Soccer

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Performance Demands of Soccer

In this chapter, we introduce the sport of soccer (called football in most of the world outside of the United States) and discuss the various factors of importance for outfield players and the relative contribution that physical performance makes to winning games.

Sport Description and Factors of Winning

Association football, more commonly known as football or soccer, and nicknamed "the beautiful game," is a team sport played between two teams of 11 players with a spherical ball. It is considered the world's most popular sport and is played by more than 250 million players in 200 countries and dependencies globally. The game is played on a 105 × 70 m outdoor (grass) pitch with a goal at each end. Player positions are typically classified as strikers (forward), midfielders (midfield), defenders (back toward the goal), and the goalkeeper. The object of the game is to score by directing the ball into the opposing goal. Players are not allowed to touch the ball with their hands or arms while the ball is in play, unless they are goalkeepers (and then only when within their penalty area). Other players mainly use their feet to strike or pass the ball, but may also use other areas of their legs, head, and torso. The team that scores the most goals by the end of the match wins.

Relative Contribution of Physical Performance

While it is important for football players to have well-developed physical and physiological qualities, technical skills, tactical awareness, and game intelligence are without doubt the main contributors of success (figure 30.1). Importantly also, contextual factors inherent in a match often prevent highly trained players from fully utilizing their physical potential during matches. Indeed, between-match high-intensity running varies greatly, irrespective of the game outcome (13). In the case of an early player dismissal, the nine outfield players remaining on the pitch generally increase their individual running demands during the match as necessary to maintain overall team running performance (14). Additionally, elite young central midfielders and strikers have been reported to reach only ~85% to ~94% of their maximal sprinting speed during matches, respectively (31). The current understanding is that elite football players do not necessarily need to be the fittest athletes, but at least fit enough to cope with the demands of the match and execute their tactical roles efficiently.

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Figure 30.1 The position of the soccer player on the three axes illustrates the relative importance of the three main physical capacities of importance for elite participation in soccer, acknowledging this varies slightly between positions (10, 30). Outside of critical psychological aspects and team chemistry components, which are difficult to quantify, the pie chart shows the general relative importance of skills (45%), tactical awareness (30%), and physical capacities (25%) for soccer success.

Adapted from G.A. Nader, "Concurrent Strength and Endurance Training: From Molecules to Man," *Medicine & Science in Sports & Exercise* 38, no. 11 (2006): 1965-1970.

Targets of Physical Performance in Soccer

Targets of physical performance in soccer depend on the playing position of the individual and can be broken down simply to that of outfield players and goalkeepers. While it may be possible to detail specific targets for each position, the brevity of the present chapter already prevents such elaboration here, and the focus will be on the main two position categories.

Outfield Players

Varying anthropometric characteristics, including a low percentage of body fat, as well as high levels of speed and explosive muscular power, are the most important physical factors needed for outfield players to gain an advantage in soccer that would translate into an improved probability of success at the elite level (36) (figure 30.1). Notwithstanding these critical factors, focused development of aerobic power and endurance should not be ignored. During match play, besides the 10 to 12 km typically covered at the professional level, players will repeat a minimum of 200 high-intensity efforts in the form of high-speed runs (for a total of 500-1300 m >19.8 km/h), accelerations, decelerations, and changes of direction (2). Thus, a well-developed aerobic system is likely to contribute not only to the acute high-intensity performance but also to metabolic recovery between the explosive efforts associated with successful soccer match performance (38, 39).

Goalkeepers

For the goalkeepers, there is no need to generate excessive neuromuscular fatigue from running, so the better strategy is to remove them from the majority of running-based conditioning exercises and have them do general aerobic conditioning on a stationary cycle, ergometer/rowing machine or, more often, perform goalkeeper-specific training exercises.

Key Weapons, Manipulations, and Surveillance Tools

Recall that weapons refer to the high-intensity interval training (HIIT) formats we can use to target the physiological responses of importance, while the surveillance tools are what we are using to monitor

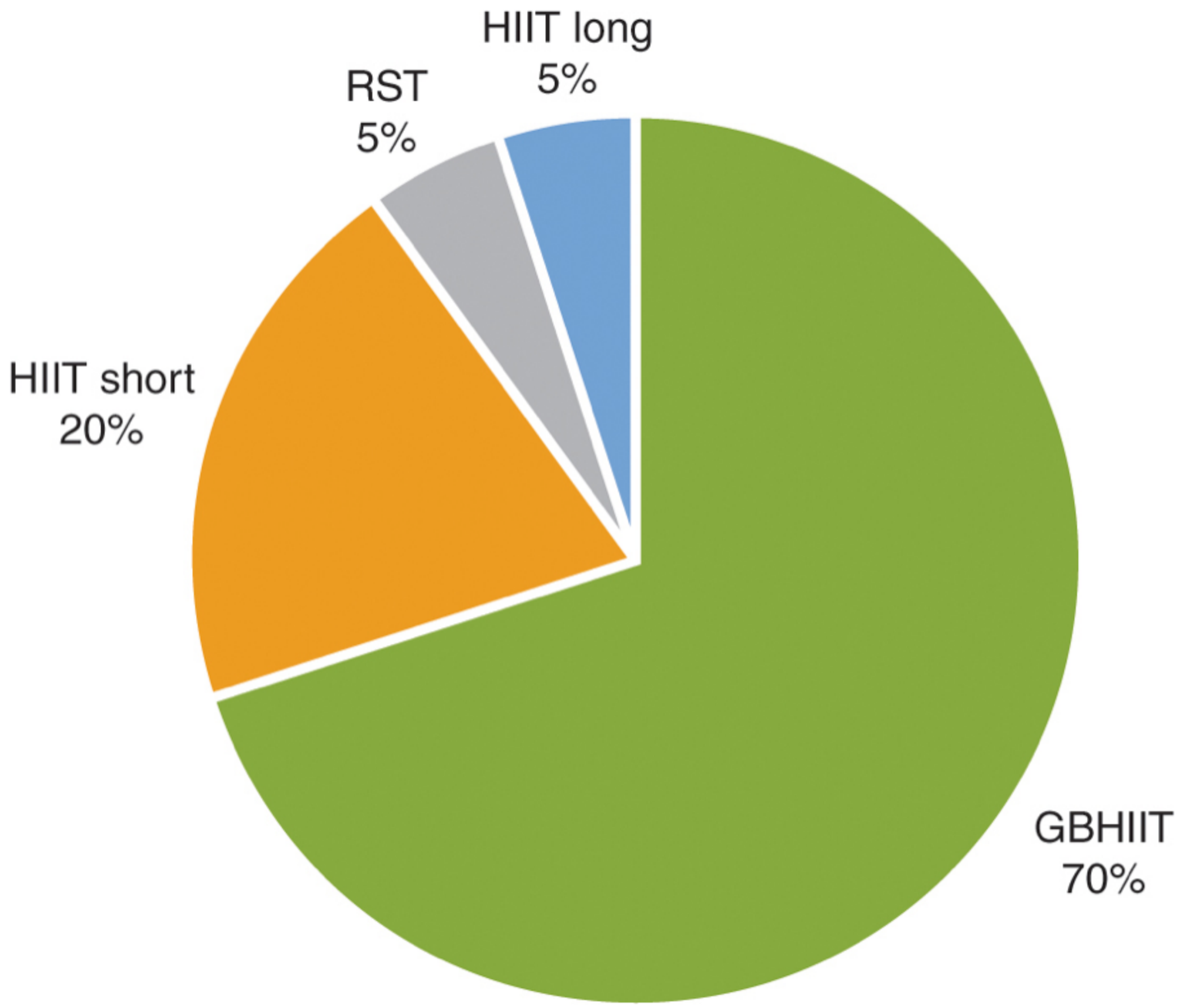


Figure 30.2 Percentage of the different HIIT formats (weapons) used throughout the annual season in elite soccer.

the individual responses to those weapons (figure 1.5). In this section, we present the different HIIT weapons, their manipulations, along with ways to monitor their effectiveness (surveillance).

HIIT Weapons

In our experience, we typically target throughout the season all HIIT target types (see figure 1.5), with the exception of type 5 (type 1: metabolic O_2 system; type 2: metabolic O_2 system + neuromuscular; type 3: metabolic O_2 + anaerobic systems; type 4: metabolic O_2 + anaerobic systems and neuromuscular) (6). As shown in figure 30.2, the very large majority of the weapons used to reach these targets are game-based HIIT, with the majority of them being in the format of small-sided games (SSGs) (70%, both pre- and in-season), followed next by short intervals (20%, both pre- and in-season, essentially for individual top-ups and rehabilitation), repeated-sprint training (RST) (5%, both pre- and in-season, essentially for individual top-ups), and long intervals (5%, preseason exclusively).

Manipulations of Interval Training Variables

The running intensity and modality of each HIIT format is systematically modulated to reach the desired acute metabolic and locomotor responses (i.e., physiological targets, types 1, 2, 3, or 4), which, in turn, solves the programming puzzle on a weekly basis for us.

Factors to consider when choosing an HIIT session type for soccer include match-play demands, player profile, desired long-term adaptations, and training periodization. Together, these factors determine the desired physiological response target type, including type 1 aerobic metabolic, with large demands placed on the oxygen (O_2) transport and utilization systems (cardiopulmonary system and oxidative muscle fibers); type 2 metabolic as per type 1 but with a greater degree of neuromuscular strain; type 3 metabolic as per type 1 with a large anaerobic glycolytic energy contribution but limited neuromuscular strain; type 4 metabolic as with type 3 but with a high neuromuscular strain. The type 5 target, a session with limited aerobic demands but with a large anaerobic glycolytic energy contribution and high neuromuscular strain, is rarely if ever used in our context. The type 6 response (not considered HIIT) refers to typical speed and strength training with a high neuromuscular strain only. Note that for all HIIT types that involve a high neuromuscular strain, possible variations of the strain include more high-speed running (HS, likely associated with a greater strain on hamstring muscles) oriented work or mechanical work (MW, accelerations, decelerations, and changes of direction, likely associated with a greater strain of quadriceps and gluteus muscles).

HIIT With Long Intervals (Outdoor)

Because of their important (but less soccer locomotor-specific) neuromuscular load and anaerobic contribution (type 4), we generally implement HIIT with long intervals exclusively during the preseason over a 300 m loop designed around the pitch. These typical HIIT exercise bouts are generally performed over 3 to 4 min at 90%-95% $V_{IncTest}$ or 80% V_{IFT} (see chapter 2). This represents 800 to 1000 m efforts completed over 3 min, depending on player fitness, with athletes running 3 to 5 repetitions interspersed by 2 min of passive recovery. Players are generally spread across 4 groups (16 km/h, 17 km/h, 18 km/h, and >18 km/h for $V_{incTest}$ or 18 km/h, 19 km/h, 20 km/h, and >21 km/h for V_{IFT}) and are requested to reach group-specific cones set across the running loop at appropriate times. These sessions are generally prescribed at the end of the day, so that athletes may benefit from a greater $\dot{V}O_2$ slow component, i.e., higher $\dot{V}O_2$ for a similar or lower running speed due to muscle fatigue and loss in metabolic efficiency (6)), which may help in limiting overall musculoskeletal strain and fatigue. Importantly, this HIIT format also has an advantage in that it stresses the cardiopulmonary system at high rates without the need for reaching high running speeds (<18-19 km/h). This is of primary importance for the weekly high-speed running load management, since it leaves room for the other sessions to target this locomotor component with less risk of locomotor or musculoskeletal overload (20).

