QUANTIFICATION OF SEASONAL TRAINING-LOAD IN ELITE ENGLISH PREMIER LEAGUE SOCCER PLAYERS

David Martin Kelly

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Abstract

To date, limited data exists regarding the seasonal training-loads incurred by elite soccer players. The purpose of the thesis was to examine the seasonal training-load incurred by elite English Premier League soccer players including the influence of different coaching philosophies on player loading and resulting player training status.

The aim of the first study (Chapter 4) was to compare two different tools used for measuring internal training load in elite English Premier League soccer players. During an in-season competitive period, the field-based training sessions of 19 elite players were monitored across a total of 1010 individual sessions. Players were also categorised in relation to playing position, with 4 central defenders, 4 wide defenders, 6 central midfielders, 2 wide midfielders, and 3 attackers participating in the study. The correlation between changes in sRPE and heart rates was r = 0.75 (95% CI: 0.71–0.78), with correlations remaining high across the different player positions (wide-defender, r = 0.81; central-defender, r = 0.74; wide midfielder, r = 0.70; central midfielder, r = 0.70; attacker, r = 0.84; $P < 0.001$). The correlation between changes in sRPE and HR, measured during a season-long period of field-based training, is high in a sample of elite soccer players.

The aim of the second study (Chapter 5) was to quantify the seasonal training loads elicited in elite English Premier League soccer players. External (global positioning system [GPS]) and internal (sRPE-TL) training loads were analysed in 26 elite soccer players across an in-season (36-week) competition phase. A stadium-based tracking system was used to record external load during 49 matches. Training and match loads were categorised into 6-week mesocycle phases, and subsequent weekly (microcycle)

calendar blocks. Players were assigned according to playing position, with 4 central defenders, 4 wide defenders, 7 central midfielders, 3 wide midfielders, and 8 attackers participating in the study. Daily sRPE-TL (95% CI range, 15 to 111 AU) and total distance (95% CI range, 179 to 949 m) were higher during the early stages (mesocycle 1 and 2) of the competition period. Across the within-week microcycles, load was greater on match day and lowest pre-match day (G-1) *vs.* all other days, respectively ($p < 0.001$). sRPE-TL (~70–90 AU per day) and total distance (~700–800 m [per day]) progressively declined over the 3-days leading into a match ($p < 0.001$). High-speed distance was greater 3-days (G-3) before a game *vs.* G-1 (95% CI, 140 to 336 m) while very high-speed distance was greater on G-3 and G-2 than G-1 (95% CI range, 8 to 62 m; $p < 0.001$). This was the first study to systematically quantify the training and match loads employed by an English Premier League team across a competitive season. The observed training and match load indicated that periodisation of training is mainly evident across the weekly microcycle, particularly during the 3-days leading into competition. The periodisation strategy adopted during the competition period, largely reflects the head coach's personal philosophy, and attempts to balance the need to ensure adequate post-match recovery with optimal preparation for the subsequent game.

The aim of the third study (Chapter 6) was to evaluate the training load distribution in elite English Premier League soccer players under two different coaching strategies. The 20 elite soccer players were monitored across the annual competition phase (36-week) of two successive seasons (2012-2013 [season 1]; 2013-2014 [season 2]). Training load was categorised into 6-week mesocycle phases, and subsequent weekly (microcycle) calendar blocks. There was a significant interaction between season and mesocycle for all variables (all $p < 0.05$). Mean match high-speed distance covered was 159 ± 79 m higher in season

1 (2334 ± 961 m) compared with season 2 (2175 ± 907 m) (95% CI range, 57 to 261 m) ($p < 0.05$). There was a higher frequency of competitive matches in season 1 ($n = 49$) than season 2 ($n = 34$). Daily training minutes were higher across mesocycles 1 and 2 in season 1 versus season 2 (95% CI range, 1.2 to 13.6 min). In contrast, all other variables (sRPE-TL, total distance, high-speed distance, very high-speed distance, accelerations, decelerations) were greater in season 2 than season 1 across selected mesocycles.

There was a statistically significant interaction between season and day type for all variables (all $p < 0.001$). Daily training minutes were higher on G-3 (95% CI range, 6.0 to 12.8 min) in season 1 versus season 2. s-RPE-TL, total distance, high-speed distance, and very high-speed distance were all greater during season 2 compared with season 1 (all $p < 0.001$). A higher number of accelerations were observed across all day types (95% CI range, 13 to 30 [*n*]), and a greater frequency of decelerations were reported on G-3, G-2, and G-1 in season 2 compared with season 1 (95% CI range, 18 – 35 [*n*]). The present findings indicate novel insights into how different periodisation strategies adopted by coaches impact the training loads elicited in a sample of elite soccer players. This was the first study to systematically evaluate the influence of different coaching philosophies in the same group of elite players at an English Premier League club.

The aims of the fourth and final study (Chapter 7) was to determine the ASRM responses in elite English Premier League soccer players under two different coaching strategies (Chapter 6). Daily ASRM (fatigue, sleep quality, and muscle soreness [DOMS]) were measured in the same 20 elite soccer players using a 7-point Likert psychometric questionnaire (Hooper et al., 1995). ASRM were taken from each player across the three training days leading into competition (G-3, G-2, and G-1). Mean differences in ARSM between mesocycles and day-type were assessed for practical relevance against a minimal practically important difference (MPID) of 1-point on the 7-point Likert scale. Match load covariate adjusted mean wellness measures were significantly higher during season 2 compared with season 1 ($p < 0.05$). Despite the observed statistically significant differences for mean daily fatigue (95% CI range, -0.2 to 0.2 AU), sleep (95% CI range, -0.1 to 0.1 AU), and muscle soreness (95% CI range, -0.04 to 0.04 AU), no MPID were observed between season 1 and season 2. The present findings demonstrate that differences in training load across the three days leading into a game did not elicit practically relevant changes (> 1-point) in the ASRM response when controlled for differences in match load. These findings have important implications for the application of ASRM across in-season training weeks in elite soccer. Future research is needed to examine the responsiveness of ASRM to changes in training and competition loads in elite players.

The results of this thesis provide novel information regarding the evaluation of training load in elite soccer players. The data demonstrate that sRPE is a valid, simple and non-invasive measurement tool for assessing the internal load in soccer players while data describing training periodisation philosophies adopted by elite teams provides valuable insights for physical coaches preparing elite players. Finally, information presented on ARSM provides practitioners with important insights regarding their implementation across the weekly training microcycle undertaken by elite players.

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Association football (soccer) is a team-game. Any scientific investigations into the sport of soccer will require a combination of contributions from an individual perspective, and from advisers and team-mates.

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List of Abbreviations

ASRM	Athlete self-report measures
AU	Arbitrary units
CI	Confidence interval
cm	Centimetres
CMJ	Countermovement jump
DOMS	Delayed-onset muscle soreness
dRPE	Differential ratings of perceived exertion
ES	Effect size
GPS	Global positioning system
HR	Heart rate (beats per minute)
HRex	Exercising heart rate
HRR	Heart rate recovery
HRV	Heart rate variability
%HRmax	Percentage of maximum heart-rate
HR-TL	Heart-rate training load
kg	Kilograms
km/h	Kilometres per hour

LSD	Least significance difference
m	Metres
m/s	Metres per second
min	Minutes
mmol	Millimole
MPID	Minimal practically important difference
RHR	Resting heart-rate
RPE	Rating of perceived exertion
s	Seconds
sRPE	Session rating of perceived exertion
sRPE-TL	Sessions rating of perceived exertion training load
SD	Standard deviation

CHAPTER 1: INTRODUCTION

1. Introduction

Training to improve athletic performance is a process of adaptation that involves the progressive manipulation of a physical training load (Manzi et al., 2010). While training should be considered a multifactorial process, enhancements in performance are achieved through planned manipulation of the training load (a product of the volume and intensity of training) (Manzi et al., 2010). As a consequence, accurate assessment of the individuals training load represents an essential component of effective training prescription.

Evaluating the physical demands of training requires accurate assessment of both the internal and external load. This is particularly important in team sports such as soccer where differences in individual responses to the same external workload occur (Manzi et al. 2010). The physiological strain resulting from the external training factors has been labelled the internal training load and represents the important stimulus for training induced adaptation (Viru and Viru, 2000). Therefore, valid and reliable indicators of internal training load are essential to monitor the training process. Several approaches derived from heart-rate have been developed in an attempt to quantify the internal training load across a range of sports (Morton et al., 1990; Impellizzeri et al., 2004; Stagno et al., 2007). Heart-rate represents a valid means through which to measure exercise intensity in endurance sports (Åstrand & Rodahl, 1986), but this method is questionable in soccer, where the overall training load can comprise anaerobic-based components (Impellizzeri et al., 2004).

The sRPE method is used to evaluate training session load in soccer by multiplying sRPE derived for the entire session by its duration (Foster et al., 2001). The application of various rating scales including the category ratio CR10, CR-100 and Borg 6-20 scales (Borg, 1982; Borg and Borg, 2001; Foster et al., 2001) have been applied to provide a valid measure of the internal training load during both aerobic (Impellizzeri et al., 2004) and anaerobic (Day et al., 2004) exercise. The sRPE has been reported to be a valid subjective measure of training intensity during endurance sports (Foster, 1998) and intermittent team-sports such as soccer (Coutts et al. 2003; Impellizeri et al., 2004; Casamichana et al., 2013). Despite attempts to validate sRPE for use in intermittent team sports such as soccer, the majority of studies have focused on sub-elite players over a small number of training sessions under well-controlled conditions (Impellizzeri et al., 2004; Alexiou and Coutts, 2008; Casamichana et al., 2013), as opposed to monitoring elite players participating in soccer-specific training sessions over extended periods of time, which is synonymous with the ‘real world’ of elite soccer. Furthermore, it is essential in longitudinal studies which ‘track’ sRPE that the most appropriate statistical approach is employed to quantify within-participant correlations. That is, the longitudinal dataset is modelled as a whole using the correct degrees of freedom, rather than by calculating correlations for individual players (Bland and Altman, 1995; Lazic, 2010; Atkinson et al., 2011). Thus, further work is needed to further investigate the usefulness of sRPE in elite soccer.

The evolution of global positioning systems (GPS) has provided the opportunity to derive more detailed, valid, and reliable estimates of the external load in multi-directional team sports such as soccer (Barbero-Alvarez et al., 2010; Portas et al., 2010). The overriding aim of the annual training programme in elite soccer is to ensure players are able to cope with the increasing physical demands of the modern game while simultaneously reducing susceptibility to injury (Barnes et al., 2014; Martin-Garcia et al., 2018; Gregson et al., 2019). The training pattern in elite soccer is largely dictated by competitive match scheduling (Fessi et al., 2016; Martin-Garcia et al., 2018), domestic and international travel requirements, and the experiences and philosophy of the head coach (Impellizzeri et al., 2005; Bangsbo et al., 2006a; Akenhead and Nassis, 2016; Weston, 2018). The day-to-day distribution of training load within elite soccer has been a highly debated issue, which has highlighted the importance of the in-season weekly training microcycle around games. In recent times, there has be an increasing interest in the structure of weekly training loads in elite soccer, but to date, few reports exist which have published data on elite players (Malone et al., 2015; Anderson et al., 2016; Los Arcos et al., 2017; Stevens et al., 2017; Martin-Garcia et al., 2018). Furthermore, no attempts have been made to understand the degree to which load is influenced by different coaches by examining the responses in the same players under different training philosophies. As a result, future work should focus on how training load is programmed during the annual competition period from the perspective of a more extensive network of elite soccer teams while under the guidance of different coaching approaches.

In elite soccer, it is paramount that training and match loads are optimally balanced with sufficient recovery time to negate escalations in fatigue levels, which serves to prevent the increased risk of injury or illness associated with the debilitating effects of overtraining (Nimmo and Ekblom, 2007). Evaluating training status allows for the assessment of individual responses to the prescribed training stimuli as well as monitoring individual fatigue levels (Halson, 2014). The individual training status in players can also be used to inform subsequent adjustments in the training loads elicited. One method currently used to monitor training status of players is psychometric questionnaires (Borresen and Lambert, 2009; Buchheit et al., 2013). It has been suggested subjective measures of athlete monitoring methods have better sensitivity and more consistency than objective measures, enabling a more accurate reflection of changes to acute and chronic training loads (Saw et al., 2016). Given the training process is athlete focused, the use of subjective measures appears to provide the ability to measure constructs and dimensions that are not objectively measurable, thus enabling the assessment of how an athlete is tolerating training demands (Jeffries et al., 2020b).

Recent surveys have shown the use of athlete self-report measures (ASRM) have increased exponentially as the most frequently adopted tool used for monitoring training status in elite sport (Thorpe et al., 2017; Jeffries et al., 2020b). Several ASRM methodologies currently exist to assess the well-being of athletes, including POMS, DALDA, TQR, and REST-Q (Genttä and Hassmén, 1998; Coutts et al., 2007b; Coutts and Reaburn, 2008; Buchheit, 2015). These methodologies are, however, often time-consuming and extensive in nature making them unsuitable for application within the team sports setting due to the large number of athletes involved in the process (Thorpe et al., 2017). To overcome this problem, simple ASRM can be implemented using a quick, customised short-duration questionnaire, offering a time-efficient and simple method to facilitate in the assessment of training status across multiple athletes (Thorpe et al., 2015; Thorpe et al., 2016). Furthermore, this approach can be used on a daily basis before the commencement of exercise, to reduce interference with the athlete's daily training routine (Thorpe et al., 2017).

Previous observations on endurance athletes have demonstrated that ASRM may be responsive to changes in performance and biological markers associated with overtraining syndrome (Hooper et al., 1995; Urhausen and Kindermann, 2002; Coutts et al., 2007b;

Meeusen et al., 2013). In soccer, morning measured ASRM have been shown to respond to changes in daily training loads experienced by English Premier League players and were more responsive than heart-rate derived measures to fluctuations in daily training session load during a standard in-season training week (Thorpe et al., 2015; Thorpe et al., 2016). These findings suggest the application of ASRM in elite soccer may represent a valid method by which to assess the training status of individual players on a daily basis across the annual competition phase. However, in light of the few studies conducted to date, further research is needed to fully understand the extent to which ASRM respond to changes in training load experienced by elite players.

1.1 Background to Research Studies

The measurement of internal load during soccer training is important since it represents the stimulus for the long-term adaptive response (Viru and Viru, 2000). The accurate assessment of an individual players training load is therefore a vital component for the effective programming of training. The sRPE correlates with the heart-rate during field-based training sessions (Impellizzeri et al., 2004; Casamichana et al., 2013). However, to date, studies in which the relationship between sRPE and HR-based estimations of training has been quantified in soccer are sparse and have principally focussed on sub-elite level players monitored over a small number of training sessions (Impellizzeri et al., 2004; Alexiou and Coutts, 2008; Casamichana et al., 2013). Elite players possess higher levels of fitness partly reflecting their exposure to more advanced training methodologies thus making it unfeasible to extrapolate the findings from sub-elite players to elite players. Furthermore, studies employing sub-elite players did not employ the appropriate statistical approach, omitting to quantify within-participant correlations across the longitudinal datasets (Bland and Altman, 1995; Lazic, 2010; Atkinson et al., 2011). In the initial investigation, the within-participant correlation between the sRPE and heart-rate based methods for estimating training load in elite soccer players will be examined across an in-season competitive phase (Chapter 4).

The physiological demands of soccer are complex. The training programmes and associated physiological demands of elite teams are largely influenced by the head coach and the coaching strategies and tactics employed (Arcos et al., 2017). In recent times, it appears the tactics employed by elite teams are becoming more wide-ranging, with a multitude of attacking and defensive playing formations employed, thus impacting the styles of play adopted by the team. For example, some coaches may employ possession soccer which is a (low-intensity) strategy designed to give the team greater control of the game, whereas an alternative approach may be counter-attacking soccer which can be very effective, particularly for teams with fast attacking players (Fernandez-Navarro et al., 2016). The employment of new strategies and tactics will influence the physical demands imposed on individual players which may have implications for both team performance and the incidence of injury. The stochastic movement demands, and sporadic high-intensity work bouts further compound the work rate profile, resulting in variability between the desired training load and the actual training load exposure (Malone et al., 2015). It is paramount that the training programmes implemented in elite soccer are multifactorial in content and serve to optimise individual player fitness levels (Morgans et al., 2014). Monitoring the individual player's daily training load therefore represents an important component of the effective planning of a soccer-specific training regimen (Weston, 2018). To date, few studies have provided insight into the training loads endured by elite players (Malone et al., 2015; Anderson et al., 2016; Los Arcos et al., 2017; Stevens et al., 2017; Martin-Garcia et al., 2018). Recent studies have centred on examining the training models adopted by elite European soccer teams, with different training periodisation strategies emerging when observed across the repeated weekly microcyles (Malone et al., 2015; Los Arcos et al., 2017; Stevens et al., 2017; Martin-Garcia et al., 2018). Whilst these studies provide valuable insights, further observations are required in order to gain a comprehensive insight into the periodisation practices adopted by professional teams (Weston, 2018). Therefore, the second aim of this thesis is to quantify the combined external and internal training and match-load distribution across the competition phase of one full season at an English Premier League club (Chapter 5).

A recent survey of elite English soccer clubs suggests team training is mainly dictated by the head coach (Weston, 2018), based on tradition, emulation, and historical precedence as opposed to consideration of the latest scientific research (Stoszkowski and Collins, 2016). In recent times, there has been a greater incidence of elite clubs changing the head coach responsible for team tactics in an attempt to achieve future success. The introduction of a new coaching philosophy applied to the same group of elite players, and how this may impact subsequent training periodisation strategies is currently unknown. While studies in elite soccer have enhanced or understanding of the nature of periodisation models adopted by elite teams, the use of different players, standards of play and different GPS technologies limit our ability to understand the degree to which different periodisation strategies adopted by coaches influence the training load encountered by elite players. Therefore, the third aim of this thesis (Chapter 6) is to examine the loads experienced by the same group of elite players wearing the same technology under different coaching philosophies, to further aid our understanding regarding the degree to which different periodisation models influence player loading.

High competition loads have dramatically influenced how training strategies are employed in elite soccer, with many coaches adopting different periodised approaches (Thorpe et al., 2017). Previous research has shown elite soccer teams with lower injury rates have an increased chance of success in domestic and European league competitions (Hägglund et al., 2013). Injury prevention strategies are therefore central to the role of the support team in an attempt to increase the availability of players for selection (Thorpe et al., 2017). In light of the importance of managing the players training and fatigue status, the use of ASRM has become a popular choice in recent times, due to its simplistic, non-invasive, and time-efficient nature (Twist and Highton, 2013). Managing fatigue status is a vital process in facilitating adaptation to daily training stimuli, ensuring players are optimally prepared for competitive matches (Pyne and Martin, 2011), while simultaneously reducing predisposition to illness and injury (Nimmo and Ekblom, 2007). The final aim of this thesis will examine ASRM responses to the different loading strategies presented in Chapter 6 to better understand the influence of different training periodisation strategies on player training status (Chapter 7).

1.2 Aims and Objectives

Table 1. 1 Aims and objectives of the thesis.

Aims	Objectives
1. To compare two different tools used for measuring internal training load in elite soccer players.	To examine the relationship between session-RPE and heart-rate for quantifying the internal training load in elite soccer players.
2. To quantify the seasonal training-loads elicited in elite English Premier League soccer players.	To quantify the internal and external training and match-load distribution across a season in elite English Premier League soccer players.
3. To evaluate the training-load distribution in elite English Premier League soccer players under two different coaching strategies.	To compare the internal and external training-load distribution in elite English Premier League soccer players under two different coaching strategies.
4. To determine the ASRM responses in elite English Premier League soccer players under two different coaching strategies.	To examine the responsiveness of ASRM to differences in training load distribution observed in elite English Premier League soccer players under two different coaching philosophies.

CHAPTER 2: LITERATURE REVIEW

2. Literature Review

The aim of this literature review is to provide the reader with information regarding the quantification and distribution of seasonal training-load in elite English Premier League soccer players. The initial section of the review outlines the physical and physiological demands of soccer match-play followed by an examination of how the different components of training are programmed across the season to physically prepare the players for competition. Subsequent sections review approaches to quantifying the training load encountered by elite players and how training load is periodised within the context of elite soccer.

2.1 Physical and Physiological Demands of Soccer Match-Play

Soccer is characterised as a high-intensity intermittent sport. During a 90-minute soccer game the activity patterns of players occur sporadically, incorporating bouts of high-intensity efforts interspersed with periods of lower-intensity activities (Svensson and Drust, 2005). The physiological consequences of performing irregular bouts of high and low-intensity activity require players to be competent in several components of 'soccer-specific' fitness, which include aerobic and anaerobic power, muscular strength and power, and agility and flexibility (Reilly and Thomas, 1976; Ekblom, 1986; Reilly and Doran, 2003). An effective training programme must therefore incorporate various components at exercise intensities experienced during competitive games to ensure that the player is 'soccer fit' and capable of meeting the demands of elite level competition (Reilly, 2005).

The overall energy demands of competitive soccer match-play are reflected in the total distance covered during a game. The general consensus within the literature is that player's cover about 10-13 km during a 90-minute game at the elite-level (Ekblom, 1986; Barros et al., 2007; Di Salvo et al., 2007; Dellal et al., 2011; Andrzejewski et al., 2016). Total distance covered during matches has been shown to fluctuate and these variances may be attributable to a number of contextual factors, namely the quality of the opposition, type / level of soccer competition participated in, playing position and tactical strategies employed by the coach (Di Salvo et al., 2009; Bradley et al., 2013; Barnes et al., 2014; Bush et al., 2015). Consequently, it appears that the behaviour of each player is strongly influenced by the team's tactical strategy. Indeed, previous observations have shown that high-speed activities are highly variable between games and are influenced by factors such as ball possession and playing position as a consequence of changes in the tactical and technical requirements of the game (Gregson et al., 2010).

Total distance covered in soccer may not truly reflect the overall energy provision during competitive games (Reilly, 1994). Superimposed onto the work-rate profile is a vast array of activities, which result in an activity profile that has been described as stochastic, acyclical and intermittent with uniqueness through its variability and unpredictability (Nicholas et al., 2000; Wragg et al., 2000). The work-rate profile in elite soccer alternates between standing still to maximal running, whereby frequent bouts of high-intensity activity, numerous accelerations and decelerations, change of directional mode, unorthodox movement patterns and the execution of various technical skills also contribute significantly to the total energy expended (Bangsbo, 1997; Reilly, 1997; Reilly, 2002). During a game, individual players workload encompasses about 1000 – 1525 discrete bouts of activity, with a change in type or intensity of activity occurring every 3.5 – 6 seconds, having a pause of 3-seconds every 2-minutes (Reilly and Thomas, 1976; Mohr et al., 2003). These are inclusive of 30 – 40 jumps and tackles, 30 – 40 sprints (Bangsbo et al., 2006a), 3 – 40 bursts of high-intensity activity (> 23.0 km/h) (Di Salvo et al., 2007), and about 726 turns (Bloomfield et al., 2007). Thus, a more thorough in-depth analysis of the high-speed elements of match-play is needed in order to better understand the physiological characteristics associated with competitive match-play (Carling et al., 2016).

Elite-level work-rate profiles in soccer indicate that overall exercise intensity for the duration of a 90-minute match is predominantly aerobic in nature (Di Salvo et al., 2007; Castagna et al., 2011). Anaerobic efforts are called upon sporadically during match-play when players are required to perform ‘match influencing’ high-intensity game-related activities such as tackling, shooting, and jumping to head the ball (Bangsbo, 1994a; Stølen et al., 2005). The magnitude of these movement patterns, and associated energy demanding activities suggest the activity profile is intermittent in nature, requiring both aerobic and anaerobic capacities (Nagahama et al., 1993). The exercise intensity in elite soccer match-play places high demands on the aerobic energy system eliciting mean peak heart rate values of ~85–98%HR_{max} (Ekblom, 1986; Bangsbo, 1994a). Energy expenditure in soccer is consequential due to the duration of a match. At least 90% of the energy release must be aerobic, and during a 90-minute game player’s work at intensities close to anaerobic threshold, or around 85% of maximal heart rate (Hoff et al., 2002), a value that is equivalent to an oxygen uptake of about 70-75% of $\dot{V}O_{2max}$ (Ekblom, 1986; Bangsbo, 1994a).

During the high-intensity intermittent exercise bouts synonymous with soccer activity, energy supply must continuously oscillate between fuelling contractile activity during work periods and restoring homeostasis during intervening recovery periods (Balsom et al., 1992). A large proportion of the activities undertaken during a soccer match are at submaximal intensities whereby bouts of walking and jogging predominantly stress the aerobic energy system (Di Salvo et al., 2009). Elite male soccer players perform around 1350 activities during a game which fluctuates every 4-6 seconds, which includes ~150–250 bouts of high-intensity efforts, indicating a high rate of anaerobic energy turnover (Mohr et al., 2003; Zamparo et al., 2015). The total duration of high-intensity exercise during matches is approximately 7 minutes (Bangsbo et al., 1991), incorporating movements such as sprints, jumps, tackles, short shuttle runs, changes of direction, and technical ball-related actions (Mohr et al., 2005), which are regarded as critical elements to influence the outcome of a match (Stølen et al., 2005; Faude et al., 2012).

The contribution of anaerobic metabolism to soccer performance has been examined previously by the analysis of blood samples, which have been utilised to establish lactate concentrations during matches. Several researchers have previously collected blood samples from players during matches, with mean blood lactate concentrations of about 10 $mmol \cdot l^{-1}$ being reported for elite-level players (Ekblom, 1986; Bangsbo, 1994a). This evidence suggests that energy provision via anaerobic pathways is a significant contributory factor to sustain physical output during elite soccer matches. However, it is still uncertain how well blood lactate measurements reflect the muscular lactate concentration as there are many different factors which can affect the release of lactate from the muscle, and removal from the blood (Bangsbo, 1994b). To achieve a better understanding of the anaerobic energy turnover during soccer match play, direct measurements of muscle lactate and other metabolites are therefore required. Krustrup and colleagues (2006) carried out a study on thirty-one Danish fourth division players, taking blood samples and muscle biopsies during three friendly games. Blood lactate levels were 6.0 ± 0.4 and 5.0 ± 0.4 mM, with muscle lactate concentrations of 15.9 ± 1.9 and 16.9 ± 2.3 mmol·kg^{-}1 d.w. reported during the first, and second halves respectively. Krustrup and co-workers (2006) showed that during intermittent exercise, the blood lactate levels can be high even though the muscle lactate concentration is relatively low, concluding that blood lactate is therefore a poor indicator of muscle lactate during soccer match play.

When studying the exercise patterns inherent in soccer, it becomes apparent that the physiological demands of the game are complex (Morgans et al., 2014). Previous researchers have shown that the incidence of high-speed activities completed by players during matches is highly variable between games (Gregson et al., 2010). Factors such as playing position, physical / fatigue status of the player, technical demands, and tactics employed by the head coach increase the highly variable nature in physical demands at the elite level (Gregson et al., 2010; Akenhead and Nassis, 2016; Weston, 2018). During a game, players may have a direct involvement in play resulting in the execution of high-intensity activities such as dribbling the ball, turning, tackling, heading, jumping, and changes in both the direction of, and velocity of movement, making the activity profile intermittent. This necessitates contributions from both aerobic and anaerobic metabolism. Soccer training must therefore incorporate the principles of training which should be utilised to provide a sport-specific methodology (Reilly, 2005), ensuring that the necessary energy systems are optimally overloaded to attain and maintain soccer-specific levels of fitness.

2.2 Physical Preparation of Soccer Players

The process of training targets the development of specific attributes with the aim of enabling the proficient execution of various sport-specific tasks (Stone et al., 2007). These include physical development, technical skills, tactical 'knowhow', psychological characteristics, and injury resistance (Bompa and Haff, 2009). To successfully acquire these attributes, it is essential that the applied training methodology is both specific to the sport and the individual athlete. A systematic and soccer-specific training programme is therefore fundamental to achieving improvements in an individual player's performance. The aim of soccer specific training is to minimise the time needed for recovery between bouts of high-intensity exercise, and to provide an optimal physical stimulus to increase the capacity to perform repeated bouts of exercise more frequently, throughout a game (Reilly, 2005). The following sections of this review will aim to evaluate the principles of soccer-specific training previously described, and the concept of 'periodisation' strategies implemented within elite soccer, as well as the systematic methodologies currently employed to monitor both training and match loads elicited.

Soccer training can help a player endure the physical demands of soccer, sustain technical ability, and maintain a high-intensity work output for the 90-minute duration of a match (Bangsbo, 2003). The soccer training programme should therefore incorporate a number of components, and the method employed by the coaches should reflect that of a multi-dimensional approach (Morgans et al., 2014). An ergonomics model of the soccer training process serves to enable the design of a specific conditioning programme tailored to meet the different physiological characteristic requirements of match-play (Reilly, 2005). Training these factors allows the player to further add training effects to his endowed characteristics in an attempt to maximally fulfil performance potential (Reilly, 2005). Soccer-specific training should therefore integrate specific training plans for the development of a number of energy systems as well as specific muscle exercises (Morgans et al., 2014). Dividing fitness training into a number of components related to the purpose of the training (Figure 2.1) would serve to increase both the robustness and endurance levels of the player by improving tolerance to the physical endurance demands of soccer, while simultaneously sustaining the necessary technical ability (Bangsbo et al., 2006b).

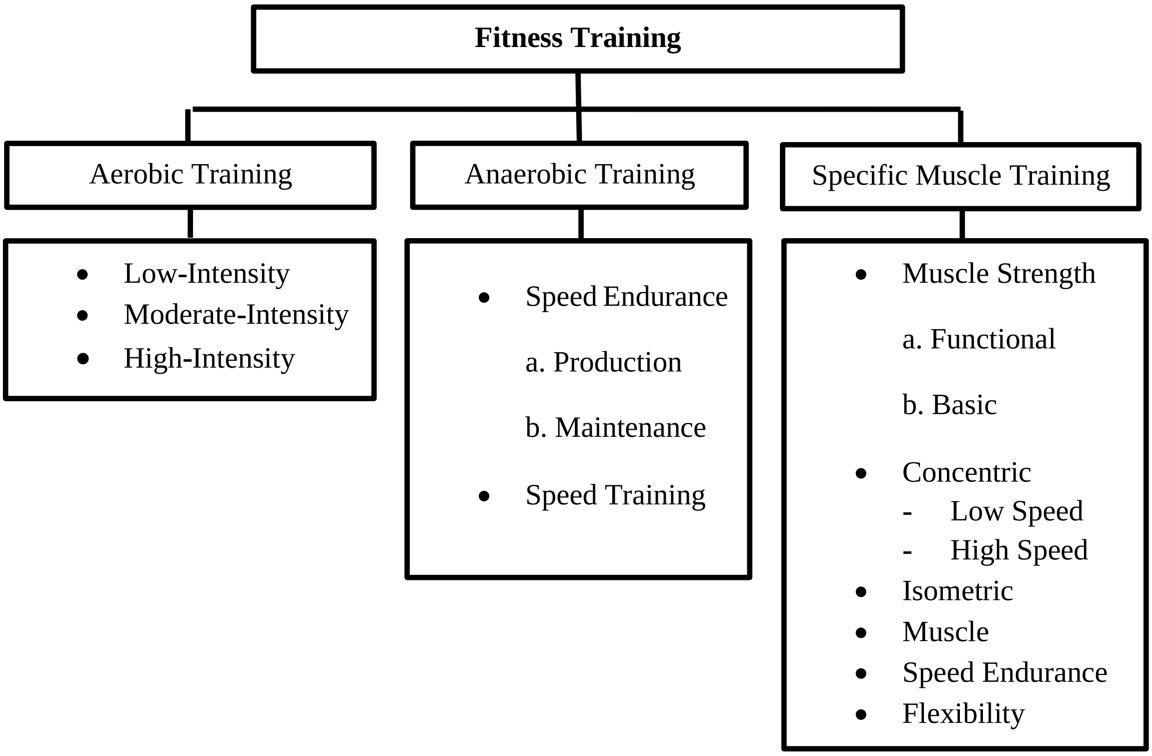


Figure 2. 1 Components of Soccer Fitness (adapted from Bangsbo et al., 2006b).

Training specific to soccer should be multifactorial in design to ensure that the complex physiological demands of the sport are met. Minimising the time needed for recovery between bouts of high-intensity exercise, and increasing the capacity to perform repeated bouts of exercise more frequently throughout a game are key elements (Reilly, 2005;

Bangsbo et al., 2006b). Aerobic training may be used to ameliorate the technical-tactical ability of the players while simultaneously increasing the ability to sustain exercise at an overall higher intensity during a match. Aerobic training should be performed where possible with a ball (Reilly, 2005). Aerobic training can be divided into three overlapping components which take into account that the player's heart rate will fluctuate continuously throughout the training session (Table 2.1) (Ekblom, 1986). During aerobic low-intensity training (aerobic$_{LI}$) the player performs light physical activities such as jogging and 'head tennis' games, carried out on designated recover days (i.e. post-match [G+1]), or to prevent 'overtraining' syndrome (Bangsbo et al., 2006b). The main purpose of aerobic moderate-intensity training (aerobic$_{MI}$) is to improve the capacity of muscles specifically used in soccer to utilise oxygen and to oxidise fat during prolonged periods of exercise (Ekblom, 1986). Aerobic high-intensity training (aerobic$_{HI}$) elicits intensities of about 90-95% of maximal heart rate, improving players' ability to recover after a period of high-intensity exercise during a game. Work bouts of 3- to 8-minutes have proved to be effective in the development of soccer endurance (Hoff and Helgerud, 2004).

Table 2. 1 Principles of Aerobic Training (adapted from Bangsbo et al., 2006b).

	Mean		**Range**		**Training Type**
	%HR$_{max}$	*Beats·min^{-1}*	*%HR$_{max}$*	*Beats·min^{-1}*	
Aerobic$_{LI}$	65	130	50-80	100-160	Recovery (e.g. jogging)
Aerobic$_{MI}$	80	160	60-90	130-180	Intermittent >5min periods
Aerobic$_{HI}$	90	180	80-100	160-200	SSG Training

Anaerobic pathways provide readily available energy for rapid development of muscle force during high-intensity exercise. It is important that players are physiologically equipped with the ability to recover quickly from high-intensity anaerobic efforts during soccer match-play. Soccer training programmes must also include anaerobic components, to increase the player's ability to act quickly, and rapidly produce power during the high-intensity periods of match-play. In order to enhance the 'production' of anaerobic power, the exercise intensity should be almost maximal and performed according to an interval principle, which can take place in the form of speed endurance training (Reilly, 2007b). During training games with exercise periods of 10-20 s it may be difficult to achieve the desired training intensity, so it is recommended that periods of more than 20 s be utilised (Bangsbo, 2003). Speed endurance training can be up to 40 s in duration per exercise bout, interspersed with recovery durations of about 160-200 s, and carried out across six to eight repetitions.

Speed training, on the other hand, requires players to work maximally for a shorter period of time (<10 s), and should be performed when the athlete is rested or completely free of residual fatigue from any previous activity, preferably at an early stage in the training session (Reilly, 2005). To enhance speed-training adaptation, functional speed sessions should be conducted in game-like situations. This will ensure that critical match-related actions such as anticipation and reactive speed can be improved in relation to the training stimulus presented. Specific muscle training involves the training of muscles in isolated movements with the aim of increasing performance of a muscle to a higher level than can be attained by just carrying out soccer-specific training (Bangsbo et al., 2006b). It is beneficial for the player to have a high level of muscular strength to ensure that the forceful and explosive movements needed in soccer, such as jumping to head, tackling, and accelerating, can be carried out repeatedly throughout a match (Bangsbo et al., 2006b). Additionally, muscle strength training forms an essential function in the stabilisation of the joints of the skeletal system, and thus is an important factor in the prevention, and reoccurrence of injuries (Ekblom, 1986).

It is essential that the soccer training process be designed to equip individual players with the capability to meet the demands of the game (Reilly, 2005). Soccer-specific type training should incorporate the required components of the principles of training to improve the fitness levels of the individual player. This will be achieved by administering a varied training load prescription, ensuring peak physiological adaptations are achieved while simultaneously reducing the negative impact of fatigue.

2.3 Quantifying Player Load

Sport-specific training has been defined as the process of systematically performing exercises to improve physical abilities and to acquire specific sports skills (Viru and Viru, 2000). To maximise the physiological adaptations induced by soccer training, coaches and scientists need to monitor and precisely control the exercise stressors applied to the individual player (Impellizzerri et al., 2019).

Training load comprises both external and internal components (Impellizzeri et al., 2005). Training load monitoring in soccer can be a useful tool for providing information used to monitor and assess the effects of training, while simultaneously reducing the incidence of injury or illness (Casamichana et al., 2013; Scott et al., 2013a; Verheul et al., 2019). It is important to evaluate both the external and internal training load responses (Impellizzerri et al., 2005) (Figure 2.2). Measurement of the external training load refers to the quantification of the physical stimuli performed as a result of the training type prescribed by the coaches (Campos-Vazquez et al., 2015). The physiological strain elicited on the player, as a result of the external training factor can be referred to as the internal training load which represents the important stimulus for training induced adaptation (Viru &Viru, 2000). The internal load can be analysed to assess the effects of training and represents an important tool that can be used to monitor daily training load (Casamichana et al., 2013; Scott et al., 2013a).

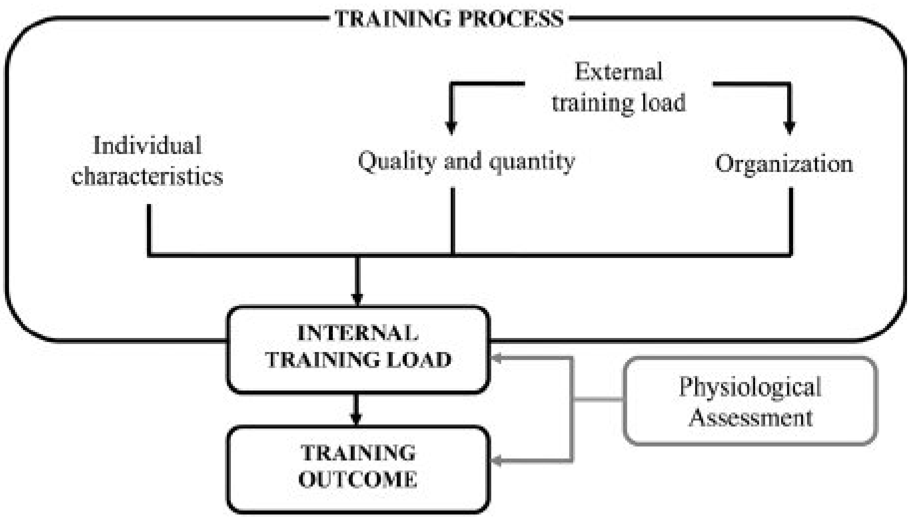


Figure 2. 2 The Training Process (Impellizzerri et al., 2005).

