AN INVESTIGATION INTO THE NUTRITIONAL HABITS OF ACADEMY PLAYERS AT A SINGLE ENGLISH PREMIER LEAGUE CLUB

ROBERT JOSEPH NAUGHTON

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Abstract

Within youth soccer high training and match loads warrant appropriate nutritional attention, although research assessing the nutritional intake and habits of youth soccer players is scarce. This thesis aimed to investigate habits and explore experiences of dietary intake methods in an English Premier League youth academy. Study one (Chapter 4) quantified the energy, macro and micronutrient intake of players from age groups under (U) 13 to U18 (7-day food diary, n = 59). Results showed players across all ages were in energy deficit, with low carbohydrate intake, and a large individual variability for micronutrient intake in comparison to current recommendations. However, under-reporting may have influenced these results. Study two (Chapter 5), a qualitative approach, explored nutritional habits (n = 15) with study one participants using one-on-one interviews. The U15 – U18s players consciously periodise their carbohydrate intake throughout the week; U18s stated this was to aid body composition. When discussing their participation in the previous food diary study, U18s expressed that a quicker, more user-friendly method would be desirable. The third study (Chapter 6), therefore, assessed the use of smartphone technology to record dietary intake. Fulltime youth soccer players (n = 22) recorded their dietary intake on a single training day, using a smartphone application and a photography method respectively compared to 24-hr recall. The 24-hr recall provided significantly higher energy and macronutrient intake in comparison to the smartphone methods. This data suggests smartphone technology was more effective in tandem with 24-hr recall. To conclude, youth soccer players are in dietary energy and carbohydrate deficit, with variable micronutrient intake when compared to current recommendations and traditional 24-hr recall is recommend if using smartphone technology. Further research for the accurate quantification of dietary intake and energy demands is required. Dietary advice provision for youth soccer to reach current nutritional recommendations is warranted.

List of Abbreviations

ANOVA; Analysis of variance

ATP; Adenosine triphosphate

AU; Arbitrary unit

BM; Body mass

BMD; Bone mineral density

CHO; Carbohydrate

DXA; Dual-energy x-ray absorptiometry

EPL; English Premier League

EPPP; Elite player performance plan

FA; Football Association

FFM; Fat free mass

FIFA; Fédération Internationale de Football Association

g; Grams

GPS; Global positioning systems

hr; Hour

IGF-1; Insulin growth factor-1

KCAL; Calories

Kg; Kilogram

Km; Kilometre

LCHF; Low carbohydrate high fat

LFC; Liverpool Football Club

Mg; Milligram

Min; Minute

MPS; Muscle protein synthesis

mRNA; Messenger ribonucleic acid

PAL; Physical activity level

PGC-1a; Peroxisome proliferator-activated receptor-gamma co-activator 1 alpha

RDA; Recommended dietary allowance

RER; Respiratory exchange ratio

RFPM; Remote food photography method

RMR; Resting metabolic rate

RNI; Reference nutrient intakes

RPE; Rating of perceived exertion

SACN; Scientific advisory committee of nutrition

SD; Standard deviation

TEE; Total energy expenditure

TEF; Thermic effect of food

TEI; Total energy intake

UK; United Kingdom

URTI; Upper respiratory tract infection

U9; Under 9 age group

U13; Under 13 age group

U14; Under 14 age group

U15; Under 15 age group

U16; Under 16 age group

U18; Under 18 age group

U21; Under 21 age group

$\dot{V}O_{2max}$; maximal oxygen uptake

WHO; World health organisation

µg; Micrograms

Publications and Conference Presentations from this thesis

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A comparison of dietary assessment methods within elite youth soccer players: a place for new technology?, presented at ECSS 2017

Contents

Chapter 1

General Introduction

1.1 General Introduction

A key objective of professional soccer clubs is to develop academy players to perform in their senior first teams. The development of adolescent players is multi-faceted, and whilst there is a strong emphasis on soccer skill-specific development (e.g. tactical and technical development), there is also a focus on physiological development (e.g. aerobic fitness and strength) (Wrigley *et al.*, 2014). Research in the area of academy level British soccer players has been steadily on the rise over the past decade with studies focusing on variables such as; training and/or match loads (Wrigley *et al.*, 2012), maturation status (Wrigley *et al.*, 2014; Teixeira *et al.*, 2015), anthropometrics (Milsom *et al.*, 2015; Perroni *et al.*, 2015) and performance testing (Chaouachi *et al.*, 2014).

Conversely, the area of nutrition within academy level British soccer players has not been as well researched as other areas of soccer sports science. Within the literature the majority of studies which have investigated the nutritional habits and demands of adolescent soccer players have come from continental Europe (Boisseau et al., 2002, 2007; Leblanc et al., 2002; Iglesias-Gutiérrez et al., 2005; Ruiz et al., 2005). Within the UK there is a particular lack of studies investigating nutritional habits and / or demands of academy level soccer players, with only two studies having investigated this area (Russell and Pennock, 2011; Briggs, Cockburn, et al., 2015). Whilst these two descriptive studies have provided valuable information on the nutritional intake of both under (U) 18 (Russell and Pennock, 2011) and U16 players (Briggs, Cockburn, et al., 2015), there is no data as of yet on players below these age groups (<U16s). In general, within British academies more research is required, and particularly in younger ages groups (<16s).

As well as there being limited information specific to academy level soccer nutritional practices, there is currently no data investigating the experience/perceptions/thought process of their nutritional practices. Within soccer nutrition, only Ono et al., (2012) has used qualitative methods to assess the nutritional habits of adult soccer players. It could be argued that by only focusing on quantifying nutritional intake, one would perhaps be missing the bigger picture of the 'why' behind reported nutritional intakes. Qualitative research focusing on nutritional intake and habits could provide valuable insight into perceptions and thought processes behind nutritional habits within academy level soccer players.

