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Abstract:

Purpose: To study concurrent-training (CT) and nutritional practices within a professional soccer team. Methods: Twenty-one professional football players competing in the English professional league participated in this study (mean ± standard deviations [M ± SD] 26 ± 4 years, stature 1.84 ± 0.1 m, body mass 83 ± 7 kg, VO2max; 58 ± 3 ml · kg−1 · min−1). A range of internal and external training metrics, the organisation of CT (training sequence, training rest period between bouts) and the nutritional intake around CT (timing, type and quantity) was collected for 10 weeks. Results: CT; n = 17 (endurance-training [ET] + resistance-training [RT]; n = 11; RT + ET; n = 6) rest period between bouts was not consistent and varied depending on the sequence of CT (RT + ET, 75 ± 48 min; ET + RT; 60 ± 5 min; P = 0.04). sRPE of football-specific ET was higher in RT + ET (RT + ET, 7 ± 1; ET + RT, 6 ± 1; P = 0.05). The timing of meals around training was influenced by the organisation of CT. Subsequently, CHO consumption before training session one was significantly less in RT + ET (CHO 0.10 ± 0.5 g · kg−1 vs. CHO 0.45 ± 0.2 g · kg−1). Conclusion: The present data demonstrate that the organisation of CT (i.e., exercise order and/or recovery time between bouts) and nutrition (i.e., timing of meal intake) can be unsystematic in the applied environment. The organisation of training and nutrition might influence the players' ability to perform high-intensity actions in secondary training sessions and could potentially impact acute metabolic processes associated with muscle recovery and muscle adaptation.

KEYWORDS: Soccer, concurrent-training, interference, nutrition, resistance-training

INTRODUCTION

It is common for team-sport athletes to perform resistance and endurance-training within the same training cycle (Fyfe et al. 2014). This training arrangement has been referred to as 'concurrent-training' and may be sub-optimal for muscle strength and power development (i.e. the 'interference phenomenon') (Wilson et al., 2012). Authors have noted that blunting in the adaptive process can be modulated by a number of training factors including the volume and frequency of training (Wilson et al., 2012), the timing of macro-nutritional intake around each training session (Bartlett, Hawley, & Morton, 2015) and potentially the organisation of exercise bouts (i.e. the order of sessions and/or the recovery period between sessions) (Enright, Morton, Iga, & Drust, 2015).

The frequency of match-play within English professional football leagues impose unique challenges for coaches and practitioners. For example, one, two and three competitive fixtures can be scheduled within a relatively short period (e.g. 6-8 days) (Morgans, Orme, Anderson, & Drust, 2014). This intensive competitive schedule can place restrictions on time and thus impact the planning and implementation of training and match preparation (e.g. technical, tactical training, injury prevention training, resistance-training, match recovery interventions and physical conditioning). As such, it is common for players to perform resistance and football-specific endurance-training on the same-day (Bangsbo et al., 2006).

The soccer training environment has been described as a dynamic and challenging setting which often creates many complex challenges for practitioners (Williams, 2013). With this in mind, it is likely that each training facility will encounter its own set of 'constraints' that limit the coaching staffs' ability to prescribe 'evidence based', systematic training interventions. Unexpected changes in the team’s training schedule could alter the organisation of concurrent-training and the timing of food intake around each exercise session. Such changes might have implications upon the acute and potentially chronic physiological response to each exercise bout. To the authors knowledge no research groups have observed how strength and conditioning practitioners prescribe same-day concurrent-training and nutritional interventions around such ‘barriers’. Studying how teams currently administer training and nutritional support to their athletes is important when trying to contextualise practical issues that might indirectly influence the ‘interference phenomenon’. This type of research will give other practitioners and researchers’ valuable insights into the training methods currently used in this setting and could allow the opportunity for individuals to consider and/or study such issues so to minimise the interference phenomenon.

The present investigation aimed to explore concurrent-training and nutritional practices carried out by a senior professional football team. Specifically, we aimed to (i) to describe the volume and intensity of all aspects of training across a 10-week period (ii) to characterise the, volume, intensity and organisation of ‘same-day’ concurrent football-specific endurance and resistance-training and (iii) to describe the quantity and timing of macro-nutrient intake around training on concurrent-training days.