2.3.1 External Training Load

2.3.1.1 Computerised Tracking Systems

Evaluation of player performances during soccer match-play has been the subject of research interest within sports science for the past four decades (Bangsbo et al., 1991). Early studies of motion analysis in soccer used notational systems to classify match-play activities according to the intensity of movement, and to calculate distance covered at different speeds of locomotion by individual players (Reilly and Thomas 1976; Strudwick and Reilly 2001). During the last two decades technological improvements have led to the advent of modern semi-automated computerised player tracking systems which present a valid means through which to examine the external load (Barros et al., 2007; Bradley et al., 2009; Di Salvo et al., 2009). These tracking systems track player and ball positions and have become a fundamental component in monitoring the external load elicited in elite players during match-play (Akenhead and Nassis, 2016). Optical tracking systems such as Stats Perform SportVU™ (STATS, Chicago, USA) are currently employed by a multitude of professional soccer teams by which to provide quantitative performance analysis data (Mara et al., 2017; Linke et al., 2018).

2.3.1.2 Global Positioning Systems (GPS)

In recent years, the use of global positioning system (GPS) technology has revolutionised the way in which external load can now be quantified, especially during training. To support the training process and optimally prepare players physically, GPS systems are frequently used in elite soccer to quantify the movement demands and consequential loads elicited in daily training sessions (Mara et al., 2017). These technologies allow the measurement of movement patterns in many intermittent sports and can provide a wealth of data on specific distances covered and speed of locomotion (Reid et al., 2008; Casamichana et al., 2013). The majority of research has implemented 1Hz, 5Hz and 10Hz sampling frequencies when assessing the measurement precision of the units. Original GPS systems used in team sports had a sampling frequency of 1Hz but were limited in their accuracy of data output relating to high-speed, short distance movements of less than 20 metres, which are crucial to performance in many team sports (Spencer et al., 2004). The advent of 5Hz GPS technologies showed increases in the accuracy and consistency of data over short high-speed running distance when compared to the 1Hz units but remains limited in accurately tracking movement which involves frequent changes of direction (Macfarlane et al., 2016). More recently, modern 10Hz GPS systems have been introduced into the team sport setting. The 10Hz devices have been reported as reliable and valid, enhancing the capability to accurately capture high-speed movements and changes of direction synonymous with team sport activity (Macfarlane et al., 2016), however, limitations do exist with these units as accuracy is compromised during accelerations of over $4ms^{-2}$ (Akenhead et al., 2014). The development of GPS tracking systems are continually improving through advancements in software and data processing (Malone et al., 2017), with developments being followed up by independent assessment of their reliability and validity (Scott et al., 2016).

2.3.2 Internal Training Load

2.3.2.1 Heart Rate

Several approaches have been used previously to quantify the internal training load across a range of sports (Banister, 1991; Edwards, 1993; Foster, 1998; Foster et al., 2001). Many of these have been derived from measures of heart rate (Morton et al. 1990) as a valid method by which to measure exercise intensity, specifically in endurance sports (Åstrand & Rodahl, 1986). However, the method is questionable in team sports such as soccer where the work-rate profile encompasses high-intensity anaerobic components (Impellizzeri et al., 2004). Despite this, heart rate monitoring has been commonplace in elite soccer over the past two decades. The development of lightweight telemetric heart rate monitors for use during training has seen the advent of techniques which have been developed to use heart rate as a means to quantify the internal training load (Laukkanen and Virtanen, 1998).

Training impulse (TRIMP) is a methodology based on using heart rate measurements during training as a direct marker of training load and previous attempts have used the TRIMP method to quantify training load. The Edwards-TRIMP method has been used previously as a criterion measure of internal training load which involves integrating the total volume with the total intensity of each physical training session relative to five individually categorised intensity phases (Edwards, 1993). A value for each exercise bout is calculated by multiplying the accumulated duration of time spent (minutes) in each of five identified intensity phases (50-60% [HR_{max}], 60-70%, 70-80%, 80-90%, and 90-100%) by the weighting factor allocated to each zone (50-60% [1], 60-70% [2], 70-80%

[3], 80-90% [4], and 90-100% [5]), and then summating the results. Contrary to this, Banister and Calvert (1980) proposed a method which uses the exercise duration, heart rate during exercise, resting heart, and maximum heart rate, to calculate a TRIMP 'value' or 'score' and assumes that heart rate during training is a good marker of exercise intensity.

Although TRIMP has been successfully used to quantify exercise load during endurance events (Morton et al., 1990; Busso, 2003), the use of this method may be limited in team sports such as soccer where the overall training load can comprise more short term, high load (anaerobic) components. Consequently, the use of heart rate in soccer is not likely to reflect the intermittent activity profiles observed (Akubat et al., 2012). Further limitations exist as there are many potential influences which may conversely impact upon the heart rate / exercise intensity relationship. These include the physiological status of individual players (hydration status, diurnal change, training state) and psychological factors which may affect individuals (Lambert et al., 1998). Furthermore, full heart rate monitoring systems can be expensive for squads, there can be poor compliance by players to use the monitors, and the transmitter belts cannot normally be worn during competition making this an unfeasible training load monitoring option in some situations (Impellizzeri et al., 2004; Lambert and Borresen, 2010).

2.3.2.2 Rating of Perceived Exertion (RPE)

Rating of perceived exertion (RPE) scales represent a non-invasive, simple, and valid method through which to measure the magnitude of internal training intensity (Weston et al., 2015). RPE is a psychophysiological construct which enables the athlete to (numerically) appraise the range of exertion signals elicited during exercise, which can then be quantified and used to inform the subsequent prescription of training activities (McLaren et al., 2017). In recent years, several RPE scales have been employed to quantify training intensity (Foster et al., 1995). The Borg 6–20 (Borg, 1982), CR100 (Borg and Borg, 2001), and CR10 scales (Foster et al., 2001) have been reported as valid for assessing exercise intensity during endurance sports such as running and cycling (Impellizzeri et al., 2004; Scherr et al., 2013; Soriano-Maldonado et al., 2014).

The RPE can be applied in the field to quantify the overall internal training session load (sRPE-TL) (Foster et al., 2001). Quantification of sRPE-TL is computed by obtaining the individual players subjective response (sRPE), taken ~20-30 minutes post-training to assess training intensity (using Borg's category ratio 10-point [CR10] scale), and multiplying this value by the duration of the session (in minutes). Measurements using the sRPE-TL method have been reported to correlate with the heart-rate during field-based training sessions reflecting the internal training load stressors elicited on individual players (Campos-Vázquez et al., 2015). Moderate to large correlations have been reported between sRPE-TL and TRIMP methodologies in endurance sports such as running (r = .79; Manzi et al., 2015) and swimming (r = .74; Wallace et al., 2009). Previous investigations have also validated sRPE-TL versus the TRIMP methodologies proposed by Banister and Edward (Banister, 1991; Edwards, 1993) to quantify the internal training load across a range of sports, including intermittent team sports such as basketball (r = .85; Manzi et al., 2010), rugby union sevens (r = .63 to .83; Elloumi et al., 2012), and in both male (r = .50 to .92; Impellizzeri et al., 2004; Akubat et al., 2012), and female (r = .85; Alexiou and Coutts, 2008) soccer players. In a study carried out by Impellizzeri and co-workers (2004), they assessed how sRPE-TL correlated with various heart-rate based methods (Banister's, Edwards, Lucia's TRIMP) (Banister, 1991; Edwards, 1993; Lucia et al., 2003) to determine internal training load of nineteen young soccer players from the same club. The published data reported slightly lower correlations (r = .71) than those reported during endurance exercise which was due to the increases in anaerobic contribution to energy provision during soccer-specific training (Impellizzeri et al., 2004). Previously, sRPE-TL has been used to compare the effects of resistance exercise training on internal training load, with reported data supporting the idea that sRPE-TL is a valid method for quantifying this type of training method (McGuigan et al., 2004; Sweet et al., 2004; Vieira et al., 2015). These findings are of interest, as they may increase the potential to improve the validity of sRPE-TL for use during intermittent sports such as soccer, which are predominantly anaerobic in nature.

In soccer, studies examining the relationship between sRPE-TL and TRIMP have principally involved sub-elite level players monitored over a small number of training sessions, under well controlled conditions (Impellizzeri et al., 2004; Alexiou and Coutts, 2008; Casamichana et al., 2013). The external load elicited during soccer-specific team training is often similar for each team member due to the extensive use of group training practices despite there being a potentially large variability in internal loads endured. However, these studies did not apply the most appropriate statistical analysis methodologies, omitting to quantify within-participant correlations, which is important when 'tracking' training load datasets longitudinally (Bland and Altman, 1995; Lazic, 2010; Atkinson et al., 2011). To date, only one research group has quantified the relationship between sRPE-TL and heart-rate methods in elite soccer players undertaking various forms of field-based soccer-specific training, over extended periods of time (Fanchini et al., 2016), which is important for generalisation to the real-world domain of elite-level soccer. The authors reported individual correlations between the Edwards TRIMP method and sRPE-TL (using the CR100 scale) were large to very large (*r* = .52 to .85) during training sessions in 19 elite Italian (Serie A) players. The study demonstrated that the Borg CR100 scale (Borg and Borg, 2001) is a valid measure for assessing the internal training load in elite soccer players.

Despite the usefulness of sRPE-TL within the elite soccer setting, several limitations to its use do, however, exist. sRPE-TL is largely dependent upon the accurate individual assessment of training intensity, and thus a familiarisation period is required in order to educate the players on the process requirements (Fanchini et al., 2016; Marynowicz et al., 2020). This serves to ensure consistency in the collection of precise data, and subsequently reduce the likelihood of resultant under- or over-estimations of training intensity and consequent sRPE values. Further considerations should be given to how an individual’s mood state can impact on subjective evaluations, given that sRPE requires a psychological input from the players (Morgan, 1994). A negative incident on the training ground, for example, may influence the sRPE score given for that particular session. Furthermore, it is advisable, wherever possible, that individual players verbally record sRPE in isolation to offset any potential effects of ‘peer pressure’ which may subsequently alter the individual’s subjective rating (Burgess and Drust, 2012). These limitations may suggest that subjective measures of physical stress alone may not fully estimate the training load exposure of individual players, given sRPE cannot provide enough objectivity as a single measure of overall loads elicited (Malone et al., 2015). It therefore becomes apparent that the sRPE-TL method should be used in conjunction with the objective (external load) data to provide a more powerful monitoring tool in elite soccer.

The previous section has focussed on the variety of methodologies employed within soccer to monitor both the internal and external training load. In order to reach an optimal state of soccer fitness, it is necessary to precisely monitor and quantify the distribution of training load. A combination of factors relating to training; namely the intensity, frequency, and duration of sessions can be manipulated to alter the training load imposed upon individual players. This will ensure maximal adaptations are stimulated and achieved, while simultaneously reducing the risk of over-reaching and subsequent injury / illness. The integration of these methodologies will ensure players maintain optimal levels of soccer-specific fitness while enhancing individual performance output (Manzi et al., 2010). Recently published research have provided data utilising these training load monitoring methodologies and how they are used currently in soccer to inform the prescription of the training load. It is evident that more elite clubs are using training load intelligence to plan the weekly, monthly, and annual soccer training calendar to ensure the distribution of physical effort is maximally strategised, in an attempt to improve competitive match performance. These concepts of training load monitoring and management are associated with periodised methodologies of training which have previously been implemented within the sporting domain (Issurin, 2010). The following section will focus on training periodisation and its application within the elite soccer setting.

2.4 Training Periodisation

The programming of training involves the manipulation of the acute training variables including the frequency (the number of training units in a week), intensity (the effort of the exercise), time (the duration of exercise [or repetitions] prescribed) and type of exercise (Reilly, 2007a). The term periodisation is used to describe the systematic manipulation of the acute training variables over a period that may range from days to a number of years (Herodek et al., 2012). Originally, periodisation strategies were developed in the late 1950's and scheduled around the competitive calendar to ensure athletes were optimally adapted to the endurance training protocols undertaken, and were fully prepared for competition (Herodek et al., 2012). The basis of periodisation was described by Seyle, (1936) as a three-stage process the athlete goes through when exposed to a physical stress, termed the general adaptation syndrome (GAS) model (Figure 2.3). The model proposes that all stressors result in similar responses and refers to the process of homeostasis, whereby the human biological system adapts to the imbalances in homeostatic status due to the external physical stressors elicited. The GAS model works on the assumption of a negative feedback principle by which the physiological sensors regulate the adaptive processes to maintain homeostasis within the body (Herodek et al., 2012). Bompa and Haff (2009) more recently described how the GAS model can be applied directly to exercise training in relation to the changes associated with Seyle's (1936) ideologies, that is, creating a temporary higher state of physiological functioning in response to an exercise stimulus. Furthermore, Bompa and Haff (2009) suggested that optimal performance output by athletes within the team setting is achieved through a targeted workout methodology in relation to a periodised approach, rather than practising the game itself.

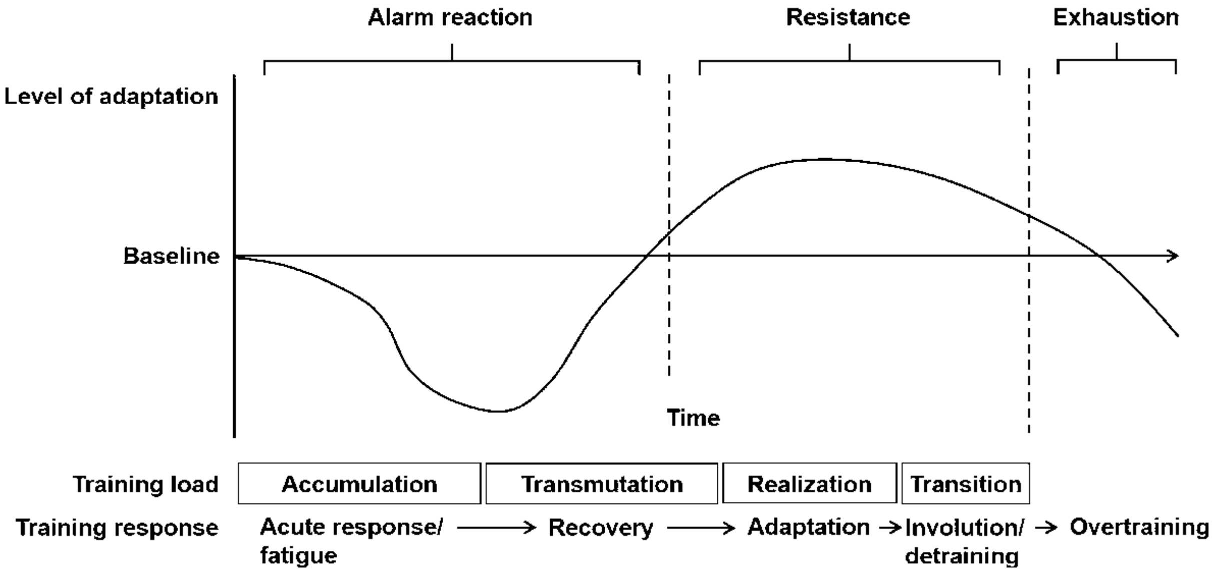


Figure 2. 3 The general adaptation syndrome (GAS) model (taken from Cunanan et al., 2018) as described by Seyle (1936).

The most comprehensive methodological models of training theory divide the annual training programme (macrocycle) into recurring cycles referred to as mesocycles (Reilly, 2007a). These are further divided into recurring shorter blocks of training termed microcycles (Bompa and Haff, 2009). It is the systematic organisation of these cycles which ensure that the athletes develop their physiological and performance capacities, thus enabling them to achieve their performance goals. The nature and dynamics of microcycles continually change in relation to the phase of training being undertaken, the training objectives, and the physical and psychological demands on the athlete (Bompa and Carrera, 2005). It is widely accepted that most athletes are successful when following a long-term training programme which incorporates structured periodised cycles (Fry et al., 1992; Foster et al., 1999), and that these fundamental principles should be applied to both endurance and team-based sports, inclusive of soccer. The following section outlines the concepts of periodisation in team sports and focus specifically upon the training programmes implemented within elite soccer.

2.4.1 Periodisation of Training in Elite Soccer

In soccer, periodisation is typically divided into three separate stages, namely the preparation, competition, and transitional phases. In soccer, these phases are more commonly referred to as the pre-season, in-season (competition), and off-season periods (Reilly, 2007a). Pre-season in professional European soccer is typically 6-weeks in duration, with the competition phase lasting around 40-weeks, leaving a 6-week period for the off-season. The early pre-season phase is utilised to increase individual levels of aerobic endurance and base conditioning, whereby late pre-season is more focussed upon the elements of specific preparation for the season ahead by means of friendly matches. The competition phase of the annual soccer calendar can be split into three separate aspects, namely early-, mid-, and late in-season which encompasses competitive fixtures and tactical-based training, while simultaneously consolidating and maintaining fitness (Reilly, 2007a). At the cessation of the competitive season, players are allowed a period of ‘non-training’ (off-loaded) recuperation (approximately 2-weeks) before undertaking a 4-week ‘maintenance-based’ training programme which may incorporate alternative activities and cross-training to minimise the effect of detraining.

2.4.2 Factors Influencing Training Periodisation in Soccer

The incorporation of a periodised programme of training into team sports can be challenging as there is the need to integrate several disparate training goals into an annual competition training programme, which for team sports can span in excess of 35-weeks (Gamble, 2006). This can be problematic in elite soccer as there is also the need to integrate technical and tactical training drills, which often precede any fitness training sessions prescribed by the fitness coaching staff including maximum strength, explosive power, metabolic conditioning, hypertrophy, injury prevention, and recovery strategies (Gamble, 2004). All of these individual elements must be addressed and incorporated into the annual training plan around the scheduled competitive fixture, and thus there is a need for planned variations in the training programme to systematically shift in emphasis by promoting these different training effects at different phases of the season. These factors indicate that the exercise prescription should be multi-dimensional and soccer-specific in its organisation (Morgans et al., 2014) (see section 2.3).

In elite soccer, the microcycle is associated with a 7-day period (Morgans et al., 2014) which is structured according to the training objectives, volume, intensity and methods that are the focus of the overall training phase, which ultimately relate to the final performance goal (Bompa and Haff, 2009). The duration of microcycles typically range between 3-7 days in elite soccer and are manipulated in accordance with the distribution of competitive matches, which is often one game every 3-4 days (Anderson et al., 2015). Additionally, factors such as travel requirements to domestic and European games, the philosophy of the head coach, individual player requirements, and national team commitments can further influence the weekly training load prescription (Akenhead and Nassis, 2016; Fessi et al., 2016; Weston, 2018).

The effective training of elite soccer players therefore requires a structured approach which allows for a variation in training load across relatively short periods of time, while simultaneously facilitating the adaptive process (Morgans et al., 2014) thus ensuring the load-recovery cycle is optimally balanced. It becomes clear that there is a necessity to adjust the training loads during the weekly microcycle phase in accordance with the upcoming fixtures to enable players to perform optimally during games (Morgans et al., 2014). This often results in the implementation of a pre-competitive load taper / reduction strategy in the three-days leading into a game (Malone et al., 2015; Los Arcos et al., 2017; Martin-Garcia et al., 2018), while further reductions in load during the post-match phase limit the number of available days to integrate high-intensity training sessions (Impellizzeri et al., 2005; Bangsbo et al., 2006b).

With this in mind, the importance of monitoring the subsequent weekly training loads becomes an important factor when observing individual physical output. It has been suggested that coaches may encounter difficulties in providing a structured training programme which facilitates recovery from competition, engaging in team-based fitness training mid-week, whilst incorporating a brief pre-game taper between fixtures (Coutts et al., 2007a; Arcos et al., 2017; Jaspers et al., 2017). The large number of competitive fixtures can place high physiological and psychological demands on individual players, and these should be taken into consideration when planning the weekly training programme. The implementation of an appropriate periodisation strategy in elite soccer therefore represents a major challenge for the head coach and fitness coaching staff alike. In recent times, it has been reported that some coaches may not embrace a scientific approach to the employment of training load monitoring strategies, often relying on non-scientific information and personal 'craft knowledge' (Burgess, 2017; Weston, 2018), which may result in the coaches training methods determining the training loads elicited (Akenhead and Nassis, 2016). This could be one explanation as to why some head coaches my find it difficult to 'balance' the need to train and recover between competitive fixtures, whilst keeping all players at optimal fitness levels. Given the diverse coaching philosophies inherent in the modern elite game, further studies are needed to enhance our understanding as to how training loads in soccer are programmed across the annual cycle (Malone et al., 2015; Anderson et al., 2016; Los Arcos et al., 2017; Martin-Garcia et al., 2018). Currently, there is a dearth of research available which describes 'real life' periodisation strategies applied within elite level team sports, in particular soccer (Gamble, 2006). The following section shall focus upon the few previous investigations carried out in relation to training periodisation currently applied in elite soccer.

2.4.3 Training Periodisation Models in Elite Soccer

Monitoring the individual player's daily training load represents an important component of the effective planning of a soccer-specific training regimen (Weston, 2018). Many clubs employ practitioners to collect, interpret and feedback information to coaches regarding the players daily load and status, offering them a greater insight into the periodisation models they employ (Akenhead and Nassis, 2016; Weston, 2018). Most of the previous work relating to periodisation models adopted within soccer has been carried out within the competitive phase of the season. These studies have examined the training load across microcycles of 1 to 3 weeks (Impellizzeri et al., 2005; Wrigley et al., 2012; Anderson et al., 2015), 1-2 mesocycles (<12 weeks) (Impellizzeri et al., 2004; Gaudino et al., 2013; Scott et al., 2013a; Owen et al., 2017; Clemente et al., 2019), and longer training periods of 3 to 4 months (Alexiou and Coutts, 2008; Casamichana et al., 2013).

More recently, Malone and co-workers (2015) quantified the seasonal training loads of elite English Premier League soccer players. The investigation reported daily total distance was 1304 m greater at the start of the season in mesocycle 1 compared with the last (mesocycle 6) when training load was analysed across the 36-week competition phase. Furthermore, the authors showed total distance covered (5181 m) was lower on the day before a match compared to all other training days. Whilst the study provided information relating to the physical, technical and tactical elements of the training programme, game-related load was omitted and thus may not be a true representation of the total overall physical load elicited upon the players.

Few studies to date have examined the overall physical load (training and matches) periodisation in elite soccer. Anderson and colleagues (2016) collected training and match data across a 39-week period inclusive of 2182 individual player training sessions, and 43 competitive matches in three official domestic competitions. The cumulative training and match load data were analysed across four (8-week) mesocycle blocks to investigate the impact of physical load in soccer players in relation to match starting status. The study demonstrated that the loading patterns across the season are mainly dependent upon the players match starting status. The authors suggested that participation in game time is of utmost importance for players to complete the necessary high-intensity physical loads needed to maintain optimal fitness levels for subsequent competition. A reduction in game time would therefore necessitate the player's training be manipulated to induce workloads comparable to match-load across the season. Monitoring the total physical loads across the entirety of a season ensures the starting status of individual players can be used to inform the training prescribed by the head coach in an attempt to elicit the required training adaptations while simultaneously optimising competitive match performance.

A more recent study provided further insight by quantifying the training load across a full competition period in players from a Spanish La Liga club competing in the reserve league (Martin-Garcia et al., 2018). Martin-Garcia and co-workers (2018) obtained GPS training and match data from 24 professional players across a 42-training week (37-match) competition phase using GPS technologies. Training load data were analysed with respect to the number of days before or after a match, with the observed training load metrics showing a distinctive taper / reduction as competition approached. Total distance (~1400-1500 m), and high-speed distance covered (~130-37 m) were reduced during the three-day period before a match. The authors reported that this periodised approach has important implications when systematically managing training load on a weekly basis. It appears that the weekly in-season training cycles in elite soccer are largely influenced by the distribution of competitive matches and philosophy of the head coach (Akenhead and Nassis, 2016; Weston, 2018).

Previous work has provided some insight into how the weekly training load is programmed within soccer. Across the competitive season, reported data show little variation in training load between the first and last (6-8 week) mesocycle blocks for players competing in the English Premier League (Malone et al., 2015; Anderson et al., 2016), and the Spanish reserve league (Los Arcos et al., 2017; Martin-Garcia et al., 2018). Previous observations also show within weekly microcyles of typically 3 to 7 days in duration are repeatedly occurring around matches, with training load being progressively reduced across the three-days leading into a game (Los Arcos et al., 2017; Stevens et al., 2017; Martin-Garcia et al., 2018). Whilst these studies provide valuable insights into the training loads experienced by elite players, further observations are required in order to gain a comprehensive insight into the collective periodisation practices adopted by professional teams (Weston 2018).

Understanding the external load stressors relative to the demands of competition is important for applied practitioners, particularly when attempting to optimise position-specific training loads. Discrepancies in load exist with regards to positional demands imposed during the game, and thus quantifying loads relative to the match could be an advantageous strategy that coaches use when implementing their periodisation model. Given competitive match play is an important stimulus for developing the physiological capacities of players regularly completing full (90-minute) games (Oliveira et al., 2019), it is imperative that practical strategies are implemented to ensure players participating in limited game time are exposed to training loads which impose loads similar to match-play, to offset any potential reductions in fitness (Martin-Garcia et al., 2018).

To address these difficulties associated with training load prescription in the applied setting, some coaches have adopted and applied a 'work-rate index' system of training load management. These methodologies, whilst not based on scientific-based research, are practically applied to aid the prescription and monitoring of weekly external training load thresholds. Individual player's (mean) total distance, high-speed distance, and sprint distance covered during a game are used to calculate an arbitrary training threshold, by using a multiplier for each measured variable (i.e. total distance [x 2.5]; high-speed distance [x 2.0]; sprint distance [x 1.5]), and subtracting the overall game distance. For example, a player covering total distance of 11,000 m in a game would be prescribed a weekly (total distance) training load threshold of 16,500 m (i.e. [11,000 m x 2.5 = 27,500 m], minus game distance [11,000 m] = 16,500 m).

Our current understanding of what is known about load monitoring in soccer derives from personal experiences, anecdotal evidence, or remains unpublished since many elite teams are often reluctant to publish data in order to maintain competitive advantage. The training methodologies employed by elite teams, and the degree to which these approaches incorporate periodisation strategies therefore remain largely unexplored in the literature. A recent survey of practitioners and coaches working in elite English soccer perceived coaches were mostly responsible, and sports scientists/fitness coaches somewhat responsible, for the planning of training (Weston, 2018). Given the diverse coaching philosophies inherent in the modern elite game, future studies are needed to enhance our understanding as to how training loads in soccer are programmed across the annual cycle.

2.5 Monitoring the Training Effects in Elite Soccer

The overriding aim of programming the weekly (microcycle) training load in soccer is to ensure players are able to cope with the increasing physical demands elicited by the modern game (Barnes et al., 2014). Changes in the volume and intensity of training inherent in periodisation models therefore serve to maximise performance while simultaneously reducing susceptibility to injury or illness (Martin-Garcia et al., 2018; Gregson et al., 2019). This can be achieved by implementing an overloading element, while simultaneously avoiding the combination of excessive overload and inadequate recovery. Furthermore, a periodised approach enables the assessment of individual players allowing for the implementation of sufficient recovery strategies, which will aid in reducing the debilitating effects associated with overtraining (Nimmo and Ekblom, 2007; Casamichana et al., 2013; Scott et al., 2013a; Verheul et al., 2019).

The introduction of a theoretical framework previously defined and conceptualised the training process by describing training load as having two (external and internal) measurable components (Impellizzeri et al., 2005). The external load has been defined as the organisation, quality, and quantity of exercise / physical work prescribed (Impellizzeri et al., 2004; Impellizzeri et al., 2005), whereby measures of internal load can be indicators reflecting the actual psychophysiological response that the body initiates to cope with the requirements elicited by the external load (Impellizzeri et al., 2019). To enhance performance during competition, it is essential that these two key constructs are controlled and manipulated by the head coach (Malone et al., 2015), as the uncoupling or divergence between the external and internal training load may differentiate between a non-fatigued, and a fatigued player (Pyne and Martin, 2011; Halson, 2014).

The training process is the systematic repetition of an organised programme of training involving the external and internal training load (Viru and Viru, 2000); with its outcome influencing subsequent training effects and performance output (Impellizzeri et al., 2005). The training effect can be positive (i.e. performance improvement) or negative (i.e. fatigue response) indicating an acute or chronic effect that directly improves, or impairs performance output (Coffey et al., 2007; Thomas et al., 2018). It is therefore paramount these components are optimally balanced across the daily microcycle, and monthly mesocycle periods during the annual training cycle. In elite soccer, a valid method to assess the training effects should be sensitive to daily changes in load (acute response), while simultaneously differentiating between individual responses to acute exercise and the longer-term changes in adaptation (Meeusen et al., 2013). However, given the multifaceted nature of fatigue, no single measure currently exists to assess the training effects in athletes (Gregson et al., 2018).

Previously, several measures have attempted to assess the training effects in team sports athletes (Andersson et al., 2008; Ispirlidis et al., 2008; Fatouros et al., 2010; Magalhães et al., 2010; Twist and Highton, 2013). Functional strength assessments have examined the recovery of neuromuscular function after competition and show promising results for the monitoring of fatigue status within the field (Gregson et al., 2018). The assessment of lower limb muscle strength using a portable force platform (McCall et al., 2015), and functional measures such as the countermovement jump (CMJ) test have been used in soccer players to quantify the acute and chronic effects of neuromuscular fatigue (Sparkes et al., 2020). The assessment of hip strength using a hand-held dynamometer has been shown to be a reliable tool to measure changes in hip strength and flexibility, classifying this methodology as a sensitive marker of localised muscular fatigue associated with soccer match-play (Paul et al., 2014). Whilst functional (physical performance) tests provide important information to the practitioner, these methods are often time-consuming and exhaustive, making them difficult to administer throughout competitive periods in elite soccer, whereby competition can occur 2 or 3 times per week (Nédélec et al., 2012), limiting the available recovery time between competitive games (Thorpe et al., 2017).

A physiological measure that can be used to measure both acute or chronic training effect is heart-rate-derived indices, which monitor the sensitivity of the heart rate to fluctuations in training and competition loads. These protocols, which may serve as promising tools to quantify fatigue status in elite soccer players (Thorpe et al., 2017), and include heart-rate recovery (HRR), heart-rate variability (HRV), exercising heart-rate (HRex), and resting heart-rate (RHR) (Buchheit, 2014). Recently reported data have shown that HRR could be sensitive to the daily fluctuations observed in endurance sports (Borresen and

Lambert, 2007; Lamberts et al., 2010), however, this association is not yet clear in team sports (Buchheit et al., 2012). Previous observations have shown a transitory decrease in HRV in response to high-speed running distance covered in elite soccer (Thorpe et al., 2015), whereas no changes were reported across a standard in-season training microcycle period (Thorpe et al., 2016). Currently, there is a dearth of evidence relating to HRV and its sensitivity to the variations in training and match load in team sports (Thorpe et al., 2017). Further limitations exist which may restrict the application of HRV in elite soccer, with measures of HRV potentially difficult to attain as a consequence of the large volume of players involved in team training on a daily basis (Plews et al., 2013).

The weekly schedule in elite soccer characteristically fluctuates between the demands of competition and a need for adequate recovery, which necessitates the implementation of non-exhaustive monitoring tools that are sensitive to more acute (daily) changes in load (Thorpe et al., 2015). A plethora of monitoring tools have been used to assess the training effects in elite team-sport athletes using methods which are non-invasive, quicker and simpler to administer, and limit any additional loading on the athlete (Thorpe et al., 2017). As an alternative to functional and physiological assessments, subjective measures are frequently used to monitor changes in athlete well-being in response to training (Saw et al., 2016). The use of athlete self-report measures (ASRM) in elite sport provide a reliable and valid method for individual players to subjectively evaluate the acute and long-term response to training in a time-efficient way, making it a more suitable and alternative application within the domain of elite soccer (Saw et al., 2016).

2.5.1 Athlete Self-Report Measures (ASRM)

ASRM are used extensively in team-sports, offering a time-efficient and simple method to assess the overall well-being of athletes (Thorpe et al., 2017; Jeffries et al., 2020b). ASRM are employed as a quick, easy-to-administer, customised short-duration questionnaire which can be implemented on a daily basis, before the commencement of exercise, to reduce interference with the player's daily training routine (Thorpe et al., 2015; Thorpe et al., 2016). ASRM covering various constructs (i.e. fatigue, sleep, muscle soreness) have grown in popularity in recent years, providing an insight into the player's ability to perform training that day, making them a valuable addition to the daily monitoring strategies implemented within team sports (Buchheit et al., 2013; Gastin et al., 2013; Thorpe et al., 2015; Thorpe et al., 2016; Gallo et al., 2017). The outcome of the ASRM questionnaire may be a useful tool to aid in adjustment of the prescribed training plan on any particular day, which can then be administered on an individualistic (bespoke) basis.

A multitude of ASRM methodologies have been employed previously in the elite-performance sports setting to assess the well-being of a variety of athletes including triathletes (Coutts et al., 2007b), and team sport players, such as rugby league (Coutts and Reaburn, 2008), handball (Buchheit, 2015), and elite soccer players (Thorpe et al., 2015). Total quality recovery process (TQR) (Kenttä and Hassmén, 1998), daily analyses of life demands for athletes (DALDA) (Coutts et al., 2007b), recovery-stress questionnaire for athletes (REST-Q) (Coutts and Reaburn, 2008), and profile of mood state questionnaire (POMS) (Buchheit, 2015) have been used extensively to assess the effects of training in athletes. These methodologies are, however, extensive and time-consuming to complete;

making them unsuitable to administer to large groups of players on a daily basis (Thorpe et al., 2017). Previously published data demonstrated that ASRM have greater sensitivity to acute and chronic training loads than commonly used objective measures (Saw et al., 2016). Furthermore, research has shown customised psychometric scales to be sensitive to the daily, within-weekly, and annual changes in loading patterns observed in Australian Football League (Buchheit et al., 2013; Gastin et al., 2013; Gallo et al., 2017), English Premier League (Thorpe et al., 2015; Thorpe et al., 2016), and English Championship players (Varley et al., 2017).

In elite soccer players, ASRM administered on a daily basis to assess fatigue, sleep quality, stress, mood, and muscle soreness, were significantly correlated with daily training load across a competitive phase of the annual cycle (Thorpe et al., 2015). In a study conducted on 10 Premier League outfield players, Thorpe and colleagues (2015) examined the relationship between daily training load (using total high-intensity-running (THIR) distance)) and ASRM during a 17-day in-season competition period. The authors reported perceived ratings of fatigue, muscle soreness, and sleep quality were sensitive to the daily variations in total high-speed running distance across the observed in-season competition period. Thorpe and co-workers (2016) used morning-measured subjective ratings of fatigue, sleep quality, and delayed-onset muscle soreness (DOMS) taken from 29 English Premier League players during standard training weeks across an in-season competition period. The reported data demonstrated that perceived ratings of fatigue were more sensitive to the daily fluctuations in training session load than comparative heart-rate derived measures which included submaximal exercise heart rate, post-exercise heart-rate recovery, and heart-rate variability (Thorpe et al., 2016).

Professional soccer players participating in the English Championship were observed by Varley and co-workers (2017), examining relationships between ASRM responses and match activity variables (total distance, sprint distance, accelerations (*n*), decelerations (*n*), sprints (*n*)). The authors used a 4-point questionnaire modified from the work of Hooper and colleagues (1995) to assess perceived energy levels, leg muscle soreness, sleep duration, and overall physical feelings. Findings from the study reported moderate to large correlations between the ASRM and number of accelerations ($r = .52$), sprint distance ($r = .40$), and total number of sprints performed ($r = .51$) 40-hours post-match. Furthermore, a moderate correlation was observed between ASRM responses and number of accelerations performed 64-hours after cessation of the match ($r = .40$). The authors concluded the number of accelerations, decelerations, and sprints carried out during competitive games can influence the fatigue status in elite players 40- and 64-hours post-match (Varley et al., 2017). These findings are in-line with data published by Thorpe and colleagues (2015) who reported variations in fatigue status ($r = –.51$) were significantly correlated with variations in total high-intensity-running (THIR) distance covered. These studies demonstrate the use of the ASRM may offer a simple to administer, non-invasive assessment of training effects that can applied across the annual competitive in-season period in elite soccer.

Previous work has shown that training loads elicited in elite soccer fluctuate across the in-season competitive period and are largely influenced by the distribution of competitive matches (Fessi et al., 2016; Martin-Garcia et al., 2018) and philosophy of the head coach (Akenhead and Nassis, 2016; Weston, 2018). Assessing load in elite soccer permits the measurement of the physiological response to training in an attempt to evaluate player adaptation, readiness to train, levels of recovery, and fatigue status (Meeusen et al., 2013).

The recording of perceived ratings of wellness, using the ASRM, is an efficient and practical process to quantify the fatigue responses to training in elite players during a short in-season microcycle phase, competitive 17-day training period (Thorpe et al., 2015), and across the longer annual competitive phase (Thorpe et al., 2016). Future work is needed to further increase our understanding of the sensitivity of ASRM to changes in training load experienced by elite players.

2.6 Summary

In summary, this section describes the physiological demands of the daily training and match-play loads elicited in elite players. The use of valid and reliable measures by which to quantify both the external and internal load has been discussed, focusing specifically on the methodologies employed. Heart-rate monitoring, sRPE-TL, GPS, stadium-based tracking, and ASRM are identified as the methods used in the current thesis to determine and quantify the training and match load periodisation strategies employed in an English Premier League team. The importance of quantifying the reliability and validity of the measurement tools used in the current thesis will be investigated to ensure the accurate analysis of data. The initial investigation in the current thesis therefore assesses the validity measures for a non-invasive, time-efficient, and easily administered measure of individual player perceived exertion. The quantification of training and match load in the current thesis focus on the periodisation strategies adopted within elite soccer, specifically in relation to factors influencing training load distribution and how these impact on the models currently employed at a Premier League club.

CHAPTER 3: GENERAL METHODOLOGY

3. General Methodology

3.1 Participants

All participants were full-time professional soccer players from an English Premier League club. Only fit and healthy players in full training were included in the experimental trials. Goalkeepers were excluded from all studies. All of the players were notified as to the aim of the study, requirements, research procedures, benefits and risks before giving written informed consent. The Ethics committee of the relevant School at Liverpool John Moores University approved the study.

3.2 Procedures

3.2.1 Experimental Design

All of the first team field-based training sessions carried out were considered for the analysis. Data derived from team technical, tactical, and physical training sessions during the in-season competition phase were included in the analysis. This was inclusive of sessions involving both the starting line-up and non-starting players. Individual training, rehabilitation, recovery, and specific fitness sessions were excluded from the analysis. Goalkeepers were not included in the study. Daily training load data was collected using the session-RPE (sRPE) method and (GPS) micro-technology. Training and match data collection was carried out at the soccer club's training ground, at the same time of day, on the same natural outdoor grass training pitches, and at both home and away grounds in the English Premier League, respectively. Individual player's activities were examined using the same methods as Bradley and colleagues (2009) and monitored during each game using a stadium-based multiple-camera match analysis system (Prozone Sports Limited, Leeds, UK). The Prozone system provides valid (Di Salvo et al., 2006) and reliable (Di Salvo et al., 2009) estimations of a variety of match performance indices. All training and match load data observed during a 36-week competition phase of the observed seasons were categorised into 6-week mesocycle phases, and subsequent weekly (microcycle) calendar blocks (Sunday to Sunday) (Figure 3.1). The inclusion of 6-week (mesocycle) training cycles in the current study were applied to reflect the clubs training methodology which used similar time periods for some areas of physical development. The adoption of this cycle duration also facilitated comparison with previous studies.