The collection of dietary intake within academy level soccer players has generally employed the traditional method of the written food diary (Leblanc et al., 2002; Iglesias-Gutiérrez et al., 2005; Ruiz et al., 2005; Russell and Pennock, 2011; Briggs et al., 2016). Whilst this method can provide valuable data when done correctly, it can be a burdensome task on participants and result in under-reporting of nutritional intake due limited participant nutritional knowledge (Burke, 2015a). However, with developments in technology, new methods of dietary assessment are being used, particularly those using smartphone technology (Josep et al., 2015). Currently, there is no data on the use of such methods within academy level soccer. An investigation assessing new technology in the collection of dietary data could provide valuable information into those working within the field.

1.2 Aims and objectives of the thesis

The aim of this project is:

1. To investigate the nutritional habits of academy level soccer players from an English Premier League (EPL) club

The PhD project will have the following objectives

1. Quantify the current energy, macronutrient, and micronutrient intake within EPL academy level soccer players

2. Quantify the distribution of energy and macronutrient intake across the course of a day within EPL academy level soccer players

3. To investigate the perceptions and thought process around nutritional intake within EPL academy level soccer players

4. To assess the use of new smartphone technology in collecting dietary intake data within EPL academy level soccer players

Chapter 2

Literature Review

The aim of this literature review is to assess the current body of literature in regard to youth soccer nutrition and, due to the relatively small amount of literature currently available, attempt to assess implications from studies assessing adult soccer nutritional practises. The main focus of this review will focus on energy, macro- and micronutrient intake, as well as reviewing current dietary collection methodologies.

2.1 Introduction into adolescent athlete nutritional demands

Nutritional recommendations for adolescent athletes are typically passed on from adult guidelines, which are generally derived from studies conducted using adult male participants (Desbrow et al., 2014). An adolescent athlete is defined as;

> ‘*An adolescent aged between 12 and 18, who applies foundational movement skills in a sports specific context, and may be associated with commitment to training, skill development, and/or formal engagement in competition.’* (Desbrow et al. 2014)

Due to ethical and practicality issues, rarely are studies carried out within an adolescent population that are beyond descriptive based protocols (Leblanc *et al.,* 2002; Ruiz *et al*., 2005; Iglesias-Gutiérrez *et al.,* 2005; Russell & Pennock, 2011; Briggs *et al.,* 2015). An exception to this is the excellent work by Boisseau et al., (2002 and 2007) who investigated the protein requirements of adolescent soccer athletes using a nitrogen balance methodology. However, the area of athlete adolescent nutrition in general has began to receive more attention, perhaps due to the increasing funding and interest within adolescent sport. A recent postion statement from the Sports Dietitians Australia (Desbrow *et al.*, 2014) provided an in-depth review of the unique demands of the adolescent athlete. This position statement pays particular attention to the micronutrient demands, such as iron, in addition to the energy and macronutrient requirements.

2.3 The rise of soccer academies

Soccer can be considered to be the most popular sport in the world, with the last published figures from FIFA estimating participation figures of 265 million participants worldwide (FIFA, 2007). Investment within the game has increased dramatically over the years particularly within the EPL which recently signed a new TV deal worth £8.3 billion. This increased deal will result in higher cash windfalls for EPL clubs, and while large amounts will be spent inevitably on player transfers, some clubs are also using this money to invest in their youth facilities. Recently, Manchester City football club opened a new £200 million soccer academy training facility with the aim of producing more first team talent, by providing state of the art facilities. Within the EPL the majority of clubs have large youth academies (usually spanning ages under U9s to U21s) looking to produce players for the first team and potentially profit from their sale. Within this elite setting youth players are exposed to top-class soccer coaching and conditioning with the aim of maximising their development as a modern soccer player.

In conjunction with EPL clubs, football league representatives and the Football Association (FA), the EPL has designed a strategy known as the 'Elite Player Performance Plan' (EPPP) which has the aim of developing more high quality home-grown soccer players. The EPPP serves as an audit to clubs, who are then categorised from 1 (being the best) to 4, dependent on the audit outcome. Within the EPPP audit there is a requirement for a nutritionist to be part of the sport science and medical staff, and for the club to show evidence of the nutritional support they provide. Going forward this will potentially lead to more specialist nutritionists and/or dieticians working within elite soccer academies, therefore the need for research backed nutritional recommendations is required.

2.4 Physical demands of soccer

2.4.1 General Characteristics

Soccer is a team invasion game that is played over 90 minutes and is divided into two halves separated by a 15-minute half time interval. Games can be extended by 30 minutes extra time in circumstances where a winner must be proclaimed on the day (i.e. a cup final) and potentially go to a penalty 'shoot-out' if there is still no victor. Soccer is intermittent by nature and is characterised by periods of intense explosive anaerobic movements (sprints, jumps, kicks) mixed with periods of moderate to low intensity aerobic exercise (jogging, walking).

For fulltime players the season typically begins mid-July, which will last for approximately six weeks. The competitive season then begins in late-August or early-September and runs to mid- to late-May. Pre-season is characteristically a period of intense training, both pitch and gym based, aimed at physically and tactically preparing players for the season ahead. The typical week during the in-season will consist of one match, four soccer-based training session and two resistance sessions (Brownlee et al., 2018). However, approaches to this training block can vary between clubs as a result of differing training philosophies of employed coaches. During the Christmas period the younger fulltime player (U18s) are commonly given some time off (i.e. 20th December to 3rd January) that consists of neither training or matches. In contrast, older fulltime players (U21s) are often required to train and be on stand-by for the 1st team although typically no fixtures solely for their age group will be scheduled during this time (Naughton et al., Unpublished observations).

For schoolboy players (≤ U16s) the season typically begins in September. The season schedule is generally linked with the academic school year with players having breaks from training and matches during the school holidays (i.e. half terms and Christmas). Players are exposed to a pre-season of sorts, which is a heavily reduced version of that which the fulltime academy players are exposed to lasting as little as two weeks. The typical week during the in-season will consist of one match, three training session for the U9-U11s which is increased to four soccer-based training for U12-U16s and resistance training once/twice a week for the U15s and U16s (Brownlee et al., 2018). Again, this is dependent on the coaching philosophy of the academy and can therefore differ from club to club. The schoolboy teams will also participate in tournaments, both domestic and aboard, which are generally characterised by multiple games (usually of shorter duration than usual for that age group) over a short period (i.e. five games over two days) (Naughton et al., Unpublished observations).