METHOD

Participants

Twenty-one full-time senior professional footballers (mean±SD: age, 26±4.0 years; height, 1.84±0.1 m; body mass, 83±7 kg; $\dot{V}O_2$ max 58±3 ml·kg^{-1}·min^{-1}) competing in the English ‘Championship’ division participated in this study. Before providing written informed consent, all participants were informed of the nature of the study, of all associated risks, and of their right to withdraw at any time. This investigation followed the guidelines of the World Medical Assembly and was approved by the University’s research ethics committee.

Experimental design

Player training load data was recorded over a 10-week period. All training sessions were performed at the football clubs training facility which included grass training pitches, an onsite gymnasium and canteen which catered for meals. The first author monitored all training sessions and recorded training data throughout the observational period. Here, internal and external training metrics were collected. Internal training data consisted of session rating of perceived exertion training-load (sRPE-TL) and heart rate data. Whereas external training load consisted of Global Positioning System (GPS) data the ‘volume load’ (VL) of each resistance-training session. Descriptive information was also collected concerning the organisation of concurrent-training and nutrition on concurrent-training days (i.e. the training time-of-day, recovery duration between training sessions and the timing of meals). Finally, to illuminate the macro-nutrient intake on concurrent-training days food diaries were used. The researchers made no attempt to influence the frequency or organisation of training during the observation phase.

Timing of the observational period

The observational period took place across the first 10-weeks of the season and included the ‘pre-season’ period (5-weeks) and the first 5-weeks of the ‘in-season’ phase (July, August and September). A 5-week ‘pre-season’ phase was prescribed by the head coach to allow the players additional time to recover following their involvement with their respective international teams at the UEFA European Championships which took place in the months leading up to the observational period (June and July).

Training categorisation.

In order to differentiate between different types of training the weekly training sessions were categorised into 5 sub-components; ‘football-specific endurance-training’, ‘resistance-training’, ‘match-play’, ‘recovery-sessions’ and ‘days off’. Football-specific endurance-training’ (ET) was defined as a ‘coach-led’ technical and (or) tactical training session which involved ‘small-sided match-play’ and running drills with and without the football. Resistance-training (RT) was categorised as a training session in the gymnasium involving external resistance exercise (typically body-weight and free-weight). Match-play was defined as a ‘pre-season friendly match-play’ or competitive match-play which took place within the ‘nPower Championship’ or the ‘Capital one Cup’. ‘Recovery-sessions’ were classified as non-weight bearing activity such as stretching, ice baths and/or aqua jogging. ‘Days off’ were considered as a day away from the training facility. The frequency of each training and match during the 10-week observational period is presented in Table 1. Prior to the training phase there were 52 ‘football-specific endurance based training sessions’, 11 ‘games, 24 ‘resistance-training sessions’, 7 ‘recovery sessions’ and 7 days off prescribed. However, due to alterations in the training plan made by the head coach some sessions were either cancelled or an additional session was included as a result 49 ‘football-specific endurance based training sessions’, 11 ‘games, 17 ‘resistance-training sessions’, 5 ‘recovery sessions’ and 5 days off were actually completed by the team. Week 9 involved international fixtures, subsequently, *n* = 12 players trained and played for their respective countries and no data are available for these players during this week.

INSERT TABLE 1 HERE

Internal training load across the 10 week observational period

Thirty minutes following each football-specific endurance-training session, resistance-training session and match the players were asked to rate the intensity of the session using a 10-point rating of perceived exertion scale (RPE) (Siegl & Schultz, 1984). The RPE rating for each training session was then multiplied by the duration of that training session (min) to provide an index of the ‘training-load’ (Foster et al., 1995). This ‘training-load’ is referred to as the sessional rating of perceived exertion training load (sRPE-TL). The validity of this approach for assessing ‘training-load’ in elite football players has been previously established (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). The duration of all training sessions was recorded using a stopwatch (Casio, Japan). The start of each training session was classified from the start of the ‘warm-up’, and the end of the session was noted when the training activities were completed. Data from all of training sessions and match-play was then added together to calculate daily and weekly training load.