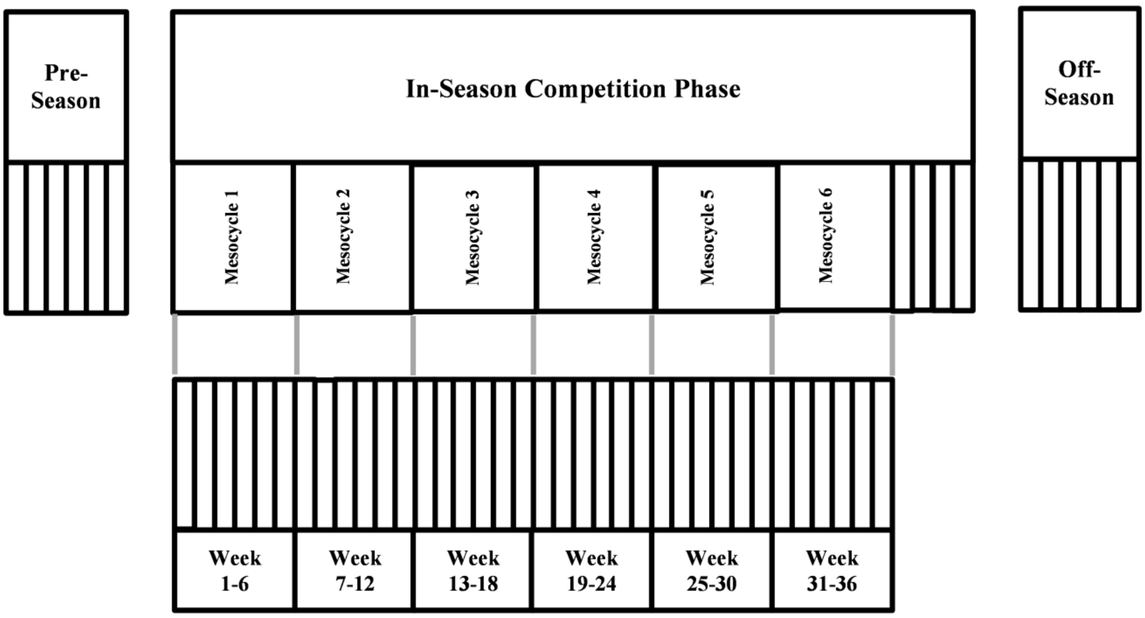


Figure 3. 1 Diagrammatic representation of the experimental design used in the current study. Each small block represents individual weeks within the annual training cycle, with larger blocks showing the 6-week mesocycle phases of the competitive season.

3.2.2 Mesocycle Analysis

All training load data observed during a 36-week competition phase of the season were categorised into 6-week mesocycle phases. These were then categorised into subsequent weekly calendar blocks (Sunday to Sunday). This enabled a full season's analysis of the training load endured by the players across the entire competition period of the annual training cycle**.**

3.2.3 Day Type

Training days (day type) were classified in relation to their proximity to the forthcoming competitive game. Different types of training were prescribed in relation to the specific day type to ensure players were optimally prepared for competition and (Table 3.1).

Table 3. 1 Training content prescribed on each training day type.

Day Type	Duration (min)	Session Theme	Exercise Descriptor	Exercise Duration (min)	Intensity
G-3	~70	Extensive Endurance	Activation exercises Field-based warm-up Technical ball work / passing drills Position-specific practices: (7 *v* 7 – 11 *v* 11) Larger pitch areas (75 m x 40 m – 105 m x 68 m)	10 15 15 30	High
G-2	~60	Intensive Endurance	Activation exercises Field-based warm-up Technical ball work 'Rondo' type practices: (3 *v* 2, 5 *v* 4, 1 *v* 1, 2 *v* 2, 3 *v* 3) Smaller pitch areas (10 m x 5 m – 30 m x 20 m)	10 15 15 20	Moderate
G-1	~50	Reactive Speed	Activation exercises Field-based warm-up Possession 'boxes' (8 m x 8 m – 10 m x 10 m) Individual technical work (i.e. attackers 'finishing' drills)	10 15 15 10	Low
G+3	~70	Extensive Endurance	Activation exercises Field-based warm-up Technical ball work / passing drills Position-specific practices: (11 *v* 11) Large (full-size) pitch area (75 m x 40 m – 105 m x 68 m)	10 15 15 30	High

3.3 Training Load

3.3.1 Internal Training Load Assessment

Individual player internal training load (sRPE-TL, arbitrary units, AU) was estimated for all players by multiplying total training or match session duration (min) with session ratings of perceived exertion (sRPE) (Foster et al., 2001). Player sRPE was collected in isolation where possible, to avoid the potential effects of peer pressure ~20-minutes after the cessation of each training session or match (using Borg's category ratio 10-point [CR10] scale [Chapter 11, Appendix]). All the players were familiarised with the use of the RPE scale during the pre-season training phase.

3.3.2 External Training Load Assessment

The player's external training session load was monitored using portable micro-technology (GPSports SPI Pro X, Canberra, Australia). The SPI Pro X (GPS and accelerometer integrated; size: 48x20x87mm; 76g) was placed inside a specially made vest, inside a mini pocket which was positioned on the player's back, located centrally between the scapulae. The player wore micro-technology for the whole duration of the session. The unit was activated ~15 min before data collection to allow for the acquisition of satellite signals (Waldron et al., 2011). During every training session observation, the minimum acceptable number of available satellite signals was 8, which is optimal for the measurement of human movement (Jennings et al., 2010). To avoid inter-unit error, each player wore the same micro-technology device for every training session observation (Jennings et al., 2010). The SPI Pro unit provides raw position, velocity and distance data at a rate of 15 samples-per-second (15 Hz). Every 3 raw data points were averaged for the purpose of the current study to provide a sampling frequency of 5 Hz. This type of system has been shown to provide a reliable and valid estimate of the high-speed distance covered during multi-directional sports such as soccer (Portas et al., 2010; Randers et al., 2010; Waldron et al., 2011; Varley et al., 2012). The observed training activities (external load markers) identified for subsequent analysis were, total distance (m), high-speed distance (m) completed at >14.4 km/h, very high-speed distance (m) completed at 19.8-25.2 km/h, and number of accelerations and decelerations completed at >3m/s^2. Acceleration and deceleration activities were recorded when a change in GPS speed data was registered for a minimum period of 0.5 second with a maximum acceleration in the period at least 0.5 m/s^2 (Gaudino et al., 2015).

CHAPTER 4: THE WITHIN-PARTICIPANT CORRELATION BETWEEN PERCEPTION OF EFFORT AND HEART RATE-BASED ESTIMATIONS OF TRAINING LOAD IN ELITE SOCCER PLAYERS

This study was published as a full manuscript in the Journal of Sports Sciences. (Appendix, Chapter 11)

4. The Within-Participant Correlation Between Perception of Effort and Heart Rate-Based Estimations of Training Load in Elite Soccer Players

4.1 Introduction

Exercise training is an adaptive process in response to the progressive manipulation of the training load. While there are many moderators and mediators of the training response, performance enhancement is generally achieved through a planned manipulation of the training load (a product of the volume and intensity of training) (Manzi et al., 2010). Consequently, the accurate assessment of an individual's training load is imperative for effective training prescription.

Training load can be quantified by recording both the internal and external loads imposed upon the individual player (Impellizzeri et al., 2004). The physiological strain resulting from the external training factors has been labelled the internal training load (Viru and Viru, 2000). Therefore, valid and reliable indicators of internal training load are essential to monitor the training process. Several approaches based on heart rates have been formulated in an attempt to quantify the internal training load across a range of sports (Banister, 1991; Edwards, 1993; Foster, 1998; Foster et al., 2001). While the heart rate represents a valid means through which the exercise intensity is measured in endurance sports (Åstrand and Rodahl, 1986), the method is questionable in team sports such as soccer, where the overall training load can comprise more short-term high load components (Impellizzeri et al., 2004). Furthermore, full heart rate monitoring systems can be expensive for squads, there can be poor compliance by individuals to use the monitors as a result of players feeling uncomfortable wearing the heart rate straps during training, and the transmitter belts cannot normally be worn during competition (Lambert and Borresen, 2010).

Session-RPE (sRPE) represents an easier to implement and cheaper alternative to heart rate systems for quantifying training loads (Foster et al., 2001). The sRPE has been reported to be a valid indicator of global internal load of training during both endurance type sports (Foster, 1998) and intermittent team sports such as soccer (Impellizzeri et al., 2004; Casamichana et al., 2013). To date, studies in which the relationship between sRPE and HR-based estimations of training has been quantified in soccer have principally involved sub-elite level players monitored over a small number of training sessions under well controlled conditions (Impellizzeri et al., 2004; Alexiou and Coutts, 2008; Casamichana et al., 2013). To the present authors' knowledge, only one research group has quantified the correlation between the two methods in elite soccer players undertaking various forms of field-based soccer-specific training over extended periods of time (Fanchini et al., 2016), which is important for generalisation to the 'real world' domain of elite-level soccer. However, it is also important in longitudinal studies of "tracking" to quantify within-participant correlations according to the most appropriate statistical approach, which models the longitudinal dataset as a whole using the correct degrees of freedom, rather than by calculating correlations for individual players (Bland and Altman, 1995; Lazic, 2010; Atkinson et al., 2011).

In elite players, marked differences in the physical demands of soccer exist between different playing positions. For example, wide defenders and midfield players frequently engage in activity which is highly dependent upon aerobic metabolism (Bangsbo, 1994a) compared to central defenders and strikers where a high proportion of activity is supported by anaerobic metabolism (O'Donoghue, 1998; Di Salvo et al., 2007). Recent observations indicate a poorer relationship between sRPE and HR-based estimations of training load during training sessions which incorporate short-term high-intensity efforts (Campos-Vazquez et al., 2014). The limitations of using heart rates for monitoring the intensity of these types of efforts may extend to affecting the magnitude of the correlation between sRPE and heart rate-load during training. Therefore, the purpose of the current investigation was to quantify the within-participant correlation between the sRPE and heart-rate methods (HR-TL) for estimating training load in elite soccer players across a typical in-season competitive phase and to determine the influence of playing positions on the magnitude of this correlation.

4.2 Methods

4.2.1 Participants

Data were collected from 19 soccer players (mean ± SD: age 27 ± 5.1 years, body mass 78 ± 6.2 kg, height 181 ± 7.1 cm) competing in the English Premier League during the in-season competition period. All players were notified of the aim of the study, research procedures, requirements, benefits, and risks before giving written informed consent. The Ethics Committee of Liverpool John Moores University approved the study.

4.2.2 Training Observations

Nineteen elite-level players were monitored during a full competition phase of the 2011-2012 (August – May) English Premier League season. Players were assigned to one of five positional groups: (central defenders [*n* = 4]; wide defenders [*n* = 4]; central midfielders [*n* = 6]; wide midfielders [*n* = 2]; and attackers [*n* = 3]). A total of 1010 individual training observations were undertaken on outfield players (goalkeepers were excluded) across the entire in-season competitive period (43-weeks) with a median of 55 training sessions per player (range: 21-102). Training observations for each positional category were, central defender ([*n*] = 179), wide defender [218], central midfielder [313], wide midfielder [76], and attacker [224]). Only data derived from team field-based technical and physical training sessions were analysed. Matches, individual rehabilitation sessions and individual fitness sessions were not included for analysis.

4.2.3 Data Collection

Session Ratings of Perceived Exertion (sRPE)

The sRPE training load (sRPE-TL) were measured as described in Chapter 3 section 3.3.

Heart-Rate Training Load (HR-TL)

To calculate heart-rate training load (HR-TL), individual player heart rate was recorded every 1 s during each training session using individual coded heart rate monitors (Team^2, Polar Electro, Kempele, Finland). After each training session, the individual heart rate monitors were downloaded onto a PC using Polar Team^2 software (version 1.4.5). The individual heart rate data were subsequently exported into a Microsoft Excel spreadsheet database (Microsoft Corporation, U. S.). The current study utilised the heart rate-based training load method proposed by Edwards (1993) as used by Foster (1998) to validate the use of sRPE training load to monitor endurance training. This heart-rate based method has also been employed as a criterion measure to examine sRPE in the non-steady state and prolonged exercise (Foster et al., 2001; Impellizzeri et al., 2004). The Edwards method (Edwards, 1993) was applied to heart rate data recorded during the 43-week in-season competitive phase. Internal training load was quantified by measuring the product of the accumulated training duration (minutes) of five separate heart rate zones by a numerical factor relative to each zone (50-59% [HR_{max}] = 1, 60-69% = 2, 70-79% = 3, 80-89% = 4, 90-100% = 5) and then summating the results.

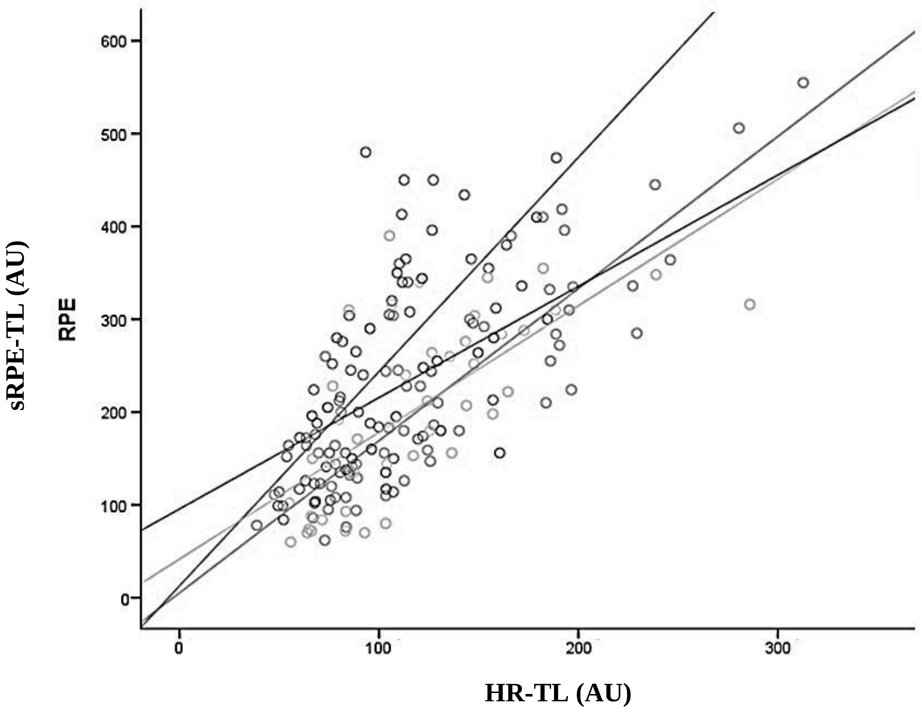
4.3 Statistical Analysis

Data are expressed as means ± S.D. Within-participant correlations were calculated between sRPE-TL and HR-TL (Bland and Altman, 1995). Rather than pooling all the data, or calculating correlations separately for individual participants, this approach quantifies the correlation, and associated 95% confidence interval (95% CI), between a covariate and outcome while taking into account the within-participant nature of the study design. Even after such appropriate modelling approaches were communicated by Bland and Altman (1995), some researchers would pool together data collected at different time periods and place this pooled data into two columns for conventional Pearson’s correlation. This spuriously inflates the degrees of freedom in the analysis and violates the assumption of independent cases in a Pearson’s correlation. This longitudinal modelling approach is based on the correct degrees of freedom and is therefore associated with higher statistical precision than the averaging of Pearson’s correlations for individual players. The latter approach also violates the assumption of case independence necessary for a Pearson’s correlation. To interpret the magnitude of correlation between the two variables, the following criteria were applied: ($r < 0.1$) trivial, ($0.1 < r < 0.3$) small, ($0.3 < r < 0.5$) moderate, ($0.5 < r < 0.7$) large, ($0.7 < r < 0.9$) very large, ($r > 0.9$) almost perfect, and ($r = 1$) perfect (Hopkins et al., 2009). Statistical analyses were carried out using the SPSS statistical analysis software for Windows (version 19.0, SPSS Inc., Chicago, IL, USA).

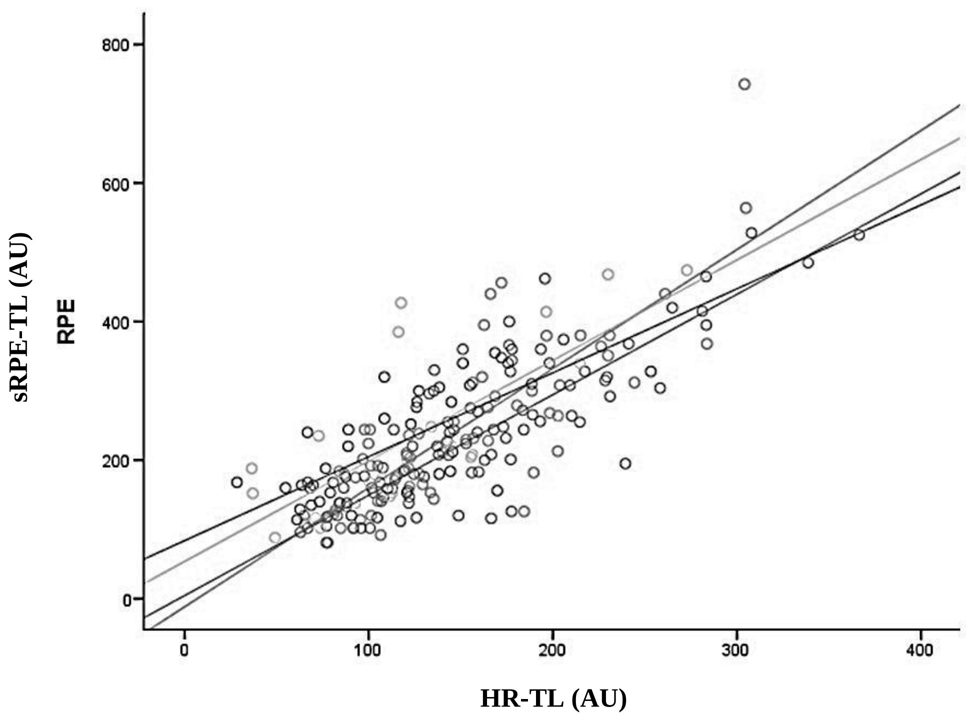
4.4 Results

Training load data according to playing position is represented in Figure 4.1 (a-e). The overall training load across the observed sessions was 229 ± 105 arbitrary units (AU) and 132 ± 57 beats per minute for sRPE and heart rate-load, respectively. Overall, the changes in sRPE-TL were highly correlated with the changes in HR-TL ($r = 0.75$; 95% CI 0.71-0.78; $P < 0.001$). Playing positions had little influence on the correlations between measurement methods. Within-participant correlations between sRPE-TL and HR-TL were large and very large in magnitude for central defenders ($r = 0.74$, $P < 0.001$, 95 % CI 0.70-0.77), wide defenders ($r = 0.81$, $P < 0.001$, 95 % CI 0.78-0.84), central midfielders ($r = 0.70$, $P < 0.001$, 95 % CI 0.66-0.74), wide midfielders ($r = 0.70$, $P < 0.001$, 95 % CI 0.66-0.74) and attackers ($r = 0.84$, $P < 0.001$, 95 % CI 0.82-0.86).

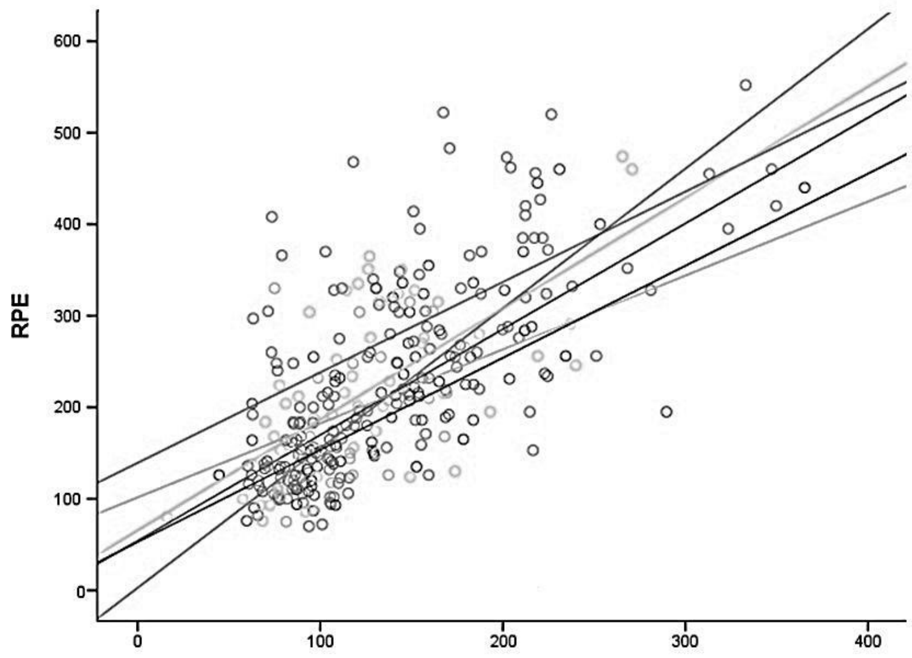
a)


sRPE-TL (AU)
RPE
600
500
400
300
200
100
0
0
100
200
300
HR-TL (AU)

b)


sRPE-TL (AU)
RPE
800
600
400
200
0
0
100
200
300
400
HR-TL (AU)

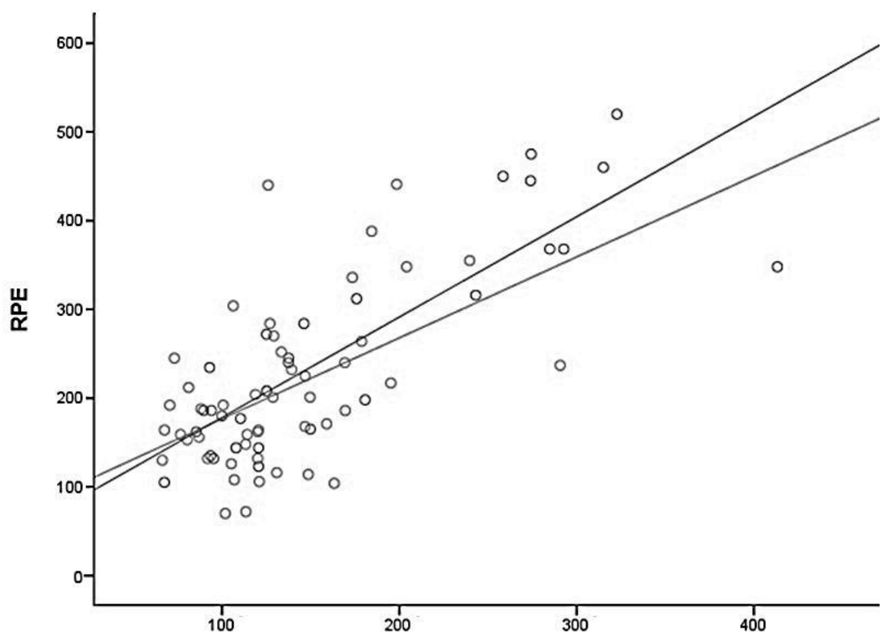
c)



sRPE-TL (AU)

HR-TL (AU)

d)



sRPE-TL (AU)

HR-TL (AU)

e)

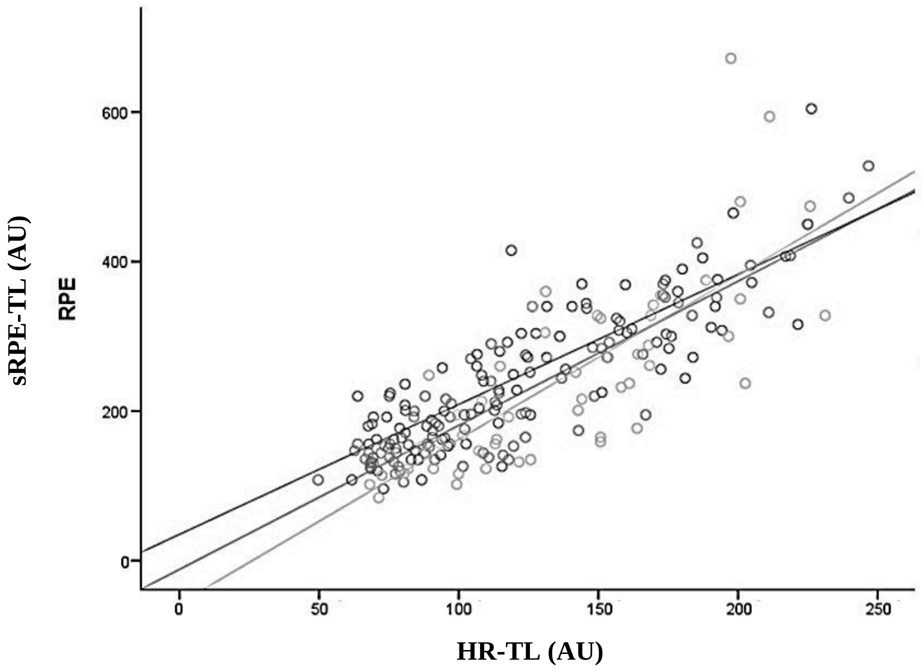


Figure 4. 1 Relationship between the sRPE-TL and HR-TL (AU) across the observed sessions for a) central defenders (r = 0.74; P < 0.001); b) wide defenders (r = 0.81; P < 0.001); c) central midfield players (r = 0.70; P < 0.001); d) wide midfield players (r = 0.70; P < 0.001); e) attackers (r = 0.84; P < 0.001).

4.5 Discussion

The purpose of the current study was to quantify the correlation between the variability in sRPE-TL and a heart rate-based method for quantifying the internal training load in elite soccer players, encompassing both technical and physical field-based soccer drills during daily training sessions, and to determine the influence of playing position on the magnitude of this correlation. The large correlation (r = 0.75; 95% CI 0.71-0.78; P < 0.001) between the overall sRPE-TL and HR-TL observed in the present study compares favourably with the moderate-large associations (r = 0.50 to 0.85) observed in young amateur (Impellizzeri et al., 2004), semi-professional males (Casamichana et al., 2013) and elite female (Alexiou and Coutts, 2008) and male soccer players (Fanchini et al., 2016).

Previous attempts to quantify the correlation between sRPE-TL and HR-TL are limited to some extent by suboptimal statistical approaches, including pooling all of the data over time for calculation of single correlation with inflated degrees of freedom, or quantifying correlations for individual players and calculating a sample mean correlation, which lacks statistical power (Atkinson et al., 2011). The 'within-subjects' correlations employed in the current study, and large number of data sets collected on a daily basis from elite-level professional English Premier League players may therefore give a more accurate representation of the relationship between the two measured variables observed in elite-level soccer.

While the heart rate represents a valid means through which to measure exercise intensity in endurance sports (Åstrand & Rodahl, 1986), the method is questionable in team sports such as soccer where the overall training load frequently comprises anaerobic components (Impellizzeri et al., 2004). Indeed, this may partly account for the failure to observe a higher correlation between sRPE-TL and HR-TL in the current study, and in previous studies which have compared the two methods during activities involving a high anaerobic contribution (Impellizzeri et al., 2004; Casamichana et al., 2013; Fanchini et al., 2016). In line with such observations, Campos-Vazquez and colleagues (2014) recently reported that the magnitude of the relationship between sRPE-TL and HR-based estimations of training load was dependent upon the type of training session undertaken. Moderate correlations (r = 0.35 to 0.55) were observed between the two methods during high-intensity sessions involving explosive drills (e.g., accelerations, changes of direction, jumps) and small side games (5 *vs.* 5 to 8 *vs.* 8) compared to very large correlations (*r* = 0.73 to 0.87) during tactical based sessions (e.g. 11 *vs.* 11) incorporating a higher proportion of aerobic activity. Players observed in the current study were regularly exposed to a variety of training drills. These were in the format of pre-training activation type drills, small-sided games, which were varied according to organisational parameters enforced by the coaches (ranging from 4 *vs.* 4 to 9 *vs.* 9 formats), high-intensity running drills and speed endurance training. The anaerobic conditioning component inherent with these types of drills may therefore have reduced the magnitude of the correlations between sRPE-TL and HR-TL observed in the current study.

Marked differences in the physical demands of soccer exist between different playing positions. For example, wide defenders and midfield players frequently engage in low to moderate-intensity aerobic activity compared to central defenders and strikers who are characterised to a greater extent by short, high-intensity anaerobic bouts (O'Donoghue, 1998; Di Salvo et al., 2007). Given the limitations inherent in using the heart rate for monitoring the intensity of anaerobic exercise, differences in the aerobic and anaerobic contribution to energy provision between playing positions may influence the magnitude of the correlation between sRPE-TL and HR-TL. A further aim of the present study therefore was to examine whether these differences in physical demands between different positions influences the magnitude of the correlation between session-RPE and heart rate-load. Playing positions had little influence on the magnitude of the relationship with the within-individual correlation ranging from large (*r* = 0.70) in central and wide midfielders to very large (*r* = 0.74 to 0.84) in the remaining positions. These findings may, to some extent, reflect a lack of position-specific training undertaken as part of the methodology implemented by the coaches in the present team. As noted above, a high proportion of small-sided games (4 *vs.* 4 to 9 *vs.* 9) were employed which reduce the degree to which players participate in 'set' positions on the field of play. These drills were supplemented with both position-specific and non-position-specific high-intensity running and speed endurance drills (with and without the ball) in order to prepare players for the most critical and/or intense periods of the games. Since match data was not included in the current study and 11 *vs.* 11 type drills formed a relatively small proportion of the weekly training time (e.g. pre-game day) it is possible that the degree of position-specific training was not sufficient enough to influence the correlation between sRPE and heart rate-load. Further work is needed to determine whether the magnitude of the correlation between sRPE and heart rate-load is influenced by playing position during training drills which demand a position-specific focus.

The present study systematically quantified the internal training loads across a 43-week competition phase in the English Premier League. The present results suggest that sRPE-TL and HR-TL are highly correlated and do reflect the internal training load stressors elicited on individual players. sRPE-TL demonstrated that it can be used as a practical global indicator of individual training load across an entire in-season period in elite-level soccer players irrespective of playing position. sRPE-TL will be used in future studies to quantify and track the internal load across the annual training and competition cycle in elite English Premier League soccer players.

CHAPTER 5: QUANTIFICATION OF TRAINING AND MATCH-LOAD DISTRIBUTION ACROSS A SEASON IN ELITE ENGLISH PREMIER LEAGUE SOCCER PLAYERS

This study was published as a full manuscript in the Journal of Science and Medicine in Football. (Appendix, Chapter 11)

5. Quantification of Training and Match-Load Distribution across a Season in Elite English Premier League Soccer Players

5.1 Introduction

The complex physiological demands of soccer necessitate the implementation of training programmes which are multifactorial in nature (Morgans et al., 2014). Such requirements are further complicated by the stochastic movement profiles observed in elite soccer. The sporadic work bouts associated with soccer training may therefore result in variability between the desired training load and the actual training load the players are exposed to (Malone et al., 2015). Monitoring the individual player's daily training load therefore represents an important component of the effective planning of a soccer-specific training regimen (Weston, 2018).

The volume and intensity of training, collectively referred to as the training load (Impellizzeri et al., 2005), requires manipulation (periodisation) to elicit an optimum training stimulus (Malone et al., 2015). Many clubs therefore employ practitioners to collect, interpret and feedback information to coaches regarding the players daily load and status (Arkenhead and Nassis, 2016; Weston, 2018). To date, studies focused on training load quantification in soccer have largely focused on isolated training drills (Coutts et al., 2009; Casamichana and Castellano, 2010; Buchheit et al., 2015) or mesocyles of up to 10 weeks (Impellizzeri et al., 2004; Gaudino et al., 2013; Scott et al., 2013a; Clemente et al., 2019). In contrast, while a plethora of studies have documented the long-term (season long) periodisation models adopted in other football codes (Gabbett and Jenkins, 2011; Moreira et al., 2016; McGahan et al., 2017), little data currently exists in elite soccer.

Recent studies have provided some insight into the seasonal training loads encountered by players competing in the Spanish reserve league (Los Arcos et al., 2017; Martin-Garcia et al., 2018), Dutch Eredivisie League (Stevens et al., 2017), and the English Premier League (Malone et al., 2015; Anderson et al., 2016). Across the competitive season there was little variation in training load between mesocycles (6–8-week training blocks) (Malone et al., 2015; Anderson et al., 2016). Within weekly microcyles, load was also generally similar between training days with the exception of a marked reduction in load on the day preceding the game (Malone et al., 2015; Martin-Garcia et al., 2018). Whilst these studies provide valuable insights into the training loads experienced by elite players, further observations are required in order to gain a comprehensive insight into the collective periodisation practices adopted by professional teams (Weston, 2018). Furthermore, a more detailed analysis of the nature of the loading incurred by players is required. For example, internal training load, or the individual physiological response to the external load administered by the coach, represents the stimulus for training induced adaptation (Viru and Viru, 2000). Valid and reliable indicators of internal training load are therefore essential when monitoring the training process. sRPE-TL represents a valid indicator of the global internal training load during intermittent team sports such as soccer (Impellizzeri et al., 2004; Casamichana et al., 2013; Kelly et al., 2016). Despite the importance of the internal load in indicating the training response, observations on elite players have also been largely restricted to descriptions of short-term periods of training (Campos-Vazquez et al., 2015) with only one research group to date reporting sRPE-TL responses to long-term periods of training in elite players (Malone et al., 2015).

Most of what is currently known about load monitoring derives from personal experiences or remains unpublished, since many elite teams are often unwilling to publish their data to retain competitive advantage. The training approaches adopted by elite teams and the degree to which these approaches incorporate periodisation strategies therefore remain largely unexplored in the literature. A recent survey of practitioners and coaches working in elite English soccer perceived coaches were mostly responsible, and sports scientists / fitness coaches somewhat responsible, for planning training (Weston, 2018). Coaching practice is heavily influenced by tradition, emulation, and historical precedence rather than through critical consideration of the latest research (Stoszkowski and Collins, 2016). Given the diverse coaching philosophies inherent in the modern elite game, further studies are needed to enhance our understanding as to how training loads in soccer are programmed across the annual cycle. The aim of the current investigation therefore was to quantify the combined external and internal training and match-load distribution across the competition phase of one full season at an English Premier League club.

5.2 Methods

5.2.1 Participants

Twenty-six elite-level soccer players were monitored across a 36-week competition phase of the 2012-2013 English Premier League (League Champions) season (mean ± SD: age 27 ± 5.4 years, body mass 77 ± 6.6 kg, height 181 ± 7.0 cm). Players were assigned to one of five positional groups, central defender (CD) (n = 4), wide defender (WD) (n = 4), central midfielder (CM) (n = 7), wide midfielder (WM) (n = 3), and attacker (A) (n = 8). The team competed in four official competitions throughout the season corresponding to 49 competitive matches in total. All of the players were notified as to the aim of the study, requirements, research procedures, benefits, and risks before giving written informed consent. The Ethics committee of the relevant School at Liverpool John Moores University approved the study.

5.2.2 Experimental Design

Training and match-load data collection were carried out as described in Chapter 3 section 3.2.

5.2.3 Day Type Analyses

For the purpose of the current study, a total of six-day types were identified in relation to their proximity to the forthcoming match (G-3, G-2, G-1, match day (MD), G+2, G+3) and were subsequently analysed. Training days (day type) were classified in relation to their proximity to the forthcoming competitive game. Three days before the game was classified as game day (G) minus three (G-3), whereas G+3 was categorised as the third day post-match. During the season there were one, two, and three game weeks. A one-game week consisted of 6 training days leading into the game. The two-game week had 1 recovery day following the first game (e.g. G+1) and 4 training days leading into the next game. A three-game week had 1 recovery session and a training day (G-1) between the first and second game and the second and third game respectively. In some instances, during two and three game weeks, games were played in closer proximity (e.g. Saturday and Tuesday), leaving only two days between fixtures. In this scenario, 1 recovery session and a training day (G-1) were implemented between games.

5.2.4 Mesocycle Analyses

Mesocycle analyses were carried out as described in Chapter 3 section 3.2.

5.3 Methodology

5.3.1 Internal Training Load Assessment

Session Ratings of Perceived Exertion (sRPE)

The sRPE training load (sRPE-TL) were measured as described in Chapter 3 section 3.3.

5.3.2 External Training Load Assessment

Global Positioning System (GPS)

External training load was measured for all players using portable micro-technology (GPSports SPI Pro X, Canberra, Australia) as described in Chapter 3 section 3.3.

5.3.3 Training and Match-Load Data Collection

All training sessions and competitive matches during the 2012-13 season were observed and subsequently recorded. The mean number of training sessions completed, and the average match observations during each month (n = 5) are shown in Figure 5.1. Mean training session duration across all positions was 59 ± 7 min (Figure 5.2). Matches were inclusive of domestic (Premier League, F.A. Cup, League Cup), and European (Champions League) fixtures. Friendly games were excluded from the analysis. A total of 49 matches were observed during the 36-week competition phase of the season. Individual player's activities were monitored during each game using a stadium-based multiple-camera match analysis system (Prozone Sports Limited, Leeds, UK). Data from both home and away fixtures were included. Only data from completed 90 min matches were used for the analysis. The median number of completed matches by individual players was 16 (range: 2-38). All Prozone data were processed using the appropriate software package (Prozone 3 Version 12.0.4.2., Prozone Sports Limited, Leeds, UK). This was carried out post-game(s) by the club's performance analyst and exported into a Microsoft Excel spreadsheet database (Microsoft Corporation, U.S.) for the analysis.