2.4.2 Monitoring Player Load

The role of technology to monitor soccer players training and match physical performances have become extremely popular in providing information for sports scientists and coaches (Malone et al. 2015). Global Positioning Systems (GPS) units are used to provide individual player feedback on a number of variables for any given training session or match (such as total distance covered, total high-speed distance, number of accelerations). This information can help sports scientists and coaches to assess whether training sessions meet their aims (i.e. to work speed endurance), help provide information to tailor sessions to meet training goals, and generally monitor a player’s external load. Data obtained from matches can give a coach a quantitative objective view on a player’s physical performance and perhaps allow for player tactical development.

2.4.3 Match Load

The modern elite European game is notorious for fast transactions from defence to attack, particularly within the EPL which is commonly considered to have physical and high-tempo game style. Barnes and colleagues (2014) recently reported that the EPL teams now cover more high-speed running distance, with an increase of ~ 30% when comparing the 2012 – 13 season to the 2006 – 07 season. Furthermore, they found that over this time period sprint distance and number of sprints increased by ~ 35% and 85%, respectively, although total overall distance covered had decreased by 2% (Barnes *et al.*, 2014). This data could potentially have an impact on nutritional requirements of elite soccer players within the EPL, for example, with more high intensity based movements the need for carbohydrate (CHO) may be higher than previously thought**.** Within soccer there are numerous different playing positions, of which have large variations in physical performance and demand (Bush *et al.*, 2015). With such apparent differences between positions, there is clearly no 'one size fits all' nutritional approach. Rather, where possible, the nutrition advice should be tailored to the position and the individual.

2.4.4 Training Load

There is currently limited data on the training loads of British academy level soccer players available, and to the authors knowledge only one study has been published within this area (Wrigley *et al.*, 2012). Wrigley *et al.*, (2012) assessed the typical weekly training and match load over a 2-week in-season period in elite youth soccer players aged U14, U16 and U18s. Training load was measured in arbitrary units (AU) and calculated by multiplying session ratings of perceived exertion (RPE) and session duration in minutes. Perhaps unsurprisingly total weekly training load (combination of training and matches) increased with age displaying a hierarchical order of U18s > U16s > U14s (Wrigley *et al.*, 2012). Furthermore, training intensity was found to be significantly lower than that of match intensity for all age groups. However, this data was only taken from one club's academy, and with different coaches and/or training philosophies perhaps different data would be reported. Nutritional recommendations for academy level players will be dependent on their training schedules, and it is important for practitioners to assess training practices when attempting to provide nutritional information. Further research using GPS systems from more academies would help provide more insight into these current findings.

2.5 Nutrition for soccer

2.5.1 Substrate utilisation during soccer

In the human body adenosine triphosphate (ATP) is the energy currency, derived from the high energy phosphate bonds. The supply of ATP within the muscle is limited, muscle tissue replenishes ATP during exercise, and can do so at different rates depending on the type of energy pathway being utilised. It is generally accepted that there are four main energy pathways; phosphocreatine, glycolytic, CHO oxidation, and lipid oxidation (Morton and MacLaren, 2011) During exercise the utilisation of the different energy pathways changes depending on exercise intensity and duration (Romijn *et al.*, 1993; Loon *et al.*, 2001). However, it is important to note that energy systems do not 'turn on and off' but rather work simultaneously on a continuum, and it is the flux through these pathways that changes. During high intensity exercise (> 75% $\dot{V}O_{2max}$) the muscle predominantly using CHO as the fuel source, mainly using muscle glycogen, whilst the use of fat is lower at this intensity it still contributes to energy production (Loon *et al.*, 2001). However, at lower exercise intensities (<

55% $\dot{V}O_{2max}$) fat is the predominant fuel source, with higher amounts of lipids, and lower amounts of CHO, being utilised (Loon *et al.*, 2001). As soccer is characterised by repeated high intensity efforts and sprints (Barnes *et al.*, 2014), it can be deduced that the primary fuel source will be muscle glycogen during soccer play, although muscle triglycerides, blood free fatty acids (FFA) and glucose will also contribute to energy production (Bangsbo, 1994).

2.5.2 Effect of maturation status on nutrition

Maturation status appears to have a significant effect on substrate utilisation. There is a general agreement from numerous research studies, which have assessed respiratory exchange ratio (RER), that for energy during exercise adolescents oxidise a higher percent of lipids and a lower percent of CHOs at a given relative intensity in comparison to adults (Armstrong, Barker and McManus, 2015). This effect also appears to be more apparent in males than in females (Boisseau and Delamarche, 2000; Aucouturier, Baker and Duche, 2008). In males, the high rate in lipid oxidation observed during exercise declines with maturation, and the development to an adult fuel utilisation profile has been reported to occur during the transition from mid-puberty to late-puberty (Stephens, Cole and Mahon, 2006; Riddell *et al.*, 2008).

In advancement of this body of work, more recent studies have investigated the potential effects which exogenous CHOs (^{13}C-enriched 6% CHO drink) may have on substrate utilisation (Timmons, Bar-Or and Riddell, 2003, 2007a, 2007b). Using both RER and ^{13}C stable isotope methodology, it has been reported that in adolescent males the oxidation of exogenous CHOs, when expressed as a percent of the total energy expenditure (TEE), was inversely linked to serum testosterone levels (Timmons, Bar-Or and Riddell, 2007a). The utilisation of exogenous CHOs appears to be strongly linked to the pubertal status of the males, with the lowest oxidation rates observed in mid- and late-pubertal boys, and the highest in pre- and early pubertal boys, this regardless of chronological age (Timmons, Bar-Or and Riddell, 2007b). From the current available data, it is unknown what the optimal exogenous CHOs strategy within adolescent boys is to improve performance (Armstrong, Barker and McManus, 2015).

2.5.3 Energy

2.5.3.1 Energy Expenditure

Within sport nutrition, a constant enigma has been trying to accurately measure TEE. With accurate knowledge of TEE, a practitioner can provide more informative nutrition advice and strategies to best support training adaptation and competitive performance than from simply guessing. Within team sports, such as soccer, and/or under free-living conditions, there are few studies which have aimed to assess daily TEE. This is in part due to the difficutity in measurement and current methods available, as traditional methods of measuring TEE require metabolic analysis that restricts typical activity habits and are conducted within laboratoary settings (Leonard, 2012). This is particuarly problematic within team sports as it means not obtaining an estimation of the energy cost of training and match play, therefore nutritional recommendations are made difficult to provide.