Organisation of concurrent-training.

When concurrent football-specific endurance-training and resistance-training were performed on the same day descriptive training information was recorded. This data included; the sequence of concurrent-training (e.g. football-specific endurance-training followed by resistance-training (ET-RT) or resistance-training followed by football-specific endurance-training (RT-ET), the start and end time of each training session and the recovery period between training sessions.

Internal and external training load on concurrent-training days.

Heart rate is commonly used to assess exercise intensity in football (Karvonen & Vuorimaa, 1988). Therefore, during each football-training training session heart rate data was collected using a heart-rate monitor (Polar, Kempele, Finland). The time distribution between 85-100% of HR_{max} (RZ) was used to represent exercise intensity during football-training (Stolen, Chamari, Castagna, & Wisloff, 2005). Players also wore a GPS tracking devise (Viper 15Hz) during each football-training session (Statsports, Ireland, Ltd). Following an internal research project at the football club (Dallaway, 2013) (unpublished data), the reliability of the Statsports Viper 15Hz pod was calculated. Here, the error for total distance (TD), sprint distance (SD) (> 6.9m/s), high speed distance (HS) (>5.5 m/s) and heart rate data was found to be low to moderate (coefficient of variation ranged from 2.1 to 11.3%), and was in agreement with a similar study (Rampinini et al., 2015). However, some metrics were found to be less reliable (e.g. accelerometer data and number of entries into speed zones), and were therefore omitted from the study. In order to minimise the intra-unit variability, each player wore the same ‘GPS device’ and ‘heart rate belt' across the observational phase. Each specific unit was worn inside a custom made vest supplied by the manufacturer; with the unit was located on the upper back between the left and right scapula. All devices were activated 30-minutes prior to data collection to allow acquisition of satellite signals (>8 satellites). Heart rate and GPS training data was downloaded immediately following each training session and stored on an encrypted database for later analysis. The researchers made no attempt to influence the frequency, intensity or duration of football-training during the observation phase.

Resistance-training consisted of upper body and lower body involving isoinertial/free weight resistance exercises. Resistance-training 'volume' was collected throughout the observational period using the 'volume load' (VL) method. Here, resistance-training volume was characterised by multiplying the reps, sets and weight lifted by each participant in each session. This method provides one arbitrary unit of resistance-training volume. This method has previously been used to quantify 'total resistance-training-load' in athletic populations (Peterson, Pistilli, Haff, Hoffman, & Gordon, 2011) and used to compare resistance-training prescription in experimental conditions. Resistance-training 'intensity' was indicated indirectly via recording the repetition maximum (RM) at which the players were lifting during each training session (e.g. 8RM or 4RM). All resistance-training sessions were further categorised into either upper body only (e.g. bench press, pull up etc.), lower body only (e.g. squat, deadlift etc.) or sessions involving a combination of upper and lower body training exercises. The researchers made no attempt to influence the resistance-training during the observation phase.

Nutritional intake on concurrent-training days.

On concurrent-training days the availability of nutritional support before the first training session, between training bouts and after the second training session was recorded using self-reported food diaries and photographs. Here the participants recorded the time of food intake, the type of macro-nutrient (e.g. Protein; chicken breast), the estimated weight/size/portion, the cooking/preparation methods and the commercial brand names of dietary supplements and time of consumption using a mobile phone application. To improve the accuracy of this information the athletes recorded each meal throughout the day (as oppose to the recall method). Food consumed at the football club was standardised and weighed by catering staff using domestic cooking scales. To improve accuracy of quantities the players were asked to take a photograph of each meal using their mobile phone which was later cross referenced by the lead author. For the purpose of analysis, the type of nutrition consumed by the athletes was subsequently categorised as a meal (Meal 1; breakfast, Meal 2; lunch or a 'nutritional sports product' such as a whey protein drink), Meal 3 and the evening food intake. Food diaries and pictures were saved and subsequently used to calculate/estimate the carbohydrate, protein and fat intake around each training session on concurrent-training days (i.e. before the first training session, between exercise bouts and after the second training session and in the evening following training). The researchers made no attempt to influence the player's diets during the observation phase.