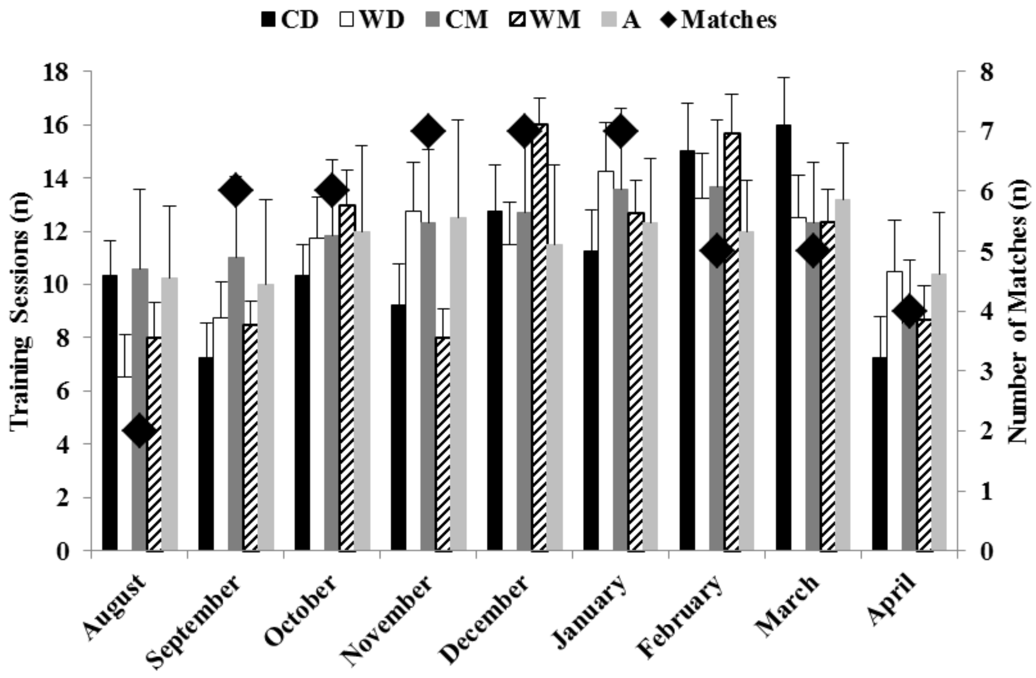


Figure 5. 1 Mean ± SD number of training sessions and competitive games by playing position during the 2012-13 season.

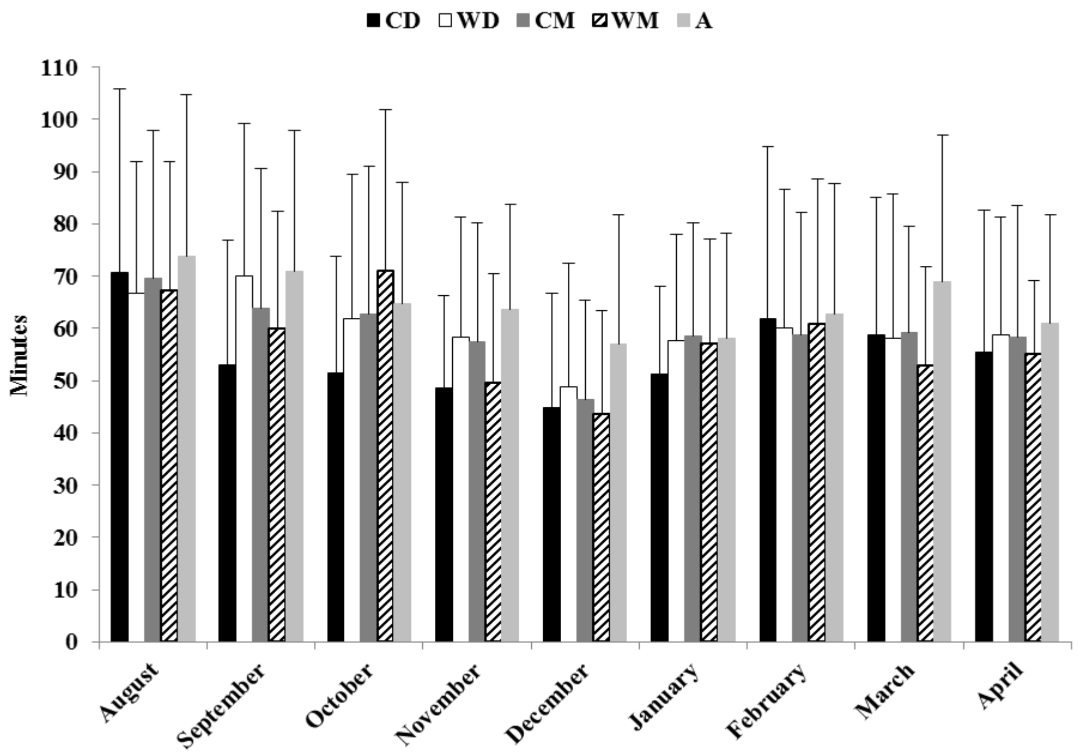


Figure 5. 2 Mean ± SD training session duration by playing position during the 2012-13 season (central defender [CD]; wide defender [WD]; central midfielder [CM]; wide midfielder [WM]; attacker [A]).

The observed training and match-play activities (external load markers) identified for subsequent analysis were, total distance (m), distance (m) completed at high-speeds >14.4 km/h (m), and distance (m) completed at very high-speeds 19.8-25.2 km/h. The current authors acknowledge that some differences in the measures derived from the micro-technology devices and Prozone system exist. In particular, it has been shown previously that high-intensity running distances are slightly-to-moderately greater when tracked using Prozone in comparison to GPSports devices (Buchheit et al., 2014). However, for the purpose of the current investigation, both the GPSports (training load), and Prozone (match load) data were combined together for the analysis (Anderson et al., 2016).

5.4 Statistical Analysis

Data are represented as means ± S.D. A multi-factorial linear mixed model was used to quantify mean differences between mesocycles, day-type and playing position. Use of linear mixed-modelling is suitable to examine repeated-measures data and unbalanced observations over time as, for example, in the context of our study where players differ in the number of training sessions and matches (Cnaan et al., 1997). Linear mixed modelling can also cope with the mixture of random and fixed level effects (Cnaan et al., 1997) as well as with missing and 'nested' data (hierarchical models). The main effects for sub-group comparisons of each factor were summarised using least significance difference (LSD) multiple contrasts (Perneger, 1998).

Mean differences are presented with 95% confidence intervals (Cl) as markers of uncertainty in the estimates. In the absence of an established anchor, despite the lack of real-world relevance of standardised effect sizes (Lenth, 2001), Cohen's d was reported as an additional statistic for interpreting the magnitude of the estimated effects (Cook et al., 2018). Effect size (ES), estimated from the ratio of the mean difference to the pooled standard deviation were also calculated. The ES magnitude was classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0) and very large (>2.0-4.0) (Hopkins et al., 2009). Within this particular context and to address the potential inflation of error rates associated with the large number of inferences in the present study, effects were declared meaningful if the point estimate for the mean difference expressed in standardised units attained threshold of moderate (ES > 0.6).

5.5 Results

5.5.1 Mesocycle

Total number of games during each of the 6 x 6-week mesocycles ranged from 6-10 (mesocycle 1 = 6; mesocycle 2 = 9; mesocycle 3 = 10; mesocycle 4 = 6; mesocycle 5 = 9, and mesocycle 6 =9). Mean daily sRPE-TL, total distance, high-speed distance and very high-speed distance across each of the 6 x 6-week mesocycles by playing position are presented in Table 5.1. A statistically significant change in all variables was observed across the six mesocyles (all $p < 0.001$). Daily sRPE-TL was higher during the early stages of the season with greater values observed in mesocycle 1 than all other mesocycles (95% CI range, 16 to 111) and greater values observed in mesocycle 2 than mesocyles 3 and 4 (95% CI range, 15 to 91 AU). Total distance was higher in mesocycles 1 and 2 than mesocycles 3, 4, and 6 (95% CI range, 179 to 949 m). Meaningful differences in high-speed distance were only observed in mesocycle 5 compared to mesocycle 4 (95% CI, 66 to 228 m) with greater very high-speed distance observed in mesocycle 2 than mesocycle 4 (95% CI, 21 to 64 m). No meaningful or statistically significant main effects of playing position or interaction between playing position and mesocycle were observed for any variable (all $p > 0.05$).

Table 5. 1 Mean ± SD weekly training and match loads during each 6-week mesocycle block for sRPE-TL, total distance, high-speed distance, and very high-speed distance.

Mesocycle, Position	sRPE-TL (AU)	Total Distance (m)	High-Speed Distance (m)	Very High-Speed Distance (m)
Mesocycle 1	**347 ± 60** $^{M, L}$	**4670 ± 662** ^{M}	**765 ± 233**	**204 ± 59**
CD	339 ± 138	4430 ± 1531	716 ± 543	206 ± 139
WD	384 ± 136	4585 ± 1520	756 ± 537	228 ± 135
CM	337 ± 96	4809 ± 1050	820 ± 367	200 ± 94
WM	322 ± 166	4762 ± 1861	850 ± 657	208 ± 165
A	351 ± 90	4762 ± 994	681 ± 350	177 ± 89
Mesocycle 2	**327 ± 60** ^{M}	**4676 ± 666** ^{M}	**815 ± 231**	**219 ± 59** ^{M}
CD	319 ± 146	4595 ± 1612	766 ± 564	162 ± 145
WD	331 ± 136	4608 ± 1489	833 ± 518	241 ± 132
CM	332 ± 100	4788 ± 1112	823 ± 386	203 ± 98
WM	314 ± 160	4557 ± 1771	838 ± 612	248 ± 156
A	341 ± 91	4831 ± 1026	817 ± 358	243 ± 91
Mesocycle 3	**291 ± 59**	**4242 ± 647**	**727 ± 225**	**192 ± 58**
CD	274 ± 134	3949 ± 1450	616 ± 508	150 ± 130
WD	306 ± 128	4216 ± 1407	653 ± 487	187 ± 123
CM	296 ± 101	4226 ± 1101	689 ± 383	181 ± 99
WM	249 ± 169	4162 ± 1860	845 ± 650	226 ± 168
A	330 ± 91	4659 ± 1017	830 ± 356	214 ± 91
Mesocycle 4	**258 ± 58** ^{M}	**3960 ± 621** ^{M}	**695 ± 216**	**177 ± 56**
CD	251 ± 129	3733 ± 1389	626 ± 486	156 ± 126
WD	270 ± 128	3977 ± 1378	644 ± 480	162 ± 123
CM	262 ± 95	3960 ± 1027	711 ± 356	174 ± 92
WM	216 ± 156	3814 ± 1685	711 ± 587	184 ± 150
A	289 ± 97	4316 ± 1054	782 ± 372	208 ± 94
Mesocycle 5	**309 ± 57**	**4416 ± 623**	**841 ± 217** ^{M}	**185 ± 55**
CD	329 ± 124	4368 ± 1350	753 ± 471	169 ± 120
WD	318 ± 130	4323 ± 1412	731 ± 494	192 ± 125
CM	294 ± 102	4642 ± 1104	866 ± 387	187 ± 99
WM	264 ± 149	4081 ± 1616	895 ± 559	177 ± 143
A	340 ± 102	4666 ± 1123	961 ± 400	201 ± 101
Mesocycle 6	**306 ± 58**	**4193 ± 653**	**821 ± 228**	**207 ± 58**
CD	308 ± 127	3947 ± 1389	746 ± 485	190 ± 124
WD	320 ± 126	4231 ± 1426	834 ± 499	228 ± 127
CM	303 ± 103	4191 ± 1166	839 ± 411	204 ± 104
WM	238 ± 160	4111 ± 1796	800 ± 627	180 ± 158
A	364 ± 101	4487 ± 1171	887 ± 414	231 ± 105

Subscripts denote moderate (M), large (L), and very large (V). *sRPE-TL:* **Mesocycle 1**; M *vs.* mesocycles 3, 5, 6. L *vs.* mesocycle 4. **Mesocycle** 2; M *vs.* mesocycles 3 and 4. **Mesocycle 4**; M *vs.* mesocycles 5 and 6. *Total Distance:* **Mesocycle 1**; M *vs.* mesocycles 3, 4, 6. **Mesocycle 2**; M *vs.* mesocycles 3, 4, 6. **Mesocycle 4**; M *vs.* mesocycle 5. *High-Speed distance:* **Mesocycle 5**; M *vs.* mesocycle 4. *Very High-Speed Distance:* **Mesocycle 2**; M *vs.* mesocycle 4.

5.5.2 Day Type

Mean daily sRPE-TL, total distance, total high-speed distance and total very high-speed distance across all day types are represented in Figures 5.3–5.6. No meaningful or statistically significant main effect of playing position were observed for any variable ($p > 0.05$). There was a statistically significant main effect of day-type for all variables (all $p < 0.001$). sRPE-TL (MD vs. other days: 95% CI range, 208 to 409 AU; G-1 vs. other days: 95% CI range, -409 to -47 AU), total distance (MD vs. other days: 95% CI range, 4188 to 6069 m; G-1 vs. other days: 95% CI range, -6070 to -430 m), total high-speed distance (MD vs. other days: 95% CI range, 1466 to 1875 AU; G-1 vs. other days: 95% CI range, -1875 to -35 m) and total very high-speed distance (MD vs. other days: 95% CI range, 425 to 542 AU; G-1 vs. other days: 95% CI range, -542 to -20 m) were higher on MD and lower on G-1 compared to all other days. sRPE-TL (~70-90 AU per day) and total distance (~700-800 m per day) progressively reduced over the three days before a match ($p < 0.001$). High-speed distance was greater on G-3 than G-1 (95% CI, 140 to 336 m) and very high-speed distance was greater on G-3 and G-2 vs. G-1 (95% CI range, 8 to 62 m; $p < 0.001$).

There was a statistically significant interaction between day-type and playing position for all variables predominantly reflecting positional differences on MD (all $p < 0.001$). During training, sRPE-TL was lower in WM than WD on G-3 (95% CI, -208 to -18 AU). sRPE-TL was higher in A than WD and CM on G-2 (95% CI range, -29 to 129 AU) and higher than all other positions on G-1 (95% CI range, -2 to 156 AU). Attackers covered greater total distance than on CD and WD on G-1 (95% CI range, 102 to 1387 m). Differences in high-speed activity between positions were only observed on MD.

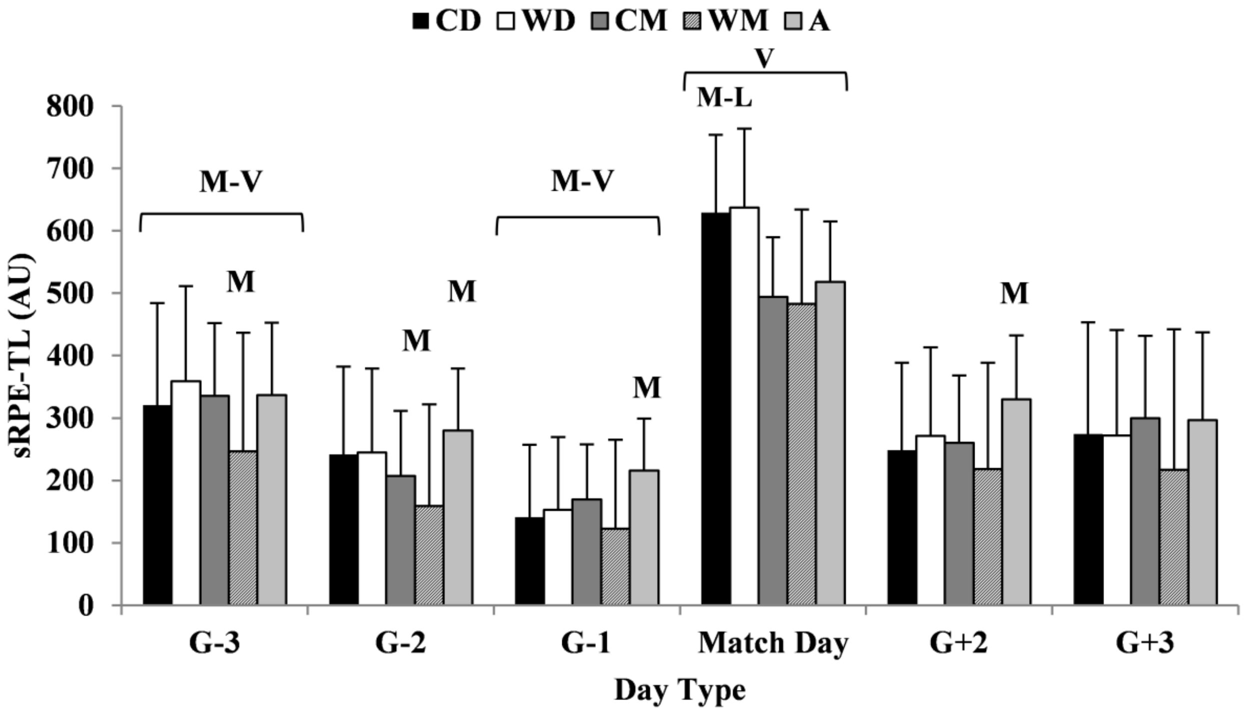


Figure 5. 3 Mean ± SD sRPE-TL for training day's pre- and post-competitive match and match-day between positions. Subscripts denote moderate (M), large (L), and very large (V). *Day Type*: **G-3;** L *vs.* G-2, V *vs.* G-1, M *vs.* G+2 and G+3. **G-1;** V *vs.* G-3, M *vs.* G-2, L *vs.* G+2, and G+3. **MD;** V *vs.* G-3, G-2, G-1, G+2 and G+3. *Day Type x Playing Position:* **G-3; WM,** M *vs.* WD. G-2; A, M *vs.* WM and CM. **G-1; A,** M *vs.* CD, WD, and WM. **MD; CD,** L *vs.* CM, M *vs.* WM and A. **WD,** L *vs.* CM, M *vs.* WM and A. **G+2; A,** M *vs.* CD, CM, and WM

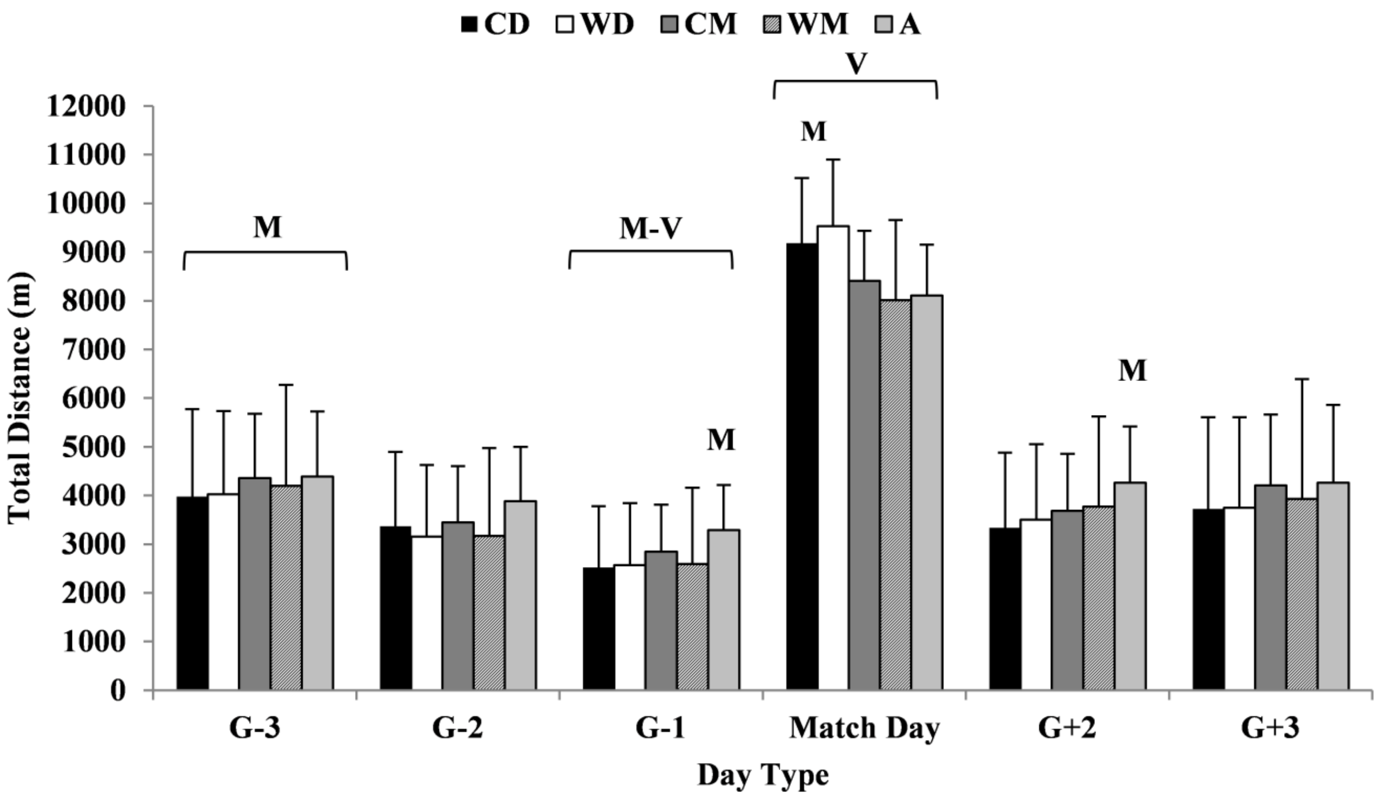


Figure 5. 4 Mean ± SD total distance for training day's pre- and post-competitive match and match day between positions. Subscripts denote moderate (M), large (L), and very large (V). *Day Type*: **G-3;** M *vs.* G-2 and G+2. **G-1;** V *vs.* G-3, M *vs.* G-2, L *vs.* G+2 and G+3. **MD;** V *vs.* G-3, G-2, G-1, G+2, and G+3. *Day Type x Playing Position:* **G-1; A,** M *vs.* CD and WD. **MD; CD,** M *vs.* CM, WM, and A. **WD,** M *vs.* CM, WM, and A. **G+2; A,** M *vs.* CD.

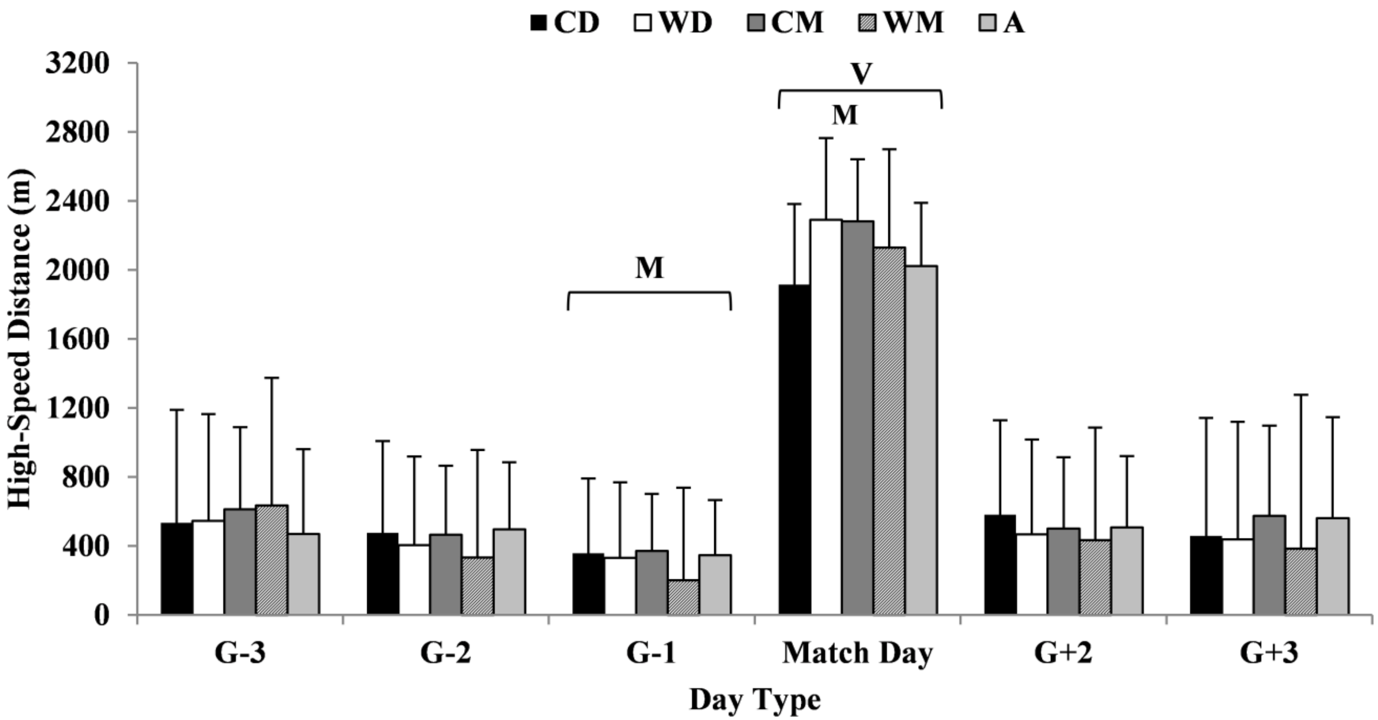


Figure 5. 5 Mean ± SD total high-speed distance for training day's pre- and post-competitive match and match day between positions. Subscripts denote (M), large (L), and very large (V). Day Type: **G-1;** M *vs.* G-3, G+2 and G+3. **MD;** V *vs.* G-3, G-2, G-1, G+2, and G+3. *Day Type x Playing Position:* **MD; WD,** M *vs.* CD and A. **CM,** M *vs.* CD and A.

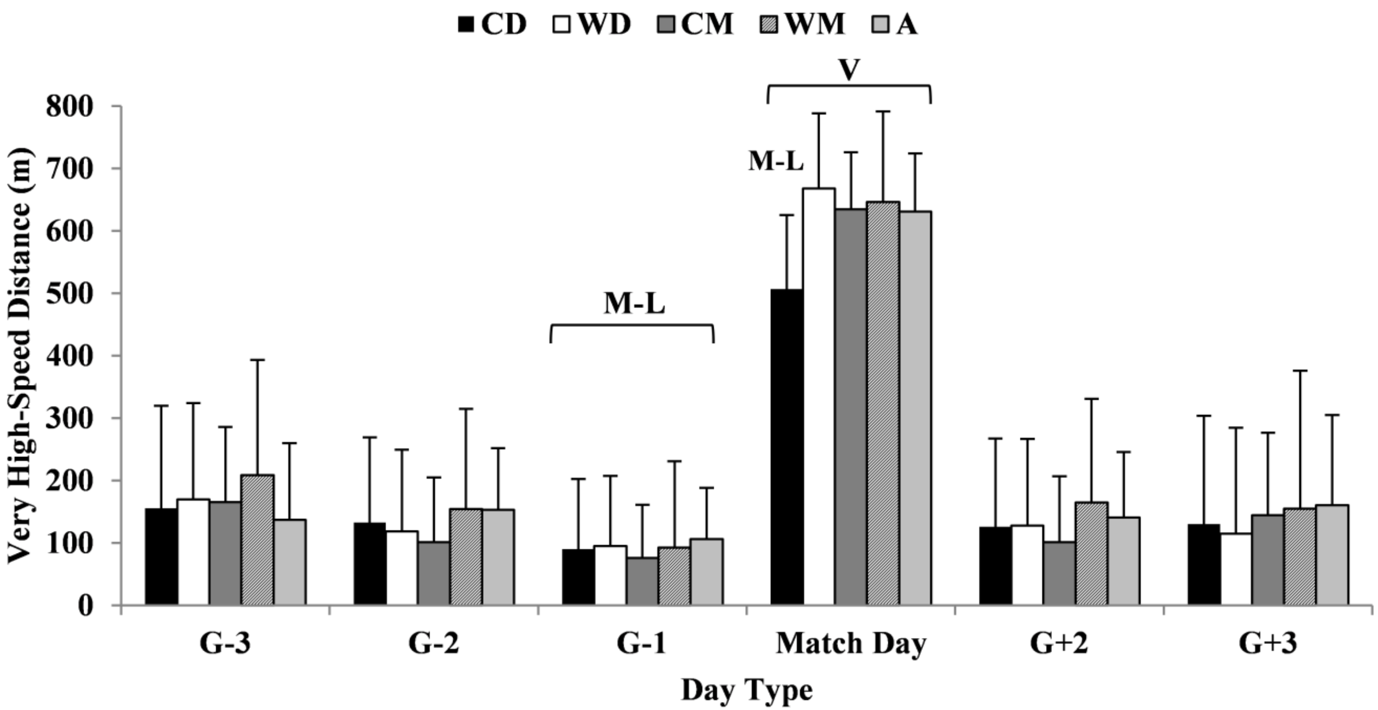


Figure 5. 6 Mean ± SD total very high-speed distance for training day's pre- and post-competitive match and match day between positions. Subscripts denote moderate (M), large (L), and very large (V). *Day Type*: **G-1;** L *vs*. G-3, M *vs*. G-2, G+2, and G+3. **MD;** V *vs*. G-3, G-2, G-1, G+2, and G+3. *Day Type x Playing Position:* **MD; CD,** L *vs.* WD and CM, M *vs.* WM and A.

5.6 Discussion

The aim of the current study was to examine the external and internal load incurred by elite soccer players across both the larger and smaller units of the annual competition period. Across the competition period there was limited variation in loading between the mesocycles with similar loads observed between playing positions. In contrast, marked fluctuations in external and internal load were evident within the weekly microcycle phase which was further influenced by playing position. This was generally characterised by a post-match recovery day (low load) followed by an increase in loading (G+2 through to G+3 and G-3) and subsequent taper through G-2, and G-1. The findings of the present study provide novel insights into the training periodisation undertaken by an elite English Premier League team during a championship winning season. Further studies of this type are required to enable a more comprehensive examination and subsequent development of the training methodologies adopted by elite coaches.

In the present study, total distance and sRPE-TL were ∼470 m (95 % CI, 228 to 724 m), and 40 AU (95 % CI, 19 to 62 AU) higher at the start of the competitive phase (mesocycle 1) versus the end (mesocycle 6), respectively. These changes in total distance are lower than those previously observed by Malone and colleagues (2015), where players covered ~1300 m more total distance in mesocycle 1 than mesocycle 6. Mean daily total distance (95 % CI, 472 to 947 m), sRPE-TL (95 % CI, 67 to 111 AU) and high-speed distance (95 % CI, -19 to 159 m) were also ∼700 m, 90 AU and 70 m higher, respectively, at the start of the season (mesocycle 1) compared with mid-season (mesocycle 4) across all positions in the present study. Greater training loads at the beginning of the in-season competitive phase may often reflect the coaches' desire to maintain the emphasis on the development of fitness levels following the pre-season training period (Malone et al., 2015).

The middle phase of the season (mesocycle 4 [mid-December]) is associated with the lead into the Christmas period, which typically has a highly congested fixture schedule in the English Premier League. We presently observed the highest number of matches (*n* = 7) and the greatest average number of training session observations 62 (range: [*n*], 40-62) during this period. However, the average training session duration (48 ± 5 min) was greatly reduced across December compared to all other periods of the season which resulted in the lowest sRPE-TL, total distance, high-speed distance, and very high-speed distances. These changes were consistent with the strategy employed by the head coach which aimed to offset the increased frequency of matches by reducing training induced fatigue in order to maintain match readiness. Our findings are in-line with Malone and colleagues (2015) who also reported reductions in training volume during the mid-season phase, whereby sRPE-TL was lower by ~80 AU across this period.

Training load prescription in soccer is largely influenced by the competition frequency, with in-season microcycles of typically 3 to 7 days in duration repeatedly occurring around matches (Morgans et al., 2014; Malone et al., 2015; Akenhead et al., 2016). sRPE-TL (~70-90 AU per day) and total distance (~700-800 m per day) progressively reduced over the three days before a match. High-speed distance was also greater on G-3 than G-1 (95% CI, 140-336 m) and very high-speed distance was greater on G-3 and G-2 *vs.* G-1. The higher training loads observed on G-3 reflected training sessions incorporating drills undertaken on larger pitch sizes (i.e. extensive endurance position-specific practices) with a greater number of players (7 *v* 7 – 11 *v*

11). More intensive endurance drills were undertaken in smaller training areas with a reduced number of players (e.g. 3 *v* 2, 5 *v* 4, and 1 *v* 1 – 3 *v* 3) as part of training sessions undertaken on G-2. The aim of these training sessions was to elicit intensities deemed suitable to produce the physiological adaptations required for soccer-specific endurance (Little and Williams, 2006) while simultaneously aiding the development of technical and tactical skills similar to situations experienced during the game. All variables were lowest on G-1 as a consequence of the implementation of lower intensity and shorter training sessions the day before a match, consisting mainly of activation and reactive speed training type drills. The decline in daily load from G-3 to G-1 in the current study is in agreement with recent observations in Spanish La Liga reserve team players who showed a marked reduction in total distance (~3000 m) and high-speed distance (~170 m) across the three-day period (Martin-Garcia et al., 2018). In contrast, Malone and colleagues (2015) reported greater high-speed distances on G-1 than G-2 in English Premier League players. The rationale for this approach was not reported by the authors, however, it would seem counterproductive and contrary to 'tapering' approaches previously discussed in the literature (Owen et al., 2017). Reducing training load on the day preceding a competitive match may enhance the capability of significantly decreasing physical stressors upon players, whilst leading to reductions in an accumulative fatigue response (Owen et al., 2017).

The present findings demonstrate that a gradual reduction in external and internal load across the three-day period leading into a game may constitute an important element of training periodisation adopted in the elite game. The 'three-day' pre-match tapering strategy facilitates the gradual 'unloading' of players which will serve to increase player readiness for the game. It is acknowledged that this type of three-day load reduction approach does not concur with the traditional tapering strategies reported for individual sports, whereby training load is typically reduced over the course of 7 to 28 days pre-competition (Mujika et al., 2004). This may be a consequence of several factors. A congested and 'ever changing' fixture schedule restricts the amount of time available to fully prepare players, making a 'one-size global approach' to periodisation unfeasible within elite soccer. There is also the need for constant flexibility to allow for the management of playing times, demanding travel schedules, and individual player 'micro-management'.

Training and match load in the current study showed limited variation between playing positions across the season's six mesocycles. This likely reflected the inclusion of match data in the analysis which may have masked any potential differences in training load per se. Analysis of the loading patterns during the weekly microcycle training days in the present study provides a more precise comparison of positional loads. For example, sRPE-TL was lower in wide midfielders than wide defenders on G-3 while attackers reported higher sRPE-TL on G-2 *vs.* wide and central midfielders and higher sRPE-TL compared with all other positions on G-1. Attacking players also covered ~600 m and ~650 m more total distance compared to CD and WD, respectively, on G-1. In contrast to the present observations, in English Premier League players, Malone et al. (2015) reported limited positional differences in the days leading into a game. In Spanish reserve team players, Martin-Garcia and colleagues (2018) reported the highest total distance in central and offensive midfielders during the three-day lead into competition whilst wide defenders covered the greatest high-speed running distance during the same period. Collectively, these positional differences likely reflect the diversity in training strategies adopted by different coaching teams which are often driven by the head coach (Akenhead and Nassis, 2016; Weston, 2018).

The establishment of a meaningful practically important difference for external load markers is difficult to derive, as there are complexities associated with translating how a change in a given performance variable influences 'real world' overall performance, especially in team sports (Atkinson, 2003). In the current study, we observed differences of ~700 m. ~150 m, and ~40 m in total distance, high-speed distance, and very high-speed distance across the mesocycle training phases, respectively. The difference in load observed across the mesocycles periods represented ~15% of the average total distance (~4200 m), ~25% high-speed distance (560 m) and ~25% very high-speed distance (~160 m) covered during the microcycle phases. In this context, these data suggest the magnitude of changes in loads prescribed between training cycles may not be insignificant and could be practically important from a training adaptation and associated performance perspective. The extent to which these differences might have a 'real world' impact in elite soccer training needs further examination. Future work is required to examine dose-response relationships in the context of soccer-specific training cycles using markers of adaptation, performance, and injury occurrence as outcome measures.

In summary, this study has systematically quantified the training and match loads employed by an English Premier League club during a championship winning season. There was limited variation in training load across the mesocycle periods which is suggestive that training schedules employed in elite soccer may be highly repetitive and likely reflect the competition demands. Periodisation of training load was evident within the weekly microcycle, particularly in the three-day period leading into competition, reflecting the head coach's approach to match recovery and preparation across the annual training cycle. Further research is needed to expand our understanding of the loads encountered by elite players and the different periodisation models adopted by coaching teams.

CHAPTER 6: A COMPARISON OF TRAINING-LOAD DISTRIBUTION IN ELITE ENGLISH PREMIER LEAGUE SOCCER PLAYERS UNDER TWO DIFFERENT COACHING APPROACHES

6. A Comparison of Training-Load Distribution in Elite English Premier League Soccer Players Under Two Different Coaching Approaches

6.1 Introduction

The training periodisation framework in soccer is typically characterised by a short preparation phase followed by repeated weekly cycles across the in-season period (Malone et al., 2015; Los Arcos et al., 2017; Chapter 5). During the weekly in-season training cycles, periodisation is largely dictated by the distribution of competitive matches (Fessi et al., 2016; Martin-Garcia et al., 2018; Chapter 5) and philosophy of the head coach (Akenhead and Nassis, 2016; Weston, 2018), with individual player requirements and national team commitments further impacting upon periodisation (Fessi et al., 2016). Irrespective of the strategy adopted, the overriding aim of the training programme is to ensure players are able to cope with the increasing physical demands elicited by the modern game while reducing susceptibility to injury (Barnes et al., 2014; Martin-Garcia et al., 2018; Gregson et al., 2019).

Recent attention has centred on examining the training periodisation models adopted by elite soccer teams. English Premier League teams showed limited variation in mean daily training load across 6-week mesocycles during the in-season competition period (Malone et al., 2015; Anderson et al., 2016; Chapter 5). In contrast, different training periodisation strategies emerge when examining the repeated weekly microcyles in elite English Premier League (Malone et al., 2015; Chapter 5), Spanish La Liga reserve (Los Arcos et al., 2017; Martin-Garcia et al., 2018), and Dutch Eredivisie teams (Stevens et al., 2017). These strategies range from a progressive reduction in training volume and intensity over the three days leading into a match

(Los Arcos et al., 2017; Stevens et al., 2017; Martin-Garcia et al., 2018; Chapter 5) to approaches where the volume of high-speed running is greater the day before a match versus two days prior (Malone et al., 2015).

A recent survey of elite English soccer clubs suggests the head coach is largely responsible for the planning of team training (Weston, 2018). In the modern game, there appears to have been a shift towards a more frequent turnover of head coach, as clubs endeavour to achieve expeditious success. Regularly changing the head coach may, however, impact on the periodisation strategies adopted as a consequence of the personal philosophies employed. Thus, variation in weekly periodisation models observed in elite soccer likely represent a combination of evolving coaching philosophies together with the application of the latest scientific knowledge (Morgans et al., 2014; Akenhead and Nassis, 2016; Weston, 2018). Recent observations on the periodisation models adopted in elite soccer have enhanced or understanding of the nature of strategies employed by elite teams. The use of different players, standards of play, together with different GPS technologies and training thresholds has, however, limited our ability to understand the degree to which different periodisation strategies may influence the training load imposed on elite players. Examining the loads experienced by the same group of elite players wearing the same technology under different coaching philosophies, would further our understanding regarding the degree to which different periodisation models influence player loading. Such study designs would also provide a basis for examining how different periodisation models may influence important outcomes including player recovery and the incidence of injury.