Within free-living scenarios the doubally labelled water method is considered the ‘gold standard’ of measuring TEE (Walker *et al.*, 2016). Over the last few years this method of assessing total daily energy expenditure has been utilised within a handful of team sport based studies (Morehen *et al.*, 2016; Anderson, Orme, *et al.*, 2017). Within elite British soccer there has only been one publication which has assessed total daily energy expenditure within an adult EPL team (Anderson, Orme, *et al.*, 2017). However, the doubly labelled water technique is extremely expensive, and requires a large amount of analysis. Despite the advantages of this technique in measuring energy intake, due to its expense doubly labelled water study sample sizes are often quite small, and therefore it can be difficult to generalise the findings from these studies' results (Ebine *et al.*, 2000; Ekelund *et al.*, 2002; Morehen *et al.*, 2016; Anderson, Orme, *et al.*, 2017).

A more feasible and readily available, yet reliable, method is to estimate the TEE of an individual using equations which factor in RMR, physical activity level (PAL) and the thermic effect of food (TEF). To work out RMR, there are several equations one can use, such as the Cunningham (Cunningham, 1980), Scholfield-HW (Scholfield, 1985), Miffin (Miffin et al., 1990), and Liu (Liu et al., 1995) equations. The Schofield-HW equation has more recently been shown to be a valid measure within adolescent populations (10-18 years old) (Carlsohn et al., 2011). For male adolescents, the equation is;

$$[\text{Kcal/24 hr}] = 16.25 * \text{BW [kg]} + 1.372 * \text{Height (cm)} + 515.5$$

Once the RMR has been worked out, it can be multiplied by a PAL factor to help estimate the energy cost of exercise. Carlsohn et al. (2011) state that when trying to estimate an athlete's TEE, the determination of the PAL factor is key to achieving an accurate estimation. For adults with a vigorously active lifestyle a PAL factor of 2.0 – 2.4 is recommended (WHO, 2001). For lightly to moderately active adolescents aged 12-18 years old, the WHO recommends PAL factors between 1.50 – 1.85 in males (Torun, 2005). Of the few studies which have assessed activity levels in adolescents partaking in large amounts of physical activity/structured training program PAL values of 2.00 – 2.15 have been reported (Kriemler et al., 1999; Torun, 2005; Eiholzer et al., 2010). However, within competitive adolescent athletes there is little data. The work of Carlsohn et al. (2011) suggests a PAL factor of 1.75 – 2.05 (with an observed value of 1.90 within the study) should be used for adolescent athletes, which is lower than that given to their adult counterparts (2.0 – 2.4). This highlights the importance of using adolescent population specific validated equations as opposed to using those designed for adult populations.

The thermic effect of food (also known as dietary induced thermogenesis) is the amount of energy used in the digestion and absorption of consumed food product (de Jonge and Bray, 1997)**.** Typically, TEF is set at 10% of an individual's energy intake (Jeukendrup and Gleeson, 2010)**.** However, the thermic effect of different food groups has a large variation. Protein, for example, has the highest thermogenic effect due to the complex enzymatic process of peptide bond synthesis, ureogenesis, and gluconeogenesis (de Jonge and Bray, 1997). This variation can result in individual variation of TEF dependent on the individual's dietary intake composition and by using a set valuable (10%) may result in the over or under estimation of TEF (de Jonge and Bray, 1997).

2.5.3.2 Energy Availability

Previously, much work in nutrition has focused on energy balance, which is defined as energy intake minus total energy expenditure (Loucks, Kiens, and Wright, 2011). This can result in an addition or subtraction of energy to the body's energy stores following a day's worth of work from the body's physiological systems. As such, energy balance can be viewed as an output from those physiological systems (Loucks, Kiens, and Wright, 2011). Loucks, Kiens and Wright (2011) argue that energy balance does not deliver reliable information about energy requirements, and that energy balance is not a useful concept to base nutritional advice on for an athlete.

The concept of energy availability has been suggested to be more appropriate for athletic populations. Energy availability has been defined as the dietary energy intake minus the energy spent in a particular metabolic demand of interest (such as thermogenesis) (Loucks, Kiens, and

Wright, 2011). However, exercise can result in substantial increases in the energy expended in locomotion depending on the intensity and duration of movement (Loucks, Kiens, and Wright, 2011). This has led exercise physiologists to refine the definition of energy availability during exercise to dietary energy intake minus the energy expended in exercise. The remaining energy after exercise is then left for other metabolic processes, therefore making energy availability an input into the body's physiological systems (Loucks, Kiens, and Wright, 2011).

For healthy young adults, energy availability should be approximately 45 kcal·kg^{-1} Fat Free Mass (FFM)·day^{-1} (Loucks, Kiens, and Wright, 2011). However, to assess energy availability the FFM of the participant must be known, and accurate means of measuring this (i.e. Dual-energy x-ray absorptiometry (DXA) scan) may not always be available to practitioners. Low energy availability (<30 kcal·kg^{-1} FFM·day^{-1} is commonly associated with the disturbance of female reproductive function and low bone mineral density (BMD) as a result of oestrogen deficiency (Loucks, 2004). However, there are now known oestrogen independent mechanisms of which low energy availability negatively affects BMD. Within 5 days of being in an energy deficient state (and therefore low energy availability state), the rate of bone protein synthesis decreases along with insulin secretion (Ihle and Loucks, 2004). Furthermore, bone remineralisation declines markedly as energy availability drops below <30 kcal·kg^{-1} FFM·day^{-1}, along with drops in insulin-like growth factor-1 (IGF-1). This can occur without any change in oestrogen concentration and is a risk for both males and females. Adolescence is a critical time bone mass development, and the increases in bone mass during puberty are dependent on increasing levels of hormones such as IGF-1 (Misra, 2008). As low BMD is an aetiological factor in stress factors it is vital important that during adolescence appropriate energy availability is achieved to ensure the optimal development of BMD.