Statistical analysis

Statistical analysis was carried out using the statistical package 'IBM SPSS Statistics' (version 17.0). The average weekly training training-loads (sRPE-TL) and training frequency (sessions•wk^{-1}) were compared between weeks 1 to week 10 using a general linear model with repeated measures. Estimated marginal means for the repeated analysis were corrected using Bonferrioni confidence intervals. Comparisons in internal and external training metrics on concurrent-training days were made using paired t-tests. The type of resistance-training performed was described as either upper body, lower body, a mixture of upper and lower body, the intended repetition maximum training intensity and were therefore presented as frequencies. Data relating to nutritional intake at each time-point was compared using paired t-tests. The statistical significance (*P*) was set at ≤ 0.05 and all information is presented as means ± standard deviations (M±SD).

RESULTS

Training prescription

Player adherence to training & match-play is presented as weekly totals (Monday to Sunday) in Figure 1. There were no players who completed all training and match-play across the 10-week observational period. On average the participants completed 74% of all football-training sessions, 60% of match-play and 60% of resistance-training sessions. Statistical analysis revealed a significantly higher frequency of football-training compared to other types of training (P=0.01). There were no changes in the frequency of football-specific endurance-training across the observational phase (4.6±0.5 sessions•wk^{-1}). Significantly higher resistance-training frequency were also observed during the first three weeks of observation (3.3±0.4 sessions•wk^{-1}) when compared to the remaining seven weeks (1±0 sessions•wk^{-1}) (P=0.05).

INSERT FIGURE 1 HERE

Internal training load across the 10-week observational period

The total weekly rating of perceived exertion training load (sRPE-TL) for each subcomponent of training and match-play is presented in Figure 2. The weekly average sRPE-TL for football-specific endurance-training and match-play was 1775±484 (AU) and 712±334 (AU) respectively. Football-specific endurance-training accounted for 62-85% of the total weekly training across the 10-week period. The average weekly sRPE-TL for resistance-training was 312±98 (AU). The highest training-load occurred in week 2 (4601±643 AU). The lowest training-load occurred in week 9 (2014±562 AU). Repeated measures analysis revealed that the sRPE-TL for week's 1, 2 and 3 were significantly higher when compared to weeks 4, 5, 6, 7, 8, 9 and 10 (P=0.04).

INSERT FIGURE 2

Organisation of concurrent-training

Across the 10-week observational phase concurrent football-specific endurance-training and resistance-training were performed on seventeen occasions. Concurrent-training sessions were always performed on the same day. Data describing the acute organisation of concurrent-training is presented in Table 2. Football-specific endurance-training was performed at 10:30 hrs, typically lasted 74±5 min and was performed on average 6±1 days$\cdot$wk^{-1}. The duration of football-specific endurance-training was the same regardless of if resistance-training was performed either before or after football-specific endurance-training (RT+ET; 71±5 min; ET+RT; 76±9 min, P= 0.34). Resistance-training was performed in the morning at ~09:30hrs on 11 occasions and in the early afternoon at ~13:30 on 6 occasions. Resistance-training was performed on 5 days•wk^{-1}, 3 days•wk^{-1} and 3 days•wk^{-1} during weeks 1-3 respectively for 40±5 min. During weeks 4-8 and 8-10 resistance-training was performed on 1 days•wk^{-1} for 40±5 min. There was no resistance-training prescribed on week 7. The 'order' in which resistance and football-training were completed was not consistent. Resistance-training was performed before football-specific endurance-training on 11 occasion (RT+ET), whilst football-specific endurance-training was performed before resistance-training on 6 occasions (ET+RT). The recovery time between football and resistance-training across the observational period was statistically different between RT+ET and ET+RT (RT+ET; 75±48 minutes. ET+RT; 60±5 minutes, P=0.04).