HIIT With Short Intervals

Our preferred HIIT short-interval weapons include 10 s on/10 s off, 15 s/15 s, 20 s/20 s, and more often 10 s/20 s (figures 30.3 and 30.4) since this latter format has been shown to be low with respect to acute neuromuscular fatigue (figure 5.41 (6)). We implement these HIIT formats for the main reason that both the volume and intensity of the locomotor load (i.e., high-speed running and mechanical work), and in turn, the associated neuromuscular load and fatigue and anaerobic contribution, can be tightly manipulated. For example, type 1, 2, 3, or 4 targets can all be hit with short intervals. While we may sometimes use these HIIT formats in the preseason during a few collective team training sessions, HIIT with short intervals is of greater use to us in-season for individual players requiring well-tailored locomotor loads, i.e., rehabilitating players or conditioning substitute players, for which collective game-based training may not be recommended or fulfill their needs completely. In fact, programming HIIT with low levels of neuromuscular load (type 1) may be required during the preseason to assist with preserving the quality of the conjoined soccer sequences (same session) as well as the type 6 strength and speed sessions planned the following day (see chapter 6). Similarly, during rehab, it may be prudent to start with type 1 HIIT before progressing, depending on the type of injury, toward hitting type 2 targets (tailored toward either more high-speed running versus mechanical work, figure 30.3), followed by type 3 targets, and finally, type 4 targets. For substitute players, HIIT with short intervals is generally the only weapon available as a top-up to compensate for the high-speed running load that players miss while not playing, since the large majority of SSGs in which they participate (figure 30.5) fail to over-load

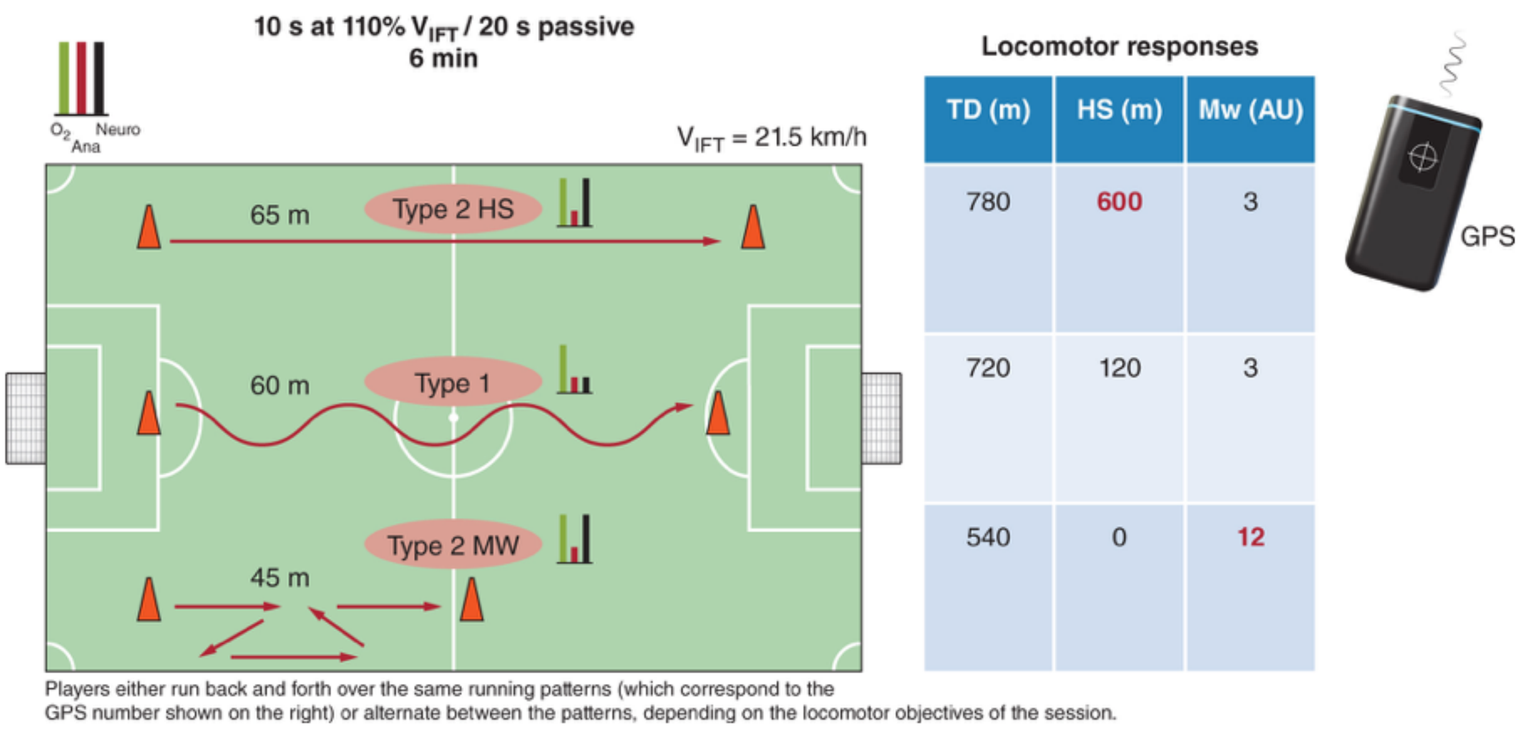
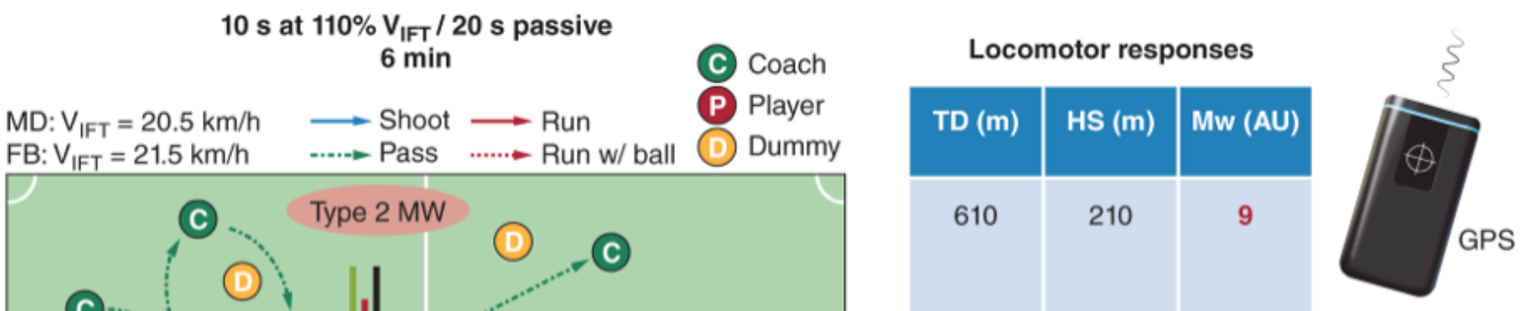


Figure 30.3 Example of three HIIT sequences with short intervals (10 s run/20 s passive recovery periods) including or not including turns at different angles to modulate the neuromuscular responses (type 1 versus type 2). The associated locomotor responses analyzed by global positioning system (GPS) are provided for each run. Run type (e.g., straight line and zig-zag runs) can be alternated to create hybrid locomotor loads that include both high-speed and mechanical work responses. Note that for longer intervals, the anaerobic participation is greater, for type 3 and 4 targeting. TD: total distance; HS: high-speed running >19.8 km/h; MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions); V_{IFT}: velocity achieved during the 30-15 intermittent fitness test (see chapter 2). Degree of contribution from oxidative (O_2), anaerobic (Ana), and neuromuscular (Neuro) systems is shown by the degree of green, red, and black bars.



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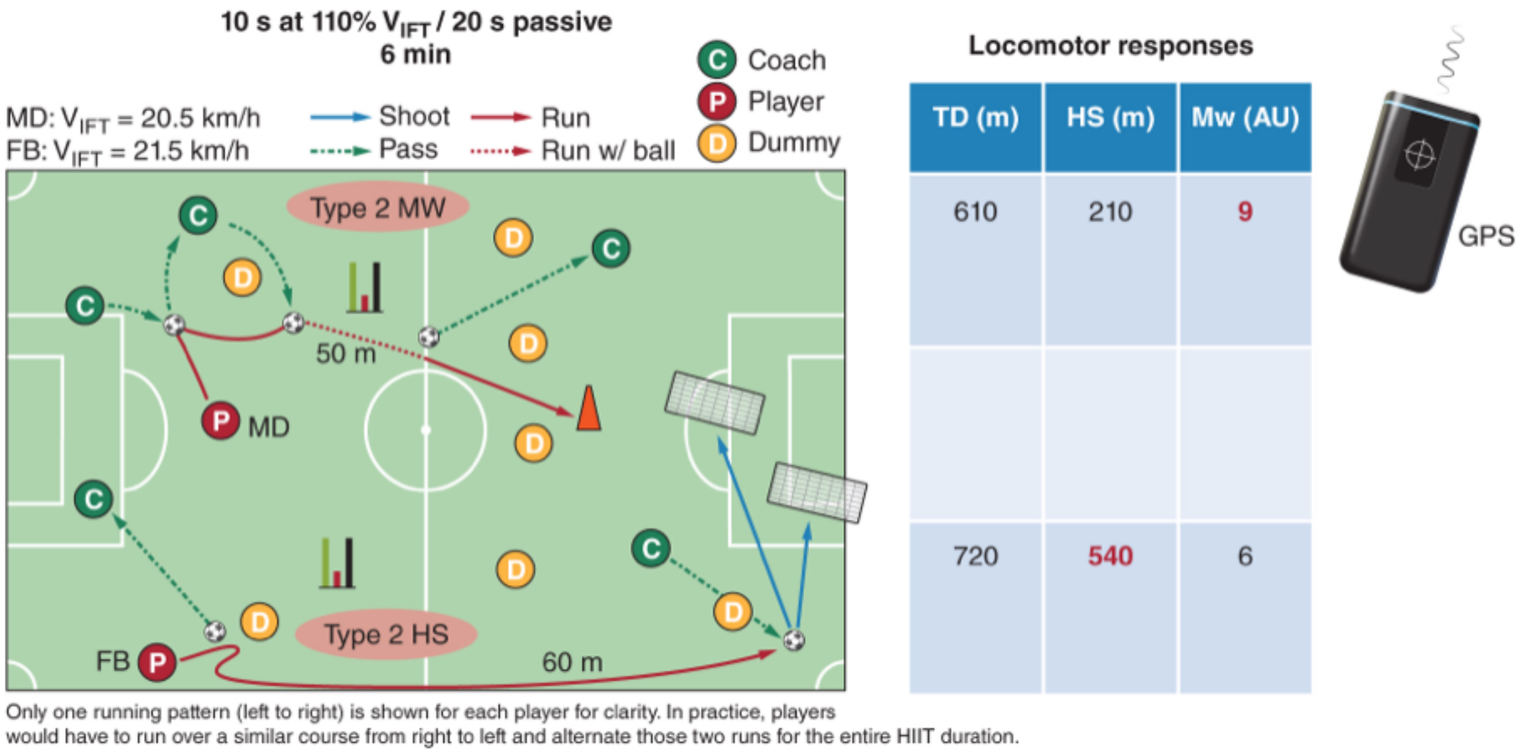