To our knowledge, no study to date has examined the influence of different training philosophies on the training load experienced by a group of elite players. Therefore, the aim of the current investigation was to quantify the external and internal training load distribution across two successive in-season competition periods at an English Premier League club overseen by two different head coaches.

6.2 Methods

6.2.1 Participants

The same 20 elite-level English Premier League players were monitored across a 36-week competition phase of the 2012-2013 (season 1) and 2013-2014 (season 2) seasons (mean ± SD: age 27 ± 4.6 years, body mass 79 ± 6.9 kg, height 181 ± 7.2 cm).

6.2.2 Experimental Design

Training load data collection were carried out as described in Chapter 3 section 3.2.

6.2.3 Day Type Analyses

Training load data were collected during the 36-week competition phase of the 2012-13 and 2013-14 seasons and were categorised into weekly blocks (Sunday to Sunday) to allow for the full analysis of each season’s training load. Training days (day type) were classified in relation to their proximity to the forthcoming competitive game. One day before the game was classified as game day (G) minus one (G-1), whereas G+3 was categorised as the third day post-match. Four core training day types were identified for the analysis (G+3, G-3, G-2, G-1). The two days immediately following a match (i.e. G+1, G+2) were excluded from the analysis as these were either a day off from training, or were identified as recovery days which were inclusive of a reduced load, non-weight bearing recovery strategy, and thus were not fully representative of normalised training days.

6.2.4 Mesocycle Analyses

Mesocycle analyses were carried out as described in Chapter 3 section 3.2.

6.3 Methodology

6.3.1 Internal Training Load Assessment

Session Ratings of Perceived Exertion (sRPE)

The sRPE training load (sRPE-TL) were measured as described in Chapter 3 section 3.3.

6.3.2 External Training Load Assessment

Global Positioning System (GPS)

External training load was measured for all players using portable micro-technology (GPSports SPI Pro X, Canberra, Australia) as described in Chapter 3 section 3.3.

6.3.3 Training Load Data Collection

All training sessions and competitive matches during the 2012-13 and 2013-14 seasons were observed and subsequently recorded. The mean number of training sessions completed, and the average match observations during each month for season 1 (n = 5) and season 2 (n = 4) are shown in Figure 6.1. A total of 49 and 34 competitive games were observed across the 36-week competition phase of the 2012-13 and 2013-14 seasons, respectively.

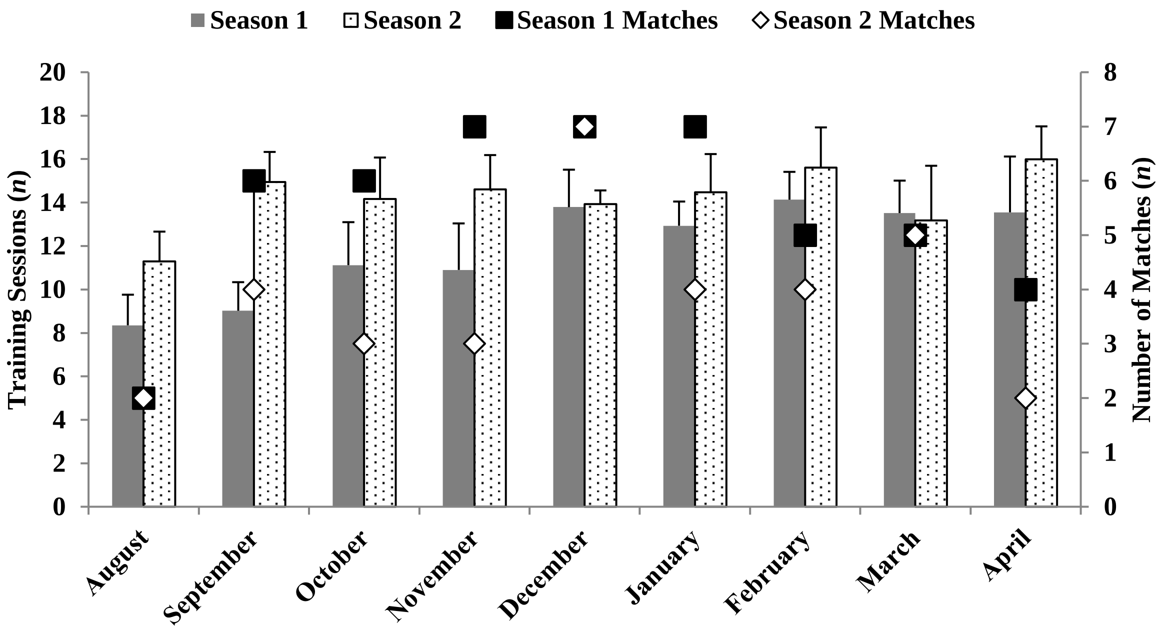


Figure 6. 1 Mean ± SD number of training sessions completed and distribution of competitive games during the 2012-13 and 2013-14 seasons.

6.4 Statistical Analysis

Data are represented as means ± S.D. A multi-factorial linear mixed model was used to quantify mean differences between mesocycles, day-type and playing position. Use of linear mixed-modelling is suitable to examine repeated-measures data and unbalanced observations over time as, for example, in the context of our study where players differ in the number of training sessions and matches (Cnaan et al., 1997). Linear mixed modelling can also cope with the mixture of random and fixed level effects (Cnaan et al., 1997) as well as with missing and 'nested' data (hierarchical models). The main effects for sub-group comparisons of each factor were summarised using least significance difference (LSD) multiple contrasts (Perneger, 1998).

Mean differences are presented with 95% confidence intervals (Cl) as markers of uncertainty in the estimates. In the absence of an established anchor, despite the lack of real-world relevance of standardised effect sizes (Lenth, 2001), Cohen's d was reported as an additional statistic for interpreting the magnitude of the estimated effects (Cook et al., 2018). Effect size (ES), estimated from the ratio of the mean difference to the pooled standard deviation were also calculated. The ES magnitude was classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0) and very large (>2.0-4.0) (Hopkins et al., 2009). Within this particular context and to address the potential inflation of error rates associated with the large number of inferences in the present study, effects were declared meaningful if the point estimate for the mean difference expressed in standardised units attained threshold of moderate (ES >0.6).

6.5 Results

Mean daily ± SD training minutes (season 1 *vs.* season 2: 95% CI range, 0.4 to 3.6 min) were significantly higher across season 1 versus season 2 ($p < 0.05$). In contrast, sRPE-TL (95% CI range, 231 to 274 AU), total distance (95% CI range, 3462 to 4392 m), high-speed distance (95% CI range, 455 to 657 m), very high-speed distance (95% CI range, 119 to 178 m) and number of accelerations (95% CI range, 18 to 25) and decelerations (95% CI range, 24 to 29) were significantly greater across season 2 versus season 1 (all $p < 0.05$). There was a higher frequency of competitive matches in season 1 ($n = 49$) than season 2 ($n = 34$). Mean match high-speed distance covered was also 159 ± 79 m higher in season 1 (2334 ± 961 m) compared with season 2 (2175 ± 907 m; 95% CI range, 57 to 261 m; $p < 0.05$).

6.5.1 Mesocycle

Mean daily ± SD training duration, sRPE-TL, total distance, high-speed distance, very high-speed distance, acceleration, and deceleration values across the 6x6-week mesocycles for season 1 and season 2 are presented in Table 6.1. There was a significant interaction between season and mesocycle for all variables (all $p < 0.05$). Daily training minutes were higher across mesocycles 1 and 2 in season 1 versus season 2 (95% CI range, 1.2 to 13.6 min), with greater values observed in mesocycle 4 during season 2 compared with season 1 (95% CI range, 1.0 to 7.6 AU). Daily training sRPE-TL was greater in mesocycle 4 during season 2 versus season 1 (95% CI range, 30 to 73 AU). Total distance was greater in mesocycles 2 to 6 (95% CI range, 282 to 1241 m) during season 2 compared with season 1. Similarly, high-speed distance (95% CI range, 34 to 318 m) and very high-speed distance (95% CI range, 21 to 87 m) were greater during mesocycles 1, 3, 4, and 5 in season 2 versus season 1. The number of accelerations was higher during mesocycles 1, 2, 4, 5, and 6 in season 2 (95% CI range, 12 to 28), with a greater number of decelerations observed in season 2 across mesocycles 1, 4, and 5 (95% CI range, 17 to 33).

Table 6. 1 Mean ± SD daily training loads (season 1 and 2) during each 6-week mesocycle block for training duration, sRPE-TL, total distance, high-speed distance, very high-speed distance, accelerations, and decelerations.

Mesocycle	**Training Duration (min)**		**sRPE-TL (AU)**		**Total Distance (m)**		**High-Speed Distance (m)**		**Very High-Speed Distance (m)**		**Accelerations (*n*)**		**Decelerations (*n*)**	
	Season 1	***Season 2***	***Season 1***	***Season 2***	***Season 1***	***Season 2***	***Season 1***	***Season 2***	***Season 1***	***Season 2***	***Season 1***	***Season 2***	***Season 1***	***Season 2***
1	68 ± 7^{M}	63 ± 6	272 ± 54	271 ± 48	3975 ± 600	4315 ± 528	516 ± 152	687 ± 132^{M}	145 ± 48	188 ± 42^{M}	20 ± 4	24 ± 4^{M}	27 ± 5	30 ± 4^{M}
2	71 ± 8^{L}	61 ± 6	281 ± 57	271 ± 49	3887 ± 673	4500 ± 538^{M}	539 ± 164	636 ± 135	140 ± 53	161 ± 43	19 ± 5	24 ± 4^{M}	26 ± 6	28 ± 4
3	62 ± 7	61 ± 6	247 ± 55	267 ± 49	3610 ± 627	4380 ± 537^{L}	464 ± 156	670 ± 134^{L}	122 ± 50	185 ± 43^{L}	20 ± 5	22 ± 4	26 ± 5	26 ± 4
4	53 ± 6	57 ± 6^{M}	187 ± 50	239 ± 49^{M}	3027 ± 546	4017 ± 533^{L}	370 ± 137	622 ± 133^{L}	96 ± 44	143 ± 42^{M}	14 ± 4	23 ± 4^{V}	19 ± 4	27 ± 4^{L}
5	64 ± 6	62 ± 7	249 ± 50	262 ± 53	3678 ± 550	4256 ± 569^{M}	452 ± 138	556 ± 143^{M}	125 ± 44	179 ± 45^{M}	19 ± 4	25 ± 4^{L}	25 ± 5	31± 5^{M}
6	60 ± 6	62 ± 6	237 ± 50	250 ± 49	3512 ± 575	4054 ± 533^{M}	605 ± 145	579 ± 133	157 ± 46	150 ± 42	20 ± 5	27 ± 4^{L}	27 ± 5	29 ± 4

Subscripts denote moderate (M), large (L), and very large (V). *Training Duration:* **Mesocycle 1 [season 1]**; M *vs.* season 2; **Mesocycle 2;** L *vs.* season 2; **Mesocycle 4 [season 2]**; M *vs.* season 1. *sRPE-TL:* **Mesocycle 4 [season 2]**; M *vs.* season 1. *Total Distance:* **Mesocycle 2, 5, and 6 [season 2]**; M *vs.* season 1. **Mesocycle 3 and 4 [season 2];** L *vs.* season 1. *High-Speed Distance:* **Mesocycle 1 and 5 [season 2];** M *vs.* season 1. **Mesocycle 3 and 4 [season 2];** L *vs.* season 1. *Very High-Speed Distance:* **Mesocycle 1, 4, and 5 [season 2];** M *vs.* season 1. **Mesocycle 3 [season 2];** L *vs.* season 1. *Accelerations***:** **Mesocycle 1 and 2 [season 2];** M *vs.* season 1. **Mesocycle 4 [season 2];** V *vs.* season 1. **Mesocycles 5 and 6 [season 2];** L *vs.* season 1. *Decelerations:* **Mesocycle 1 and 5 [season 2];** M *vs.* season 1. **Mesocycle 4 [season 2];** L *vs.* season 1.

6.5.2 Day Type

Mean daily ± SD training load data across the four-day types are presented in Figures 6.2 – 6.8. There was a statistically significant interaction between season and day type for all variables (all $p < 0.001$). Daily ± SD training minutes were higher on G-3 (95% CI range, 6.0 to 12.8 min) in season 1 versus season 2 but were significantly elevated on G-1 (95% CI range, 0.7 to 5.0 min) in season 2 compared with season 1 (all $p < 0.05$). sRPE-TL was greater on G+3 (95% CI range, 71 to 124 AU) in season 2 versus season 1. Total distance was greater on G+3, G-3, and G-1 in season 2 versus season 1 (95% CI range, 147 to 1718 m). High-speed distance (95% CI range, 151 to 461 m), and very high-speed distance covered (95% CI range, 31 to 135 m) were greater on G+3 and G-3 during season 2 versus season 1 (all $p < 0.001$). Number of accelerations was higher across all day types in season 2 than season 1 (95% CI range, 13 to 30), with a greater number of decelerations observed on G-3, G-2, and G-1 in season 2 compared with season 1 (95% CI range, 18 – 35 [*n*]).

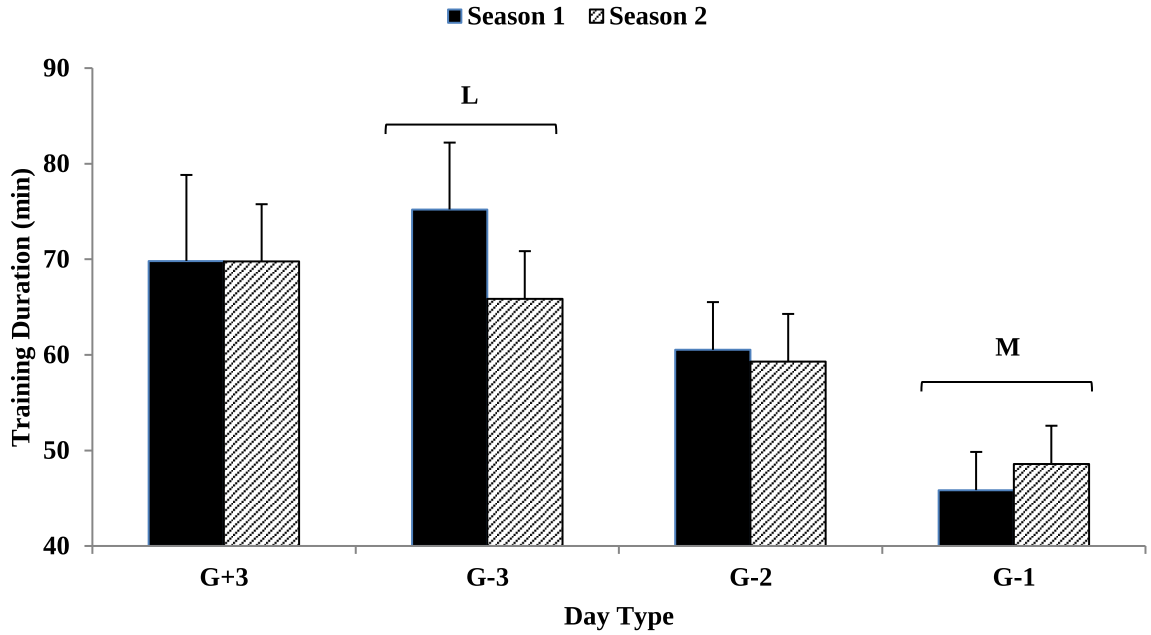


Figure 6. 2 Mean ± SD session duration (min) for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 1 *vs.* season 2:** L *vs.* G-3. **Season 2 *vs.* season 1:** M *vs.* G-1.

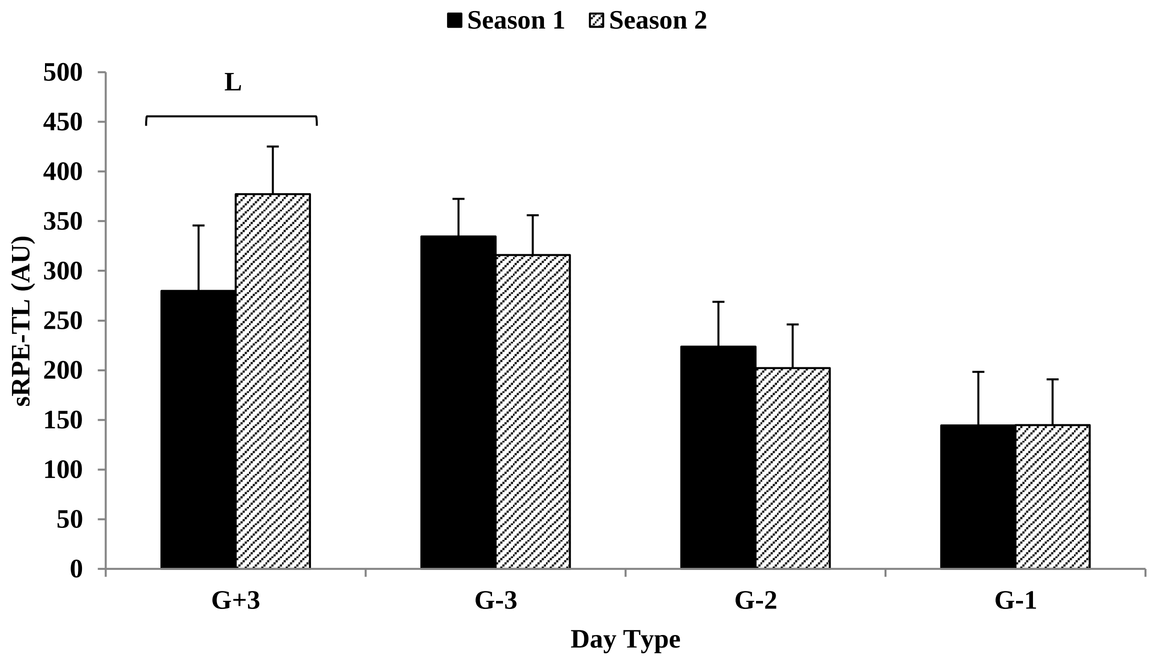


Figure 6. 3 Mean ± SD sRPE-TL values for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 2 *vs.* season 1:** L *vs.* G+3.

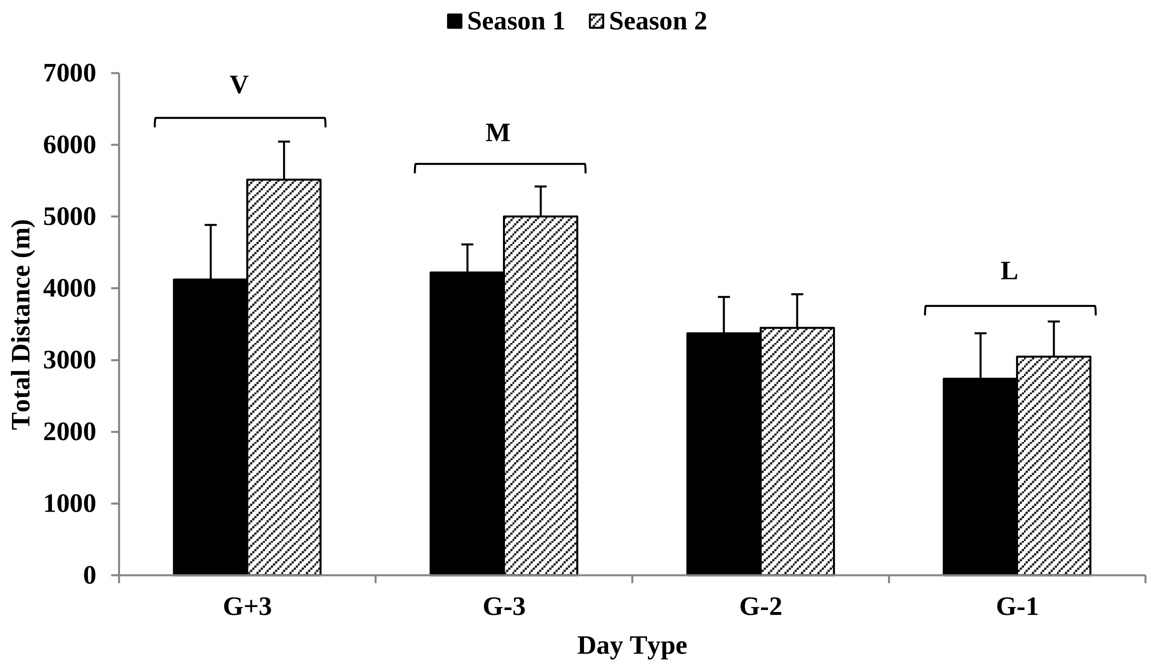


Figure 6. 4 Mean ± SD total distance for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 2 *vs.* season 1:** V *vs.* G+3. M *vs.* G-3. L *vs.* G-1.

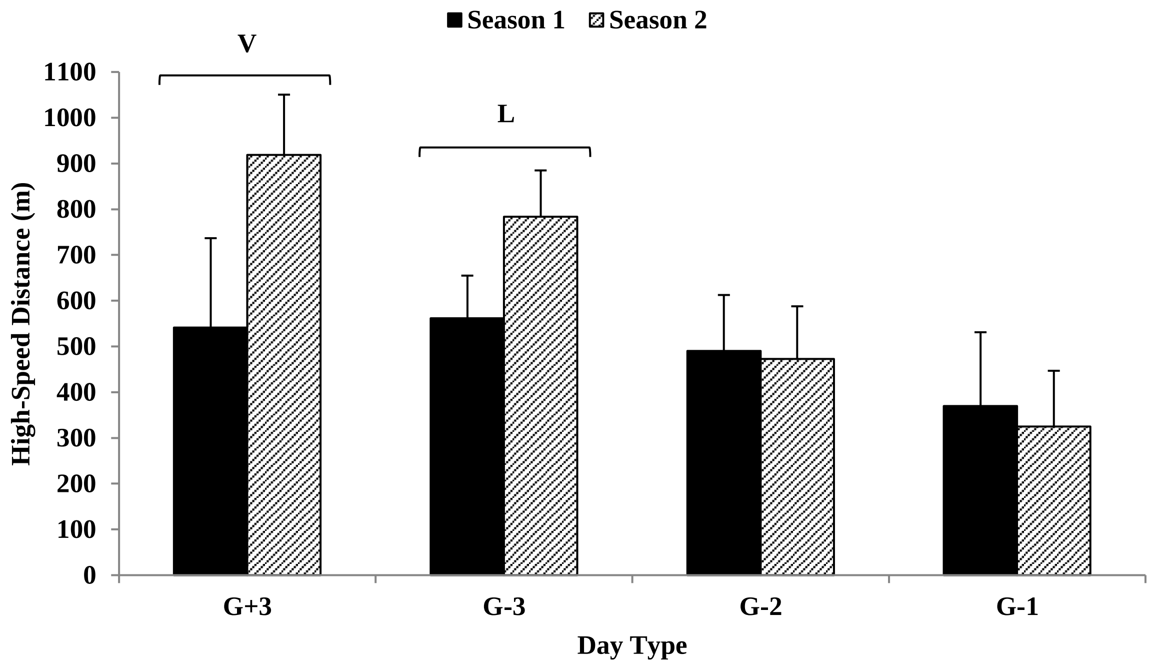


Figure 6. 5 Mean ± SD total high-speed distance for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 2 *vs.* season 1:** V *vs.* G+3. L *vs.* G-3.

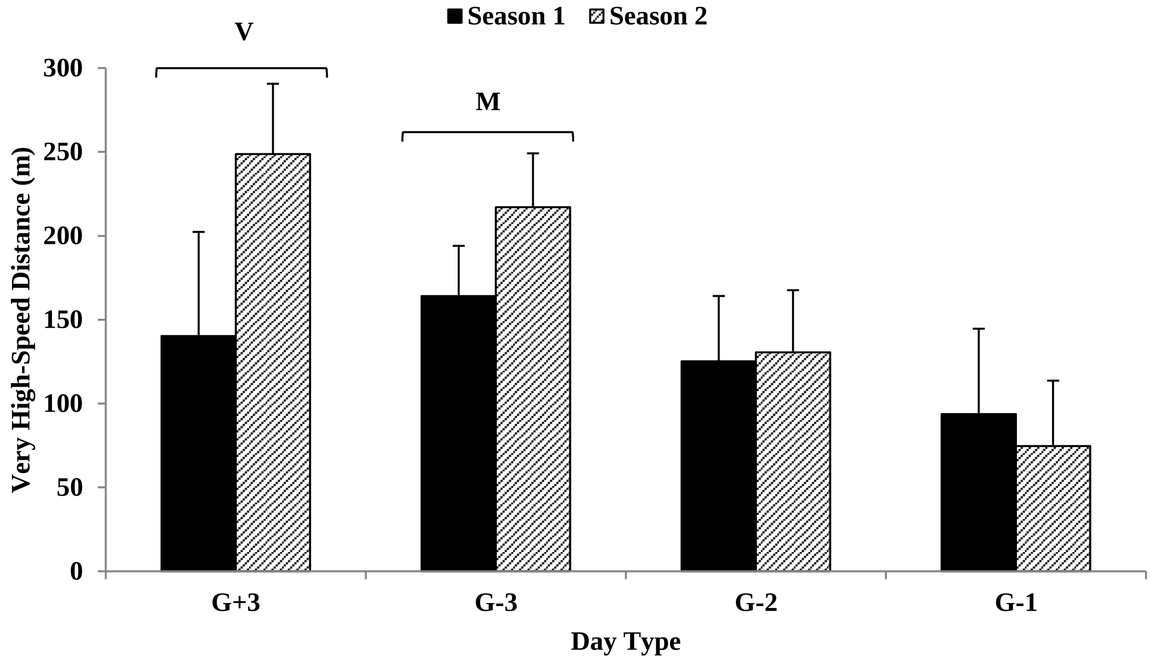


Figure 6. 6 Mean ± SD total very high-speed distance for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 2 *vs.* season 1:** V *vs.* G+3. M *vs.* G-3.

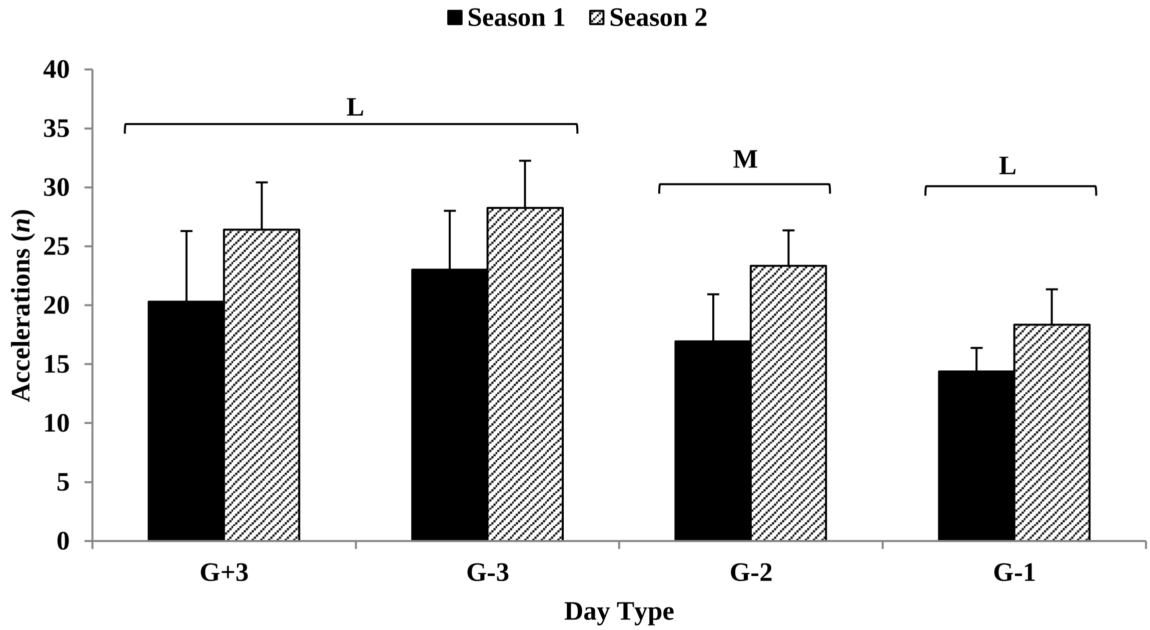


Figure 6. 7 Mean ± SD number of accelerations for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 2 *vs.* season 1:** L *vs.* G+3, G-3, and G-1. M *vs.* G-2.

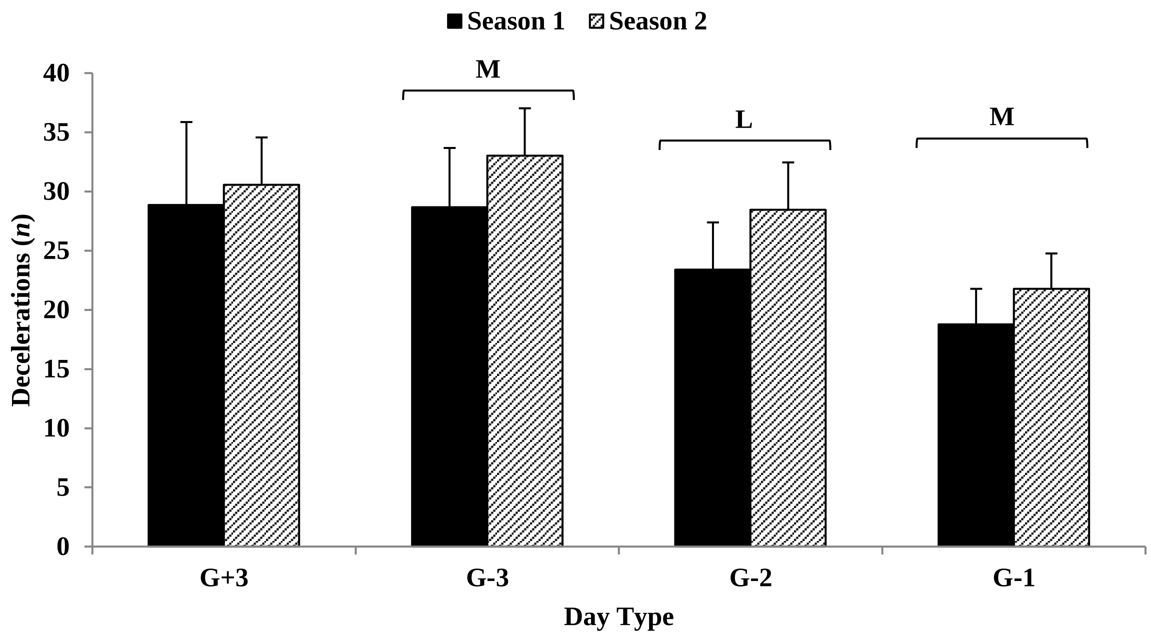


Figure 6. 8 Mean ± SD number of decelerations for training days across the two observed competitive seasons. Subscripts denote moderate (M), large (L), and very large (V). **Season 2 *vs.* season 1:** M *vs.* G-3 and G-1. L *vs.* G-2.

6.6 Discussion

To our knowledge, this is the first study to examine the influence of coaching philosophy on the training load experienced by the same group of elite players. Match high-speed running distance was higher in season 1 than season 2, with a greater frequency of games also observed in season 1 (n = 49) compared with season 2 (n = 34). Mean daily training minutes was also higher in season 1 than season 2, with all other training load variables greater in season 2 compared with season 1. The weekly microcycle phase across both seasons was characterised by a progressive decrease in training volume and intensity during the three-day period leading into a game. Training minutes were higher on G-3 in season 1 versus season 2. sRPE-TL (G+3), total distance (G+3, G-3, and G-1), high-speed distance and very high-speed distance (G+3 and G-3), accelerations (G+3, G-3, G-2, and

G-1), and decelerations (G-3, G-2, and G-1) were higher on selected days during season 2 than season 1. sRPE-TL was similar on G-3 across both seasons, despite higher external training loads elicited. The findings of the present study provide novel insights into how different periodisation strategies impact the training loads elicited by a group of elite English Premier League players. Future work is needed to understand how such modifications in training load influence player recovery and injury status.

The training load incurred by elite English Premier League players has previously been shown to demonstrate limited variation across the season (Malone et al., 2015; Chapter 5). In the present study, limited variation in seasonal loading was also evident across season 2 with small increases in sRPE-TL, high-speed and very high-speed distance observed in mesocycle 1 versus all other mesocycles. Our findings differ to recently published data in elite English Premier League players where greater total distance was observed in mesocycle 1 compared with all other 6-week blocks (Malone et al., 2015). All training load variables were lowest across mesocycle 4 in season 1 (Chapter 5), with training duration, sRPE-TL, total distance, and very high-speed distance reduced during mesocycle 4 in season 2. The middle phase of the season (mesocycle 4) was associated with the busy Christmas fixture period, with the highest frequency of competitive games (n = 7) being played in both seasons. A reduction in training load across this period reflected the coach's intention to preserve player energy levels between matches to ensure optimum physical preparation for subsequent games (Chapter 5).

In elite soccer, increased variation in training load is frequently observed across the shorter microcycles (typically 3 to 7 days), with microcycle duration largely determined by the distribution of competitive matches (Morgans et al., 2014; Malone et al., 2015;

Akenhead et al., 2016; Chapter 5). In the present study, we observed similar periodisation strategies across the three-day period leading into a game during both seasons, with training duration (~14-15 min [per day]), sRPE-TL (~110-60 AU), total distance (~1500-400 m), high-speed distance (~300-120 m), very high-speed distance (~80-30 m) and the number of accelerations (~6-3), and decelerations (~6-4) progressively declining. All training load variables were lowest on G-1 in both seasons as low-intensity, short-duration sessions consisting of activation and reactive speed training drills were implemented as part of pre-match day preparation (Clemente et al., 2019). This periodisation approach is in line with observations in Dutch Eredivisie, Spanish La Liga reserve, and players from Portugal and the Netherlands, whereby training load was gradually reduced across the three-days leading into competition (Stevens et al., 2017; Martin-Garcia et al., 2018; Clemente et al., 2019).

Despite similar progression of training load between G-3 and G-1 across both seasons, the relationship between G+3 and G-3 differed between seasons. During season 2, with the exception of accelerations and decelerations, a progressive decline in load typically occurred from G+3 to G-1 reflecting a greater emphasis on extensive endurance position--specific practices in large areas (e.g. 11 *vs.* 11) on G+3. This distribution of training load is similar to recent observations in Dutch Eredivisie, and Spanish La Liga reserve players where selected metrics (total distance, high-speed distance, and very high-speed distance) approached match-day levels on G+3 (Stevens et al., 2017; Martin-Garcia et al., 2018). During season 1, total distance, high-speed distance and very high-speed distance were similar across G+3 and G-3 reflecting the smaller playing areas adopted on G+3. Reducing the volume of high-speed running on G+3 was undertaken in an attempt to further facilitate recovery between matches whilst reducing the risk of injury through early exposure to high-speed running following a game (Owen et al., 2017; Gregson et al., 2019).

Total distance (~800 m), high-speed distance (~200 m), very high-speed distance (~50 m), and the number of accelerations (~5) and decelerations (~4) were greater on G-3 in season 2 compared with season 1. This reflected a greater focus on 11 *vs.* 11 games played in large spaces (full-size pitch areas) for a higher proportion of the training time. In contrast, during season 1, position-specific practices (7 *vs.* 7 – 11 *vs*. 11) undertaken in smaller spaces ($^3/_4$ size pitch areas) accounted for a large proportion of the training time. These findings confirm previous work which showed increasing the number of players and concomitantly the size of playing area, serves to elevate total distance covered, the frequency of high-speed running efforts, and number of accelerations and decelerations completed (Lacome et al., 2017; Olthof et al., 2018). Conversely, a reduction in pitch size limits the amount of total distance and high-speed distance covered due to the restricted space available (Gaudino et al., 2014; Gaudino et al., 2015; Lacome et al., 2017; Olthof et al., 2018).

Greater total distance (~300 m) and number of accelerations (~4) and decelerations (~3) were observed on G-1 in season 2 compared with season 1. The increased total distance and number of accelerations / decelerations were partly mediated through individualised warm-up routines (unrestricted time) and rondo-type practices (e.g. ‘overloaded’ 3 *vs*. 1, 4 *vs*. 2, 5 *vs.* 4) undertaken in bigger spaces. Likewise, possession-themed drills and small-sided games were carried out in larger areas, with tactical set-play rehearsals, and individualised technical work being completed before cessation of the training session. In contrast, G-1 training sessions in season 1 largely comprised activities carried out in smaller spaces with the specific aim of closely monitoring (and reducing) the pre-match loading volume. To achieve this, activation and reactive speed drills were carried out, and these likely reflected the slight elevation in high-speed (~45 m) and very high-speed (~19 m) distances covered, which falls into line with recently reported data in elite players on the day preceding a match (Stevens et al., 2017; Martin-Garcia et al., 2018; Clemente et al., 2019).

The measurement of relative physiological stress during training is important because this is the stimulus for the long-term adaptive response. The accurate assessment of an individuals' training load is therefore imperative for effective training prescription. In elite soccer, training load is frequently quantified according to both the external and internal loads imposed upon the individual player (Impellizzeri et al., 2004). The physiological strain resulting from the external training factors has been labelled the internal training load (Viru and Viru, 2000), which can be analysed to assess the effects of training (Casamichana et al., 2013; Scott et al., 2013b). A valid and reliable measure of internal training load is therefore essential to monitor and manipulate the training process in elite soccer.

Despite the greater external load currently observed across season 2, similar sRPE-TL values were reported across both seasons on G-3, G-2, and G-1. Between-season differences in sRPE-TL due to sRPE per se (similar training duration ~70 min) were only observed on G+3. This increase in sRPE-TL on G+3 in season 2 coincided with the greatest increase in high-speed running, very high-speed running and the number of accelerations compared to season 1. These findings are supported by previous observations in English Premier League players which showed high-speed running and frequency of accelerations are two of the three external load parameters influencing sRPE (Gaudino et al., 2015). Within-season day comparisons showed sRPE-TL was higher on G-3 than G-1, which was reflected by differences in training session duration, and not sRPE per se. More accelerations and decelerations were reported on G-3, G-2, and G-1 in season 2 as a consequence of training in larger spaces; however, the increases in high-intensity activities were not reflected in sRPE-TL (Vigne et al., 2010; Gaudino et al., 2013; Gaudino et al., 2014; Gaudino et al., 2015). Our findings suggest sRPE-TL may lack the sensitivity to accurately quantify the small changes in external load observed across the within-season day periods and might only be sensitive to large differences in external load elicited.