Internal and external training load on concurrent-training days

The players sRPE of football-specific endurance-training was rated significantly higher when resistance exercise was performed before football-specific endurance-training (RT+ET; 7±1, ET+RT; 6±1; P=0.05). Total distance covered (avg. RT+ET; 5942±1057; ET+RT 6213±958, P=0.04), and time distribution in a high heart rate zone of 85–100% of HR_{max}, (RT+ET 5±12 min; ET+RT 11±2 min P=0.04) was statistically higher when endurance based training was performed first (i.e. ET+RT).

INSERT TABLE 2 HERE

The intensity of resistance-training as indicated by the repetition maximum (RM) performed during each training session ranged from 4 to 8 RM (90 – 80% of 1RM) across the observational period and is presented in Table 2. Here, upper body only (n = 8) lower body only (n = 4) and upper and lower body (n = 5) were performed at the following intensities (upper body only; 6 RM; n = 1; 8 RM; n = 3, 10 RM; n = 3, 12 RM; n = 1) (lower body only; 6 RM; n = 3; 8 RM; n = 1), (upper and lower body; 4 RM; n = 1; 5 RM; n=3, 8 RM; n=1). Mean ± SD VL completed by the team are presented in Figure 3. When compared to weeks 4 to 10 VL was significantly higher in weeks 1, 2 and 3 (wk; 36187 wk2; 22617 wk3; 16642; P=0.04). There was no significant difference in training volume between weeks 4 to 10 as only one comparable session was performed each week (P=0.11).

INSERT FIGURE 3 HERE

Nutritional intake on concurrent-training days

Descriptive data concerning the player's nutritional intake on concurrent-training days is presented in Table 3. Despite the total amount of calories not differing between concurrent-training scenarios the timing of nutritional intake was different and dependant on the order of concurrent-training. For example; when resistance-training was performed before football-specific endurance-training the players did not consume a meal and instead consumed a 'whey protein drink' (PRO; ~0.30±0.1g·kg^{-1}, CHO; 0.10±0.5g·kg^{-1}, F; 0.1g·kg^{-1}) (~08:30hrs) immediately prior to resistance-training. The players then subsequently, consumed a meal ('Meal 1'; breakfast) between training sessions (PRO; 0.40±0.1g·kg^{-1} CHO; 0.45±0.2g·kg^{-1}, F; 0.22±0.2g·kg^{-1}) (09:30hrs), following the second training session ('Meal 2'; Lunch PRO; 0.60±0.2g·kg^{-}1, CHO; 0.80±0.4g·kg^{-1}, F; 0.16±0.15g·kg^{-1}) (12:30hrs) and in the 'evening meal' ('Meal 3'; PRO; 0.70±0.3g·kg^{-1} CHO; 1.0±0.3g·kg^{-1}, F; 0.22±0.3g·kg^{-1}) (18:00). When resistance-training was performed after football-specific endurance-training the players consumed a meal (‘Meal 1’; breakfast) before football-specific endurance-training (PRO; 0.40±0.1g·kg^{-1} CHO; 0.45±0.2g·kg^{-1}, F; 0.22±0.2g·kg^{-1}) (09:30hrs), between training sessions (‘Meal 2’; Lunch PRO; 0.60±0.2g·kg^{-}1, CHO; 0.80±0.4g·kg^{-1}, F; 0.16±0.15g·kg^{-1}) (12:30hrs), consumed a ‘whey protein drink’ immediately following resistance-training (PRO; ~0.30±0.1g·kg^{-1}, CHO; 0.10±0.5g·kg^{-1}, F; 0.1g·kg^{-1}) (13.30hrs±30min) and an ‘evening meal’ (‘Meal 3’; PRO; 0.70±0.3g·kg^{-1} CHO; 1.0±0.3g·kg^{-1}, F; 0.22±0.3g·kg^{-1}) (18:00±30min).