2.5.4 CHOs

2.5.4.1 Role of CHOs for performance

The role of CHOs to improve exercise performance has been extensively researched for over fifty years with early work in this area coming from observational studies, which found a link between exercise capacity and CHO consumption, in that higher CHO improved exercise capacity (Bergstrom and Hultman, 1967; Hermansen, Hultman and Saltin, 1967; Hultman and Bergstrom, 1967). The development of the muscle biopsy technique by Bergstrom and Hultman (1967), provided some of the first evidence that a diet high in CHO can increase endurance capacity when exercising to fatigue via increased muscle glycogen stores. In more recent years, a number of well controlled laboratory based studies have demonstrated the beneficial effect of CHO consumption pre and during exercise in performance related testing protocols, for an in depth review please consult; (Cermak and van Loon, 2013).

One of the first publications regarding soccer nutrition came from the late Bengt Saltin (1973). In a paper titled ‘Metabolic fundamentals in exercise’ Saltin displayed findings from a simulated soccer game regarding the effect of two separate pre-match muscle glycogen concentrations on physical performance. The results shown clear benefits in physical performance variables (e.g. total distance covered) as a result of increased CHO ingestion before the simulated match (Saltin, 1973). In specific guidelines to soccer, early work in the 1990s from Jens Bangsbo reported that the average soccer game is performed at ~ 70% of maximal oxygen uptake ($\dot{V}O_{2max}$) (Bangsbo, 1994). More recently it has been reported that the game of soccer has developed into a faster, higher intensity game which has resulted in players completing more repeated sprints throughout the game (Barnes *et al.*, 2014). This increase is intensity is likely to result in the CHOs utilisation also increasing to support these match play demands.

2.5.4.2 Daily Amount of CHO

The guidelines regarding the amount of CHOs an athlete should consume is currently a topic of debate within the current literature. Carbohydrate recommendations for team sports such as soccer, have come as a result mainly from the earlier work from studies which have focused on how to maximally load the muscle glycogen stores (Bergstrom and Hultman, 1967). Current adult recommendations suggest a daily intakes of ~ 6 - 10 $g \cdot kg^{-1}$ Body Mass (BM) are required to meet training and match demands (Burke, Loucks and Broad, 2006). However, these recommendations vary based on training and competition demands, and it is important to consider this when providing athletes with advice and information. These adult recommendations have then typically been fed down to adolescent athletes. Whilst these guidelines may be suitable to match play, they may be out of synchronisation with the training energy demands of soccer players. Soccer training sessions usually last ~ 60 - 90 minutes and players will typically cover distances of ~ 3 – 6 km (Wrigley *et al.*, 2012). A developing theme used within soccer, is the periodisation of CHOs throughout the week based on training and match loads (Anderson, Orme, *et al.*, 2017) although this has not yet been observed within youth soccer. When investigating the energy and macronutrient distribution across different training days and match days with an elite youth soccer population (U16s), Briggs *et al.* (2015) reported similar CHO across the different days and no clear evidence of CHO periodisation.

2.5.4.3 CHO loading

Carbohydrate loading strategies have been developed since the late 1960s with the aim of storing supra-physiological quantities of muscle glycogen to optimally fuel subsequent exercise. Two of the most popular CHO loading strategies are from the lab of Bergstrom and Hultman (Bussau *et al.*, 2002), the classical 3-day and 6-day approaches (Ahlborg and Brohult, 1967; Bergstrom and Hultman, 1967). The classical 3-day approach involves performing a glycogen depletion exercise protocol three days before the event the participant is preparing for, then consuming a high CHO (> 8 $g \cdot kg^{-1}$ BM) diet in that subsequent 3-day window with little to no training on these days. The classical 6-day approach encompasses two phases of glycogen depleting exercise protocols, separated by 3-days of a low CHO / high fat diet, followed by 3-days of a high CHO diet (> 8 $g \cdot kg^{-1}$ BM) with little to no training on these days, as described by Bussau et al. (2002). With it proposed that these methods will then lead to the desired super compensation of muscle glycogen and maximise an athlete's CHO stores. However, performing glycogen depleting exercise in close proximity to competition may potentially have negative performance consequences. Certainly, in an applied soccer setting where often between competition recovery strategies are prioritised due to high game loads (Anderson *et al.*, 2016), such a protocol would not be suitable.

These CHO loading strategies were updated by Sherman *et al*. (1981), who designed a strategy which did not involve a glycogen depletion protocol. The protocol is based around a tapering down of training load in the 6-days leading in to competition, with no exercise on the last day before, whilst simultaneously consuming a regular diet in the first 3-days followed by 3-days of high CHOs (Sherman *et al.*, 1981). However, new research has suggested that a 24-hr CHO load protocol can result in similar muscle glycogen concentrations achieved through a 3-days protocol (Bussau *et al.*, 2002). Therefore, this protocol can be used just the day before a game, and minimalise the risk of players over-consuming CHOs during the week which can potentially result in an increase in adipose tissue and subsequently hamper performance. This technique of a short CHO load in preparation for a game appears to be currently utilised within elite adult soccer (Anderson, Orme, *et al.*, 2017), but there is currently no published data within youth populations.

2.5.4.4 CHO intake during exercise

Current recommendations advise consuming 30 - 60 g·hr of CHO during intermittent sports which last over 1-hr (Burke *et al.*, 2011). The utilisation of exogenous CHOs is limited by absorption from the gut (Jeukendrup, 2004). Glucose can be absorbed from the gut at a rate of ~ 60 g·hr, although this value can be increased to ~ 90 g·hr by ingesting multiple transportable CHOs, e.g. 1.2 $g \cdot min^{-1}$ glucose and 0.6 $g \cdot min^{-1}$ fructose (Cermak and van Loon, 2013). However, the consumption of CHO during exercise can potentially cause gut discomfort, particularly when ingested in large quantities (> 1.5 $g \cdot min^{-1}$) (de Oliveira, Burini and Jeukendrup, 2014). Within a soccer specific setting, the ingestion of CHO during exercise has displayed physical and cognitive benefits. The ingestion of a CHO drink (~7% solution) in comparison to placebo has been repeatedly shown to significantly increase soccer specific skills such as agility, dribbling, heading and kicking (Ostojic and Mazic, 2002; Ali and Williams, 2009; Currell, Conway and Jeukendrup, 2009). Russell, Benton, and Kingsley (2014) investigated the metabolic effects of consuming a 6% CHO-electrolyte beverage before and during match within elite academy soccer players (U16s) in comparison to an electrolyte placebo beverage. They reported that the intake of a 6% CHO-electrolyte beverage did not maintain blood glucose concentrations in the second half of the match, with a sharp decline in blood glucose concentrations in both groups following the half-time rest period. The authors recommended that CHO feeding strategies be developed that help maintain blood glucose concentration during match play (Russell, Benton and Kingsley, 2014).