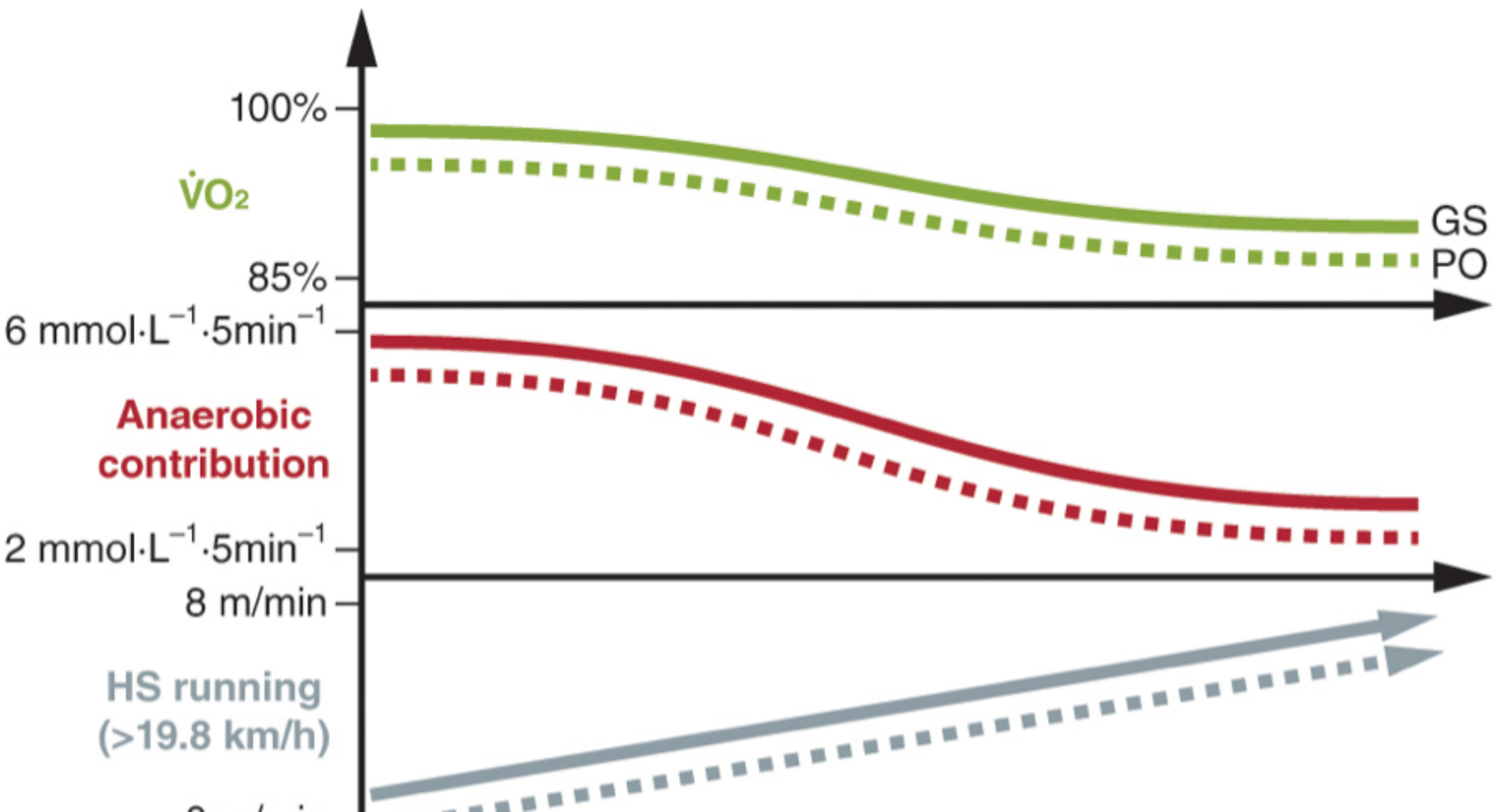
Locomotor responses

TD (m)	HS (m)	Mw (AU)
610	210	9
720	540	6

Figure 30.4 Example of two position-specific (midfielder, MD, and fullback, FB) HIIT with short intervals (10 s/20 s format, type 2) based on V_{IFT}. The associated locomotor responses analyzed by GPS are provided for each run. HS: high-speed running >19.8 km/h. The FB can't progress because of an opponent (dummy), so he passes the ball to a coach playing as a central defender, then runs along the sideline to receive from a second coach another ball close to the box where he shoots into one of two mini-goals (as if he were crossing). The MD comes close to the central defender to receive the ball, then to eliminate a defender, passes and receives to/from a second coach situated on the sideline as an FB, before running forward with the ball where he passes to a third coach and finishes his run toward the box. Note the large differences in terms of high-speed running and mechanical work between the two position-specific efforts, which likely equal their match-specific loading targets (28). TD: total distance; HS: high-speed running >19.8 km/h; MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions); V_{IFT}: velocity achieved during the 30-15 intermittent fitness test (see chapter 2). Degree of contribution from oxidative (O_2), anaerobic (Ana), and neuromuscular (Neuro) systems are shown by the degree of green, red, and black bars (figure 30.3).

this locomotor component respective to match demands.

In practice, we generally spread the players into 5 groups (17 km/h, 18 km/h, 19 km/h, 20 km/h, and >21 km/h for V_{IFT}) and request they run over group-based distances using cones on the pitch. For example, for players with a V_{IFT} of 19 km/h, and for a 15 s/15 s HIIT run at 95% V_{IFT} (relief interval: passive), the target distance will be (19/3.6) × 0.95 × 15 = 75 m (19 is divided by 3.6 to convert the speed from km/h to m/s, for convenience) (3). When we plan runs with changes of directions (CODs) to decrease the amount of high-speed running and modulate mechanical work, the time needed for COD must also be considered when setting the target run distance in order to ensure a similar cardiorespiratory load compared to straight-line runs. Therefore, in relation to the estimated energetic cost of COD during HIIT (see chapter 2, V_{IFT} section), if the players have to run over a 40 m shuttle, for example, they would instead cover 71 m. If the shuttle length is divided in half (i.e., 20 m shuttle), the distance they must cover drops to 65 m (3). (A spreadsheet that completes this calculation for 180° CODs for 15 players at a time is available through the 30-15 IFT App: https://30-15ift.com/.) Finally, to further modulate the locomotor demands and, in turn, the neuromuscular load of these runs, we use turns at different angles that can either decrease or increase braking and acceleration demands. In fact, using research technology that included measures of ground impacts and muscle activity and oxygenation during (repeated) high-intensity runs (8, 21, 22) (https://www.youtube.com/watch?v=KFL8STOyaB0), we showed that while straight-line runs promote stride work (and hamstring loading) via increased high-speed running (HS, type 2 or 4), sharp turns (90°-180°) rather increase thigh work (quads and



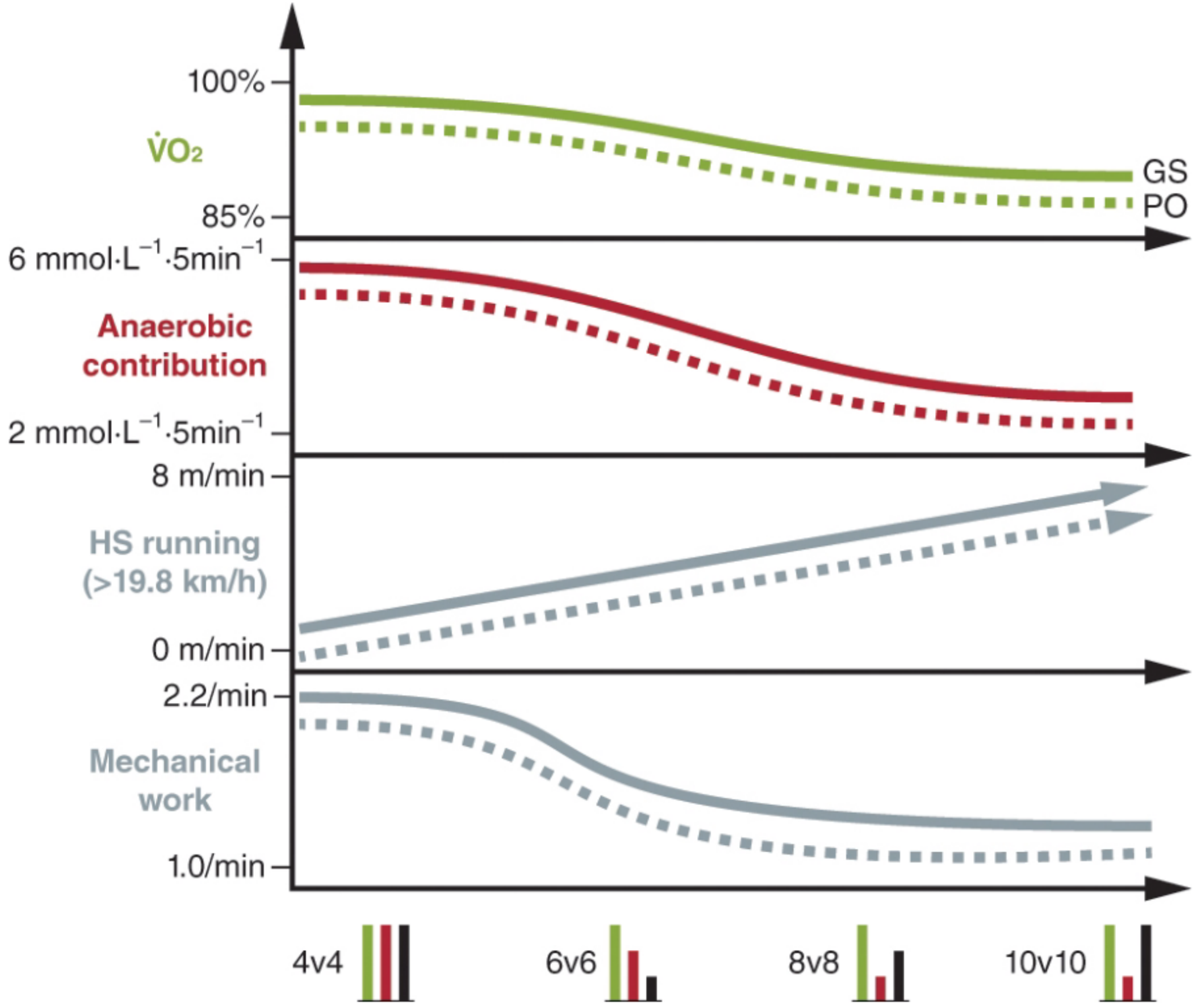


Figure 30.5 Schematic effect of increasing player number (and relative pitch size) on metabolic and locomotor responses to SSGs (personal data) with (game simulation, GS) or without (possession, PO, dotted lines) goalkeepers. Possession tends to systematically be associated with lower locomotor and metabolic responses compared with GS (18). Note that 6v6 to 10v10 may not be considered as HIIT due to their relatively lower metabolic responses. Degree of contribution from oxidative (O_2), anaerobic (Ana), and neuromuscular (Neuro) systems is shown by the degree of green, red, and black bars. $\dot{V}O_2$: oxygen uptake.

glutes) via the increased neuromuscular requirements associated with deceleration and acceleration phases (i.e., increased mechanical work, type 2 or 4). Interestingly, we also showed that 45° turns were likely associated with the lowest neuromuscular load, since neither high-speed nor sharp decelerations and accelerations are involved within this condition (8, 22) (type 1).

To make HIIT with short intervals more appealing to players and a bit more specific in terms of movement patterns and locomotor loading, the ball is often integrated into the activity on different occasions. For example, players run following position-specific running patterns for the required duration while reproducing position-specific technical sequences including passes, receptions, and/or shots on mini-goals at the end of the run (figure 30.3).

Finally, while the optimal loading in terms of HIIT volume and, in turn, high-speed running distance and mechanical work is difficult to define, we often use match demands as targets. For example, we progressively build up locomotor loads during rehab to reach the match-play distance equivalent of 45, 60, and 90 min or sometimes more. We also use within-player load modeling such as the acute/chronic ratio (20) (and associated predictions) for both rehab and healthy players to define volume targets at different times of the week. For example, considering that a competitive match requires players to cover 600 to 1300 m >19.8 km/h (2), compensation training the day following the match including a 6 min HIIT (in which series duration and volume are based on player's profile and position) may allow substitutes to maintain their weekly high-speed running volume at a stable level, which may limit injury risk before the next match (20).

Repeated-Sprint Training

We implement RST (type 4 target) with the overall team at some very specific moments during the last stages of the preseason, with substitute players in-season, or with rehabilitation players at the end of their return-to-play process. We tend to implement RST formats that involve large amounts of mechanical work rather than straight-line running, so as not to overload high-speed running while still stressing the ability to repeat high-intensity efforts. Our RST blocks are generally implemented as 5 s efforts with 15 to 25 s passive recovery periods over 4 min (2 sets) (6), or less commonly as 6 s efforts with 6 s rest over 1 min (2 to 4 sets), with the same approach as described for HIIT with short intervals (i.e., modulation of mechanical work with varying COD angles, and using position-specific running patterns and technical sequences, figure 30.3).

Game-Based Training

As in many sports, we organize the majority of game-based training in the format of SSGs (24, 34), which we consider to be the main HIIT weapon when it comes to conditioning the overall group of players. Despite the fact that players and the global soccer culture today tend to disregard run-based types of conditioning in the name of training specificity (15), the science-informed coaches we are finally were convinced to embrace and implement this particular HIIT format in light of the near-to-

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In practice, using SSGs based on the expected metabolic, locomotor, and neuromuscular responses (figures 30.5 and 30.6) is appropriate, but can we do even better? If we compare the locomotor responses to match demands, this might help ensure optimal loading (not too much, not too little) and a more manageable work/recovery balance from one day to the next (figure 30.7). One of the challenges of assessing match demands, however, is that the intensity and density of actions is likely time dependent, i.e., the longer the period of play, the lower the average intensity of that period. For this reason, it is difficult to compare the locomotor intensity of different SSG formats of various durations with the demands of a 90 min game. To examine the extent that different SSG formats could be used to either under- or overload the running and/or mechanical demands of competitive matches, we recently used power law modeling (figure 30.7) to compare the peak locomotor intensity of different typical SSGs with those of official matches in terms of running demands and mechanical work over different rolling average durations (28). We found that match simulations (10v10 SSG, 102 × 67 m) were the only games that allowed players to reach similar running intensities compared to official matches (total distance and HS running). However, 4v4 was the only SSG that allowed players to reach a greater mechanical work intensity than during official games (from 50% to 100% more than during matches over 1 to 5 min, respectively) and was strongly associated with much less running above 14.4 km/h (from 30% to 40% less over 1 to 5 min, respectively) (figure 30.7). The other SSG formats (6v6 or 8v8) were not shown to overload mechanical work or high-speed running (28).