INSERT TABLE 3 HERE

DISCUSSION

The aim of the present investigation was to explore the concurrent-training and nutritional practices carried out by a senior professional football team across 5 weeks of pre-season training followed by 5 weeks of in-season training. Football specific endurance based training/match-play was the most frequent mode of training and accounted for between 62-85% of the total weekly training volume. Across the observational period concurrent football-specific endurance-training and resistance-training was performed on 17 occasions and was always performed on the same day. Here, the order of concurrent resistance-training and football specific endurance training sessions were not systematic and were often completed within close proximity of each other. The order of training bouts and the recovery duration between training sessions directly influenced the timing of meal intake and therefore influenced and quantity and type of protein and carbohydrate intake before, between and following concurrent-training. Current evidence suggests that unsystematic orders of concurrent-training combined with diverse intake of key macro-nutrients might have implications to acute muscle responses and potentially for muscle performance and for chronic muscle adaptations. However, more work is required to elucidate the chronic adaptive responses of the unsystematic concurrent-training protocols and nutrition witnessed in this investigation.

When weekly average total RPE-TL was compared between weeks significant differences were evident. Weeks 1, 2 and 3 were significantly higher when compared to weeks 4, 5, 6, 7, 8, 9, and 10. This may be explained by the periodisation approach used by the team across the observational phase. The first 5 weeks of the observational were categorised as the ‘pre-season’. This phase of the season is typically devoted to increasing player fitness following the ‘off-season’ when detraining may have occurred (Reilly, 2005). Although it is acknowledged that the ‘pre-season’ preparatory phase is typically 6 to 8 weeks, however this was not possible as a significant proportion of the team (n=12) were involved in international fixtures at the end of the previous season. The subsequent reduction in the amount of training time available restricted the coaches’ ability to plan a longer preparation phase prior to the start of the season. It is reasonable to suggest that a longer ‘pre-season’ would allow incremental increases in training volume and intensity therefore reducing the likelihood of injury occurrence whilst also allowing a longer phase to improve physical adaptation (Mallo et al., 2012). In the present observation, the intensity and volume was relatively high during the first week of training following the ‘off-season’ period but was only maintained for 3 weeks. It is possible that this training prescription may have increased the risk of injury to the players and reduced the potential to produce favourable adaptations so to enhance physical performance (Williams, 2013). However, the reduced training time available and the inclusion of an additional competitive ‘cup competition’ in week 4 (the capital one cup) restricted the coaches’ ability to effectively periodise the training across the preseason. This restriction of training time through increased demand from different competitions (both domestic and international) has not been extensively reported within the literature. Therefore, the present observation in-part highlights some of the unique contextual constraints coaches and practitioners face when designing the annual training plan. Indeed our data describing the frequency of training planned prior to the observational phase verses the actual number of sessions completed, highlight that some sessions were cancelled and in other cases additional sessions were included (table 1). This suggest that despite pre-agreed training plan in place the team’s training was altered on an ongoing basis throughout the observational period, thus, highlighting the complexities of applying training theory in the applied environment, a phenomenon that has not been well documented within the literature.

Concurrent football-specific endurance-training and resistance-training was performed on seventeen occasions across the observational phase. The sequence of concurrent-training was not consistent (RT+ET; n=11; ET+RT; n=6). It is possible that the unsystematic nature of training could be explained by the fact that multiple teams from this football club shared one training facility (e.g. 1st team, U21 team & U18 team), thus increasing the demand upon the training facilities (i.e. training pitches & the gymnasium). Indeed, the lead author (an affiliate of the football club) noted that coaches reported that due to “the small dimensions of the gymnasium, with only two weight lifting platforms meant that teams were required be scheduled at different times of the day depending upon each teams weekly schedule”. It is therefore, likely that organising training around the other teams, subsequently influenced the resistance training time-of-day and the order of concurrent-training.

This finding suggests that the training programme design in this instance was largely influenced by the logistics of the environment as oppose to the training recommendations put forward in the academic literature (e.g. Haff & Triplett, 2015). In order to improve the training process more research is required to understand the barriers which restrict coaches and practitioners ability to apply theory to practice.