Building on from this, the intake of nutrients at half-time during a soccer match has not received much attention. This is somewhat surprising as during this period soccer players have the most access to nutrition products such as CHO based drinks and gels. One study that did investigate this area was that of Kingsley et al. (2014). Recreational soccer players (n = 14) completed a 90-minute soccer simulation protocol on 3 different occasions, in which they consumed equal amounts of one of the following 3 beverages on each occasion; 1) - 9.6% CHO-caffeine-electrolyte (caffeine ~ 6 $mg \cdot kg^{-1}$ BM) solution with additional CHO-electrolyte gels, 2) - 5.6% CHO-electrolyte solution with additional electrolyte only gels or, 3) - electrolyte solution and electrolyte only gels (control) (Kingsley *et al.*, 2014). Interestingly the authors reported that none of the conditions prevented a drop-in blood glucose at 60 minutes, with results suggesting a rebound-hypoglycemic effect post half time feeding similar to what was reported in Russell, Benton, and Kingsley (2014). However, the combination of high CHO availability and caffeine resulted in elevated blood glucose in blood samples taken throughout the first half and at 90 minutes. Additionally, this condition provided a performance benefit with improvement in sprint performance observed compared to the control condition.

These data taken together appear to potentially show a benefit in performance (Ostojic and Mazic, 2002; Ali and Williams, 2009; Currell, Conway and Jeukendrup, 2009) from the feeding of CHOs. Although though some research (Kingsley *et al.*, 2014; Russell, Benton and Kingsley, 2014) have reported reduced blood glucose concentrations in the second half of matches following CHO intake, it is not clear if this has resulted in a negative effect to performance. However, these studies have all been conducted in a post-pubertal population and the utilisation of exogenous CHOs is altered by pubertal status.

2.5.4.5 CHO intake post exercise

It has been reported that following a soccer match, muscle glycogen concentrations are depleted (<50 mmol·kg^{-1} dry weight) and repletion of these stores is a key goal (Mohr, Krustrup and Bangsbo, 2003). A common characteristic of soccer is heavy fixture congestion, with teams often playing up to three games a week, post-match recovery of muscle glycogen stores becomes vitally important to help prepare players to perform in subsequent fixtures (Nedelec *et al.*, 2013). Within youth academy soccer, fixture congestion only appears to become an issue during tournament play in which multiple matches can be played within a short period of time (Unpublished observations).

Research in the area of post-exercise glycogen resynthesis has given a lot of attention to the early phase (0 – 4 hr) of recovery due to the muscle being more sensitive to glucose uptake during this period (Burke, van Loon and Hawley, 2017). Earlier guidelines suggested that athletes consume a CHO intake of ~ 1 g·kg^{-1} BM every two hours during this initial early period of recovery (Burke, 1997). Burke, van Loon and Hawley (2017) suggest this was due to early observations of comparable rates of post-exercise muscle glycogen resynthesis from CHO intakes of 0.7 and 1.4 g·kg^{-1} BM (Blom *et al.*, 1987) or 1.5g and 3.0 g·kg^{-1} BM (Ivy *et al.*, 1988) at similar time intervals. A recent detailed review on post-exercise muscle glycogen resynthesis was published by Burke, van Loon and Hawley (2017). The authors recommend that in the first 4-hr post-exercise CHO intake is > 1 g·kg^{-1} BM across multiple small feedings, suggesting this can result in 30 - 50% higher rates of glycogen resynthesis (Burke, van Loon and Hawley, 2017). Presently however little is known about current post-exercise habits of elite adult and adolescent soccer players, particularly within this initial 4-hour window, more research is required to devise optimal re-feeding strategies within soccer.

2.5.4.6 CHO intake and Health

Within the UK, current guidelines recommend the consumption of a relatively high CHO diet, with males and females both advised a diet in which 50% of total energy intake (TEI) is derived from CHOs (Scientific Advisory Committee on Nutrition (SACN), 2015). However, over the past few years the consumption levels of sugar have become an increased area of interest within the UK, as it has been linked to adverse health effects particularly when consumed in excess. For example, a high free-sugar intake (> 5% TEI) has been associated with increased obesity (Siervo *et al.*, 2014), hypertension (Siervo *et al.*, 2014), metabolic diseases (Stanhope, 2016) and dental caries (Freeman, 2014). The concern is such in the UK that the government have proposed a 'sugar-tax' as part of the 2016 budget, which will be aimed at targeting soft drink companies who supply high-sugar beverages (Briggs *et al.*, 2013).

Furthermore, the SACN recently updated the recommendation around sugar intake in their recent published reported on dietary CHOs and health. Firstly, the SACN advised an update in the terminology used, adopting the term 'free-sugars' in place of 'non-milk extrinsic sugars', defining free-sugars as '*all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices'* (SACN, 2015). Secondly, the SACN recommended a new intake limit for free-sugars, 5% of TEI (SACN, 2015). Currently within the UK it has been reported that adolescents (11-18 years old) consume a mean total sugar intake of 103.4 ± 44.8 g·day^{-1} (21.7 ± 6.6 % TEI), with a free-sugars intake of 74.2 ± 39.8 g·day^{-1} (15.4 ± 6.4 %TEI) (Newens and

Walton, 2016). These data suggest that current dietary intake of free-sugar by British adolescents is triple that of the new dietary reference value (DRV) (SACN, 2015).