As an alternative, the differential ratings of perceived exertion (dRPE) has been proposed to increase the precision of estimating the internal load (McLaren et al., 2016). The dRPE serves to differentiate between central (e.g. breathlessness), and peripheral (e.g. legs) exertion signals which may enhance its ability to discriminate between highly variable external loads elicited during training and match-play (Weston, 2013; Arcos et al., 2014; Weston et al., 2015). dRPE may therefore enable a more detailed understanding of the dose-response relationship to be established (Weston et al., 2015; McLaren et al., 2017; Barrett et al., 2018). In elite soccer, the dRPE can be used to evaluate perceived central loading during large-sided games (e.g. 11 *vs.* 11) where players are afforded more space to explore resulting in greater total and high-speed distance covered, increasing the magnitude of physiological strain on the respiratory system (Clemente et al., 2018). Peripheral measures of internal load can be quantified during small-sided games, whereby a reduction in playing area serves to increase the frequency of accelerations and decelerations, increasing muscular loading on the legs (Olthof et al., 2018). Previous studies have also shown that the dRPE can be a useful tool in assessing the exertion associated with technical and tactical-based sessions, enabling players to quantify the intensity of the training tasks prescribed (Barrett et al., 2018; Coyne et al., 2018). The dRPE approach may ultimately provide a more valid insight into the internal responses to training and match-play in soccer by offering a more sensitive evaluation of the internal load elicited in elite soccer (Weston, 2013).

To our knowledge, the current study is the first to investigate the influence of different training philosophies on the training load experienced by the same group of elite players across successive seasons. In the current study, G-3, G-2, and G-1 were matched between seasons and used in the same way by the head coaches. During this three-day period, the training sessions implemented were similar between seasons, with both coaches adopting a standardised approach to preparation for competition, irrespective of the frequency of games. These observations demonstrate, whilst match congestion could have influenced training intensity to some extent, it is highly likely the differences in the coach's training philosophy played the biggest role.

These findings highlight the distribution of weekly training load during season 1 was programmed in synchrony with the competitive games schedule. Adequate 'load-reduction' and recovery sessions were integrated between matches, suggesting the coach's philosophy was predominantly based on match preparation and 'readiness to play'. In contrast, the increased training loads reported in season 2 were likely influenced by the head coach's desire to work the players harder during training sessions to compensate for the reduction in physical loads imposed as a result of playing in less competitive matches.

The present results provide an opportunity for the first time to examine the influence of different coaching philosophies on the fatigue status in the same group of elite English Premier League soccer players. Future research is needed to understand the extent to which fluctuations in the diverse periodisation strategies employed elicit ASRM responses in elite players. Examining both the variation of training loads and resultant ASRM responses across longer (multiple-season) periods, in the same population of players, represent an opportunity to further our understanding of how to optimally prepare elite players.

CHAPTER 7: INFLUENCE OF CHANGES IN TRAINING-LOAD DISTRIBUTION ON ATHLETE SELF-REPORT MEASURES (ASRM) IN ENGLISH PREMIER LEAGUE SOCCER PLAYERS

7. Influence of Changes in Training-Load Distribution on Athlete Self-Report Measures (ASRM) in English Premier League Soccer Players

7.1 Introduction

Elite soccer teams with lower injury rates have an increased chance of success in domestic and European league competitions (Hägglund et al., 2013). Injury prevention strategies are therefore central to the role of the players support team (Thorpe et al., 2017). During the training cycle, alterations made to training load frequency, duration, and intensity serve to either increase or decrease fatigue (Thorpe et al., 2017). Elite soccer players are also exposed to high competition loads on a frequent basis, which necessitates the need for sufficient recovery between games. Disproportion between training / match loads and allotted recovery time may lead to escalations in fatigue levels, resulting in an increased risk of injury and / or illness and the detrimental long-term effects associated with overtraining (Nimmo and Ekblom, 2007; Coutts et al., 2009; Kellmann, 2010; Twist and Highton, 2013; Martin-Garcia et al., 2018; Gregson et al., 2019). It is therefore important to manage player fatigue to facilitate adaptation to training while simultaneously ensuring optimal preparation for competition (Pyne and Martin, 2011).

Increasing attention in the literature has centred on developing monitoring systems to evaluate the training status of athletes (Thorpe et al., 2017). When implemented effectively, they can assist head coaches and sports scientists to better control and optimise the training process (Impellizzeri et al., 2019). In team sports, various exercise indices have been employed to assess the training status in athletes, which include neuromuscular function protocols (i.e. squat jump and countermovement jump), maximal-physical performance assessments (i.e. repeated sprints and jumps), ASRM, and a multitude of indices derived from heart-rate (e.g. submaximal heart-rate, heart-rate variability, and heart-rate recovery) (Thorpe et al., 2017). Potential monitoring tools should be simplistic, non-invasive, and time-efficient to limit interference with the player's daily training routines (Twist and Highton, 2013), as well as responsive to fluctuations in training load (Meeusen et al., 2013).

In team sports, ASRM are widely used to evaluate athlete well-being (Taylor et al., 2012; Thorpe et al., 2017; Jeffries et al., 2020b). A multitude of ASRM tools are currently employed including (TQR) (Senttä and Hassmén, 1998), (DALDA) (Coutts et al., 2007b), (REST-Q) (Coutts and Reaburn, 2008), and (POMS) (Buchheit, 2015), but these methodologies are extensive in nature and often time-consuming, making them unsuitable for use on a daily basis with multiple athletes (Thorpe et al., 2017). In team sports, ASRM have been shown to be more responsive to variations in training load compared to various objective measures (Buchheit et al., 2013; Gastin et al., 2013; Thorpe et al., 2015; Saw et al., 2016; Thorpe et al., 2016; Gallo et al., 2017). Furthermore, shorter, customised psychometric questionnaires have shown promise as a non-invasive assessment of training status in elite soccer (Thorpe et al., 2015; Thorpe et al., 2016). Despite there being limited published data in elite soccer, daily ASRM (perceived ratings of wellness, fatigue, sleep quality, stress, mood, and muscle soreness) seem to be most responsive to daily variations in load across a 17-day assessment period, and annual competition cycle in English Premier League players, compared with maximal-performance assessments and heart-rate derived indices (Thorpe et al., 2015; Thorpe et al., 2016).

Periodisation models applied in elite soccer requires a structured approach which allows for a variation in training load across relatively short periods of time (Morgans et al., 2014). The effective training of elite soccer players should facilitate the evaluation of individual player’s positive (i.e. adaptation and improved performance) or negative (i.e. maladaptation, injury, illness and staleness) adaptive responses, whilst ensuring the load-recovery cycle is optimally balanced (Kenttä and Hassmén, 1998; Thorpe et al., 2017). Variation in weekly periodisation strategies adopted in elite soccer are largely influenced by the combination of evolving coaching philosophies as well as the application of the latest scientific knowledge (Morgans et al., 2014; Akenhead and Nassis, 2016; Weston, 2018). In Chapter 6, we reported marked differences in training load across two successive in-season competitive periods in the same players, whereby fluctuations in loading patterns reflected the periodisation strategies adopted and microcycle planning methodologies employed by the respective head coaches. As a consequence, these data afford the opportunity to examine the influence of different training periodisation strategies across a season on ASRM in the same group of elite players. Therefore, the aim of the current investigation was to examine the influence of external load markers on ASRM in English Premier League soccer players during the competition phase of two successive seasons.

7.2 Methods

7.2.1 Participants

The same 20 elite-level English Premier League players were monitored across a 36-week competition phase of the 2012-2013 (season 1) and 2013-2014 (season 2) seasons (mean ± SD: age 27 ± 4.6 years, body mass 79 ± 6.9 kg, height 181 ± 7.2 cm).

7.2.2 Design

Players took part in daily team training sessions during the annual competition periods of two successive seasons, as prescribed by the respective head coach. All players were fully familiarised with the wellness assessment questionnaire in the weeks prior to (pre-season phase) completion of the experimental trials. Only ASRM taken on specific training days (G-3, G-2, and G-1) were used in the analysis. Assessments were conducted at the same time of the day at the clubs training ground prior to the commencement of team training.

7.2.3 Athlete Self-Report Measures (ASRM)

Player daily wellness measures were collected on a daily basis prior to the commencement of the training session using a psychometric questionnaire as described by Hooper et al. (1995). The ASRM questionnaire was composed of three questions relating to perceived sleep quality, muscle soreness and fatigue (Chapter 11, Appendix) which were used to assess each player's general indicators of wellness. Each question scored on a 7-point Likert scale (scores of 1-7, with 1 and 7 representing very, very poor [negative state of wellness] and very, very good [positive state of wellness], respectively) (Thorpe et al., 2015). During season 1, the ASRM questionnaire was in the format of a printed paper sheet showing each of the three wellness questions (and scales). Each player was given a sheet upon their morning arrival at the training ground and asked to highlight each wellness score using a marker pen. These scores were were subsequently exported into a Microsoft Excel spreadsheet database (Microsoft Corporation, U. S.) for later analysis. In season 2, the wellness questionnaire was uploaded to an iPad (Apple Incorporated, U.S.) whereby players rated sleep quality, muscle soreness and fatigue using a slider bar on the device, with scores automatically exported and stored for analysis.

7.3 Statistical Analysis

Data are presented at each level of each factor of interest as means ± S.D. However, mean differences between factors, derived from the inferential statistical models, are presented alongside the respective 95% confidence intervals (Cl). A multi-factorial general linear model was used to quantify mean differences between mesocycles and day-type (both fixed effects), with participant entered as a random effect to allow for multiple observations within participants. The main effects for sub-group comparisons of each factor, as well as any statistically significant interactions were followed-up using least significance difference (LSD) multiple contrasts (Perneger, 1998).

For the ARSM, mean differences between mesocycles and day-type were assessed for practical relevance against a minimal practically important difference (MPID) of 1-point on the 7-point Likert scale. This value was based on the change in ASRM observed in elite soccer players across a standard in-season training week using the same 7-point

Likert scale (Thorpe et al., 2016). Statistical inference was then based on the disposition of the lower limit of the 95% CI for the mean differences to our MPID, with differences deemed practically relevant when the lower confidence interval was equal to or exceeded the MPID. Differences not reaching this threshold were declared not practically relevant. *P* values are also presented but not used as the primary method of statistical inference, as the *P* value does not measure the size of an effect or the practical importance of a result (Greenland et al., 2016; Wasserstein and Lazar, 2016).

Due to a higher occurrence of competitive games played in season 1, a sensitivity analysis was conducted whereby the difference between seasons in mean daily fatigue, sleep and muscle soreness data were covariate-adjusted for season differences in match load (high-speed running distance [>14.4 km/h]). Unfortunately, the "day" factor (relative to match-day) could not be entered into this model because daily wellness measures collected during training did not coincide with the match-day (when match-load was measured). Because of this discrepancy between matchday covariate load and training data, the statistical model would not have been robust for the specific factor of "day" effects and any interaction between season and day.

7.4 Results

Match load covariate adjusted mean wellness measures were significantly higher during season 2 compared with season 1 ($p < 0.05$). Despite the observed statistically significant differences for mean daily fatigue (95% CI range, -0.2 to 0.2 AU), sleep (95% CI range, -0.1 to 0.1 AU), and muscle soreness (95% CI range, -0.04 to 0.04 AU), no MPID were observed between season 1 and season 2.

7.4.2 Mesocycle

Mean daily ± SD perceived ratings of wellness values (fatigue, sleep, and muscle soreness) across the 6 x 6-week mesocycles for season 1 and season 2 are presented in Figure 7.1. There was a statistically significant interaction between season and mesocycle for fatigue and sleep ($p < 0.05$). Despite the observed statistically significant differences, no MPID were observed between season 1 and season 2 across the 6 x 6-week mesocycles (95% CI range, -0.6 to 0.6 AU; Figure 7.1).

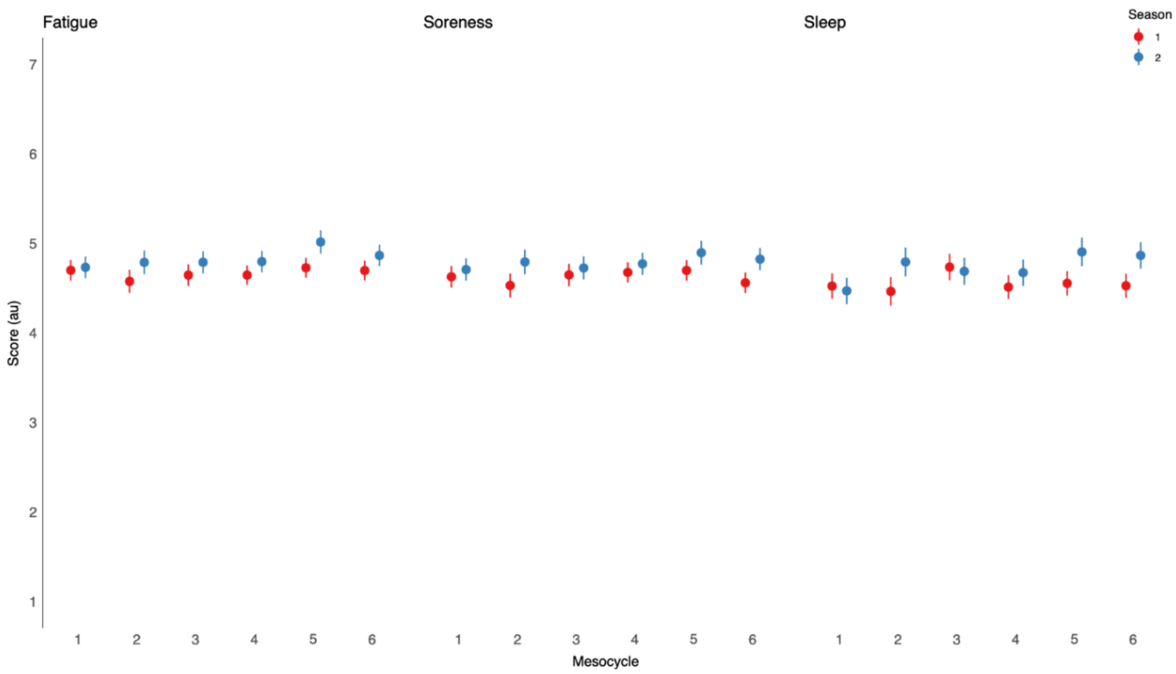


Figure 7. 1 Mean ± SD daily fatigue, sleep, and muscle soreness values across the two observed competitive seasons during each 6-week mesocycle block (mean ±.95% confidence interval). Practical relevance was assessed against a minimally practical importance difference of 1-point on the 7-point Likert scale.

7.4.3 Day Type

Mean daily ± SD fatigue, sleep, and muscle soreness data across the three-day types are presented in Figure 7.2. There was a statistically significant interaction between season and day-type for fatigue and muscle soreness variables (both $p < 0.05$). Despite the observed statistically significant differences, no MPID were observed between season 1 and season 2 across the three day-types (95% CI range, -0.5 to 0.5 AU; Figure 7.2).

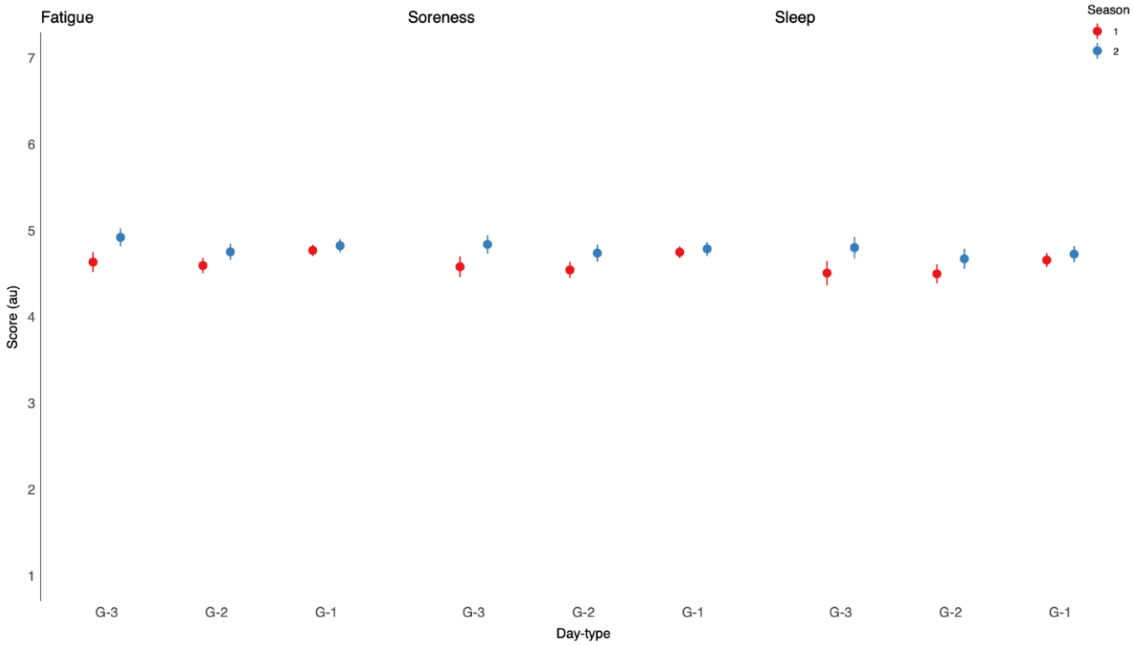


Figure 7. 2 Mean ± SD daily fatigue, sleep, and muscle soreness values across the two competitive seasons during each day type observation (mean ±.95% confidence interval). Practical relevance was assessed against a minimally practical importance difference of 1-point on the 7-point Likert scale.

7.5 Discussion

The aim of the current study was to examine the responsiveness of morning measured ASRM in a group of elite soccer players exposed to two different training periodisation strategies. Although the lower 95% confidence limits were found to be higher than zero (indicating "statistical significance"), no practically relevant differences (> 1-point) were observed in the ASRM responses between seasons. Further work is needed to better understand the relationship between ASRM, and the loading incurred by elite players during training and competition.

In the present study, all training load indices were systematically higher during season 2 reflecting differences in the training philosophy adopted by the two different coaching teams (Chapter 6). The present data therefore provided a unique opportunity to examine the influence of different periodisation models on ARSM in the same group of elite soccer players. The ASRM responses were significantly higher across the annual training cycle in season 2 compared with season 1. High-speed distance covered in competitive matches was greater in season 1 compared with season 2. As a consequence, covariate adjustment analyses were employed in the current study to control for the difference in match loads. Despite covariate adjusted match load and statistically significant differences being reported for the ASRM, in the context of a MPID, there was no difference greater than 1-point on the 7-point Likert scale. Ideally, the relevance of effect sizes should not be judged exclusively on whether a particular effect size is "statistically significant" or not (Stapleton et al., 2009). This issue would be especially pertinent in the present study because the within-subjects and longitudinal nature of the design provided relatively high statistical power (compared with a cross-sectional study design). In general, the mean differences between factors were found to be "statistically significant" (lower 95% confidence limit did not overlap zero), but whether these mean differences had practical relevance was unclear in our study because the lower confidence limit overlapped considerably our MPID of 1-point on the Likert scale. Our findings demonstrate that ASRM were not responsive (to a practically relevant degree) to the differences in training loads observed across both seasons' annual competition cycles, despite higher loads being elicited across the three-days leading into a match in season 2. The current investigation demonstrates that despite the different periodisation models employed, there were no practically relevant changes (> 1-point on the 7-point Likert scale) in the ASRM response observed in this sample of elite soccer players across the in-season competition periods.

All training load markers in both seasons gradually declined across the three-day period leading into a game mirroring the periodisation strategies typically observed in elite players (Stevens et al., 2017; Martin-Garcia et al., 2018; Clemente et al., 2019). Despite this progressive change in load, there were also no practically relevant changes (> 1-point on the 7-point Likert scale) in the ASRM response across this period in either season. The present findings are consistent with previous data reported in English Premier League players where perceived ratings of fatigue, sleep quality, and muscle soreness showed little change (< 1-point on the 7-point Likert scale) across the three-days leading into competition despite marked changes in training load (Thorpe et al., 2016). In contrast, the same authors observed a MPID greater than 1-point in the ASRM across the entire weekly micro-cycle namely between the post-match (G+1) and pre-match (G-1) training days (Thorpe et al., 2016). These findings suggest MPID in ASRM may only arise in response to relatively large fluctuations in training loads such as those encountered across the typical in-season microcycle. This suggests that ASRM typically used in the field may only be useful at designated strategic points within the weekly training cycle in order to support decisions around the training status of players.

A possible explanation for similar ASRM between seasons is that players were largely able to tolerate the training loads encountered during the different training strategies resulting in similar ASRM responses. Previous studies examining the dose-response relationship between training load and performance outcomes in soccer have predominantly used functional (performance-based) tests to evaluate the acute or chronic training effects (Jeffries et al., 2020a). For example, marked changes in agility (Dragijsky et al., 2017), sprinting (Los Arcos et al., 2020), countermovement jump height (Meckel et al., 2018), and soccer-specific intermittent endurance (Krustrup et al., 2003; Bangsbo et al., 2008) performance have been shown to occur across the pre-season phase. In contrast, little attention has focused on examining the responsiveness of ASRM to systematic changes in training load in elite players (Thorpe et al., 2015; Thorpe et al., 2016; Varley et al., 2017). ASRM represent a non-invasive and time-efficient means through which derive information concerning players training status. Such methods may therefore potentially serve as an important tool through which to facilitate the key performance outcomes of the training process, namely enhancements in performance and the prevention of injury / illness. Further research, however, is needed to examine the responsiveness of ASRM to changes in training load in elite players.

Surveys conducted in high-performance sport have shown ASRM are extensively used to evaluate the well-being of elite team-sport athletes (Thorpe et al., 2017). The lack of responsiveness in ASRM to the fluctuations in load presently observed may also reflect measurement issues associated with the ASRM tools currently employed. It is important to acknowledge that the ASRM scales used in the current study may not have fully met the stringent clinical guidelines outlined by the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN), potentially influencing validity of the data currently analysed. The COSMIN guidelines have been developed by an international multidisciplinary team to assess the quality of measurement properties within clinical research (Jeffries et al., 2020b). In high performance sports, short, customised ASRM questionnaires consisting of 4 to 12 items are frequently used (Thorpe et al., 2017; Jeffries et al., 2020b), with fatigue and muscle soreness showing particular promise as practical subjective measures of acute training effects (Jeffries et al., 2020a). Several limitations exist in relation to the effectiveness of ASRM scales, which are dependent upon a number of practical and theoretical (interrelations between the ASRM measure, social environment, and training outcomes) factors which need to be addressed within the applied sporting domain (Saw et al., 2016). Published data on the validity of ASRM scales applied within elite team-sports is limited (Jeffries et al., 2020b). It is paramount that the measurement properties of ASRM are scientifically validated in order to provide accurate, meaningful, clear, useful, and specific information which can then be used to assess an individual athlete's tolerance to training loads elicited. (Jeffries et al., 2020b). This has led to the recent development of a conceptual framework for validating subjective measures to enhance the validity of ASRM scales (Jeffries et al., 2020a). Future work using ASRM which have been subjected to more rigorous validation will therefore enhance our understanding of the potential effectiveness of ASRM for evaluating the training status of elite players.

In summary, the current investigation demonstrated simple ASRM were not generally responsive (> 1-point on the 7-point Likert scale) to differences in training load periodisation experienced by the same group of elite soccer players across two successive seasons, when differences in match high-speed running distance were controlled for. However, the strategic employment of ASRM during specific periods in the training week, where large fluctuations in load occur, may improve the usefulness of ASRM as a monitoring tool to assess individual player training status. Further research is needed to understand the responsiveness of ASRM to changes in training load in elite players in order to enhance the application of such tools for monitoring the training status of players.

CHAPTER 8: SYTHESIS OF FINDINGS

8. Synthesis of Findings

The aim of this chapter is to interpret and consolidate the findings reported within the current thesis. The possible applications and limitations of the studies outlined will be discussed. The realisation of aims will be confirmed before a review of the original hypotheses will be focussed upon. The following general discussion and conclusion sections will provide interpretations of the individual studies in relation to the quantification of training-load in elite English Premier League soccer players.

8.1 Realisation of Aims

The experimental sections of this thesis have fulfilled all the aims stated in Chapter 1. The comparison of two different tools used for measuring internal load in elite soccer players was investigated (Aim 1). The within-participant correlations between variability in sRPE and heart-rate were large across a season-long competitive period and independent of playing position. This indicated that sRPE measures could be applied in soccer to examine the internal load during training and match-play in future experimental work. The quantification of seasonal training-loads elicited in elite English Premier League soccer players was then examined (Aim 2). Internal (sRPE-TL) and external (GPS) training and match-load (stadium-based tracking system) showed limited variation across the season suggesting training prescription is highly repetitive in elite soccer, likely reflecting the nature of the competition demands. Greater variability in training load (periodisation) was evident across the weekly microcycle reflecting the recovery and preparation for matches. The evaluation of training-load distribution in elite English Premier League soccer players under two different coaching strategies were subsequently analysed (Aim 3). Both match frequency (season 1, *n* = 49 *vs.* season 2 *n* = 34) and match high-speed running distance was higher during season 1. Mean daily average training session duration was higher in season 1, with all other training load markers (sRPE-TL, total distance, high-speed distance, very high-speed distance, accelerations, decelerations) significantly greater on selected training days in season 2, despite similar sRPE-TL values reported on G-3, G-2, and G-1. Training periodisation was evident in both seasons during the three-day period leading into a competitive match, whereby all training load markers progressively declined between G-3 and G-1. The responsiveness of ASRM was determined in elite English Premier League soccer players under two different coaching strategies outlined in fulfilling Aim 3, were subsequently analysed (Aim 4). When adjusted for differences in match high-speed distance, practically important differences in the ASRM responses (at least > 1-point on the 7-point Likert scale) were not observed between seasons despite the adoption of different periodisation strategies.

8.2 General Discussion

The aim of this thesis was to quantify the seasonal training load in elite English Premier League soccer players. The relationship between different measures of internal load were examined initially. The internal and external loading patterns across the competition period and the influence of different training methodologies were subsequently investigated followed by the final study which centred on the responsiveness of ASRM to changes in training load in elite soccer players. The following section aims to discuss the general outcomes of this thesis with reference to the theoretical and methodological frameworks associated with the periodisation strategies employed in elite soccer.

Chapter 4 centred on quantifying the correlation between the variability in sRPE and heart-rate based methods for quantifying the internal training load in elite soccer players across a season-long competitive period. Large correlations between the overall sRPE and heart rate-load were reported, which compared favourably with previous observations found in young amateur, semi-professional males, and elite female and male soccer players (Impellizzeri et al., 2004; Alexiou and Coutts, 2008; Casamichana et al., 2013; Fanchini et al., 2016). Previously, studies quantifying the correlation between sRPE and heart-rate based load were limited by suboptimal statistical approaches. Such studies included pooling of all data over time for the calculation of a single correlation with inflated degrees of freedom, or quantifying correlations for individual players and calculating a sample mean correlation, which lacks statistical power (Atkinson et al., 2011).

During high-intensity intermittent sports such as soccer the heart-rate based method is questionable due to the frequent anaerobic efforts (Impellizzeri et al., 2004). Failure to observe a higher correlation between sRPE-TL and heart-rate training load in Chapter 4 largely reflected the type of training undertaken by the player which frequently involved a high anaerobic contribution (Impellizzeri et al., 2004; Casamichana et al., 2013; Fanchini et al., 2016). In Chapter 4, irrespective of playing position, players were regularly exposed to various training drills including pre-training activation type drills, small-sided games (ranging from 4 *vs.* 4 to 9 *vs.* 9 formats), high-intensity running drills and speed endurance training. The validity of heart-rate is therefore clearly going to be greater for some parts of the training versus others due to the type of training administered. Thus, the anaerobic conditioning component inherent in some of these types of drills is likely to have reduced the magnitude of the correlations between sRPE and heart-rate. Therefore, there we may need to apply a combination of methods (e.g. RPE and heart-rate) to get a more comprehensive insight of the internal load imposed on individual players across the spectrum of training activities they encounter on the field. Despite this, the correlation between changes in sRPE and heart-rates observed remained high in relation to playing position (range r = 0.70 to r = 0.84), when measured during a season-long period of field-based training in elite soccer players. The recent emergence of dRPE may extend the insights we can derive from RPE per se which could increase our understanding of the internal stressors associated with elite soccer training. For example, dRPE could be applied on G-3 to assess central (breathlessness) exertion during 11 *vs.* 11 position-specific practices, whereas peripheral (muscular) loading components could be measured during small-sided games on G-2. As a consequence of the findings in Chapter 4, the sRPE methodology were used in subsequent chapters as a valid measure of the internal training load.

Currently, there is a dearth of published information which has examined the training loads experienced by elite players. Recent studies have provided some insight into the training load distribution across the in-season competition period in elite soccer players (Malone et al. 2015; Anderson et al., 2016; Los Arcos et al., 2017; Stevens et al. 2017; Martin-Garcia et al. 2018). However, further observations are required from a wider perspective of elite teams in order to gain a more comprehensive insight into the collective periodisation practices adopted by professional teams (Weston, 2018). Chapters 5 and 6 were concerned with quantifying the external and internal load (match and training) distribution across the in-season competition periods in elite English Premier League soccer players. These investigations would provide initial insights regarding the current training periodisation practices adopted by an elite soccer team using valid methods of training load assessment.

The findings from Chapter 5 demonstrated variations in the total distance (~700 m), high-speed (~150 m), and very high-speed (~40 m) distance covered across the 6-week mesocycles. When compared with the average daily training load prescribed across the cycles, the magnitude of these observed differences (range, ~15% to ~25%) may not be insignificant and could be practically important in relation to training adaptation and performance outcomes. The variation in training load observed across the larger mesocycle blocks suggests the programming of training in elite soccer may be programmed in-line with the demands of competition. Greater sRPE-TL and total distance were observed at the start of the competitive season in mesocycle 1, with all training load markers reported lowest during the mid-season phase (mesocycle 4), which align with the reported data of Malone and co-workers (2015). Chapter 5 documented a larger number of games were played across the (mid-season) Christmas period, which influenced the programming of training employed by the head coach during this competitive phase. Consequently, training session duration was decreased to ‘off-set’ the additional loads elicited during competitive match-play, which led to a reduction in the sRPE-TL, total distance, high-speed and very high-speed distances observed. The data presented in Chapter 5 demonstrates the high-density of matches played (2–3 per week) influenced the scheduling of daily training sessions, which incorporated repeated bouts of short training periods interspersed with post-match recovery sessions across the weekly cycle.

In elite soccer, frequent changes in the scheduling of competitive fixtures are more prevalent in successful teams. The team observed in Chapter 5 were the English Premier League champions, while also undertaking prolonged cup ‘runs’ in the same season. This resulted in a higher volume of competitive match participation. Furthermore, matches may be rescheduled due to the obligations of sports broadcasters to televise ‘live’ games on particular days and at certain times, or there might be the requirement to play additional games, during a replayed cup tie, for example. The application of a consistent ‘one-size global approach’ to periodisation may therefore be unfeasible within elite soccer due to the ‘ever-changing’ and congested fixture calendar, and other conflicting factors such as demanding travel schedules. Indeed, the implementation of individual player ‘micro-management’ strategies is likely to be present amongst elite teams leading to a wider range of bespoke periodised approaches which need to be refined by the coaching teams.

As demonstrated in Chapter 5, the programming of training across the mesocycle blocks is in elite soccer is difficult. This necessitates each mesocycle block is ‘broken-down’ into smaller microcycle units which represent the main area of training load control for the coaches when preparing and recovering players around competition. The periodisation strategy adopted in elite soccer is unique in design, facilitating the physical conditioning of players to optimally prepare for the demands of competition using short repetitive training cycles. Microcycles have been presented previously as one of the most important tools adopted when planning the overall training process (Stone et al., 2007). Given the cyclical nature of the competition period, the microcycle is the most important training unit in elite soccer, facilitating the scheduling of recovery periods through to pre-match training preparation. Furthermore, microcycles can be effectively organised and structured within the weekly cycle to enable the modification of training frequency, duration, and intensity in accordance with the 'often-sporadic' competitive fixture calendar (Thorpe et al., 2017).

In Chapter 5, several scenarios were reported in relation to how training was structured. The irregular match schedule led to various types of microcycles, with varying numbers of training days implemented between matches. During a 'standardised' one-game week, there were 6 training sessions between successive matches which aligns with the training patterns observed in reserve Spanish La Liga, and players from Portugal and the Netherlands (Martin-Garcia et al., 2018; Clemente et al., 2019). During a two-game weekly cycle there was a recovery / 'off-loaded' day on G+1 followed by 4 training days leading into the next match. A three-game weekly microcycle had one recovery session and a training day on G-1 between the first and second game, and the second and third game, respectively. During two and three-game weeks where games were played in closer proximity (e.g. Saturday and Tuesday), with only two days between fixtures, training constituted a recovery session on G+1 followed by a training day on G-1.

sRPE-TL, total distance, high-speed distance, and very high-speed distance were progressively reduced over the 3 days before a game. These findings concur with previous observations which demonstrate within weekly microcyles of typically 3 to 7 days in duration are repeated around competition, with a decrease in training load across the three-days leading into a game (Los Arcos et al., 2017; Stevens et al., 2017; Martin-Garcia et al., 2018). Training load variables were lowest on G-1 due to the employment of shorter-duration, low-intensity sessions, as the head coach attempted to diminish fatigue prior to competition (Mujika, 2010; Clemente et al., 2019). Reducing training load on G-

1 serves to reduce fatigue levels while simultaneously optimising the recovery time available on the day before a match (Mujika, 2010). The weekly microcycle structure adopted by the head coach in Chapter 5 allowed an adaptable approach to the prescription of training, whereby the training loads were planned and administered in relation to the demands of the forthcoming game(s). Furthermore, this approach enabled the opportunity to employ higher loadings during the early phases of the week (during a one-game week) to promote training adaptation without compromising match physical output. The findings of Chapter 5 provide insights into the training periodisation strategies employed by an elite soccer team during a championship-winning Premier League season. The variation in weekly training loads reported were likely representative of the head coaches personal training philosophies and subsequent periodisation model employed.

Chapter 6 was the first study to examine the influence of different coaching philosophies on the internal and external training load experienced by the same group of elite players. This provided the unique opportunity to compare the loads of the same players under two coaching approaches. When studied alongside simple ASRM this also afforded the opportunity to evaluate the influence of any difference in training load on the players perceived daily training status (Chapter 7). The training patterns in elite soccer are a consequence of the head coach's philosophy, where an individual approach to training is adopted in an attempt to optimally prepare players for the intended style of play (Akenhead and Nassis, 2016; Weston, 2018; Chapter 5). It may be evident that the periodisation strategies employed in Chapter 6 cannot be applied universally due to the individual training requirements of elite teams. Chapter 6 indicated there were some similarities in how the training week was structured across both seasons, suggesting the periodisation strategy was to some extent comparable between the respective head coaches. This may imply both coaches intentionally adopted similar approaches, particularly during the three-day weekly microcycle phase to preserve player physical 'freshness' in preparation for competition. Therefore, it may be evident that the microcycle structure employed in both seasons allowed the coaches greater flexibility to modify training load on designated days in relation to the demands of competition.

Despite adopting a similar periodisation strategy across the weekly microcycles (i.e. during the three-days leading into competition), Chapter 6 demonstrated that internal and external training loads were greater across season 2, while daily training session duration was longer in season 1. A key factor possibly mediating the greater loading stemmed from the varying types of drills employed. Different types of training drills profoundly influence the physiological response and consequential overall training loads elicited (Little and Williams, 2006). In Chapter 6, it was evident the content of training session drills were organised differently on certain days, characterising the individual approaches adopted by the respective head coaches. Smaller playing areas were utilised on G+3 in season 1 to facilitate recovery between matches (Owen et al., 2017; Gregson et al., 2019), whereas extensive endurance practices were carried out in larger areas on G+3 in season 2 to promote training adaptation during the earlier phase of the week. These findings align with previous work which showed the magnitude of training load can be modified by either increasing (Lacome et al., 2017; Olthof et al., 2018), or decreasing the size of the playing area adopted (Gaudino et al., 2014; Gaudino et al., 2015; Lacome et al., 2017; Olthof et al., 2018). It is likely these diverse approaches to the organisation of training session content directly influenced the magnitude of training loads elicited across the observed seasons.

A marked difference in match frequency and intensity was demonstrated in Chapter 6, with more competitive game observations, and greater high-speed running distance covered across the 36-week competition phase during season 1, compared with season 2. During the weekly microcycle phase, training days carried out on G-3, G-2, and G-1 were matched between seasons and used in the same way by the head coaches to prepare for competition. Training sessions carried out on these day types were never changed due to the frequency of games, and a standardised approach was adopted by the coaches during this three-day phase to ensure consistency was maintained in preparation for competition. Match congestion could have influenced the differences in training load to some extent, but it was evident the main predominant factor was the coaching philosophies employed. Working closely on a daily basis with both coaching teams revealed there was a large disparity in the training methodologies adopted, which had a major influence on the magnitude of daily loads prescribed between seasons. The head coach in season 1 ensured the integration of adequate 'load-reduction' and recovery sessions between matches suggesting his philosophy was predominantly focused on maintaining 'player readiness'. In contrast, the coach observed in season 2 appeared to lack an understanding in terms of how to implement 'load-management' strategies, whereby his beliefs were centred on regularly exposing the players to high physical training loads during the course of the week. The diverse methods employed by the head coaches, and the way in which these influenced the differences in daily training loads elicited is apparent in the current study. These findings reinforce the need for further studies to gain a better understanding of the wide-ranging loading patterns experienced by elite teams.

Chapter 6 demonstrated sRPE-TL and all external training load markers were greater on G+3 across season 2 compared with season 1. The increase in sRPE-TL was a consequence of players performing more high-speed running, very high-speed running, and accelerations in season 2, which concurs with previous research showing high-speed running and frequency of acceleration are two key parameters influencing the sRPE response (Gaudino et al., 2015). It was found that sRPE-TL was higher on G-3 than G-1 which was due to the differences in training session duration, and not sRPE per se. An increased frequency of accelerations and decelerations were reported on G-3, G-2, and G-1 in season 2 due to the players training in large areas, however, the elevations in high-intensity activities were not reflected in the observed sRPE-TL (Vigne et al., 2010; Gaudino et al., 2013; Gaudino et al., 2014; Gaudino et al., 2015). The degree to which the differences in daily load were practically important, and whether they led to an increase in the physical capabilities of the players (i.e. elevated fitness levels) and performance outcome improvements is difficult to determine from the current study (Atkinson, 2003). Furthermore, the reported findings in Chapter 6 suggest sRPE-TL may lack the responsiveness to accurately quantify changes in external load within the weekly training cycles, and thus may only be sensitive to larger differences in external loads elicited. As an alternative, the differential ratings of perceived exertion (dRPE) has been proposed to increase the precision of estimating the internal load (McLaren et al., 2016), which serves to differentiate between central (e.g. breathlessness), and peripheral (e.g. legs) exertion signals. This may enhance the ability of dRPE to discriminate between highly variable external loads elicited during training and in matches (Weston, 2013; Arcos et al., 2014; Weston et al., 2015). As a consequence, dRPE may enable a more detailed understanding of the dose-response relationship to be established in elite soccer (Weston et al., 2015; McLaren et al., 2017; Barrett et al., 2018).