There is some evidence to suggest that altering the sequence of same day concurrent-training can influence the acute intramuscular signalling process associated with endurance and resistance exercise (i.e. PGC-1α mRNA & mTOR phosphorylation) and the subsequent downstream targets that affect protein synthesis (V. G. Coffey et al., 2009; Coffey, Pilegaard, Garnham, O'Brien, & Hawley, 2009). Although, the chronic effect of manipulating such proteins through altering organisation of concurrent training not well understood and requires further work. Few studies have investigated the long-term effect of concurrent-training sequence (Bell et al. 1988; Collins et al. 1993; Gravelle and Blessing 2000; Chtara et al. 2005; Chtara et al. 2008; Small et al. 2009; McGawley and Andersson 2013). Those who have investigated the effect of concurrent-training sequence have reported conflicting results, although such studies have used untrained participants and diverse concurrent-training protocols unlike those used by professional football teams. The only study to investigate the impact of the organisation of concurrent-training in elite football players (Enright et al., 2015) demonstrated that performing resistance-training immediately before football-specific endurance-training can attenuate longer term training adaptation in elite football players. Although, due to the real-world nature of the above study and the subsequent lack of control it was not clear if it was the training order or the diverse recovery period between exercise bouts that was responsible for the results of this study. However, no studies to date have investigated the chronic effects of performing concurrent-training with alternating exercise sequences like those observed in the present study. Therefore, whilst it is possible that changing the sequence of concurrent-training would influence the acute and chronic response it is difficult to state if the present training protocols might be detrimental to muscle adaptation and therefore this would seem to warrant further attention. Collectively, this suggests that training design and implementation in the applied environment is largely dictated by the constraints unique to each environment as oppose to the theoretical considerations which exist within the published academic literature.

Whilst training twice per day is a common training paradigm for many elite athletes understanding how to organise training is not well understood. In the present study concurrent-training sessions were completed with relatively little recovery time between exercise bouts (ET+RT; 75±48 minutes, RT+ET; 60±5). There is some evidence to suggest that this training situation could be improved to promote training adaptation. For example; when concurrent training endurance and resistance-training is separated by more than 24 hours (i.e. on different days) greater strength performance can be achieved when compared to performing concurrent training on the same day (Sale, Jacobs, MacDougall, & Garner, 1990). This suggests that completing concurrent training sessions within close proximity is likely to create additional metabolic stress and/or cause acute fatigue during the secondary training session (Fitts, 1994). Increased muscle fatigue following high-intensity exercise might have implications for injury risk (Lovell et al., 2016). A recent study investigating the effects of performing the ‘Nordic hamstring exercise’ either immediately before or following a football-specific training (Lovell et al., 2016) has found that performing eccentric training immediately before football training attenuates sprint performance and eccentric hamstring strength during a subsequent training session. Collectively the above evidence suggests that the organisation of concurrent training might have implications for acute muscle performance and also might influence injury risk.

Considering that reductions in acute muscle performance immediately following intense exercise has been attributed to in part peripheral mechanisms (e.g. depletion of muscle glycogen) (Haff et al., 1999) it would be logical to supplement concurrent-training with additional carbohydrate intake before, between and following training. In the present observation we found that the organisation of concurrent-training influenced the timing of meals and subsequently the amount of carbohydrate intake was altered around each training situation. It was evident that when players were required to resistance train in the morning (08:30hrs) (RT-ET) carbohydrate consumption before training was significantly less when compared to when football-specific endurance-training was performed first (10:30hrs) (CHO; $0.10 \pm 0.5 g \cdot kg^{-1}$ *vs.* CHO; $0.45 \pm 0.2 g \cdot kg^{-1}$). Moreover, when resistance-training was performed after football-specific endurance-training (ET-RT) the players consumed relatively less carbohydrate post resistance-training (CHO; $0.10 \pm 0.5 g \cdot kg^{-1}$ *vs.* CHO; $0.80 \pm 0.4 g \cdot kg^{-1}$). The role of carbohydrate in maintaining muscle performance during extended periods of exercise has been well documented (Jeukendrup, 2010). Subsequently, it has been recommended that athletes should increase carbohydrate in accordance with training volume ($4\text{-}8 g \cdot kg^{-1}$), especially when multiple training sessions are performed on the same day (for reviews see; Jeukendrup, 2004). Considering that muscle glycogen content is typically reduced (~40-60%) following high-intensity endurance/resistance exercise like that used by the present football team (Haff et al., 2000; Rico-Sanz, Zehnder, Buchli, Dambach, & Boutellier, 1999) the pattern of carbohydrate observed when the players performed resistance exercise before endurance training might not have been optimal for muscle performance in the secondary training session. Furthermore, as reductions in muscle glycogen are typically prominent following activity such as heavy resistance training (Tesch, Colliander, & Kaiser, 1986) it is likely that the lack of carbohydrate intake between training bouts influenced glycogen availability during the secondary training bout. This might have practical implications for the participants taking part in same-day concurrent-training particularly if the focus of the secondary training session on high intensity activates such as sprinting or repetitive skilled actions (Abernethy, Jurimae, Logan, Taylor, & Thayer, 1994; Mohr, Krustrup, & Bangsbo, 2005; Tesch, Colliander, & Kaiser, 1986). Although, the actual effect of lowered glycogen levels upon muscle performance was not measured in the present study and remains speculative. Therefore, more work is required to evaluate the influence of the training and nutritional paradigms observed in this study.