Currently there is no literature that has assessed the sugar intakes of elite adolescent soccer players in the UK. There is a potential risk of high sugar intakes in this population for two reasons; 1) evidence from the general adolescent population as highlighted above (Newens and Walton, 2016), and 2) recommendations to increase soccer performance capacity are high CHO (Burke, Loucks and Broad, 2006), which may consist of high free-sugar. For example, current soccer nutritional guidelines (Burke, Loucks and Broad, 2006), albeit in adults, recommend a diet high in CHO (6 - 10 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$), due to their ergogenic effect on soccer performance (Hawley, Dennis and Noakes, 1994) (Cermak and van Loon, 2013). Furthermore, sugary based energy drinks (i.e. Lucozade sport) are frequency consumed and recommended to soccer players before, during, and after training/match sessions to attempt to help improve performance and recovery (Russell, Benton and Kingsley, 2014). Due to the apparent need to consume high amounts of CHO, soccer players may also be consuming high amounts of free-sugar from other sources. However, it is currently not clear if the guidelines set by the SACN are appropriate for adolescent athletes for who are engaged in daily high-intensity physical activity.

2.5.4.7 Current practises in elite youth soccer players

A recent study form Bettonviel et al. (2016) collected and compared data from senior and youth players from an elite Dutch Premier Division team. Interestingly, senior players failed to meet current CHO guidelines of 6 – 10 $g \cdot kg^{-1}$ BM (Burke, Loucks and Broad, 2006) with a mean daily intake of 4.7 ± 0.7 $g \cdot kg^{-1}$ BM, whereas in comparison the youth players consumed a mean daily intake of 6.0 ± 1.5 g·kg^{-1} BM. These findings within the youth players as similar previous results within similar populations from Briggs et al. (2016), Russell and Pennock (2011), and Caccialanza et al. (2007) and suggest that players are at the lower end of the 6 – 10 g·kg^{-1} BM recommendations from Burke, Loucks and Broad (2006) (Table 2.1). The two British based studies from Russell and Pennock (2011) and Briggs et al. (2015) show similar CHO intake close to 6 g·kg^{-1} BM from similar age groups, currently no data from academy level British soccer players is available for <U16s.

Table 2.1 – Adolescent soccer player CHO intake

Study	**Population** (club level, age)	**Reported Daily Intake** (g·kg^{-1} BM)
Bettonviel et al. 2016	Dutch Premier Div, ~ 17	6.0 ± 1.5
Caccialanza et al, 2007	Seria A, ~ 16	5.0 ± 1.3
Briggs et al. 2015	EPL, ~ 16	5.6 ± 0.4
Russell and Pennock, 2011	UK Championship, ~ 17	5.9 ± 0.4
Iglesias et al, 2005	Spanish 1st Div, 14 - 16	5.6

2.5.5 Protein

2.5.5.1 The role of protein for performance

The human body has a daily protein turnover of 1 – 2%, and without the adequate consumption of dietary protein degradation of skeletal muscle will occur (Phillips & Van Loon 2011). For athletes, the loss of skeletal muscle mass is an unfavourable scenario that should be avoided due to its potential impact on performance. Currently, the UK RDA for daily protein intake is

0.8 g·kg^{-1} BM to meet the protein requirements of ~98% of the population (Department of Health, 1991). A recent position stand from the Academy of Nutrition, Dietitians of Canada and the American College of Sports Medicine (ACSM) advise that athletic population should have a daily protein intake of 1.2 – 2 g·kg^{-1} BM to necessary to support metabolic adaptation, repair and daily turnover (Thomas, Erdman and Burke, 2016).

Previously, it has been reported that elite youth soccer players within an EPL U18 squad present with ~6 kg less lean mass than their 1st team senior counterparts (Milsom *et al.*, 2015). Consequently, a desirable training goal for youth soccer players is muscle hypertrophy, to attain a body composition that is more representative of the physical attributes of 1st team players. This may be necessary to manage with the physical training and match-play demands of an EPL athlete (Milsom *et al.*, 2015). The intake of dietary protein plays a key role in the development and growth of skeletal muscle mass when consumed in tandem with resistance training (Phillips and Van Loon, 2011; Morton, McGlory and Phillips, 2015).

Within this area there has been some excellent research into the amount, timing and distribution of protein over the last few years. The optimal single dose of protein for maximal stimulation of muscle protein synthesis (MPS) has been investigated in a couple of well-designed studies. Firstly, Witard *et al.* (2014) compared the effect of four separate doses of whey protein isolate: 0, 10, 20 or 40 g on MPS immediately following a lower body resistance-training session in young resistance-trained males. The results showed that maximum stimulation of MPS was achieved at the two higher doses (20 and 40 g), resulting in common practice to advise 20-25 g of protein intake following resistance training to aid hypertrophy adaption (Witard *et al.*, 2014). From this study, it became common practice to advise an intake 20 – 25 g protein following resistance training to maximally stimulate MPS in an attempt to facilitate adaptation to training.

In a recent follow up study, the same group investigated the influence of lean muscle mass (≤ 65 kg vs. ≥ 70 kg), and amount of muscle activated on the maximal response of MPS to ingestion of 20 or 40 g whey protein succeeding a single bout of whole-body resistance training (Macnaughton *et al.*, 2016). Their data revealed that a 40 g ingestion of whey protein stimulates a greater MPS response following a single-bout of whole body resistance training in comparison to a 20 g dose, in both lean mass categories. This finding potentially suggests that this dose would also be applicable for youth soccer players, especially those with relatively lower lean mass (Milsom *et al.*, 2015) following whole-body resistance exercise.

Furthermore, research from Areta et al. (2013) has assessed the quantity and timing of protein ingestion in a well-designed study. During a 12-h period following a bout of bilateral resistance exercise (leg exercise 4 x 10 sets ~ 80 % 1 rep max), healthy trained males were given 80 g of whey protein in one of three conditions; 8 x 10 g every 1.5-h (pulse), 4 x 20 g every 3-h (intermediate) or 2 x 40 g every 6-h (bolus). They reported that over the 12-h recovery period, MPS was highest in the intermediate condition which was significantly higher than both the pulse and bolus conditions. Which suggests that consuming approximately 20 g high quality PRO every 3-hr following a bout of lower body resistance exercise will help optimally stimulate MPS to facilitate training adaptations (Areta *et al.*, 2013). The practicality of this within an applied athletic context may be difficult, particularly for meals earlier in the day (i.e. breakfast and lunch) as has been previously reported (Gillen *et al.*, 2017). However, data from Bettonviel *et al.* (2016) within a youth and adult soccer population suggest that the recommendation of Areta *et al.*, (2013) is in line with current practises within soccer. This is discussed in more detail further below.