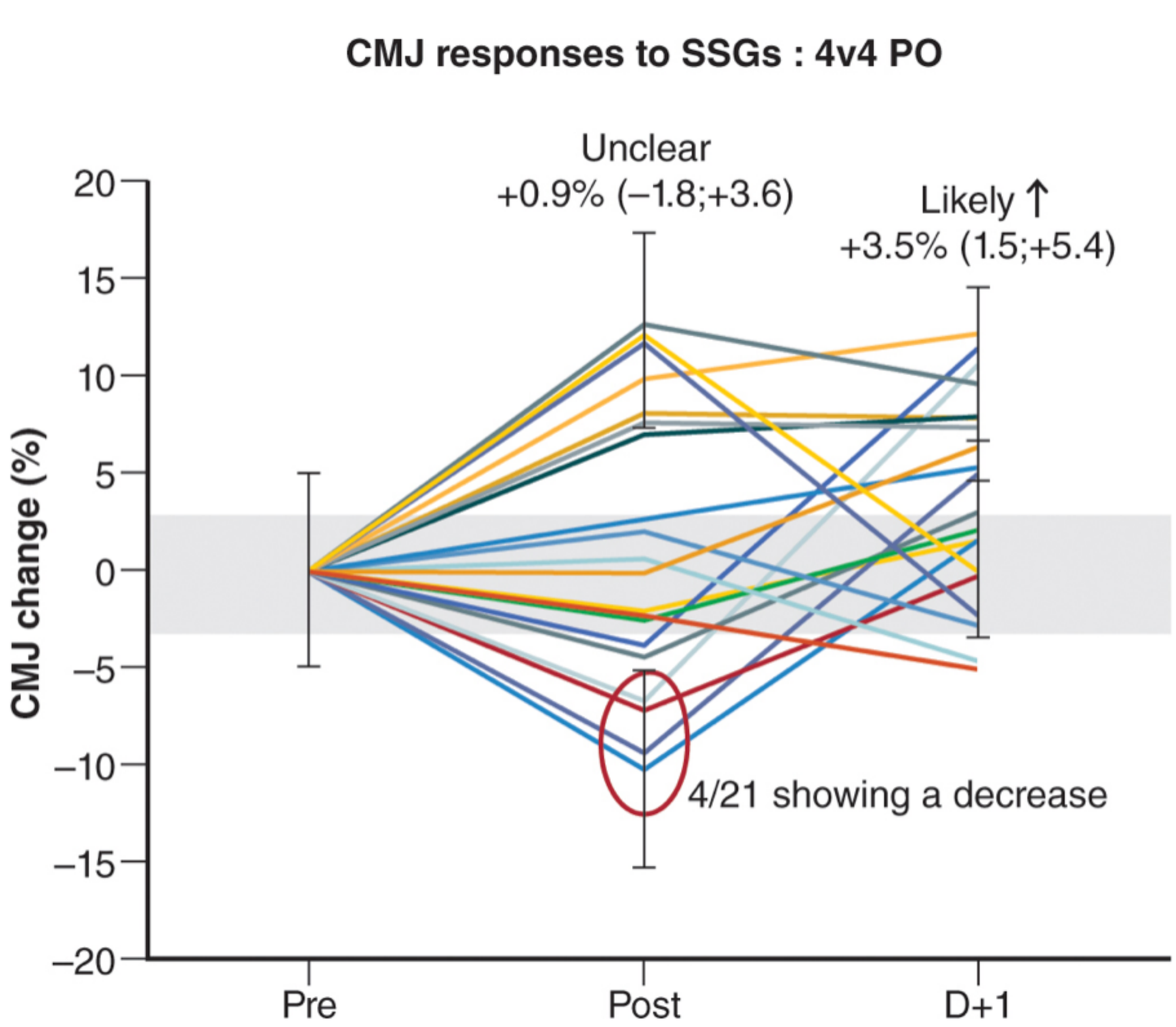

Figure 30.6 Changes in countermovement jump (CMJ) immediately (post) and 24 h after a session including 4 × 3 min, 4 versus 4 SSGs (40 m × 16.5 m, possession (PO) without goalkeeper, free touch) in highly trained U14 soccer players from an elite academy (29). Despite the limitation of CMJ height to assess neuromuscular fatigue per se, these data suggest that the level of neuromuscular fatigue associated with such SSGs may be limited. The following day (D+1), all players (including the 4 individuals showing a performance decrement immediately after the session) had at minimum recovered or even showed small to large improvements. The gray zone represents the smallest worthwhile change (SWC, 3%). Error bars representing the error of the measurement (TE, 5%) have been added to the two extreme individual player responses at post. This data revealed that only 4 players out of 21 were affected with likely substantial changes, i.e., greater than TE + SWC.

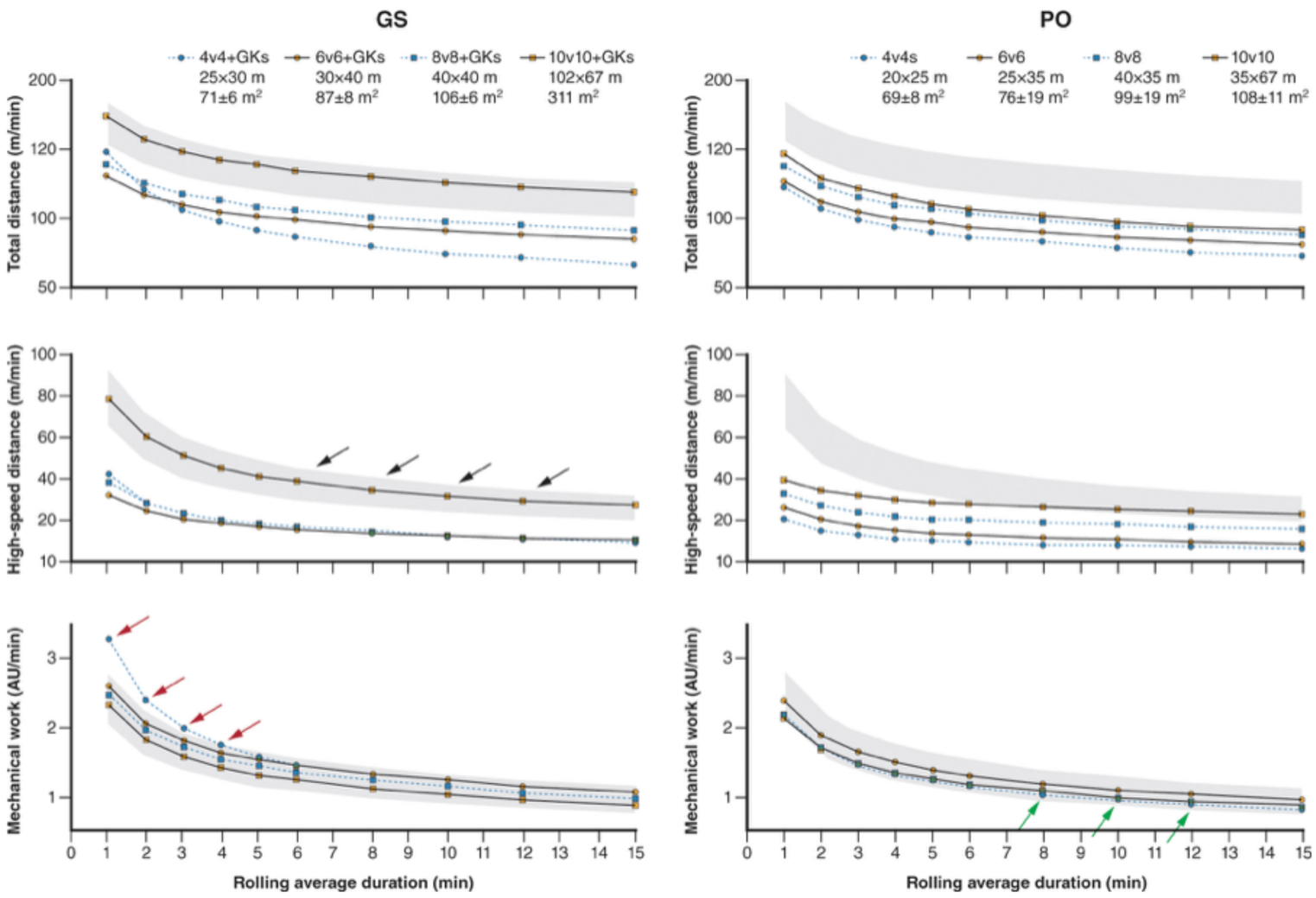

Figure 30.7 Peak locomotor intensity during typical small-sided games (SSGs) including two additional goalkeepers (game simulation, GS) or not (possession game, PO), compared with match demands as a function of each rolling average period in a group of 25 professional soccer players (gray zones stand for match average ± standard deviation) (28). Red arrows highlight how mechanical work can be overloaded compared to match demands using short periods of 4v4 GS. Black arrows highlight how match high-speed running intensity can be replicated using 10v10 GS. Finally, green arrows highlight how match mechanical work can be underloaded or at least matched using various periods of 8v8 PO. High-speed running: >14.4 km/h.

USE OF THE DIFFERENT SSG FORMATS

• Based on these modeling data (figure 30.7) and others (figure 30.5), we often use 4 to 6 × 3 to 4 min bouts of 4v4 SSGs as our primary HIIT weapons. These SSGs are generally implemented on days when we are targeting strength and high levels of metabolic power (high $\dot{V}O_2$ and blood lactate values), when most of the training sequences tend to overload the neuromuscular system at high levels, both in terms of intensity (mechanical work per min) and volume (see Program Structure and Progression). Interestingly, despite this intense neuromuscular load (as inferred from the high mechanical work values), CMJ (figure 30.6 (29)), sprint performance (35), and stride kinematic (vertical stiffness (11)) data collected immediately after such sessions and the following day suggest that these sessions are associated with a limited amount of neuromuscular fatigue. In fact, the neuromuscular responses to 4v4 SSGs are likely individual (some players, but not all, may experience a temporary decrease in performance immediately after the session, figure 30.6) and more importantly for our programming purpose, overall performance tends to fully recover for the majority of players the following day. Note that the metabolic responses to such SSGs are also almost near to maximal (24), which shows us again that during such soccer-specific drills, it is unlikely that we can train physical capacities in complete isolation (resulting in HIIT type 4 targeting). These formats are likely suited to develop maximal aerobic power rather than endurance per se, which explains why this SSG format fits better into locomotor "strength" than endurance-oriented conditioning sessions.

• We use 6v6 and 8v8 SSGs for the so-called "endurance days" (type 1 and 2 targets). Despite the lower running pace compared to matches (figure 30.7), the high but not maximal metabolic responses (high heart rate responses, moderate lactate levels (24)) help to improve a player's ability to maintain high work rates over time (i.e., endurance) when programmed over prolonged durations (e.g., >8 min for 6v6 and >15 min for 8v8). Importantly, these formats allow players to train at the same mechanical work intensity (i.e., game simulation including goalkeepers, GS) or at lower work intensity (i.e., possession game without goalkeepers, PO) than during matches (figure 30.7) resulting in relative recovery compared to a "strength day," while at the same time limiting the volume of high-speed running. With these constrained locomotor demands, large volumes of work can be accumulated without excessive (at least acute) neuromuscular fatigue. This likely allows a more complete recovery from the session of the day(s) before (often a strength day), and may help to promote freshness for the following days and lower overall injury risk.

• For "speed days," we use 10v10 (type 1 and 2) and variations in the forms of possession games over large spaces (especially field length >60 m, systematically greater than field width), often using specific rules (e.g., players need to receive the ball behind the goal line while respecting the offside rule (11)), that leads players to sprint more often and/or over longer distances. Additionally, most of the tactical sequences over at least half of a pitch (building up, crossing, finishing) tend to promote high-speed running, which nicely complements the large SSGs used.

Finally, in addition to variations in player number and pitch area (figure 30.6), there are many simple options available to modulate the intensity of the mechanical work, for example, as shown in figure 30.5, using possession games (without GK) instead of game simulations (with GK) or adding wide players to the sides of the playing area who can serve as relay targets to

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Longitudinal Training Effects of HIIT

We completed an important study in young elite players in Iran (33), in which we compared the performance effects of a biweekly training supplementation of run-based HIIT with long intervals (3 sets of 3 min 30 s), the difference being the way exercise intensity was prescribed, i.e., 65% to 70% V_{IFT} versus 90% to 95% HR_{max}. Interestingly, the group for which HIIT was prescribed using the $\%V_{IFT}$ approach showed an 86% greater weekly improvement than the other group (figure 30.9) (33).

With the large majority of the professional players we have worked with, however, we were unable to implement training interventions that would appropriately isolate the effect of HIIT per se and realize physiological or performance testing to actually monitor the effect of these potential interventions. Therefore, for a better understanding of the possible training effects of the other HIIT formats that we also use routinely, and especially SSGs, the reader is referred to the following publications: (17, 23, 26).