The findings from Chapter 6 provided the unique opportunity to examine the influence of different coaching philosophies on training status using simple athlete self-report measures (ASRM) in the same group of elite soccer players. The observed players wore the same (GPS) tracking technology devices which served to minimise differences in the evaluation of external loads elicited (Beato and De Keijzer, 2019; Chapter 7). In Chapter 7, a 7-point Likert scale was used to evaluate ASRM in the format of a three-question psychometric questionnaire (Hooper et al., 1995, Thorpe et al., 2016). Covariate adjustment analyses were employed in the current study to adjust for differences in match high-speed distance. No practically important differences were reported in the ASRM responses between seasons, despite the scheduling of different periodisation strategies. Although the lower 95% confidence limits were found to be higher than zero (indicating "statistical significance"), no MPID (> 1-point) were observed in the ASRM responses between seasons. Preferably, the relevance of effect sizes should not be judged entirely on whether a particular effect size is "statistically significant" or not (Stapleton et al., 2009). Overall, the mean differences between factors were found to be "statistically significant" (lower 95% confidence limit did not overlap zero), but whether these mean differences had practical relevance was unclear in our study because the lower confidence limit overlapped considerably our MPID of 1-point on the Likert scale.

The findings of Chapter 7 align with previous data published in elite players which reported little change (< 1-point) in perceived ratings of fatigue, sleep quality, and muscle soreness (DOMS) across the three-days leading into competition (Thorpe et al., 2016). Our reported data demonstrate that despite the different periodisation models employed, there were no practically relevant changes (> 1-point on the 7-point Likert scale) in the ASRM response observed in this sample of elite soccer players across the in-season competition periods. From a practical perspective, this may suggest the players were able to cope with the changes in load administered. However, it may be evident that the fluctuations in training loads, specifically, during the three-days leading into competition (Chapter 6), were simply not large enough in magnitude to elicit a significant change in the ASRM response. However, these observations need to be verified in conjunction with objective measures to facilitate a more comprehensive assessment of the physical stressors associated with the training methodologies employed, particularly during heavy fixture periods.

Previous research has indicated the fatiguing effects of training and match-loads may transpire over several days, rather than immediately after a session or match (Nédélec et al., 2012). The findings reported in Chapter 7 suggest the employment of ASRM in elite soccer may only be responsive under certain conditions. For example, a previous study has shown larger changes in the ASRM response (>1-point) did occur in elite soccer players when observed across the longer (6-day) in-season training weeks (Thorpe et al., 2016). Assessing the ASRM across longer weekly periods may to some extent give a verifiable indication of the training cycles undertaken in elite soccer, and as a consequence the current training status of individual players. Future investigations should focus on the effectiveness of ASRM as a simple, efficient, and non-invasive method of assessing player training status from the perspective of a wider range of elite teams.

8.3 Practical Applications

The findings from the current thesis provides unique data concerning the physical demands of training in elite male English Premier League soccer players. These reported data helped to give further understanding to the influence of training type and its impact on the physical status of players, which was used by the coaching staff to plan subsequent training sessions and to prepare for competition. In Chapter 4, we showed that sRPE represents a valid and practical tool which can be used to monitor internal training load in elite soccer. Chapters 5 and 6 highlight the periodisation strategies employed across season-long periods. Greater physical demands were imposed during training in season 2 compared with season 1, however, both seasons showed training loads were reduced in a tapering fashion across the three-days leading to competition. In Chapter 7, observations on simple ASRM indicated that the players were able to tolerate marked increases in load provided by different training methodologies.

The results of this thesis have shown that simple, non-invasive sRPE, to some extent, can be applied as a valid tool to evaluate certain parts of the field-based training session load in elite soccer players, irrespective of playing position. Player engagement via this process can be used to further understand individual tolerances to training and match loads and practically inform future modifications to external training load stressors. The collection of daily RPE values (per se) was implemented as an alternative to heart-rate-based measures, as it was identified there was generally poor compliance to wearing heart-rate monitors during training, and the head coach prohibited their use in competitive games. Daily RPE measures were collected after the cessation of each training session, although taking RPE values after each training drill (i.e. several per session) may have provided a better understanding of the internal loads elicited. This approach, however, is not practical within the elite soccer setting. As an alternative, the collection of dRPE during training sessions may provide more detailed information on internal loading by focusing specifically on the central (respiratory) and peripheral (muscular) components.

This approach may enable a more detailed assessment of the load intensities associated with the diverse training drills employed.

Ratings of match RPE in the current thesis were obtained from players at the end of pre-season games, whereas no data was collected after a competitive match. Practically, it proved very challenging to obtain RPE ratings after a competitive game as it was difficult to ascertain individual player mood state post-match. Factors such as personal performance level in the game, outcome of the match, and potential altercations in the dressing room could all negatively influence the players subjective feelings, making data collection extremely difficult post-match. Furthermore, the employment of this methodology could often be viewed as a 'hinderance' within the changing room environment by members of the coaching staff. Therefore, the in-season competitive match RPE values used in the current thesis were based on individual player average pre-season values. However, where practically possible, competitive match RPE should be recorded, as participation in competitive games elicits the highest physical load a player is exposed to during a typical week, with RPE values likely greater than those observed in pre-season games. Thus, a match RPE score may show us more in terms of cumulative internal load, especially during heavy fixture periods.

Monitoring of internal (sRPE-TL) and external (GPS, stadium-based tracking system) daily training and match-load distribution across the competitive cycle was used to evaluate the training load patterns employed by two different coaches. The data collected characterised the structure of training adopted in both a 'championship winning' team, and in the same group of players during the following season. The organisation (periodisation) of training load was more evident across the three-days leading into a game, with both head coaches progressively reducing load during this period. Data collected in the current thesis suggest the coaching staff understood the need to taper the weekly training load towards the forthcoming competitive fixture(s) in an attempt to optimise player's physical condition. However, we found the magnitude of loading during these days was influenced by the philosophy of the head coach. Training sessions during this phase were prescribed in preparation for the approaching match, where the head coach imposed his planned system and style of play in relation to the opposing team, which influenced the physical stressors elicited on individual players.

There was a clear disparity in the training methodology of the respective head coaches observed in the present thesis. The observed coach in season 1 implemented a style of play that was distinctly based upon a strong philosophy to attack, to pass the ball forwards quickly using a dynamic attacking approach, whilst imposing his style of soccer onto the opposing team. The head coach demanded a high level of physical effort from all players for the full duration of each match to ensure his team were dominant and resilient, never giving up irrespective of the current game situation. The team were also tactically versatile which was evident in relation to the various formations and team shapes utilised, which heavily influenced the periodisation strategy employed. The head coach organised training sessions with the emphasis on maintaining a consistently high tempo, which served to increase the training intensity, and thus optimally prepare the players to undertake their role within his designated style / system of play. This was achieved by minimising the length of recovery time available during the transition period between drills, and ensuring sufficient footballs were readily available pitch side during small-sided games practices to help reduce the incidence of 'breaks in play'. The head coach approached the programming of training based on his many years of successful experiences in elite soccer. His pragmatic attitude and 'buy in' to training load management ensured the establishment of a healthy working relationship and synergy with the sports science team. This developed into the advent of daily meetings which were utilised to review training data and inform future training prescription. Furthermore, individual players were 'micro-managed' by using training and match-load intelligence to inform team selection, with varying microcycle planning strategies implemented in accordance with the weekly match schedule and number of fixtures played per week.

This approach contrasted with the other head coach observed in season 2, who mainly deployed one team formation (4-2-3-1) across the entirety of the competition phase in relation to the tactics and style of play. His team were instructed to 'press' relentlessly to win possession of the ball, but generally the teams play was less-possession based, often relying on resilience and discipline with a tenacious style of play adopted. On many occasions, the head coach would personally conduct a high proportion of the fitness-based training sessions with the players, suggesting he was not as diligent in his understanding of the effects of cumulative load, thus the monitoring and controlling of load was given a lesser priority. From a practical point of view, this made it difficult for the sports science team to integrate and plan weekly training cycles around competitive matches, therefore making it impractical to apply interventions in relation to load control and management. During the competitive season, the players would be 'worked' physically harder during the days following matches which had resulted in an unsuccessful outcome (i.e., poor playing performance / defeat). On such days the head coach would assign load for reasons other than physical development (e.g. as a 'punishment'), and it is possible these situations may have given rise to the greater training loads elicited in season 2. These findings suggest a more impromptu approach to management of player loading was employed, which was based on the head coach's (instinctive) 'gut feeling', rather than being informed and driven by the data processes managed by the sports science team.

The information presented in this thesis demonstrates training load in elite soccer is programmed in synchrony with the competitive fixture calendar, particularly during the three-days leading into a match. There are, however, difficulties associated with programming the weekly training cycle in elite soccer due to its sporadic nature. Factors such as the rescheduling of matches due to the requirements of sports television broadcasters, cup replay games (occasionally), and domestic and international travel commitments all present challenges when programming daily training. Our findings suggest elite soccer cannot practically follow certain elements of 'traditional' training periodisation and must therefore adapt its own methodology specific to the sport. Indeed, it is highly possible that each individual soccer team will have a distinctive / bespoke training approach that is tailored to prepare players for the intended style and system of play. The data presented are therefore only representative of the elite soccer teams that were observed across the annual competitive cycle in the current thesis. The findings suggest the periodisation of training in elite soccer is unique and cannot be applied universally, as the individual requirements of teams may differ significantly in how they prepare for competition.

The team observed in season 1 had more successful outcomes during competition compared with season 2, however, there are many underpinning factors which can define the success of a team such as quality of players and tactics employed etc. Given the team in season 2 were less successful may have served to increase the occurrence of more 'heavy' training load days being administered by the head coach as he attempted to improve results. Ultimately, the training undertaken by the team needs to reflect the style of play adopted by the coach. In the modern game, the advent of teams implementing a ‘high-pressing’ game is more prominent, so it is paramount that the training programme is designed with this in mind (i.e. a ‘train as you play’ approach). For the Sports Science team, however, success may be characterised by having a tighter control of the training loads to ensure an increased incidence of player availability. This approach would facilitate the careful management of any large changes in load to ensure players can gradually adapt without increasing the risk of injury. Further insights are therefore needed to gain a better understanding of the extent to which markedly different training methods adopted by head coaches influence subsequent match performance as well as both injury rates in training and competition.

Observations on ASRM in the present thesis indicated that such indices do not respond to marked fluctuations in training loads in elite soccer players during the three-days leading into a competitive match. Between season differences in ASRM ratings did not exceed a change of at least 1-point on a 7-point Likert scale for ratings of fatigue, sleep, and muscle soreness. These data are also consistent with sRPE values which were similar between seasons despite the large fluctuations in external load. These findings therefore suggest the players physical capacity may have been sufficient to enable them to absorb the increase in loading. This may indicate we are able to train players harder by exposing them to training stressors which replicate the head coach’s tactical approach to the game. However, it is paramount such increases in load are implemented gradually and are optimally balanced to ensure sufficient recovery occurs, otherwise there is an increased likelihood injury will arise. In the future, the addition of objective measures may help enhance our understanding of the dose-response relationship. Neuro-muscular assessments such as countermovement jump and groin squeeze are increasingly used to monitor the training status of elite soccer players. Such protocols need to be quick, efficient, easy to administer, and without any additional load to ensure they can be feasibly applied as an appropriate tool to assess the fatigue status of elite players (Thorpe et al., 2017). The combination of both subjective and objective measures may help to give us further understanding with regards to the training status of individual players, thus ensuring the required balance between fitness and fatigue is maintained irrespective of the training methodology.

The ASRM data presented in the current thesis was collected from individuals upon entry to the training ground, and before the commencement of training, to reduce interference with the players daily routine(s). Players were regularly in close proximity to each other during the data collection process due to the bustling nature of the changing room environment. From a practical perspective, however, it is suggested the protocol for collection of ASRM responses are, where possible, collected from individual players in isolation, and not within the group setting. Given the high levels of peer pressure associated with elite soccer and the competitive nature of individuals, it is unknown whether the ASRM responses were influenced as a direct result of individuals giving their responses whist in the presence of other players. Prior to data collection, all observed players were exposed to a Microsoft PowerPoint presentation, which was used as an educational tool to facilitate a better understanding of the ASRM reporting procedures. The presentation was utilised to encourage player participation / 'buy-in' to the process, and to nullify any misconceptions the players may have had with regards to the usefulness of ASRM. This approach ensured the concept of ASRM data collection was solidly embedded within the daily training routines of the players to enable the commencement of monitoring player training status.

A critical factor inherent in the use of self-report measures clearly stems from the need for players to provide true and accurate information. Previous research has shown limitations exist with regards to the interrelation between the ASRM and social environment, which may influence the effectiveness of ASRM scales within the applied sporting domain (Saw et al., 2016). One such limiting factor we encountered was the possibility that some players did not communicate their true perception of wellness, particularly during the 3-day lead up to competitive games. This may have been a consequence of players' reluctance to report increased levels of perceived sleep quality, muscle soreness and fatigue, in an attempt to 'communicate' to the head coach that they were 'match ready' and therefore fully available for selection. Indeed, some players did express concerns (i.e. exclusion from the team) in relation to the feedback of ASRM responses to the head coach, and how they believed this process may potentially 'influence' team selection for the forthcoming game.

The collection of daily ASRM appears to be more complex than simply asking individual players for a subjective number, and thus is a procedure which can be fraught with difficulties within the domain of elite soccer. The successful implementation of daily ASRM requires players to view ASRM as a worthwhile (and trustworthy) process, to ensure maximum 'buy-in' from the players is established. Furthermore, it is paramount all key stakeholders (i.e. head coach, coaching staff, sports scientists) are consulted on ASRM outcomes to optimise the process. This will facilitate the information is used in the most effective way to make informed decisions on individual players.

The studies carried out within this thesis have been the result of working within the applied setting of an elite English Premier League soccer club across several competitive seasons. The professional soccer club environment is notoriously fast-moving and ever-changing, often combined with long hours, lengthy travel excursions, while presenting challenging conditions. Thus, there are many difficulties associated with researching in the applied elite soccer environment, which must be overcome when attempting to accomplish the goal of the sports scientist, that is, to improve the fitness levels of the players while simultaneously aiming to reduce the occurrence of injury. The development of robust and trustworthy relationships had to be built with the head coaches and players initially, to enable the possibility of data collection for this thesis. Ultimately it is the head coach making all critical decisions within the club on a daily basis, so it is paramount that he had full trust in the processes being implemented from a sports science perspective. Indeed, this was a straightforward process during Chapters 4, 5, 6 (season 1), and 7 as the head coach had a pragmatic approach to training load planning and match preparation, often showing a high level of interest in the data sets presented, and thus opting to 'buy-in' to the sports science processes. In contrast, it was more difficult to 'connect' with the head coach in Chapter 6 (season 2), given he distanced himself from the available data, and instead relied heavily upon his personal experience and knowledge-base. From a practical standpoint, these situations proved difficult to manage with collected data often being overlooked, despite its usefulness to advise on training loads elicited and individual player physical status.

Working with individual professional soccer players also had its challenges. Initial efforts to integrate session-RPE into the daily training routines of players was met with some scepticism. Indeed, several presentations to the players were needed to 'convince' them as to why the data was being collected and how it was going to be used. Furthermore, a small selection of the players did not see any benefit to the use of RPE and refused to give a daily value to the investigator, while two players ('jokingly') gave the same value every day, irrespective of the training session intensity (these data were subsequently removed from the analyses). Similarly, daily wellness measures proved challenging initially, with some players simply refusing to participate, or showing little interest as to why the data was being collected. Throughout the whole processes, communication and education was constantly used as an effective means to try to reassure players as to why data was being collected, and how we could use it to inform us as to their current levels of fitness, whilst potentially reducing overtraining and subsequent injury.

Going forward, it is paramount the sports scientist working in elite soccer focusses heavily on building healthy (trusting) relationships to enhance synergy with key stakeholders within the club. Once established, this should facilitate the implementation and evolvement of the sports science monitoring processes on a daily basis. Furthermore, it is vital the provision of such concepts is easily presented to the head coach and playing staff alike to ensure maximum 'buy-in', with the aim of improving the physical capacity and performance of elite soccer players. When attempting to implement new technologies or systems of work, it is strongly advised to provide an educational presentation in the initial planning phases to ensure optimal commitment is achieved from key personnel within the club. To conclude, the production of this thesis has been challenging from an applied and practical perspective, but it is noteworthy that persistence and effective communication can help to unlock some of the 'traditional' beliefs still upheld within elite soccer which may, at times, hinder the application of sports science practices.

In summary, the quantification of the internal and external daily training loads may assist a multidisciplinary approach to guide coaches in the programming and prescription of training. The success of such a framework will be greatly influenced by the honesty and compliance of individual players (i.e. truthful reporting of RPE / ASRM responses, wearing GPS units daily) and the 'buy-in' / trusting nature of the coaching staff. It is important there is a cohesive network of staff to ensure the efficient feedback of data is disseminated to coaches and players to create an effective training load management structure. Future considerations should establish the variation in training periodisation strategies form a wider range of elite soccer teams to ascertain how different training philosophies impact training load distribution, and how such modifications can influence player recovery and injury status.

CHAPTER 9: RECOMMENDATIONS FOR FUTURE RESEARCH

9. Recommendations for Future Research

The studies completed within this thesis have provided novel information relating to the quantification of seasonal training loads in elite soccer. Furthermore, insights into how diverse coaching philosophies influence training periodisation strategies and the subsequent training status of elite players were attained. In achieving the aims of this thesis, several issues and subsequent findings have arisen which have prompted the formulation of recommendations for future research.

9.1 Research proposals in response to the findings in Chapter 4

The findings presented in Chapter 4 demonstrate sRPE and heart-rate are highly correlated and do reflect the internal training load stressors elicited in elite soccer players, suggesting these methods and techniques can be used as a valid assessment tool across a competitive season. Future research is needed to investigate whether the magnitude of the correlation between sRPE and heart-rate load is influenced by playing position during training drills which demand a position-specific focus, in order to enhance the application of sRPE as a tool for monitoring the internal training loads elicited in elite players. Furthermore, the inclusion of gym-based RPE should be considered and used in conjunction with field-based measures may provide a more global measure of the internal load stressors elicited.

The introduction of dRPE may be one way to move forward in the provision of a valid monitoring tool to quantify the internal training stressors associated with elite soccer training. The emerging application of dRPE in elite soccer may be better suited to the evaluation of perceived central loading during specific types of drills, for example, during large-sided games where players are afforded more space to explore resulting in greater total and high-speed distance covered, increasing the magnitude of physiological strain on the respiratory system (Clemente et al., 2018). Furthermore, peripheral measures of internal load can be quantified during small-sided games, whereby a reduction in playing area serves to increase the frequency of accelerations and decelerations, increasing muscular loading on the legs (Olthof et al., 2018). Employment of the dRPE approach in elite soccer may provide a more valid insight into the internal responses to training and match-play in elite soccer players by offering a more sensitive evaluation of the internal load elicited (Weston, 2013).

9.2 Research proposals in response to the findings in Chapter 5 and Chapter 6

Chapter 5 indicated the training patterns employed were influenced by the philosophies adopted by the head coach in response to the sporadic competitive games schedule. The findings indicate training periodisation in elite soccer cannot be applied universally, due to the individual requirements of different teams in relation to the intended style(s) of play adopted. Further investigations are needed to examine the different approaches to training periodisation currently employed from a wider range of elite teams. Based on the recommendations established in Chapter 5, the work from Chapter 6 is the first report to provide information which details how the diverse periodisation strategies employed by different head coaches affects training load distribution in the same group of elite players. More information is required to quantify how the head coaches training philosophies influences the weekly periodisation practices in elite soccer from the perspective of a wider range of clubs. Future research is needed which focusses on the analysis of training load encountered by the same players under different coaches and / or periodisation strategies in the major European leagues across extended periods of time, or between seasons. By examining the variation in training load, as well as factors such as performance testing, player wellness, and injury rates, such approaches could represent a move towards a better understanding of how to optimally prepare elite soccer players.

9.3 Research proposals in response to the findings in Chapter 7

ASRM represent a non-invasive and time-efficient means through which to derive information concerning players training status. Such methods may therefore potentially serve as an important tool through which to facilitate the key performance outcomes of the training process, namely enhancements in performance and the prevention of injury / illness. Future research is needed to understand the extent to which fluctuations in the diverse periodisation strategies employed elicit ASRM responses in elite players, particularly during the periods in close proximity to competitive matches, to enhance the application of such tools for monitoring the training status of individual players. Furthermore, future work should focus on the provision of education in relation to ASRM monitoring to establish a 'trusting' relationship between the players and Sports Scientist, which may encourage a more open and honest forum when reporting subjective feelings of wellness. Examining both the variation of training loads and resultant ASRM responses across longer (multiple-season) periods, in the same population of players, represent an opportunity to further our understanding of how to optimally prepare elite players. Further research should focus on the effectiveness of ASRM as a simple, efficient, and non-invasive method of assessing player training status from the perspective of a wider range of elite soccer teams.

CHAPTER 10: REFERENCES

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CHAPTER 11: APPENDIX

11. Appendix

THE WITHIN-PARTICIPANT CORRELATION BETWEEN PERCEPTION OF EFFORT AND HEART RATE-BASED ESTIMATIONS OF TRAINING LOAD IN ELITE SOCCER PLAYERS

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The within-participant correlation between perception of effort and heart rate-based estimations of training load in elite soccer players

David. M. Kelly[a], Anthony. J Strudwick[a], Greg Atkinson[b], Barry Drust[a] and Warren Gregson[a]

[a]Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK; [b]Health and Social Care Institute, Teesside University, Middlesbrough, UK

ABSTRACT
The measurement of relative physiological stress during training is important because this is the stimulus for the long-term adaptive response. Measurements of perceived exertion (RPE) have been reported to correlate with the heart rate during field-based training sessions. Nevertheless, there are few studies on how well RPE tracks with the heart rate over repeated training sessions in elite soccer players. Therefore, we aimed to quantify the within-participant correlations between variability in session-RPE (sRPE) and the heart rate in elite male soccer players, and to determine whether the playing position moderated these correlations. The field-based training of four central defenders, four wide defenders, six central midfielders, two wide midfielders and three attackers from an elite English Premier League squad were monitored over an entire in-season competitive period, giving a total of 1010 individual training sessions for study. Correlations between session-RPE and heart rates were quantified using a within-participant model. The correlation between changes in sRPE and heart rates was $r = 0.75$ (95% CI: 0.71–0.78). This correlation remained high across the various player positions (wide-defender, $r = 0.81$; central-defender, $r = 0.74$; wide midfielder, $r = 0.70$; central midfielder, $r = 0.70$; attacker, $r = 0.84$; $P < 0.001$). The correlation between changes in RPE and heart rates, measured during a season-long period of field-based training, is high in a sample of elite soccer players.

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Introduction

Exercise training is an adaptive process in response to the progressive manipulation of the training load. While there are many moderators and mediators of the training response, performance enhancement is generally achieved through a planned manipulation of the training load (a product of the volume and intensity of training) (Manzi et al., 2010). Consequently, the accurate assessment of an individuals' training load is imperative for effective training prescription.

Training load can be quantified by recording both the internal and external loads imposed upon the individual player (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). The physiological strain resulting from the external training factors has been labelled the internal training load (Viru & Viru, 2000). Therefore, valid and reliable indicators of internal training load are essential to monitor the training process. Several approaches based on heart rates have been formulated in an attempt to quantify the internal training load across a range of sports (Banister, 1991; Edwards, 1993; Foster, 1998; Foster et al., 2001). While the heart rate represents a valid means through which the exercise intensity is measured in endurance sports (Åstrand & Rodahl, 1986), the method is questionable in team sports such as soccer, where the overall training load can comprise more short-term high load components (Impellizzeri et al., 2004). Furthermore, full heart rate monitoring systems can be expensive for squads, there can be poor compliance by players to use the monitors and the transmitter belts cannot normally be worn during competition (Lambert & Borresen, 2010).

Session-RPE (sRPE) represents an easier to implement and cheaper alternative to heart rate systems for quantifying training loads (Foster et al., 2001). The sRPE has been reported to be a valid indicator of global internal load of training during both endurance type sports (Foster, 1998) and intermittent team sports such as soccer (Casamichana, Castellano, Calleja, San Roman, & Castagna, 2013; Impellizzeri et al., 2004). To date, studies in which the relationship between sRPE and HR-based estimations of training has been quantified in soccer have principally involved sub-elite level players monitored over a small number of training sessions under well controlled conditions (Alexiou & Coutts, 2008; Casamichana et al., 2013; Impellizzeri et al., 2004). To the present authors' knowledge, only one research group has quantified the correlation between the two methods in elite soccer players undertaking various forms of field based soccer-specific training over extended periods of time (Fanchini et al., 2015), which is important for generalisation to the "real world" domain of elite-level soccer. However, it is also important in longitudinal studies of "tracking" to quantify within-participant correlations according to the most appropriate statistical approach, which models the longitudinal dataset as a whole using the correct degrees of freedom, rather than by calculating correlations for individual players (Atkinson et al., 2011; Bland & Altman, 1995; Lazic, 2010).

CONTACT David M. Kelly david.kelly@manutd.co.uk Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Tom Reilly Building, Byrom Street, Liverpool-L3 3AF, UK

In elite players, marked differences in the physical demands of soccer exist between different playing positions. For example, wide defenders and midfield players frequently engage in activity which is highly dependent upon aerobic metabolism (Bangsbo, 1994) compared to central defenders and strikers where a high proportion of activity is supported by anaerobic metabolism (Di Salvo et al., 2007; O'Donoghue, 1998). Recent observations indicate a poorer relationship between sRPE and HR-based estimations of training load during training sessions which incorporate short-term high-intensity efforts (Campos-Vazquez et al., 2014). The limitations of using heart rates for monitoring the intensity of these types of efforts may extend to affecting the magnitude of the correlation between sRPE and heart rate-load during training. Therefore, the purpose of the current investigation was to quantify the within-participant correlation between the sRPE and heart rate methods for estimating training load in elite soccer players across a typical in-season competitive phase and to determine the influence of playing positions on the magnitude of this correlation.

Methods

Experimental approach to the problem

Nineteen elite-level players were monitored during a full competitive playing season. Players were assigned to one of five positional groups: (central defenders (n = 4, wide defenders (n = 4), central midfielders (n = 6), wide midfielders (n = 2) and attackers (n = 3)). A total of 1010 individual training observations were undertaken on outfield players (goal-keepers were excluded) across the entire in-season competitive period (43 weeks) with a median of 55 training sessions per player (range: 21–102). Training observations for each positional category were: central defender ((n) = 179), wide defender (218), central midfielder (313), wide midfielder (76), and attacker (224)). Only data derived from team field-based technical and physical training sessions were analysed. Matches, individual rehabilitation sessions and individual fitness sessions were not included for analysis.

Participants

Data were collected from 19 soccer players (mean ± SD: age 27 ± 5.1 years, body mass 78 ± 6.2 kg, height 181 ± 7.1 cm) competing in the English Premier League during the in-season competition period. All players were notified of the aim of the study, research procedures, requirements, benefits and risks before giving written informed consent. The Ethics Committee of Liverpool John Moores University approved the study.

Data collection

sRPE training load: the sRPE training load was computed by multiplying training duration (min) by the sRPE as described by Foster et al. (2001) (Table 1). Each player's sRPE was collected in isolation where possible, to avoid the potential effects of peer pressure ~20 minutes after each training session. This ensured that the perceived effort reflected the whole session and not the most recent exercise intensity. All the players were familiarised with the use of the scale during the pre-season training phase.

Table 1. Category ratio rating of the perceived exertion (RPE) scale utilised in the current study (CR-10 scale) Foster et al. (2001).

Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Maximal

Heart-rate training load: individual player heart rate was recorded every 1 s during each training session using individual coded heart rate monitors (Team[2], Polar Electro, Kempele, Finland). After each training session, the individual heart rate monitors were downloaded onto a PC using Polar Team[2] software (version 1.4.5). The individual heart rate data were subsequently exported into a Microsoft Excel spreadsheet database (Microsoft Corporation, U. S.). The current study utilised the heart rate-based training load method proposed by Edwards (1993) as used by Foster (1998) to validate the use of sRPE training load to monitor endurance training. This heart-rate based method has also been employed as a criterion measure to examine sRPE in the non-steady state and prolonged exercise (Foster et al., 2001; Impellizzeri et al., 2004). The Edwards method (Edwards, 1993) was applied to heart rate data recorded during the 43-week in-season competitive phase. Internal training load was quantified by measuring the product of the accumulated training duration (minutes) of five separate heart rate zones by a numerical factor relative to each zone (50–59% [HR_{max}] = 1, 60–69% = 2, 70–79% = 3, 80–89% = 4, 90–100% = 5) and then summating the results.

Statistical analysis

Data are expressed as means ± S.D. Within-participant correlations were calculated between sRPE load and heart rate-load (Bland & Altman, 1995). Rather than pooling all the data, or calculating correlations separately for individual participants, this approach quantifies the correlation, and associated 95% confidence interval (95% CI), between a covariate and outcome while taking into account the within-participant nature of the study design. This longitudinal modelling approach is based on the correct degrees of freedom, and is therefore associated with higher statistical precision than the averaging of Pearson's correlations for individual players. The latter approach also violates the assumption of case independence necessary for a Pearson's correlation. To interpret the magnitude of correlation between the two variables, the following criteria were applied: (r < 0.1) trivial, (0.1 < r < 0.3) small, (0.3 < r < 0.5) moderate, (0.5 < r < 0.7) large, (0.7 < r < 0.9) very large, ($r > 0.9$) almost perfect and ($r = 1$) perfect (Viru & Viru, 2000). Statistical analyses were carried out using the SPSS statistical analysis software for Windows (version 19.0, SPSS Inc., Chicago, IL, USA).

Results

The overall training load across the observed sessions was 229 ± 105 arbitrary units (AU) and 132 ± 57 beats/min for sRPE and heart rate-load, respectively. Overall, the changes in sRPE training load were highly correlated with the changes in heart rate-load ($r = 0.75$; 95% CI 0.71–0.78; $P < 0.001$). Playing positions had little influence on the correlations between measurement methods. Within-participant correlations between sRPE and heart rate-load were large and very large in magnitude for central defenders ($r = 0.74$, $P < 0.001$, 95 % CI 0.70–0.77; Figure 1), wide defenders ($r = 0.81$, $P < 0.001$, 95 % CI 0.78–0.84; Figure 2), central midfielders ($r = 0.70$, $P < 0.001$, 95 % CI 0.66–0.74; Figure 3), wide midfielders ($r = 0.70$, $P < 0.001$, 95 % CI 0.66–0.74; Figure 4) and attackers ($r = 0.84$, $P < 0.001$, 95 % CI 0.82–0.86; Figure 5).

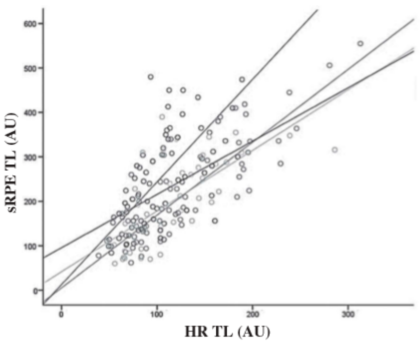

Figure 1. Relationship between the sRPE TL and HR TL for *central defenders* ($r = 0.74$; $P < 0.001$).

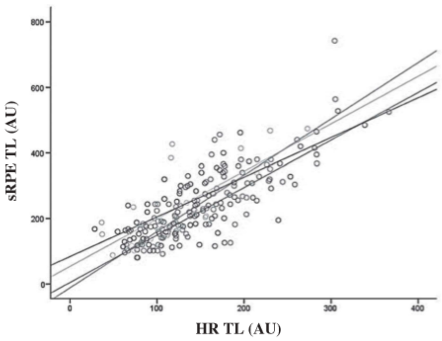

Figure 2. Relationship between the sRPE TL and HR TL for *wide defenders* ($r = 0.81$; $P < 0.001$).

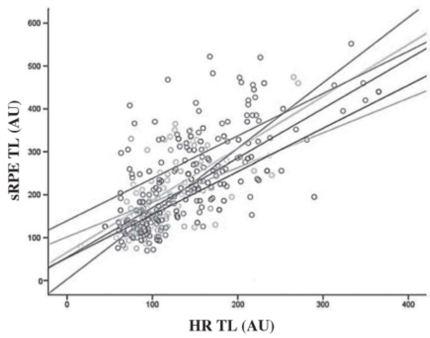

Figure 3. Relationship between the sRPE TL and HR TL for *central midfield* players ($r = 0.70$; $P < 0.001$).

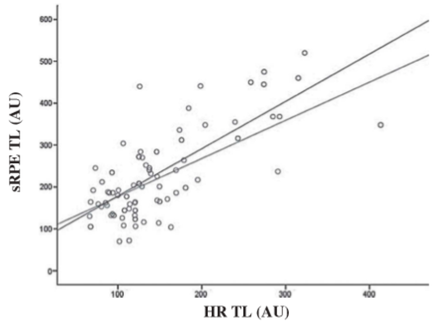

Figure 4. Relationship between the sRPE TL and HR TL for *wide midfield* players ($r = 0.70$; $P < 0.001$).

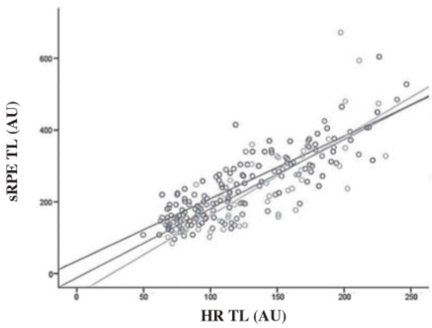

Figure 5. Relationship between the sRPE TL and HR TL for *attackers* ($r = 0.84$; $P < 0.001$).

Discussion

The purpose of the current study was to quantify the correlation between the variability in sRPE and a heart rate-based method for quantifying the internal training load in elite soccer players, encompassing both technical and physical field-based soccer drills during daily training sessions, and to determine the influence of playing position on the magnitude of this correlation. The large correlation ($r = 0.75$; 95% CI 0.71–0.78; $P < 0.001$) between the overall sRPE and heart rate-load observed in the present study compares favourably with the moderate-large associations ($r = 0.50$ to $r = 0.85$) observed in young amateur (Impellizzeri et al., 2004), semi-professional males (Casamichana et al., 2013) and elite female (Alexiou & Coutts, 2008) and male soccer players (Fanchini et al., 2015).

Previous attempts to quantify the correlation between sRPE and heart rate-load are limited to some extent by suboptimal statistical approaches, including pooling all of the data over time for calculation of single correlation with inflated degrees of freedom, or quantifying correlations for individual players and calculating a sample mean correlation, which lacks statistical power (Atkinson et al., 2011). The "within-subjects" correlations employed in the current study, and large number of data sets collected on a daily basis from elite-level professional English Premier League players may therefore give a more accurate representation of the relationship between the two measured variables observed in elite-level soccer.

While the heart rate represents a valid means through which to measure exercise intensity in endurance sports (Åstrand & Rodahl, 1986), the method is questionable in team sports such as soccer where the overall training load frequently comprises anaerobic components (Impellizzeri et al., 2004). Indeed, this may partly account for the failure to observe a higher correlation between sRPE training load and HR-derived training load in the current study, and in previous studies which have compared the two methods during activities involving a high anaerobic contribution (Casamichana et al., 2013; Fanchini et al., 2015; Impellizzeri et al., 2004). In line with such observations, Campos-Vazquez and colleagues (2014) recently reported that the magnitude of the relationship between sRPE and HR-based estimations of training load was dependent upon the type of training session undertaken. Moderate correlations ($r = 0.35$ to 0.55) were observed between the two methods during high-intensity sessions involving explosive drills (e.g., accelerations, changes of direction, jumps) and small side games (5 *vs.* 5 to 8 *vs.* 8) compared to very large correlations ($r = 0.73$ to 0.87) during tactical based sessions (e.g., 11 *vs.* 11) incorporating a higher proportion of aerobic activity. Players observed in the current study were regularly exposed to a variety of training drills. These were in the format of pre-training activation type drills, small-sided games, which were varied according to organisational parameters enforced by the coaches (ranging from 4 *vs.* 4 to 9 *vs.* 9 formats), high-intensity running drills and speed endurance training. The anaerobic conditioning component inherent with these types of drills may therefore have reduced the magnitude of the correlations between sRPE and heart rate-load observed in the current study.

Marked differences in the physical demands of soccer exist between different playing positions. For example, wide defenders and midfield players frequently engage in low to moderate-intensity aerobic activity compared to central defenders and strikers who are characterised to a greater extent by short, high-intensity anaerobic bouts (Di Salvo et al., 2007; O'Donoghue, 1998). Given the limitations inherent in using the heart rate for monitoring the intensity of anaerobic exercise, differences in the aerobic and anaerobic contribution to energy provision between playing positions may influence the magnitude of the correlation between sRPE and heart rate-load. A further aim of the present study therefore was to examine whether these differences in physical demands between different positions influences the magnitude of the correlation between session-RPE and heart rate-load. Playing positions had little influence on the magnitude of the relationship with the within-individual correlation ranging from large ($r = 0.70$) in central and wide midfielders to very large ($r = 0.74$ to 0.84) in the remaining positions. These findings may, to some extent, reflect a lack of position-specific training undertaken as part of the methodology implemented by the coaches in the present team. As noted above, a high proportion of small-sided games (4 *vs.* 4 to 9 *vs.* 9) were employed which reduce the degree to which players participate in "set" positions on the field of play. These drills were supplemented with both position-specific and non-position-specific high-intensity running and speed endurance drills (with and without the ball) in order to prepare players for the most critical and/or intense periods of the games. Since match data was not included in the current study and 11 v 11 type drills formed a relatively small proportion of the weekly training time (e.g., pre-game day) it is possible that the degree of position-specific training was not sufficient enough to influence the correlation between session-RPE and heart rate-load. Further work is needed in order to determine whether the magnitude of the correlation between session-RPE and heart rate-load is influenced by playing position during training drills which demand a position-specific focus.

Practical applications

The present study findings indicate that session-RPE shows promise as a simple and practical global indicator of individual training load in elite-level soccer players irrespective of playing position. Session-RPE and heart rate-load are highly correlated and do reflect the internal training load stressors elicited on individual players.

Disclosure statement

No potential conflict of interest was reported by the authors.

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QUANTIFICATION OF TRAINING AND MATCH-LOAD DISTRIBUTION ACROSS A SEASON IN ELITE ENGLISH PREMIER LEAGUE SOCCER PLAYERS

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Quantification of training and match-load distribution across a season in elite English Premier League soccer players

David M. Kelly, Anthony J. Strudwick, Greg Atkinson, Barry Drust & Warren Gregson

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Quantification of training and match-load distribution across a season in elite English Premier League soccer players

David M. Kelly[a,b], Anthony J. Strudwick[a], Greg Atkinson[c], Barry Drust[b] and Warren Gregson[b]

[a]Department of Football Medicine and Science, Manchester United Football Club, AON Training Complex, Manchester, UK; [b]Football Exchange, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK; [c]Health and Social Care Institute, Teesside University, Middlesbrough, UK

ABSTRACT

Objective: To examine training and match loads undertaken by soccer players competing in the English Premier League.

