantially greater distances were covered at high intensities in players belonging to the English Premier League compared to peers in the Spanish Liga (Dellal et al., 2011). International-level male basketball players sprinted significantly more than national-level male
basketball players (Ben Abdelkrim et al., 2010a). In cricket, test-level fielders covered moderately greater (29–48%) distances in the higher-intensity movement categories (running, striding, and sprinting) than fielders in first-class competition (Petersen et al., 2011b). In contrast, high-intensity activity profiles and fatigue patterns were similar between international and professional domestic soccer players (Bradley et al., 2010). Similarly, high-intensity activity in professional soccer was unrelated to team success as players in lower-ranked teams in the English Premier League covered significantly greater distances compared to peers belonging to teams finishing in the top five positions (Di Salvo et al., 2010). In addition, motion analyses have also demonstrated differences between different formats of the same sport. The shorter formats of cricket (Twenty 20 and one-day) were shown to be more ‘physically intensive’ per unit of time than multi-day cricket, but a greater overall physical load was the reported in the latter (Petersen et al., 2010).

Motion analysis of classical ballet and contemporary dance performance has shown the former to be associated with substantially higher levels of intensity (Wyon et al., 2011). While other factors such as team formation, score line, opposition standard, environmental conditions, match congestion and stage across the season, player dismissals and substitutions, time spent in ball possession and time the ball is in play are also known to substantially affect competitive physical activity profiles, their discussion is beyond the scope of this chapter. For additional information, the reader is referred to work by Carling et al. (2005) and Carling et al. (2008).

The effect of playing position on the physical contributions of players must be taken into account when evaluating motion analysis data as marked differences are known to exist in the overall work pattern and intensity of various running activities performed in competition. Thus, there is a need for a criterion model for the tailoring of training programmes to suit the particular needs across individual positions. The total distance run by elite junior Australian rules football players ranged from 10,419 m to 16,691 m across playing positions (Veale et al., 2007). Mean distances covered during professional rugby league match-play by hit-up forwards, wide-running forwards, adjustables and outside backs were 3,569 m, 5,561 m, 6,411 m and 6,819 m, respectively (Gabbett et al., 2012). In an analysis of English Premier League soccer, position was shown to have a significant influence on time spent sprinting, running, shuffling, skipping and standing still (Bloomfield et al., 2007). The total number of sprints and explosive and leading sprints performed according to playing position in the European Champions League and UEFA Cup competitions is shown in Table 23.3. In netball, centres have been shown to run significantly greater distances than the other playing positions, covering around 6 km per match compared to distances ranging from 2 to 4.6 km in other positions (O’Donoghue and Loughran, 1998). Fast bowlers in international cricket sprinted twice as often and covered over three times the distance sprinting, with much smaller work-to-recovery ratios in comparison to other positions (Petersen et al., 2010). Finally, analysis of Super 12 rugby union play has shown that backs sprint more often and have a longer duration of each sprint, whereas forward players spent more time in overall work activities (Duthie et al., 2005). Further detailed analyses of sprint patterns in rugby union players during competition showed that forwards commenced sprint actions from a standing start most frequently (41 per cent), whereas backs sprinted from

<table>
<thead>
<tr>
<th>Position</th>
<th>Central defenders</th>
<th>Wide defenders</th>
<th>Central midfielders</th>
<th>Wide midfielders</th>
<th>Attackers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosive sprints</td>
<td>4.5 ± 4.2</td>
<td>7.2 ± 5.5</td>
<td>6.3 ± 5.8</td>
<td>8.4 ± 6.3</td>
<td>7.2 ± 5.7</td>
</tr>
<tr>
<td>Leading sprints</td>
<td>12.8 ± 6.0</td>
<td>22.2 ± 8.5</td>
<td>17.3 ± 8.2</td>
<td>27.4 ± 9.5</td>
<td>22.8 ± 8.8</td>
</tr>
<tr>
<td>Total sprints</td>
<td>17.3 ± 8.7</td>
<td>29.5 ± 11.7</td>
<td>23.5 ± 12.2</td>
<td>35.8 ± 13.4</td>
<td>30.0 ± 1.0</td>
</tr>
</tbody>
</table>

Table 23.3 Total number of sprints and explosive and leading sprints performed according to positional role in European Champions League and UEFA Cup competition (data from Di Salvo et al., 2010)
standing (29 per cent), walking (29 per cent), jogging (29 per cent) and occasionally striding (13 per cent) starts (Duthie et al., 2006).

Finally, physical activity profiles from time-motion analyses of competition have shown that a decline in exercise intensity is frequently inevitable over the course of competition and successive games, especially when these are played in a short time-frame. The profiling of a player’s physical performance can highlight a susceptibility to fatigue, shown up as a drop-off in efforts towards the end of the first or second half of games or a need for a long recovery period after successive high-intensity actions. A fall in activity may also be observed towards the end of competition and after breaks in play. In professional soccer, a substantial drop in running performance was observed at the beginning of the second half and was linked to the players getting ‘cold’ in the half-time break (Mohr et al., 2004). Work by Coutts et al. (2010) in Australian rules football has demonstrated significant reductions in the total distance covered in the second (–7.3 per cent), third (–5.5 per cent) and fourth (–10.7 per cent) quarters compared to the first quarter and high-intensity running (> 14.4 km.hour⁻¹) was substantially reduced after the first quarter. Activity profiles of elite-level female field hockey players during competition have shown that players undertake significantly less high-intensity exercise in the second half of the game, despite the continual substitution rule (MacLeod et al., 2007). However, the total distance covered or that in sprinting in some sports is unaffected across playing halves, as observed in an analysis of professional futsal competition (Barbero-Alvarez et al., 2008). Finally, fatigue may be evident as a prolonged recovery during the game itself. After the five-minute period during which the amount of high-intensity running peaked, performance was reduced by 50 per cent in the following five minutes compared with the game average in professional soccer players (Bradley et al., 2009). In addition, the authors reported that transient declines in high-intensity running immediately after the most intense five-minute period were most evident in attackers and central defenders compared to other positional roles. These data show there is a need for countermeasures to fatigue in order to maintain physical performance throughout match-play. As well as physical conditioning interventions, other potentially useful means of preventing drops in and maintaining competitive physical performance include appropriate warm-up and nutritional interventions, post-match recovery treatment (e.g. cryotherapy, sports massage, compression tights) and the use of substitutions (Carling et al., 2011).

Concluding remarks

A key step in the conditioning process for the contemporary team sport player is the monitoring of exercise intensity via time-motion analyses during competition and training. The events underpinning physical performance are recorded and analysed to quantify the physical efforts of the player. Technological advances in computer software and digital video techniques, as well as miniaturised portable tracking devices, have enabled accumulation of a substantial body of knowledge on the physical demands of play, despite the rules and regulations of certain sports restricting the use of some approaches during competition. Contemporary systems are now providing opportunities for real-time monitoring of physical activity, enabling split-second evaluation and objective decision making at any moment during performance.
References


Time-motion analysis