Load Surveillance and Monitoring Tools

Chapters 8 and 9 outline our general approach to load surveillance and individual response monitoring. With the recent developments of global positioning systems, inertial sensors, and semiautomatic video systems, the use of wearables and tracking technologies is very common in soccer, during both training and matches (1, 7). In our practice, we compute individual daily locomotor

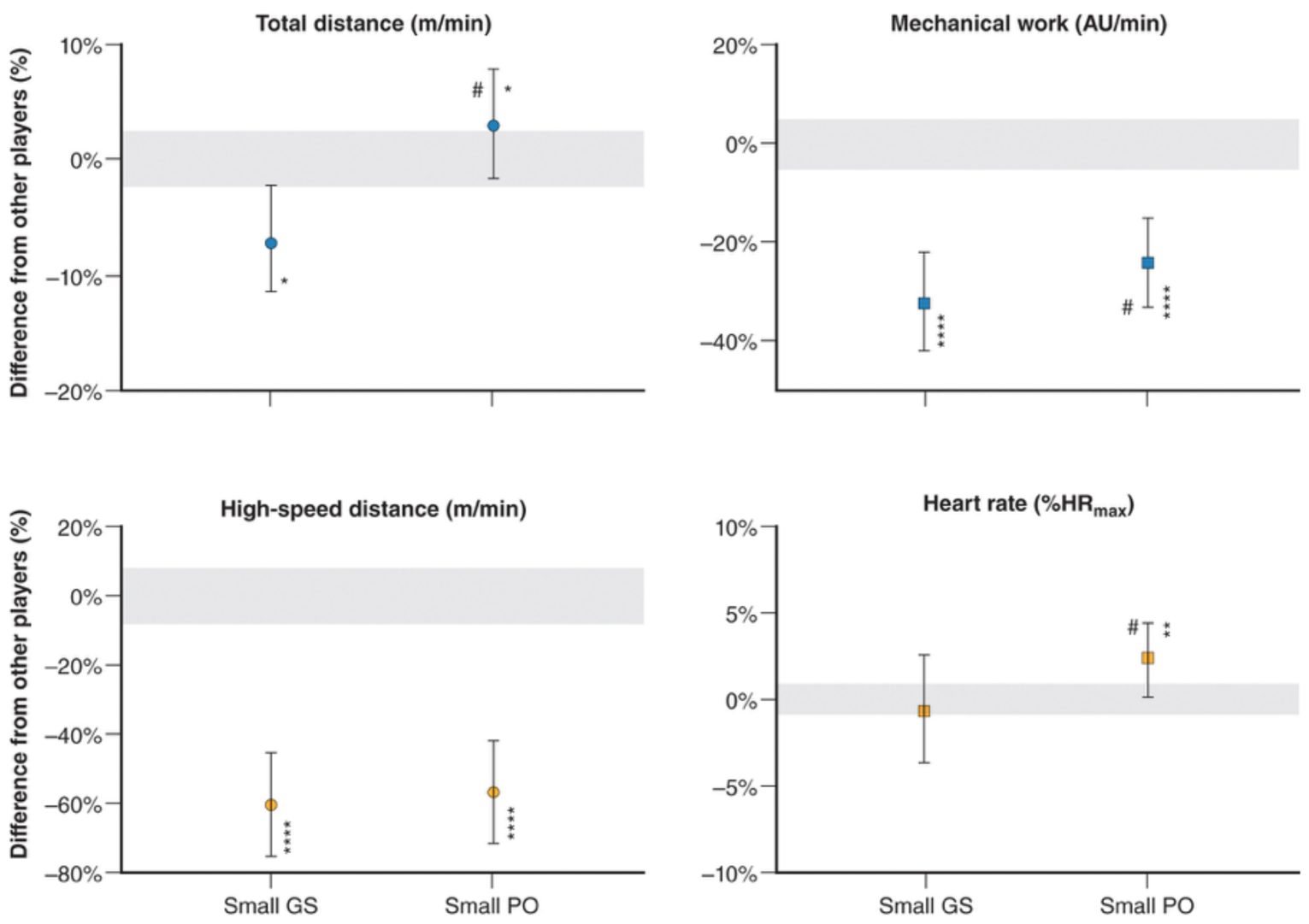

Figure 30.8 Locomotor (with high-speed referring to distance >14.4 km/h) and heart rate responses of joker players (i.e., playing with both teams but not allowed to shoot) compared to the rest of the group during small and large SSGs (with two additional goalkeepers, game simulation, GS, or without goalkeepers, possession game, PO). *: possible difference vs. other players; **: likely difference vs. other players; ***: very likely difference vs. other players; ****: almost certain difference vs. other players; #: between game (GS vs. PO) difference.

Data from M. Lacome, B.M. Simpson, Y. Cholley, and M. Buchheit, "Locomotor and Heart Rate Responses of Floaters During Small-Sided Games in Elite Soccer Players: Effect of Pitch Size and Inclusion of Goalkeepers," *International Journal of Sports Physiology and Performance* 13 no. 5 (2018): 668-671.

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load and track potential changes over time (20). Despite their limitations (see chapters 3, 8, and 9), we also generally monitor HR during most training sessions that include a metabolic component (and hence, HIIT) and collect RPE after each session. Perceived training load can then be calculated via the popular session RPE method (25), to be considered alongside the locomotor load.

Training Status Surveillance and Monitoring Tools

The training status monitoring tools that we've used in soccer are generally limited to noninvasive and player-friendly measures and include wellness questionnaires (overall well-being (37)), exercise HR (fitness (4)), and GPS/accelerometer-derived data (including both locomotor loads and mechanical work (7)). More specifically, we use the locomotor (GPS-related), HR, and RPE responses to either standardized SSGs (figure 30.10 (7)), HIIT (12), or submaximal runs (9) (figure 30.11) as markers of readiness to perform or adaptation. More precisely, the greater the activity/min and lower the HR and RPE, the better we consider a player's readiness or fitness level in comparison to the player's historical data. We then often use these individual responses to tailor a player's subsequent training (top-up HIIT training in the case of insufficient fitness or physio interventions when imbalances are detected, figure 30.11).

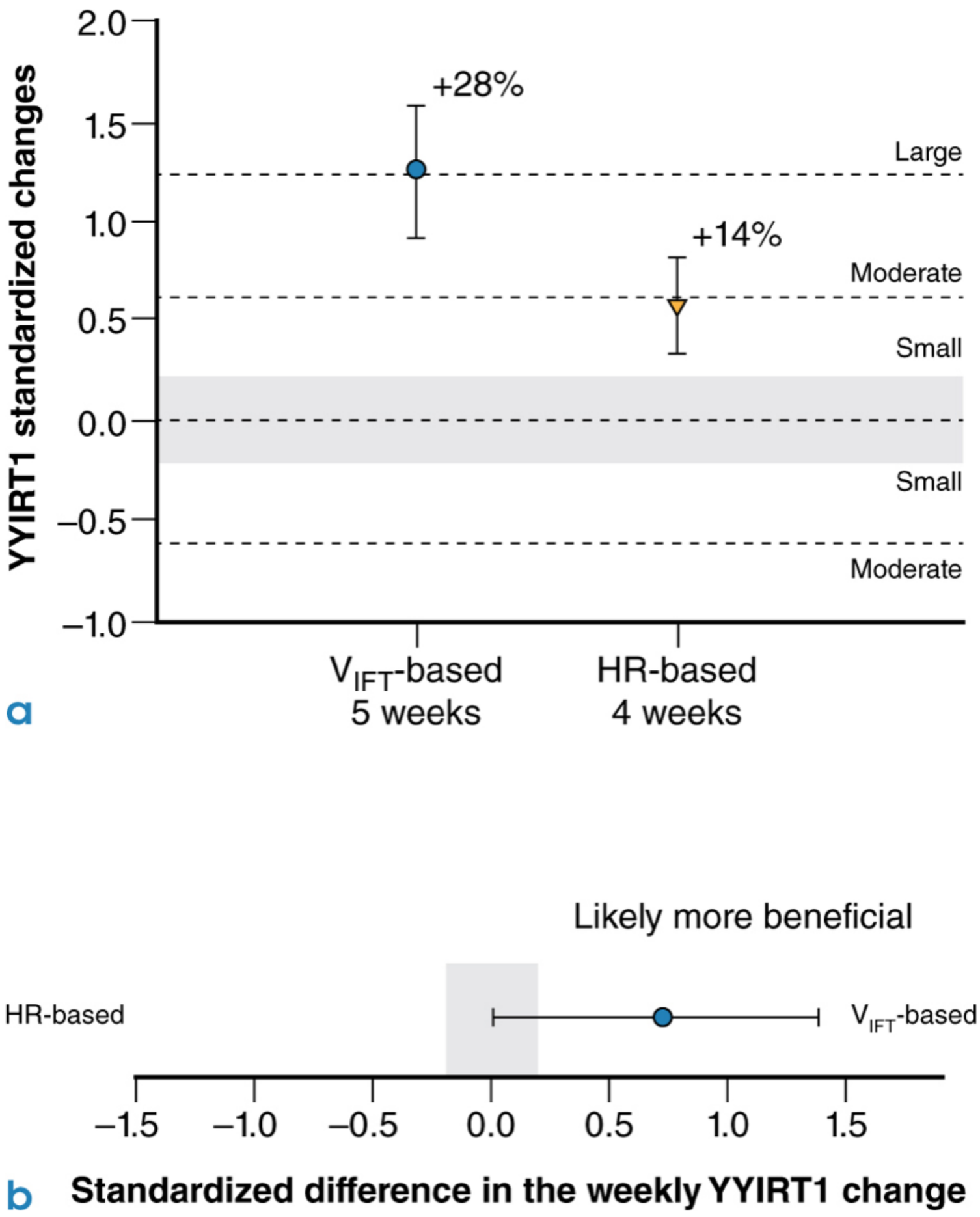

Figure 30.9 Standardized changes following the two high-intensity interval training (HIIT) approaches: (a) within-group changes; (b) difference in weekly improvements. The shaded areas represent trivial changes/differences (0.2 × pooled standard deviation). YYIRT1: Yo-Yo intermittent recovery interval level 1.

Reprinted from A. Rabbani and M. Buchheit, "Heart Rate-Based Versus Speed-Based High-Intensity Interval Training in Young Soccer Players." In *International Research in Science and Soccer II,* edited by T. Favero, B. Drust, and B. Dawson (New York: Routledge, 2015).

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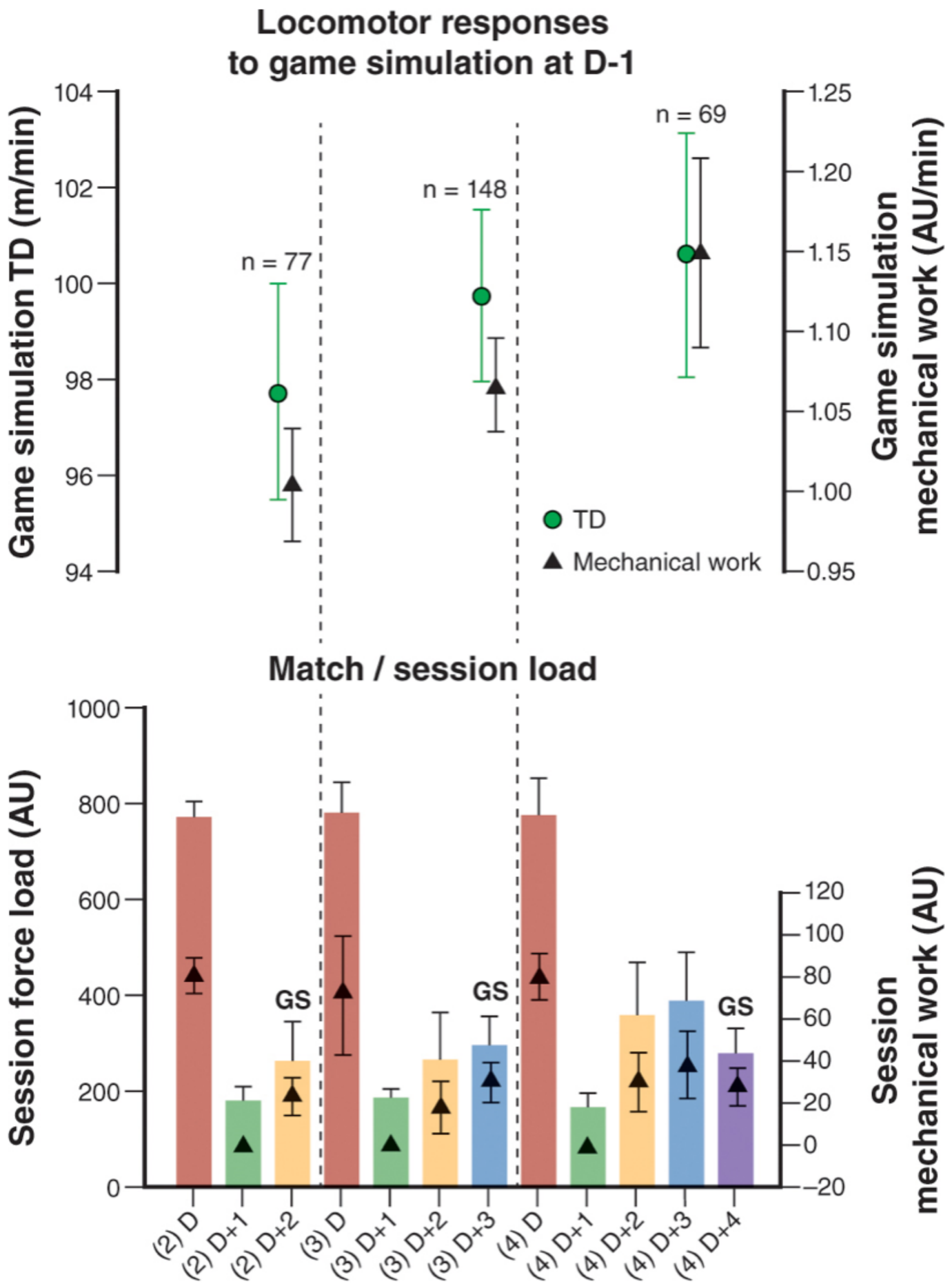


Figure 30.10 Locomotor responses (total distance covered (circles) and mechanical work (triangles) per minute) during game simulation drills (MS) the day before a game (D-1), as a function of the number of days between two consecutive matches in professional soccer players from an elite French team (upper panel). Sessions/match force load (bars) and mechanical work (triangles) as a function of the number of days between two consecutive matches (lower panel). Game simulations: 9 vs. 9 players (2 goalkeepers), 50 × 55 m, free touches, 2 × 8 min. Mechanical work is a variable provided by the ADI analyzer (7) as a compound measure of accelerations, decelerations, and changes of direction.