Methods: Using a retrospective design, external (GPS) and internal training loads (sessions ratings of perceived exertion [sRPE-TL]) were examined in 26 players across the competition phase of the 2012–2013 English Premier League season. Within-subject linear mixed-models estimated the mean effects (95% confidence interval [CI]) for load data across 6-week mesocycles and 1-week microcycles.

Results: Daily sRPE-TL (95% CI range, 15 to 111 AU) and total distance (95% CI range, 179 to 949 AU) were higher during the early stages (mesocycle 1 and 2) of the competition period. Overall, high-speed activity was similar between mesocycles. Across the training week, load was greater on match day and lower pre match-day (G-1) vs. all other days, respectively ($p < 0.001$). sRPE-TL (~70–90 AU per day) and total distance (~700–800 m per day) progressively declined over the 3 days before a match ($p < 0.001$). High-speed distance was greater 3 days (G-3) before a game vs. G-1 (95% CI, 140 to 336 m) while very high-speed distance was greater on G-3 and G-2 than G-1 (95% CI range, 8 to 62 m; $p < 0.001$).

Conclusion: Periodisation of in-season training load is mainly evident across the weekly microcycle reflecting the recovery and preparation for matches.

ARTICLE HISTORY
Accepted 24 July 2019

KEYWORDS
Soccer training; mesocycle; microcycle; sRPE-TL; periodisation

Introduction

The complex physiological demands of soccer necessitate the implementation of training programmes which are multifactorial in nature (Morgans et al. 2014). Such requirements are further complicated by the stochastic movement profiles observed in elite soccer. The sporadic work bouts associated with soccer training may therefore result in variability between the desired training load and the actual training load the players are exposed to (Malone et al. 2015). Monitoring the individual player's daily training load therefore represents an important component of the effective planning of a soccer-specific training regimen (Weston 2018).

The volume and intensity of training, collectively referred to as the training load (Impellizzeri et al. 2005), requires manipulation (periodisation) to elicit an optimum training stimulus (Malone et al. 2015). Many clubs therefore employ practitioners to collect, interpret and feedback information to coaches regarding the players daily load and status (Arkenhead and Nassis, 2016; Weston 2018). To date, studies focused on training load quantification in soccer have largely focused on isolated training drills (Coutts et al. 2009; Casamichana and Castellano 2010; Buchheit et al. 2015) or mesocycles of up to 10 weeks (Impellizzeri et al. 2004; Gaudino et al. 2013; Scott et al. 2013; Clemente et al. 2019). In contrast, while a plethora of studies have documented the long-term (season-long) periodisation models adopted in other football codes (Gabbett and Jenkins 2011; Moreira et al. 2016; McGahan et al. 2017), little data currently exist in elite soccer.

Recent studies have provided some insight into the seasonal training loads encountered by players competing in the Spanish reserve league (Los Arcos et al., 2017; Martin-Garcia et al. 2018), Dutch Eredivisie League (Stevens et al. 2017), and the English Premier League (Malone et al. 2015; Anderson et al. 2016). Across the competitive season, there was little variation in training load between mesocycles (6–8-week training blocks) (Malone et al. 2015; Anderson et al. 2016). Within weekly microcycles, load was also generally similar between training days with the exception of a marked reduction in load on the day preceding the game (Malone et al. 2015; Martin-Garcia et al. 2018). Whilst these studies provide valuable insights into the training loads experienced by elite players, further observations are required in order to gain a comprehensive insight into the collective periodisation practices adopted by professional teams (Weston 2018). Furthermore, a more detailed analysis of the nature of the loading incurred by players is required. For example, internal training load, or the individual physiological response to the external load administered by the coach, represents the stimulus for training induced adaptation (Viru and Viru 2000). Valid and reliable indicators of internal training load are therefore essential when monitoring the training process. Session RPE-TL (sRPE-TL) represents a valid indicator of the global internal training load during intermittent team sports such as soccer (Impellizzeri et al. 2004;

CONTACT David M. Kelly david.kelly@manutd.co.uk Manchester United Football Club, AON Training Complex, Birch Road off Isherwood Road, Carrington, Manchester M31 4BH, UK

Casamichana et al. 2013; Kelly et al. 2016). Despite the importance of the internal load in indicating the training response, observations on elite players have also been largely restricted to descriptions of short-term periods of training (Campos-Vazquez et al. 2015) with only one research group to date reporting session RPE-TL responses to long-term periods of training in elite players (Malone et al. 2015).

Most of what is currently known about load monitoring derives from personal experiences or remains unpublished, since many elite teams are often unwilling to publish their data in order to retain competitive advantage. The training approaches adopted by elite teams and the degree to which these approaches incorporate periodisation strategies therefore remain largely unexplored in the literature. A recent survey of practitioners and coaches working in elite English soccer perceived that coaches were mostly responsible, and sports scientists/fitness coaches somewhat responsible, for planning training (Weston 2018). Coaching practice is heavily influenced by tradition, emulation and historical precedence rather than through critical consideration of the latest research (Stoszkowski and Collins 2016). Given the diverse coaching philosophies inherent in the modern elite game, further studies are needed to enhance our understanding as to how training loads in soccer are programmed across the annual cycle. The aim of the current investigation therefore was to quantify the combined external and internal training and match-load distribution across the competition phase of one full season at an English Premier League club.

Methods

Participants

Twenty-six elite-level soccer players were monitored across a 36-week competition phase of the 2012–2013 English Premier League (League Champions) season (mean ± SD: age 27 ± 5.4 years, body mass 77 ± 6.6 kg, height 181 ± 7.0 cm). Players were assigned to one of five positional groups: central defender (CD) (n = 4), wide defender (WD) (n = 4), central midfielder (CM) (n = 7), wide midfielder (WM) (n = 3), and attacker (A) (n = 8). The team competed in four official competitions throughout the season corresponding to 49 competitive matches in total. All of the players were notified as to the aim of the study, requirements, research procedures, benefits and risks before giving written informed consent. The Ethics committee of the relevant School at Liverpool John Moores University approved the study.

Design

For the purpose of the current study, all of the first team field-based training sessions carried out were considered for the analysis. This was inclusive of sessions involving both the starting line-up and non-starting players. Individual training, rehabilitation, recovery and specific fitness sessions were excluded from the analysis. Goalkeepers were not included in the study. Daily training load data were collected using the sRPE-TL method and micro-technology. Training and match data collection were carried out at the soccer club's training ground on the same natural outdoor grass training pitches, and at both home and away grounds in the English Premier League, respectively. A stadium-based tracking system was used to record match-play activities. All training and match-load data observed during a 36-week competition phase of the season were categorised into 6-week mesocycle phases, and subsequent weekly calendar blocks (Sunday to Sunday). This enabled a full season's analysis of both the training and match-play load (Figure 1).

Training and match-load data were also analysed in relation to the proximity of the forthcoming competitive game (day type). Six-day types in total were identified and analysed in the current study (G-3, G-2, G-1, match day (MD), G + 2, G + 3). For example, 1 day before the game was classified as game day minus one (G-1), 2 days before was G-2, etc., whereby G + 2 and G + 3 were the second- and third-day post-match, respectively. The day immediately following a game (i.e. G + 1) was not included in the analysis as this was classified as a recovery day which involved a reduced load non-weight bearing recovery strategy and was therefore not representative of a training day.

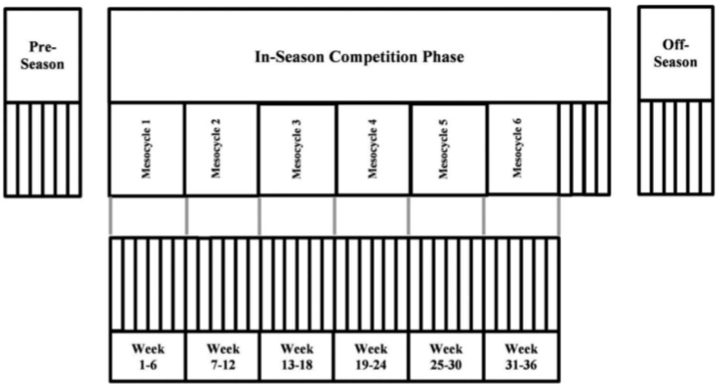

Figure 1. Diagrammatic representation of the experimental design used in the current study. Each small block represents individual weeks within the annual training cycle, with larger blocks showing the 6-week mesocycle phases of the competitive season.

During the season there were one-, two-, and three-game weeks. A one-game week consisted of six training days leading into the game. The two-game week had one recovery day following the first game (e.g. G + 1) and four training days leading into the next game. A three-game week had one recovery session and a - training day (G-1) between the first and second game and the second and third game, respectively. In some instances during two and three-game weeks, games were played in closer proximity (e.g. Saturday and Tuesday), leaving only 2 days between fixtures. In this scenario, one recovery session and a - training day (G-1) was implemented between games.

Methodology

Training load assessment

Internal training load. Internal training load (sRPE-TL, arbitrary units, AU) was estimated for all players by multiplying total training or match session duration (min) with session ratings of perceived exertion (sRPE) (Foster et al. 2001). Player sRPE was collected in isolation where possible, to avoid the potential effects of peer pressure ~20 min after each training session or match. All the players were familiarised with the use of the RPE scale during the pre-season training phase.

External training load: team training and matches. The player's external training session load was monitored using portable micro-technology (GPSports SPI Pro X, Canberra, Australia). The SPI Pro X (GPS and accelerometer integrated; size: 48 × 20 × 87 mm; 76 g) was placed inside a specially made vest, inside a mini pocket and positioned on the player's back, which was located centrally between the scapulae. The player wore micro-technology for the whole duration of the session. The unit was activated ~15 min before data collection to allow for the acquisition of satellite signals (Waldron et al. 2011). During every training session observation, the minimum acceptable number of available satellite signals was 8, which is optimal for the measurement of human movement (Jennings et al. 2010). To avoid inter-unit error, each player wore the same micro-technology device for every training session observation (Jennings et al. 2010). The SPI Pro unit provides raw position, velocity and distance data at a rate of 15 samples-per-second (15 Hz). Every three raw data points were averaged for the purpose of the current study to provide a sampling frequency of 5 Hz. This type of system has been shown to provide a reliable and valid estimate of the high-speed distance covered during multi-directional sports such as soccer (Portas et al. 2010; Randers et al. 2010; Waldron et al. 2011; Varley et al. 2012).

All training sessions and competitive matches during the 2012–13 season were observed and subsequently recorded. The mean number of training sessions completed, and the average match observations during each month ($n = 5$) are shown in Figure 2. Mean training session duration across all positions was 59 ± 7 min (Figure 3). Matches were inclusive of domestic (Premier League, F.A. Cup, League Cup), and European (Champions League) fixtures. Friendly games were excluded from the analysis. A total of 49 matches were observed during the 36-week competition phase of the season. Individual player's activities were monitored during each game using a stadium-based multiple-camera match analysis system (Prozone Sports Limited, Leeds, UK). Data from both home and away fixtures were included. Only data from completed 90 min matches were used for the analysis. The median number of completed matches by individual players was 16 (range: 2–38). All Prozone data were processed using the appropriate software package (Prozone 3 Version 12.0.4.2., Prozone Sports Limited, Leeds, UK). This was carried out post-game(s) by the club's performance analyst and exported into a Microsoft Excel spreadsheet database (Microsoft Corporation, U.S.) for the analysis.

The observed training and match-play activities (external load markers) identified for subsequent analysis were: total distance

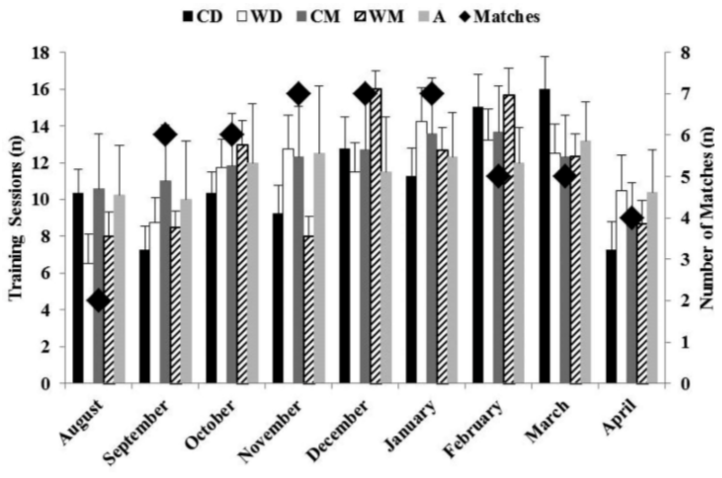

Figure 2. Mean ± SD number of training sessions and competitive games by playing position during the 2012–13 season.

(m), distance (m) completed at high-speeds >14.4 km/h (m), and distance (m) completed at very high-speeds 19.8–25.2 km/h. The current authors acknowledge that some differences in the measures derived from the micro-technology devices and Prozone system exist. In particular, it has been shown previously that high-intensity running distances are slightly-to-moderately greater when tracked using Prozone in comparison to GPSports devices (Buchheit et al. 2014). However, for the purpose of the current investigation, both the GPSports (training load), and Prozone (match load) data were combined together for the analysis (Anderson et al. 2016).

Statistical analysis

Data are represented as means ± S.D. A multi-factorial linear-mixed model was used to quantify mean differences between mesocycles, day-type and playing position. Use of linear mixed-modelling is suitable to examine repeated-measures data and unbalanced observations over time as, for example, in the context of our study where players differ in the number of training sessions and matches (Cnaan et al. 1997). Linear mixed modelling can also cope with the mixture of random and fixed level effects (Cnaan et al. 1997) as well as with missing and 'nested' data (hierarchical models). The main effects for sub-group comparisons of each factor were summarised using least significance difference (LSD) multiple contrasts (Perneger 1998).

Mean differences are presented with 95% confidence intervals (CI) as markers of uncertainty in the estimates. In the absence of an established anchor, despite the lack of real-world relevance of standardised effect sizes (Lenth 2001), Cohen's d was reported as an additional statistic for interpreting the magnitude of the estimated effects (Cook et al. 2018). Effect size (ES), estimated from the ratio of the mean difference to the pooled standard deviation were also calculated. The ES magnitude was classified as trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0) and very large (>2.0–4.0) (Hopkins et al. 2009). Within this particular context and to address the potential inflation of error rates associated with the large number of inferences in the present study, effects were declared meaningful if the point estimate for the mean difference expressed in standardised units attained threshold of moderate (ES > 0.6).

Results

Mesocycle

Total number of games during each of the 6 x 6-week mesocycles ranged from 6 to 10 (mesocycle 1 = 6; mesocycle 2 = 9; mesocycle 3 = 10; mesocycle 4 = 6; mesocycle 5 = 9, and mesocycle 6 = 9). Mean daily sRPE-TL, total distance, high-speed distance and very high-speed distance across each of the 6 x 6-week mesocycles by playing position are presented in Table 1. A statistically significant change in all variables was observed across the six mesocycles (all $p < 0.001$). Daily sRPE-TL was higher during the early stages of the season with greater values observed in mesocycle 1 than all other mesocycles (95% CI range, 16 to 111) and greater values observed in mesocycle 2 than mesocycles 3 and 4 (95% CI range, 15 to 91 AU). Total distance was higher in mesocycles 1 and 2 than mesocycles 3, 4, and 6 (95% CI range, 179 to 949 AU). Meaningful differences in high-speed distance were only observed in mesocycle 5 compared to mesocycle 4 (95% CI, 66 to 228 m) with greater very high-speed distance observed in mesocycle 2 than mesocycle 4 (95% CI, 21 to 64 m). No meaningful or statistically significant main effects of playing position or interaction between playing position and mesocycle were observed for any variable (all $p > 0.05$).

Table 1. Mean ± SD weekly training and match loads during each 6-week mesocycle block for sRPE-TL, total distance, high-speed distance and very high-speed distance.

Mesocycle, Position	sRPE-TL (AU)	Total Distance (m)	High-Speed Distance (m)	Very High-Speed Distance (m)
Mesocycle 1	**347 ± 60** $^{M, L}$	**4670 ± 662** ^{M}	**765 ± 233**	**204 ± 59**
CD	339 ± 138	4430 ± 1531	716 ± 543	206 ± 139
WD	384 ± 136	4585 ± 1520	756 ± 537	228 ± 135
CM	337 ± 96	4809 ± 1050	820 ± 367	200 ± 94
WM	322 ± 166	4762 ± 1861	850 ± 657	208 ± 165
A	351 ± 90	4762 ± 994	681 ± 350	177 ± 89
Mesocycle 2	**327 ± 60** ^{M}	**4676 ± 666** ^{M}	**815 ± 231**	**219 ± 59** ^{M}
CD	319 ± 146	4595 ± 1612	766 ± 564	162 ± 145
WD	331 ± 136	4608 ± 1489	833 ± 518	241 ± 132
CM	332 ± 100	4788 ± 1112	823 ± 386	203 ± 98
WM	314 ± 160	4557 ± 1771	838 ± 612	248 ± 156
A	341 ± 91	4831 ± 1026	817 ± 358	243 ± 91
Mesocycle 3	**291 ± 59**	**4242 ± 647**	**727 ± 225**	**192 ± 58**
CD	274 ± 134	3949 ± 1450	616 ± 508	150 ± 130
WD	306 ± 128	4216 ± 1407	653 ± 487	187 ± 123
CM	296 ± 101	4226 ± 1101	689 ± 383	181 ± 99
WM	249 ± 169	4162 ± 1860	845 ± 650	226 ± 168
A	330 ± 91	4659 ± 1017	830 ± 356	214 ± 91
Mesocycle 4	**258 ± 58** ^{M}	**3960 ± 621** ^{M}	**695 ± 216**	**177 ± 56**
CD	251 ± 129	3733 ± 1389	626 ± 486	156 ± 126
WD	270 ± 128	3977 ± 1378	644 ± 480	162 ± 123
CM	262 ± 95	3960 ± 1027	711 ± 356	174 ± 92
WM	216 ± 156	3814 ± 1685	711 ± 587	184 ± 150
A	289 ± 97	4316 ± 1054	782 ± 372	208 ± 94
Mesocycle 5	**309 ± 57**	**4416 ± 623**	**841 ± 217** ^{M}	**185 ± 55**
CD	329 ± 124	4368 ± 1350	753 ± 471	169 ± 120
WD	318 ± 130	4323 ± 1412	731 ± 494	192 ± 125
CM	294 ± 102	4642 ± 1104	866 ± 387	187 ± 99
WM	264 ± 149	4081 ± 1616	895 ± 559	177 ± 143
A	340 ± 102	4666 ± 1123	961 ± 400	201 ± 101
Mesocycle 6	**306 ± 58**	**4193 ± 653**	**821 ± 228**	**207 ± 58**
CD	308 ± 127	3947 ± 1389	746 ± 485	190 ± 124
WD	320 ± 126	4231 ± 1426	834 ± 499	228 ± 127
CM	303 ± 103	4191 ± 1166	839 ± 411	204 ± 104
WM	238 ± 160	4111 ± 1796	800 ± 627	180 ± 158
A	364 ± 101	4487 ± 1171	887 ± 414	231 ± 105

Subscripts denote moderate (M), large (L), and very large (V). *sRPE-TL*: **Mesocycle 1**; M *vs.* mesocycles 3, 5, 6. L *vs.* mesocycle 4. **Mesocycle** 2; M *vs.* mesocycles 3 and 4. **Mesocycle 4**; M *vs.* mesocycles 5 and 6. *Total Distance*: **Mesocycle 1**; M *vs.* mesocycles 3, 4, 6. **Mesocycle 2**; M *vs.* mesocycles 3, 4, 6. **Mesocycle 4**; M *vs.* mesocycle 5. *High-Speed distance*: **Mesocycle 5**; M *vs.* mesocycle 4. *Very High-Speed Distance*: **Mesocycle** 2; M *vs.* mesocycle 4.

Day type

Mean daily sRPE-TL, total distance, total high-speed distance and total very high-speed distance across all day types are represented in Figures 4–7. No meaningful or statistically significant main effect of playing position were observed for any variable ($p > 0.05$). There was a statistically significant main effect of day-type for all variables (all $p < 0.001$). Session RPE-TL (MD vs. other days: 95% CI range, 208 to 409 AU; G-1 vs. other days: 95% CI range, −409 to −47 AU), total distance (MD vs. other days: 95% CI range, 4188 to 6069 m; G-1 vs. other days: 95% CI range, −6070 to −430 m), total high-speed distance (MD vs. other days: 95% CI range, 1466 to 1875 AU; G-1 vs. other days: 95% CI range, −1875 to −35 m) and total very high-speed distance (MD vs. other days: 95% CI range, 425 to 542 AU; G-1 vs. other days: 95% CI range, −542 to −20 m) were higher on MD and lower on G-1 compared to all other days. sRPE-TL (~70–90 AU per day) and total distance (~700–800 m per day) progressively reduced over the 3 days before a match ($p < 0.001$). High-speed distance was greater on G-3 than G-1 (95% CI, 140 to 336 m) and very high-speed distance was greater on G-3 and G-2 vs. G-1 (95% CI range, 8 to 62 m; $p < 0.001$; Figures 6 and 7).

There was a statistically significant interaction between day-type and playing position for all variables predominantly reflecting positional differences on MD (all $p < 0.001$; Figures 4–7). During training, sRPE-TL was lower in WM than WD on G-3 (95% CI, −208 to −18 AU). sRPE-TL was higher in A than WD and CM on G-2 (95% CI range, −29 to 129 AU) and higher than all other positions on G-1 (95% CI range, −2 to 156 AU). Attackers covered greater total distance than CD and WD on G-1 (95% CI range, 102 to 1387 m). Differences in high-speed activity between positions were only observed on MD.

Discussion

The aim of the current study was to examine the external and internal load incurred by elite soccer players across both the larger and smaller units of the annual competition period. Across the competition period, there was limited variation in loading between the mesocycles with similar loads observed between playing positions. In contrast, marked fluctuations in external and internal load were evident within the weekly microcycle phase which was further influenced by playing position. This was generally characterised by a post-match recovery day (low load) followed by an increase in loading (G + 2 through to G + 3 and G-3) and subsequent taper through G-2, and G-1. The findings of the present study provide novel insights into the training periodisation undertaken by an elite English Premier League team during a championship-winning season. Further studies of this type are required to enable a more comprehensive examination and subsequent development of the training methodologies adopted by elite coaches.

In the present study, total distance and sRPE-TL were ~470 m (95% CI, 228 to 724 m), and 40 AU (95% CI, 19 to 62 AU) higher at the start of the competitive phase (mesocycle 1) versus the end (mesocycle 6). These changes in total distance are lower than those previously observed by Malone et al (2015), where players covered ~1300 m more total distance in mesocycle 1 than mesocycle 6. Mean daily total distance (95% CI, 472 to 947 m), sRPE-TL (95% CI, 67 to 111 AU) and high-speed distance (95% CI, −19 to 159 m) were also ~700 m, 90 AU and 70 m higher, respectively, at the start of the season (mesocycle 1) compared with mid-season (mesocycle 4) across all positions in the present study. Greater training loads at the beginning of the in-season competitive phase may often reflect the coaches' desire to maintain the emphasis on the development of fitness levels following the pre-season training period (Malone et al. 2015).

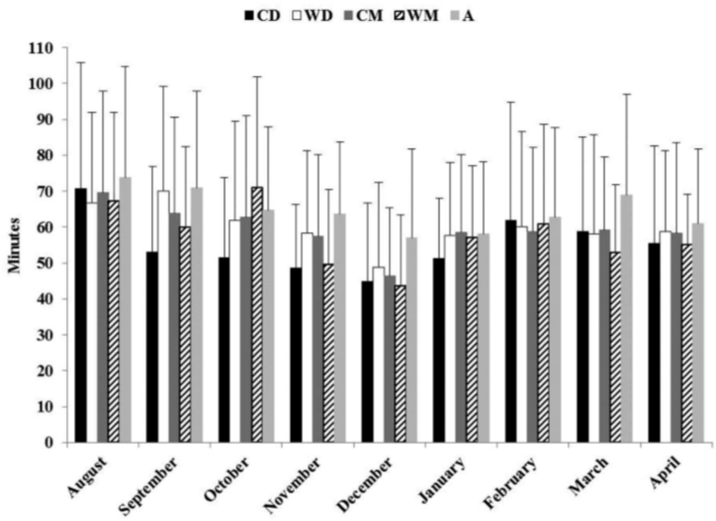

Figure 3. Mean ± SD training session duration by playing position during the 2012–13 season (central defender [CD]; wide defender [WD]; central midfielder [CM]; wide midfielder [WM]; attacker [A]).

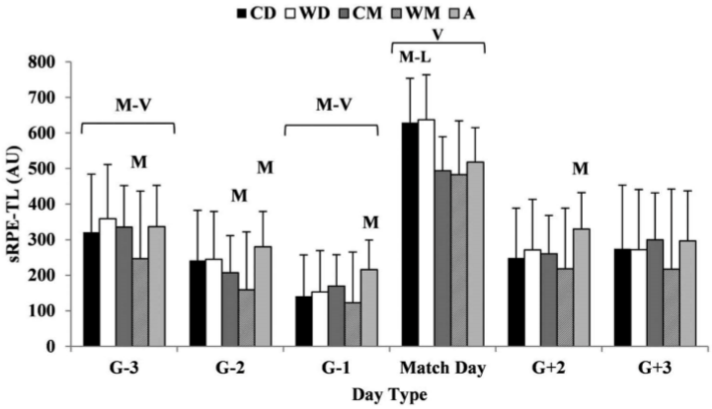

Figure 4. Mean ± SD sRPE-TL for training day's pre- and post-competitive match and match-day between positions. Subscripts denote moderate (M), large (L), and very large (V). *Day Type*: **G-3**; L *vs.* G-2, V *vs.* G-1, M *vs.* G + 2 and G + 3. **G-1**; V *vs.* G-3, M *vs.* G-2, L *vs.* G + 2, and G + 3. **MD**; V *vs.* G-3, G-2, G-1, G + 2 and G + 3. *Day Type x Playing Position*: **G-3; WM**, M *vs.* WD. **G-2; A**, M *vs.* WM and CM. **G-1; A**, M *vs.* CD, WD, and WM. **MD; CD**, L *vs.* CM, M *vs.* WM and A. **WD**, L *vs.* CM, M *vs.* WM and A. **G + 2; A**, M *vs.* CD, CM, and WM.

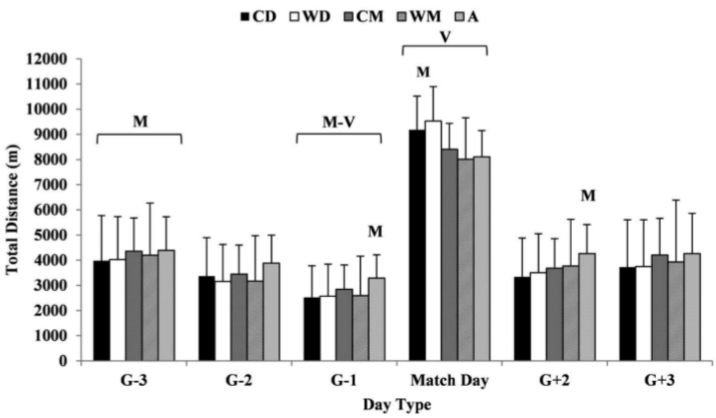

Figure 5. Mean ± SD total distance for training day's pre- and post-competitive match and match day between positions. Subscripts denote moderate (M), large (L), and very large (V). *Day Type*: **G-3**; M *vs.* G-2 and G + 2. **G-1**; V *vs.* G-3, M *vs.* G-2, L *vs.* G + 2 and G + 3. **MD**; V *vs.* G-3, G-2, G-1, G + 2, and G + 3. *Day Type x Playing Position*: **G-1; A**, M *vs.* CD and WD. **MD; CD**, M *vs.* CM, WM, and A. **WD**, M *vs.* CM, WM, and A. **G + 2; A**, M *vs.* CD.

The middle phase of the season (mesocycle 4 [mid-December]) is associated with the lead into the Christmas period, which typically has a highly congested fixture schedule in the English Premier League. We presently observed the highest number of matches ($n = 7$) and the greatest average number of training session observations 62 (range: [*n*], 40–62) during this period. However, the average training session duration (48 ± 5 min) was greatly reduced across December compared to all other periods of the season which resulted in the lowest sRPE-TL, total distance, high-speed distance, and very high-speed distances. These changes were consistent with the strategy employed by the head coach which aimed to offset the increased frequency of matches by reducing training-induced fatigue in order to maintain match readiness. Our findings are in-line with Malone et al (2015) who also reported reductions in training volume during the mid-season phase, whereby sRPE-TL was lower by ~80 AU across this period.

Training load prescription in soccer is largely influenced by the competition frequency, with in-season microcycles of typically 3 to 7 days in duration repeatedly occurring around matches (Morgans et al. 2014; Malone et al. 2015; Akenhead et al. 2016). sRPE-TL (~70–90 AU per day) and total distance (~700–800 m per day) progressively reduced over the 3 days before a match. High-speed distance was also greater on G-3 than G-1 (95% CI, 140–336 m) and very high-speed distance

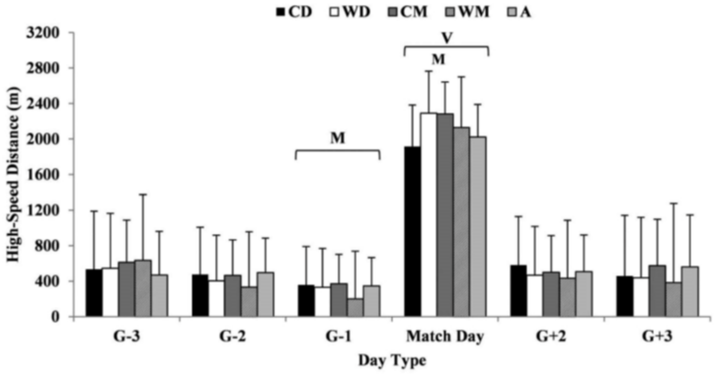

Figure 6. Mean ± SD total high-speed distance for training day's pre- and post-competitive match and match day between positions. Subscripts denote (M), large (L), and very large (V). *Day Type*: **G-1**; M *vs.* G-3, G + 2 and G + 3. **MD**; V *vs.* G-3, G-2, G-1, G + 2, and G + 3. *Day Type x Playing Position*: **MD; WD**, M *vs.* CD and A. **CM**, M *vs.* CD and A.

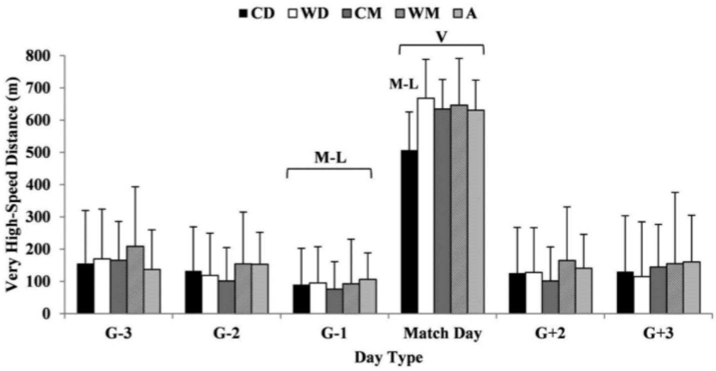

Figure 7. Mean ± SD total very high-speed distance for training day's pre- and post-competitive match and match day between positions. Subscripts denote moderate (M), large (L), and very large (V). *Day Type*: **G-1**; L *vs.* G-3, M *vs.* G-2, G + 2, and G + 3. **MD**; V *vs.* G-3, G-2, G-1, G + 2, and G + 3. *Day Type x Playing Position*: **MD; CD**, L *vs.* WD and CM, M *vs.* WM and A.

was greater on G-3 and G-2 vs. G-1. The higher training loads observed on G-3 reflected training sessions incorporating drills undertaken on larger pitch sizes (i.e. extensive endurance position-specific practices) with a greater number of players (7 *v* 7–11 *v* 11). More intensive endurance drills were undertaken in smaller training areas with a reduced number of players (e.g. 3 *v* 2, 5 *v* 4, and 1 *v* 1–3 *v* 3) as part of training sessions undertaken on G-2. The aim of these training sessions was to elicit intensities deemed suitable to produce the physiological adaptations required for soccer-specific endurance (Little and Williams 2006) while simultaneously aiding the development of technical and tactical skills similar to situations experienced during the game. All variables were lowest on G-1 as a consequence of the implementation of lower intensity and shorter training sessions the day before a match, consisting mainly of activation and reactive speed training type drills. The decline in daily load from G-3 to G-1 in the current study is in agreement with recent observations in Spanish La Liga reserve team players who showed a marked reduction in total distance (~3000 m) and high-speed distance (~170 m) across the three-day period (Martin-Garcia et al. 2018). In contrast, Malone et al (2015) reported greater high-speed distances on G-1 than G-2 in English Premier League players. The rationale for this approach was not reported by the authors; however, it would seem counterproductive and contrary to 'tapering' approaches previously discussed in the literature (Owen et al. 2017). Reducing training load on the day preceding a competitive match may enhance the capability of significantly decreasing physical stressors upon players, whilst leading to reductions in an accumulative fatigue response (Owen et al. 2017).

The present findings demonstrate that a gradual reduction in external and internal load across the three-day period leading into a game may constitute an important element of training periodisation adopted in the elite game. The 'three-day' pre-match tapering strategy facilitates the gradual 'unloading' of players which will serve to increase player readiness for the game. It is acknowledged that this type of three-day load reduction approach does not concur with the traditional tapering strategies reported for individual sports, whereby training load is typically reduced over the course of 7 to 28 days pre-competition (Mujika et al. 2004). This may be a consequence of several factors. A congested and 'ever changing' fixture schedule restricts the amount of time available to fully prepare players, making a 'one-size global approach' to periodisation unfeasible within elite soccer. There is also the need for constant flexibility to allow for the management of playing times, demanding travel schedules, and individual player 'micro-management'.

Training and match load in the current study showed limited variation between playing positions across the season's six mesocycles. This likely reflected the inclusion of match data in the analysis which may have masked any potential differences in training load per se. Analysis of the loading patterns during the weekly microcycle training days in the present study provides a more precise comparison of positional loads. For example, sRPE-TL was lower in wide midfielders than wide defenders on G-3 while attackers reported higher sRPE-TL on G-2 vs. wide and central midfielders and higher sRPE-TL compared with all other positions on G-1. Attacking players also covered ~600 m and ~650 m more total distance compared to CD and WD, respectively, on G-1. In contrast to the present observations, in English Premier League players, Malone et al. (2015) reported limited positional differences in the days leading into a game. In Spanish reserve team players, Martin-Garcia et al (2018) reported the highest total distance in central and offensive midfielders during the three-day lead into competition whilst wide defenders covered the greatest high-speed running distance during the same period. Collectively, these positional differences likely reflect the diversity in training strategies adopted by different coaching teams which are often driven by the head coach (Akenhead and Nassis, 2016; Weston 2018).

Conclusions

In summary, our study has systematically quantified the training and match loads employed by an English Premier League club during a championship-winning season. Training load across the mesocycle periods showed limited variation and suggests that training schedules employed in elite soccer may be highly repetitive likely reflecting the nature of the competition demands. Periodisation of training load was evident within the weekly microcycle including the three-day period leading into competition. This reflected the coaching teams approach to match recovery and preparation across the long competitive period. Further research is needed to expand our understanding of the loads encountered by elite players and the different periodisation models adopted by coaching teams.

Practical implications

The present data center on a championship-winning season and extends the limited literature by providing novel insights into the training loads encountered by elite soccer players. The present findings provide coaches and practitioners with insights into a successful periodisation strategy that was adopted during weekly microcycles in an attempt to facilitate match recovery and preparation. Such strategies are likely to be important in the modern game due to the relatively constant loading incurred across the season as a consequence of the high frequency of matches encountered by elite teams. Methodological challenges inherent in soccer, limit the ability to determine the direct influence of training load on team match physical performance and/or success and therefore our understanding of what may constitute optimal periodisation of training. Future work could therefore focus on the analysis of training load encountered by the same players under different coaches and/or periodisation strategies across extended periods of time or between seasons. By examining both the variation in load, as well as factors such as performance testing, player wellness and injury rates, such approaches could represent a move towards a better understanding of how to best prepare elite players.

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No potential conflict of interest was reported by the authors.

ORCID

Warren Gregson http://orcid.org/0000-0001-9820-5925

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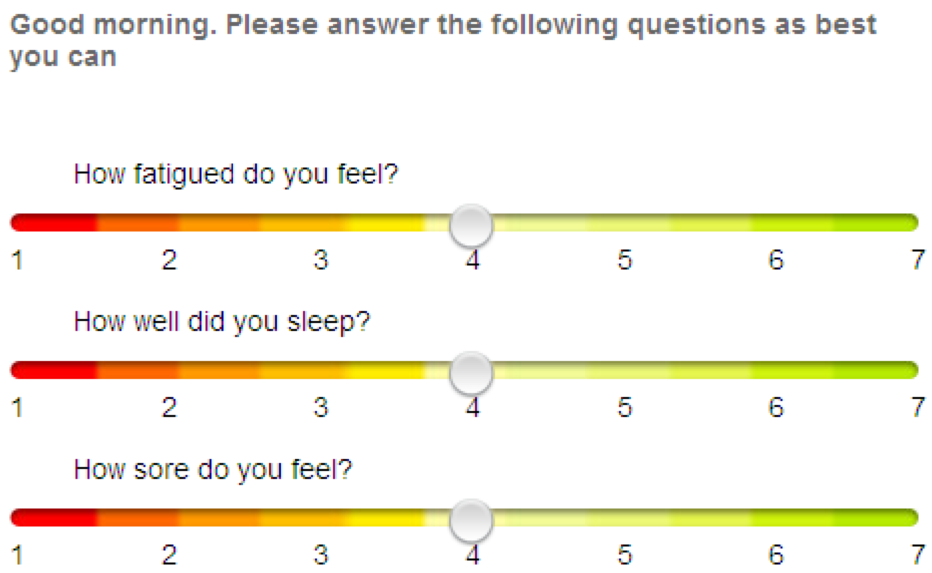
CATEGORY RATIO RATING OF PERCEIVED EXERTION (RPE) CR-10 SCALE

Rating	Descriptor
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Maximal

Each player was asked "how hard was the session physically today", in isolation approximately 20 minutes post-training. Internal training load was computed (in arbitrary units [AU]) by multiplying the individual's RPE (using Borg's category ratio 10-point [CR10] scale by the duration of the session (in minutes) (Foster et al., 2001).

RATING OF PERCEIVED WELLNESS SCALE



A psychometric questionnaire was used to assess general indicators of player wellness which contained 3 questions relating to perceived overall fatigue, sleep quality, and delayed-onset muscle soreness (DOMS). Each question was scored on a 7-point Likert scale (scores of 1-7, with 1 representing very, very poor [negative state of wellness], and 7 representing very, very good [positive state of wellness]).