The organisation of concurrent-training also influenced the timing and quantity of protein intake. When resistance-training was performed before football-specific endurance-training the athletes consumed a ‘whey protein drink’ immediately before the resistance-training session, breakfast between training sessions, and a larger meal at ‘lunch time’ following football-specific endurance-training. Whereas, when resistance-training was performed after football-specific endurance-training the athletes consumed a breakfast approximately one hour prior to football training, lunch between training sessions and a ‘whey protein drink’ immediately following the resistance-training session, all with varying amounts of protein (Table 3). The present protein intake around training may have not been optimal for net protein balance across the entire day. It has been recommended that athletes should aim to take between 0.25g to 0.30g of a leucine-rich protein source for every kilogram of body mass every 3 hours to maintain net protein balance throughout the day (i.e. 5 feeds per day; ~1.5–2.0$g\cdot kg^{-1}\cdot d^{-1}$) (Areta et al., 2013; Morton, McGlory, & Phillips, 2015).Whereas, in the present study the quantity of protein intake varied considerably between meals (0.1 to 0.8$g\cdot kg^{-1}$) and was not consumed at consistent time intervals throughout the day. Moreover, the total protein and carbohydrate intake was significantly higher when resistance training was performed after endurance type activity (table 3), largely due to higher protein intake consumed in the evening. A recent meta-analysis examining protein timing and hypertrophy concluded that total protein intake was a robust predictor of muscular hypertrophy (Schoenfeld, Aragon, & Krieger, 2013). Therefore, in this context, the organisation of training may have influenced the players' access to food and/or appetite, subsequently changing the quantity and timing of protein intake. Although not conclusive this suggests that even small modifications of the training programme (i.e. change in the sequence of concurrent-training or the time-of-day) may be able to influence the pattern of meal intake around training bouts. The longer-term effects of such changes in nutrient intake are not clear and certainly cannot be elucidated from the present study. Therefore, more work is required to better understand the acute and chronic responses of various concurrent-training and nutrition conditions in more controlled environments. Findings from this type of research might have indirect implications for muscle recovery, muscle performance and potentially chronic muscle adaptation.

CONCLUSION

This study highlights, in part, the training and nutritional practices within an English professional football club. The results suggest that despite pre-agreed training plan in place the team's training was altered on an ongoing basis throughout the observational period, thus, highlighting the complexities of applying training theory in the applied environment. Within this particular professional football club whilst resistance-training was performed on the same day, training was often performed within close proximity and with various recovery durations between bouts of football-specific endurance-training. Moreover, it was also found that the order of concurrent-training sessions was not systematic and subsequently influenced the timing of meal intake and which impacted the quantity of macro-nutrient intake before, between and following training. Altering the above variables might have implications on acute muscle responses (e.g. glycogen availability), muscle performance (e.g. sprinting ability) performance and potentially for chronic muscle adaptations (e.g. hypertrophy). It is hoped that this study may allow practitioners to consider some of the issues that might indirectly occur in response to the organisation of training. In addition, we believe that this paper might stimulate debate between practitioners who prescribe concurrent-training, thus promoting them to question their own training methods. Therefore, we encourage practitioners to interrogate their own training paradigms in an ongoing process in an attempt to formulate more effective training strategies.

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