Reprinted by permission from M. Buchheit and B.M. Simpson, "Player-Tracking Technology: Half-Full or Half-Empty Glass?" *International Journal of Sports Physiology and Performance* 12 Suppl 2 (2017): S35-S41.

Strategies for Structuring the Training Program Using HIIT

Strategies for structuring HIIT programming in soccer may be confined by various controllable and uncontrollable factors before proper progression and periodization can be appropriately implemented. This section discusses some of the nuances of training program and HIIT structuring in soccer.

Controllable and Uncontrollable Factors

In our experience, the only truly uncontrollable factors within our training program design are the game schedule timing and match locations, which are controlled by the sport federation and media. Next is the constant requirement for high-quality technical sessions often including strength and speed components, which together constrain the timing, volume, and objective (HIIT type) of the HIIT sequences within a given training week. For example, some HIIT sequences require a large amount of mechanical work (i.e., strength sessions, types 2 and 4), while with others, we want these

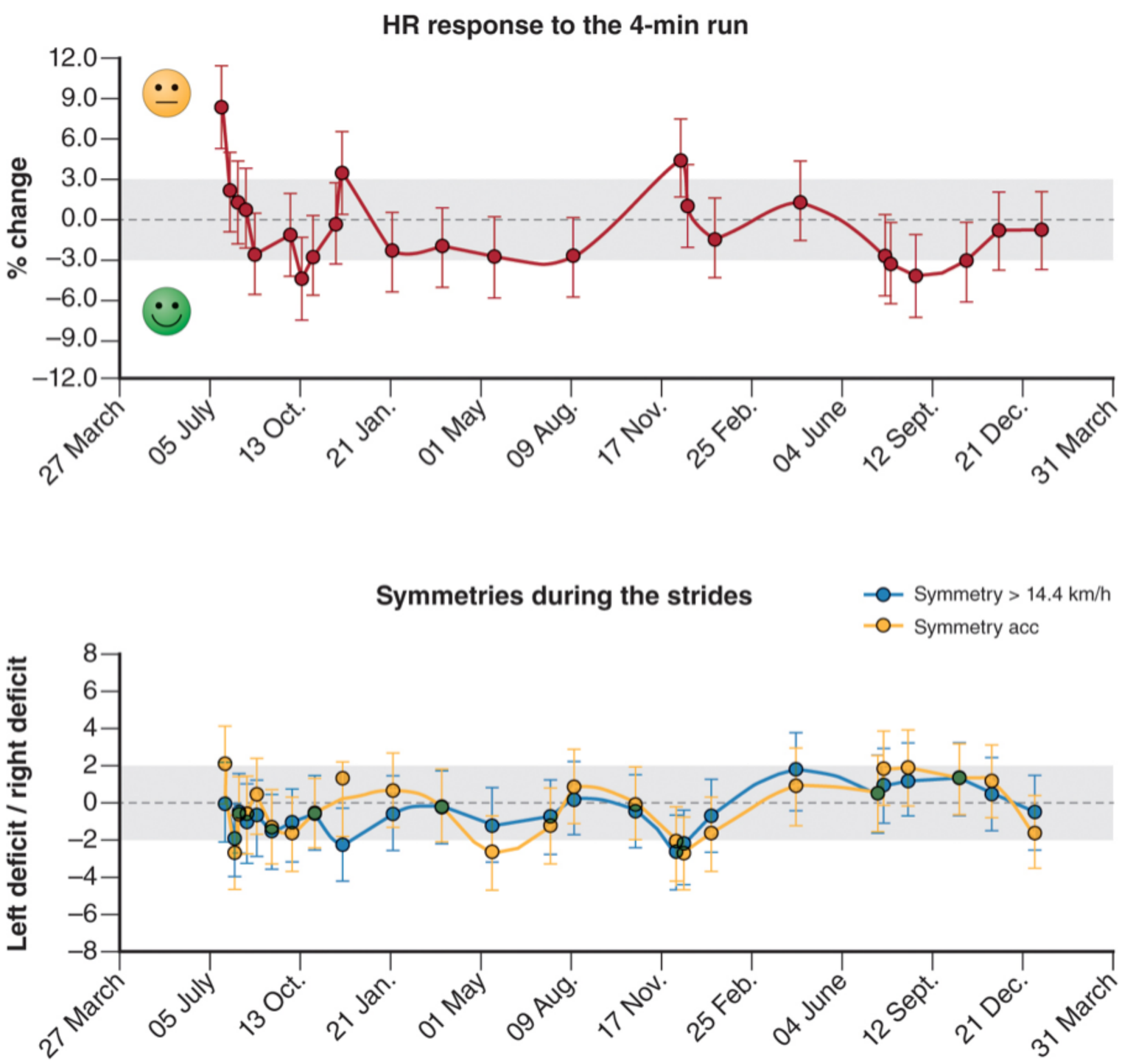


Figure 30.11 Individual report showing both the changes in HR response to a 4 min submaximal run (12 km/h) and the right versus left force load balance during stride runs (4 × 60 m high-speed runs) (personal data).

components as low as possible to minimize the subsequent level of neuromuscular fatigue (i.e., recovery or endurance sessions, type 1). Finally, with soccer being a skill and tactical sport (figure 30.1), the time allocated to HIIT will never be more than that permitted for team tactics, for example, and high levels of specificity are often expected, which constrains further the HIIT formats available. Therefore, these must be short and with ball integration. This shows that it's not only the physiological objectives of the HIIT sequences that determine its format, but more importantly, the contextual considerations.

Program Structure and Progression

In soccer, as with many team sports, there actually is very little periodization in terms of training cycles, except during the preseason. In-season, we try to keep the weekly training load almost constant throughout the months and focus on the successive match preparation–match recovery cycles, with a short emphasis on development during the midweek days when possible (15). For these reasons, the skeleton of the weekly program and the program objectives remains similar across the season. The only differences arise from the different macrocycles possible, which depend directly on the number of days of recovery and training between two consecutive matches (generally from 2 to 7).

To program and select the most appropriate HIIT type (and, in turn, format) and solve the puzzle during the training week, we first define the physiological targets of the sequence (5) and then use the anticipated acute metabolic and locomotor and neuromuscular responses to each HIIT weapon to make the decision (figures 30.5 and 30.12). The physiological goal of the session or day is generally easy to define, since we tend to orient as much as possible the training stimuli toward a given physical quality on a given day, i.e., strength and high metabolic power, endurance, and speed days. While we know many roads lead to Rome (chapter 4), the training approach that we have embraced so far follows the main orientations of the tactical periodization training paradigm, in which daily training components are not only structured in relation to technical and tactical objectives but also in line with the physical capacities to be targeted ("Physiological dimensions provide the biological framework where the soccer-specific training/recovery continuum lies" (15)). Focusing on the successive development and maintenance of the main three physical capacities on separate (often consecutive) days likely allows the training stimulus to be maximized when the other qualities recover, which may decrease physiological interferences (19) and, in turn, lead to greater adaptations (6). Practically, we organize all within-session training sequences toward the same quality. For example, a strength-conditioned session would include a strength-oriented warm-up (e.g., light plyometric drills, single-leg horizontal hops), locomotor-based strength work (e.g., accelerations, changes of direction, sled pulling), and game-play sequences, including, irrespective of the actual technical and tactical requirements, high and qualitative neuromuscular demands (e.g., high number of player-to-playing area ratio, maximal intensity of actions with adequate rest periods).

Incorporation of HIIT

We incorporate HIIT sequences into training sessions both at the team and individual levels either between two other technical and tactical sequences (mostly SSGs) or at the end of the session (mostly run-based HIIT). As shown in figure 30.12, the two most important aspects to consider when selecting the desired types of metabolic and neuromuscular responses to the HIIT sequences are (1) the demands of the other sequences of the training (or day) in which HIIT is incorporated and (2) the individual locomotor loading patterns over the actual weekly cycle. By doing so, HIIT can be used to compensate or complement the load arising from training and matches played or missed, while minimizing as much as possible fatigue accumulation to promote the quality of the adjacent sessions.

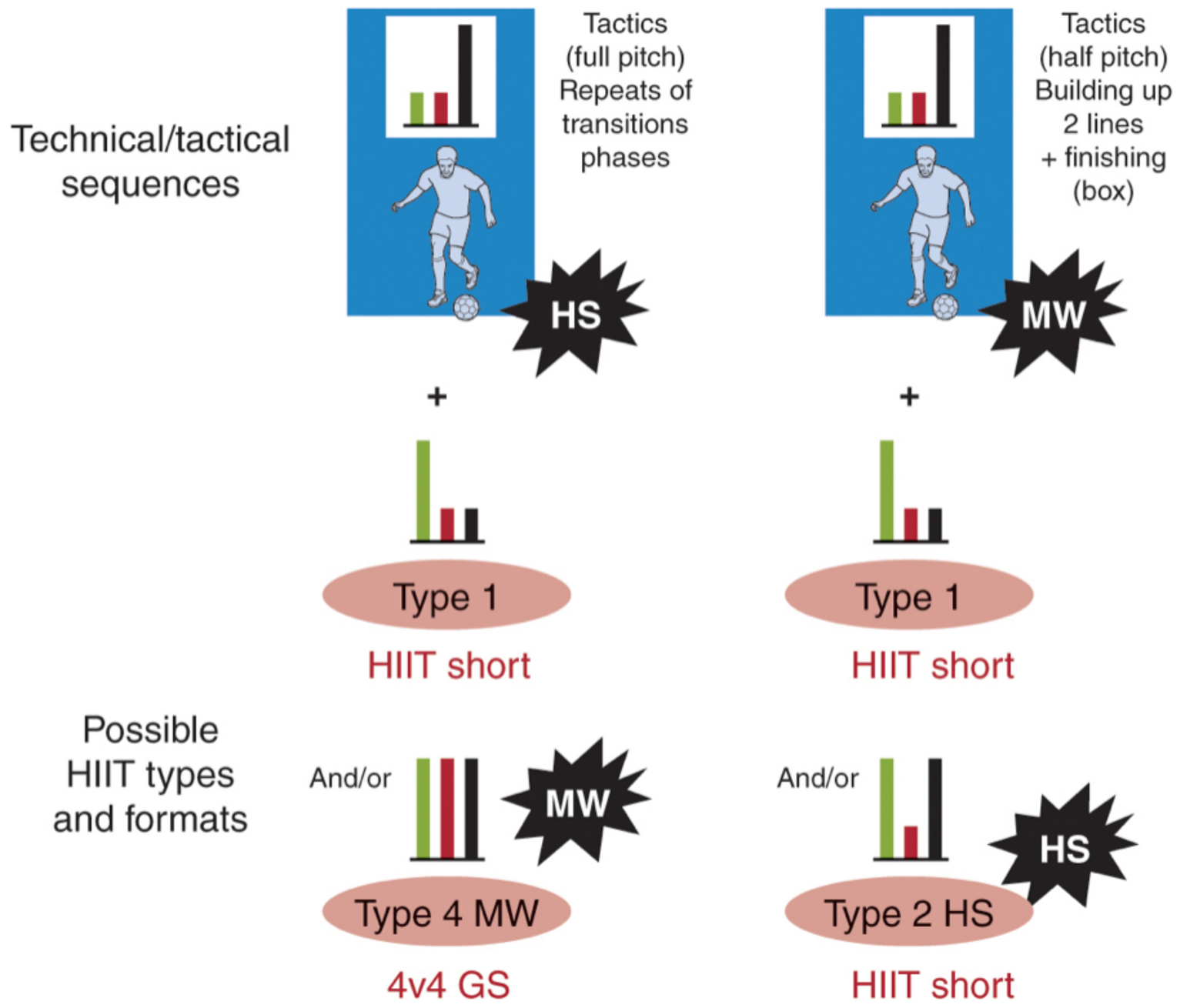


Figure 30.12 Example of the decision process used to select the desired types of metabolic and locomotor (and in turn neuromuscular) responses to HIIT, when this latter aspect is programmed alongside tactical and technical sequences during a given training session. The simple idea is that the added HIIT demands should compensate or complement those of the tactical and technical sequences. HS: high-speed running >19.8 km/h; MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions).

The optimal within-session (HIIT at the start versus at the end of the session) and within-day (HIIT included in the morning versus afternoon session) programming of the different HIIT sequences is often defined by the overall training dynamics (e.g., coaches and players often reluctant to train skills after run-based HIIT, harder HIIT sequences better programmed before a day off to allow recovery) rather than on a purely scientific basis in terms of adaptations, mechanisms, and interferences. For more details about this fascinating topic, the reader is referred to the work of Jackson Fyfe in chapter 6.

In-season, when match schedules dictate the training program, there are likely to be only two weekly scenarios, with 1 (figure 30.14) or 2 (figure 30.15) matches per week, although the actual number of days between the games may be used to fine-tune the programming, especially for substitutes (figure 30.16). The amount of weekly HIIT prescribed is therefore player dependent and takes into account individual overall playing volume and loading history over the past few days and weeks. Our goal is to make sure all players are sufficiently loaded to maintain their fitness and be prepared for possible increases in load during congested periods of matches, while still remaining fresh to compete on a weekly to biweekly basis. This requires a highly individualized HIIT prescription that can be achieved through a combination of different HIIT types and formats (figures 30.14 and 30.15). For example, during a week with 2 games (figure 30.15), while the starters of the first match will only complete recovery (D+1) and light (D+2/D+3) sessions during the days following their match, substitutes will likely complete a combination of HIIT formats at D+1 (compensation session), targeting both mechanical work (type 4 via SSG, 4v4) and high-speed running (types 2 or 4 via HIIT with short intervals, often with the ball under the form of finishing drills) that may help to maintain a stable weekly locomotor load and balance their overall fitness and freshness (28). The neuromuscular load of these compensation sessions may also play an important role in preserving substitutes' muscle power, as recently highlighted (32). In practice, a D+1 session (with a minimum of 3 d between matches) for substitutes that aims to compensate for a ~60 min match (TD: ~6000 m; HS: ~1200 m, mechanical work (MW): ~50) could include the following (not including warm-up) (28):

1. 8v8 (possession), 2 sets of 10 min (1920 m with 260 m at HS, MW: 11)
2. Type 4 MW HIIT in the form of an SSG: 4v4 (+ 2 GK), 4 sets of 4 min (1660 m, 290 m at HS, MW: 28)
3. Type 4 run-based HIIT (15 s on/15 s off), 1 set of 6 min (1020 m, 850 m at HS, MW: 2)

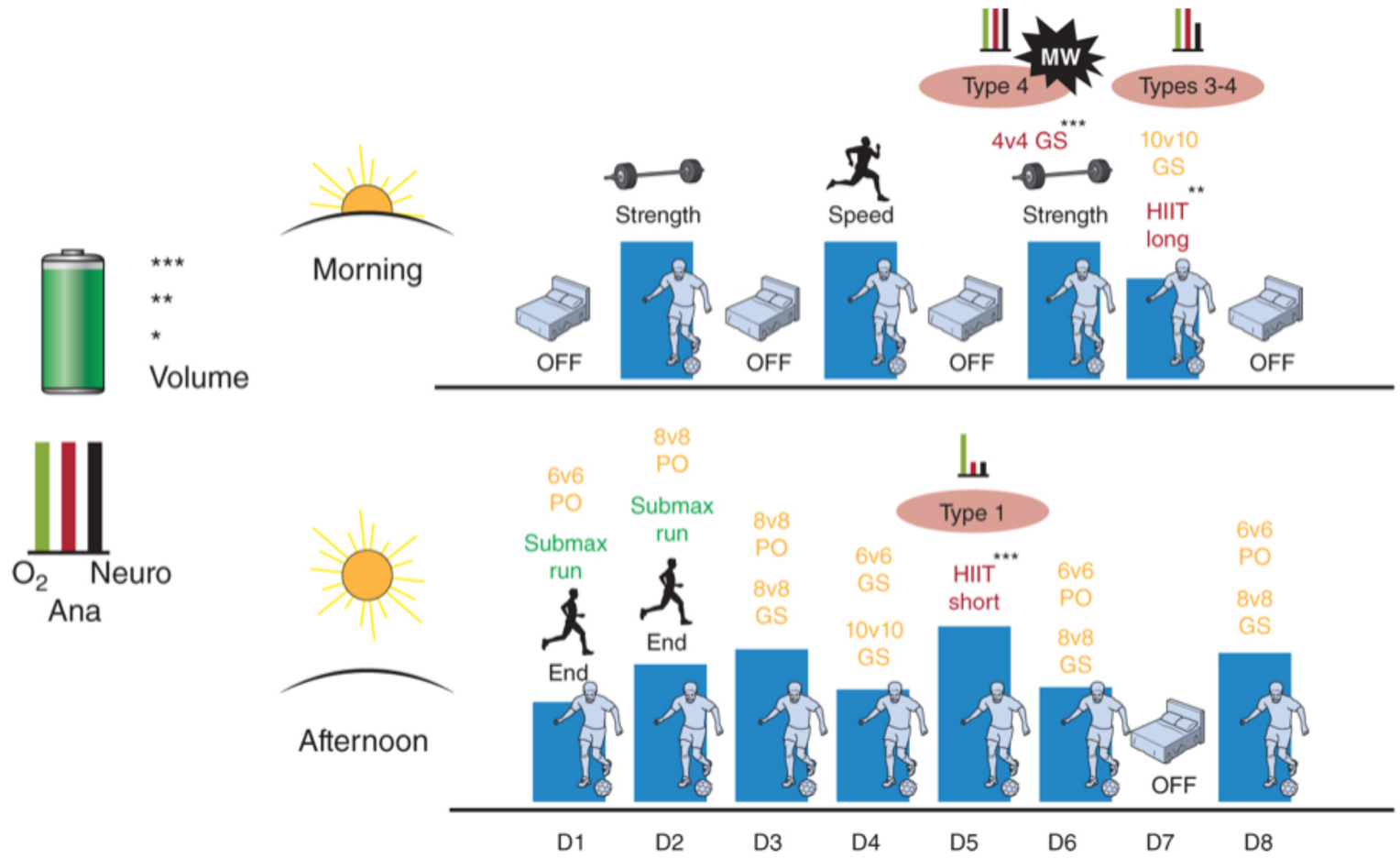


Figure 30.13 Example of preseason programming in an elite team (typically 1-2 wk duration, but there is likely a friendly match during the second week that may replace the HIIT sequence with long intervals). The physical orientation of some of the sessions is given. Those with no indication have only technical and tactical objectives. Red: HIIT; orange: submaximal intensity exercises. The blue bars refer to all technical and tactical training content in forms other than SSGs. The programming principle follows the principle shown in figure 30.12 and is based on the metabolic and locomotor responses summarized in figures 30.5 and 30.7. Run-based HIITs are always performed at the end of the session. MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions).

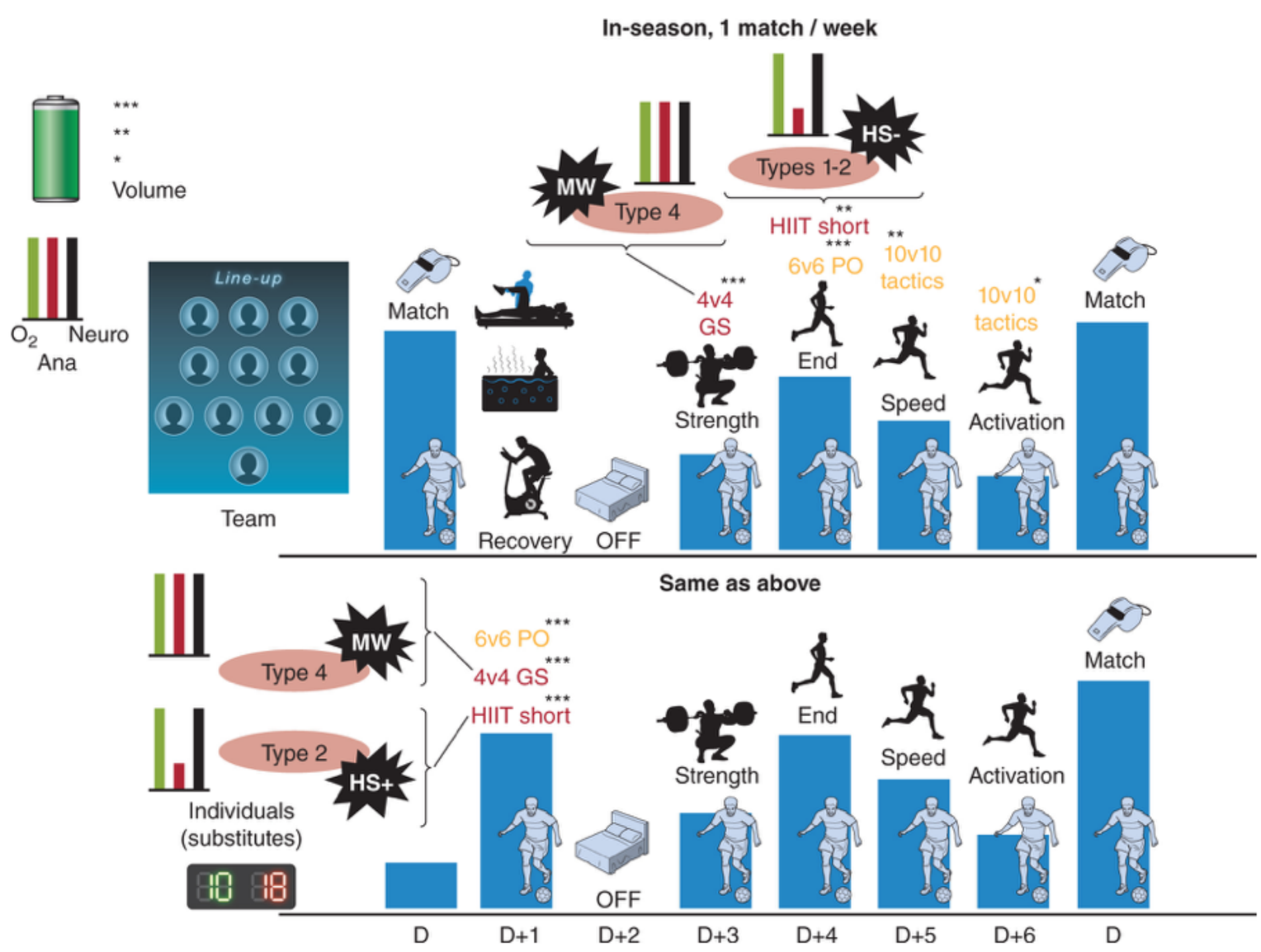


Figure 30.14 Example of in-season programming with one game per week. Red: HIIT; orange: submaximal intensity exercises. The blue bars refer to all technical and tactical training content in forms other than SSGs. The programming principle follows the principle shown in figure 30.12 and is based on the metabolic and locomotor responses summarized in figures 30.5 and 30.7. Run-based HIITs are always performed at the end of the session. HS: high-speed running >19.8 km/h, MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions).

resulting in a total of ~60 min training duration, ~4600 m covered with ~1400 m at HS and an MW of 41. Note that the individual tailoring of locomotor loads can be maximized during the latter compensation session when using the variations shown in figure 30.3.

When there are only 2 d between matches, the same substitutes may in contrast perform lower dose, type 1 run-based HIIT,

with high running speeds reached via progressive (and safer) type 6 exercise (low metabolic demands) rather than HIIT (figure 30.15).

Sample Training Programs

During the preseason (figure 30.13), we tend to restrict locomotor load and high neuromuscular load during the first few days, using the most applicable SSG formats (6v6 and 8v8, PO) and type 1 HIIT with short intervals. On specific days, however, type 4 HIIT may be programmed, such as 4v4 GS during a strength-oriented session and HIIT with long intervals before 24 h of rest.

In-season, as detailed in Manipulations of Interval Training Variables, we program 4v4 SSG (GS) during strength-oriented sessions, which may be the major HIIT format used with starters. For substitutes, however, these 4v4 GS are often complemented with run-based HIIT including various levels of neuromuscular constraints, depending on the timing of the following match, with greater emphasis on locomotor load with one (figure 30.14, type 2 HS) versus two (figure 30.15, types 1 or 2) games a week. Finally, note also that the overall training volume of work for the substitutes is adjusted based on their playing time the preceding day (i.e., they generally played for 5 to 40 min or didn't play at all, figure 30.16).

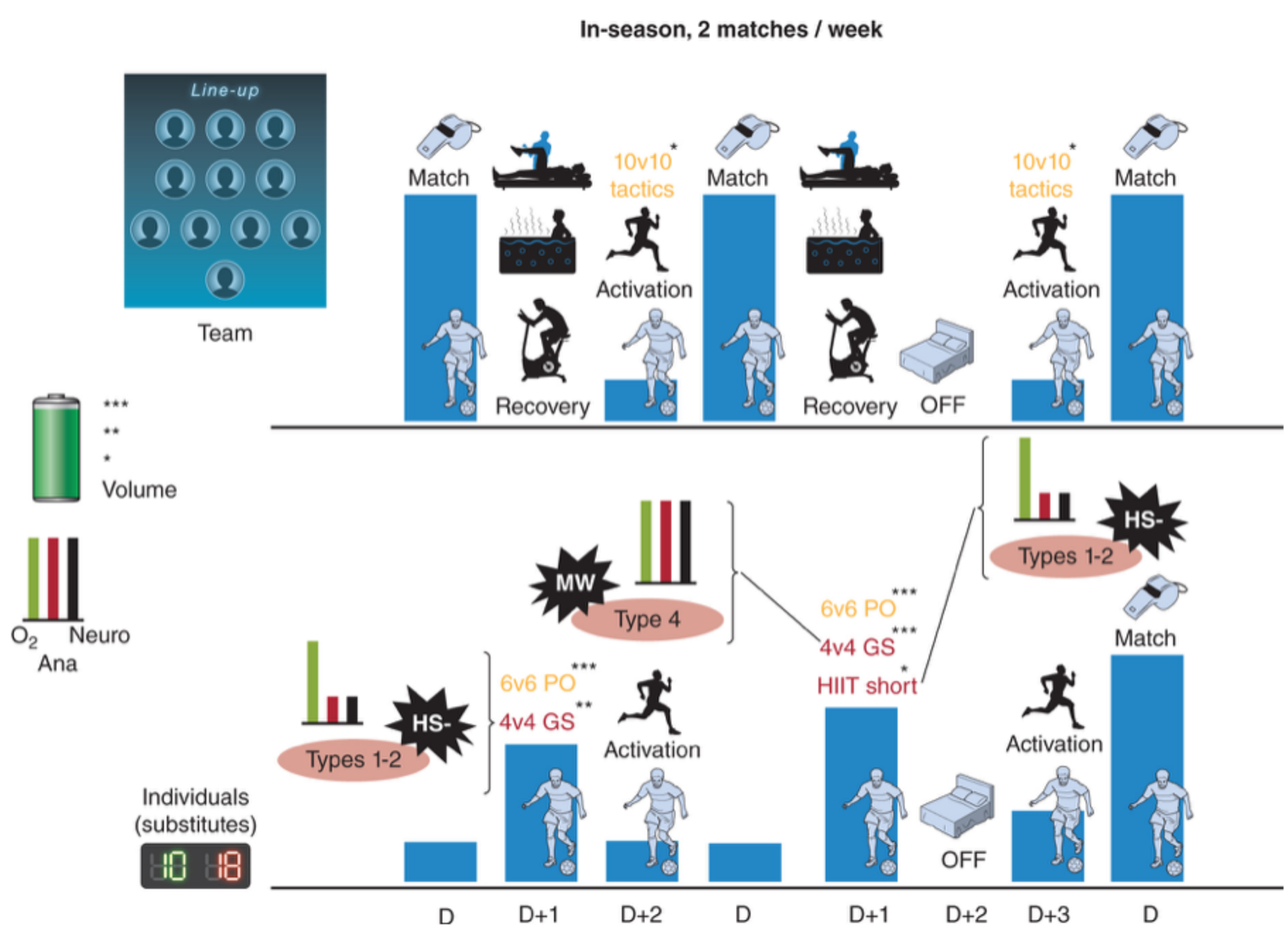
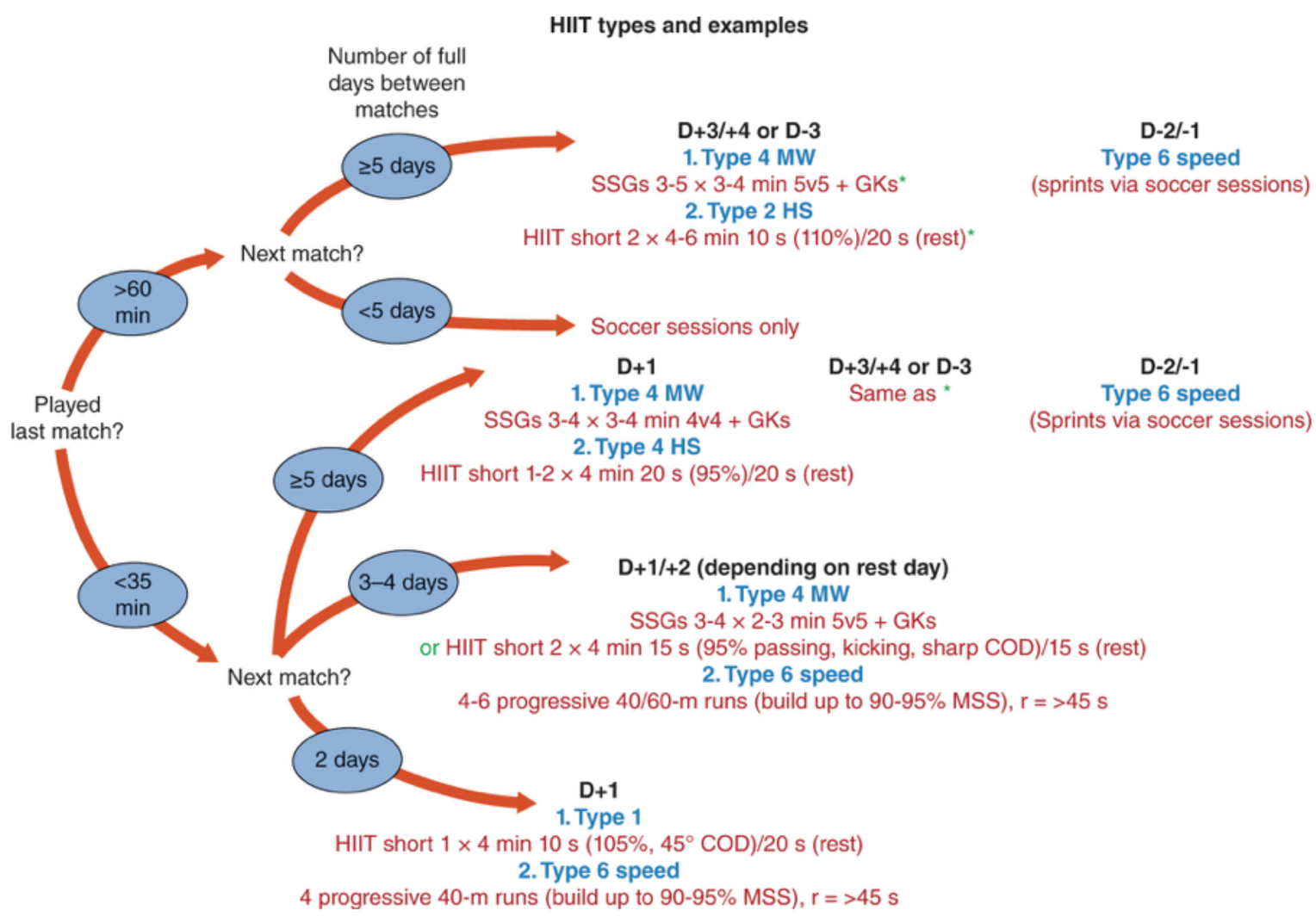


Figure 30.15 Example of in-season programming with two games per week. Red: HIIT; orange: submaximal intensity exercises. The blue bars refer to all technical and tactical training contents in forms other than SSGs. The programming principle follows the standard shown in figure 30.12 and is based on the metabolic and locomotor responses summarized in figures 30.5 and 30.7. Run-based HIITs are always performed at the end of the session. MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions).



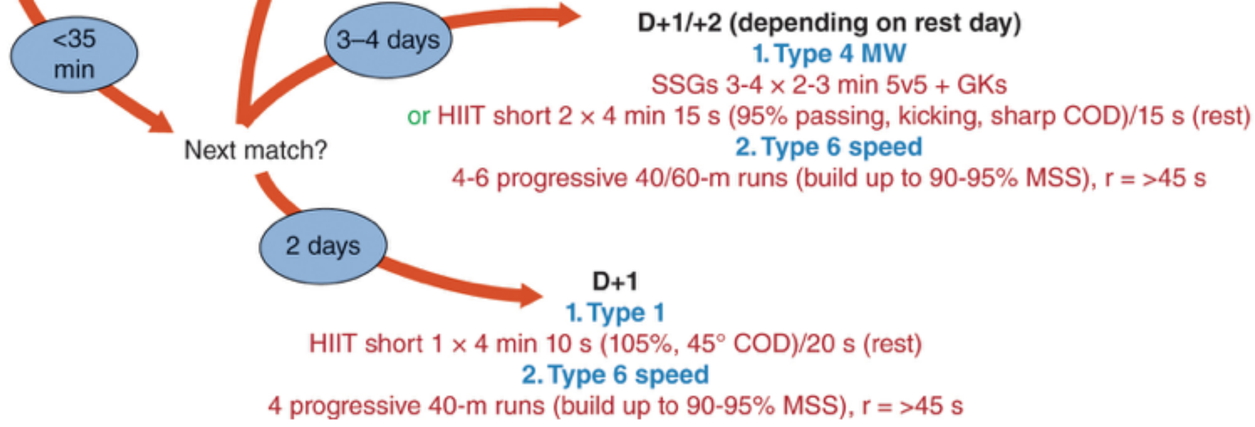


Figure 30.16 Decision process for programming the different HIIT target types with respect to competition/match participation. SSGs: small-sided games; MW: mechanical work (>2 ms^2 accelerations, decelerations, and changes of directions); HS: high-speed running (>19.8 km/h).

CASE STUDY

Martin Buchheit

The location and year of occurrence for the following story can't be revealed in the name of confidentiality, but it did occur. The team I was with was back in training after a 5 wk break. It may be the fact that the previous season had been very successful (winning nearly all possible titles), but regardless, the feeling I had, which was shared by the coaching staff, was that the players might have taken it a bit easier than usual during their break. In fact, players had for the most part spent their entire holidays at the beach. With the exception of a few beach soccer matches, they had been very likely sedentary during their (well-deserved) holidays. The HR responses to the 4 min run (see surveillance section) confirmed our fears—many players were greatly out of shape compared to historical data. We had 6 wk to get them fit again for the first official game, but we had never before started from such a low level of fitness. We were rightly concerned.

Because of the integration of new players and slight changes in our coaching approach, we dived straight into high-intensity soccer-specific exercises during the first sessions (small-sided games, finishing work including some high-speed running), which at first glance surprised most of the players, who expected a more gradual increase in soccer-specific and speed loading. At the same time, we needed to fit some conditioning work within the puzzle, and in fact, more than usual in response to the poor fitness levels highlighted at the start of the preseason.

Admittedly, I had never been so happy to be using GPS to monitor soccer-specific content than during these first weeks. Due to the high-intensity demands of the technical sessions (both metabolic and neuromuscular), I realized that we would have to dramatically adapt our usual HIIT programming. Programming the most appropriate HIIT doses and formats is never easy, but needs to be tailored around the technical sessions (and not the other way around, figure 30.12). One of the first adjustments we made was to change our HIIT targets from type 3 and 4 targets, including some important volume at high speed such as HIIT with short intervals (e.g., using 15 s/15 s or 30 s/30 s in a straight line at 90%-100% V_{IFT} as weapons), to type 1 targets (e.g., using 10 s at 90% V_{IFT}/10 s (passive) with 45° angles or 20 s at 85% V_{IFT}/10 s (passive) in a straight line as weapons) to avoid overloading the neuromuscular system, which was already highly taxed during the technical sequences. We also tried to implement as much as possible some submaximal run-based intervals at the end of the training days (i.e., 3 min runs at 90%-95% $V_{incTest}$) to make the most of the increased energetic cost of running when fatigued while decreasing locomotor load. These changes in conditioning formats were initially challenging for everyone, players and coaches included. As we had all seen the benefits from the previous year, no one understood why anything should be changed. Additionally, with longer intervals and little ball integration, the formats we used that year were definitely less appealing for the players. Most players complained, which increased further the pressure on the conditioning staff to explain why suddenly everything had changed. "What for?" they would ask. While we did our best to explain the situation to the players, our reasoning appeared to fall on deaf ears.

Fortunately, a few weeks later, players and staff started to feel more reassured. In fact, the new approach had allowed us to reach the start of the preseason with the large majority of the group remaining injury free, and more importantly, with players getting their fitness back to or above the levels of the previous years (4 min run). We easily won our first official match against one of our direct rivals for the league and left a great impression of both fitness and freshness, as emphasized by the media. Moreover, we learned that despite the natural tendency to go back to what worked previously, the start to every season needs to be challenged. Indeed, a flexible approach and willingness to adapt content to fit the overall context can highly affect the efficacy of a program, rather than the contents per se.

The authors thank Philippe Lambert and Julen Mirena Masach Urrestilla for their valuable contributions to the work presented, and strength and conditioning coach Nicolas Mayer for his helpful collaboration.