Recently, the distribution of daily protein intake has been suggested to be an important aspect of an athlete's nutritional strategy. Data from Mamerow *et al.* (2014) presented that an uneven distribution of daily protein intake across meals (skewed to a higher intake at dinner) resulted in a reduced stimulation of MPS in comparison to steady even intake of protein (~ 30 g) at each meal (breakfast, lunch and dinner) even when total daily protein is matched in healthy male adults. Within an athlete setting, Gillen *et al.* (2016) reported that highly trained Dutch athletes have a high protein intake (> 1.2 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$), but this intake is skewed across the different meals. In this four week study, a large cohort (male n = 327 and female n = 226) of athletes completed multiple web-based 24-hr recalls, from this data the contribution of both plant- and animal-based proteins to total daily intake, and protein intake at six eating points were analysed (Gillen *et al.*, 2017). Results revealed that 57% of protein intake came from animal sources, and 43% from plant sources, which may potentially have implications for the quality of protein the athletes are consuming, with plant sources often low in high quality proteins (lacks one or more essential amino acid) (Phillips, 2012). Furthermore, they found that protein intake per meal was below the recommended 20 g for 58% of athletes at breakfast, 36% at lunch and 8% at dinner. So while athletes may be habitually hitting daily protein targets, the skewed distribution over the course of the day may be suboptimal to support training adaptation (Gillen *et al.*, 2017).

Within soccer, a recent study from Bettonviel *et al.* (2016) investigated the nutritional habits of soccer players across different days, with specifically interest in the pattern of protein intake. Data was collected on match, post-match, rest and a training days via a 24-hr web-based recall method in both senior professional (n = 14) and elite youth (*n* = 15) soccer players from a club based in the Dutch premier division (Bettonviel A *et al.*, 2016). Results found no significant difference between the seniors and youth players for mean total energy intake over the 4-days (2988 ± 583 v 2938 ± 465 kcal·day^{-1}) and all players met or exceeded current protein intake recommendations (1.9 ± 0.3 and 1.7 ± 0.4 g·kg^{-1} BM, respectively) (Phillips and Van Loon, 2011) on all days in both groups. When looking at the individual days, protein recommendations were met or exceeded on all the days analysed for both groups. Bettonviel and colleagues (2016) reported that the mean distribution protein intake across main meals (breakfast, lunch, and dinner) was in excess of 20 g for both squads. For afternoon and pre-bed snacks the senior players reported protein intakes of 15 - 20 g, which is close to current recommendations for optimal stimulation of MPS for a single dose (Witard *et al.*, 2014). Conversely, youth players reported a suboptimal intake of ~ 10 – 15 g for the same time point. While the authors conclude that when taken together these data suggest that senior and youth soccer players have a more balanced distribution of protein intake in contrast to that of the general population (De Castro, 1997; Valenzuela *et al.*, 2013) there is potential for greater MPS with the youth players by increasing protein intake in between major meals. A limitation to this data set is that the sources of protein have not been disclosed and therefore it is unclear on the type/quality of the protein being commonly consumed at different meal times.

2.5.5.2 Health

Within the UK current government guidelines, the daily Reference Nutrient Intake (RNI) for protein is 0.8 g·kg^{-1} BM albeit in adults. This is in stark contrast to the recommendations for adult athletic populations, of 1.3 – 1.8 g·kg^{-1} BM (Phillips and Van Loon, 2011), also deemed appropriate for adolescent athletes (Desbrow *et al.*, 2014). The UK RNI is set at a level of consumption proposed to be sufficient to meet the requirements of 97.5% of the population. Emerging literature is suggesting that a protein intake higher than that of the current UK RNI may be more beneficial to health than simply being sufficient (Phillips *et al.*, 2015). Health benefits reported include the prevention of body fat gain (Leidy *et al.*, 2015), increasing weight loss (Halton & Hu 2004; Clifton *et al.*, 2014), limits weight gain following weight loss (Westerterp-Plantenga *et al.*, 2004), increasing TTE (Binns, Gray and Di Brezzo, 2015), satiety (Westerterp-Plantenga, Lemmens and Westerterp, 2012), reducing sarcopenia (Witard *et al.*, 2016), and potential to increase overall diet quality (Phillips *et al.*, 2015). More research investigating the possible benefits of increased protein intake (i.e. that above the current RDA) is required.

2.5.5.3 Current protein practices in elite youth soccer

The above evidence would suggest that protein is a vital component of an athlete's diet, particular when skeletal muscle and strength is a key factor as it is for a youth soccer player (Milsom *et al.*, 2015). Within elite British youth soccer only two publications are currently available which detail habitual protein intake (Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015). The first study to do this was from Russell and Pennock (2011) who studied an U18 squad (n = 10) from professional British Championship soccer club. Dietary intake was recorded via a self-reported 7-day food diary over a period that consisted of a match day, four training days and two rest days during the in-season period. They reported a mean total protein intake of 114 ± 8 g·day^{-1}, which relatively equated to 1.7 ± 0.1 g·kg^{-1} BM and contributed 16% of TEI (Russell and Pennock, 2011). More recently, Briggs et al. (2015) studied an U16 squad (n = 10) from a professional EPL soccer club. Similar to the methodology used by Russell and Pennock (2011), dietary intake was recorded via a self-reported weighed 7-day food diary, and additionally performed a 24-hr recall, over a period that consisted of a match day, four training days and two rest days during the in-season period (Briggs et al. 2015). They reported a mean relative protein intake of 1.5 ± 0.2 g·kg^{-1} BM and contributed 16% to TEI (Briggs et al. 2015), which are comparable to the previous findings of Russell and Pennock (2011). From these two data sets it would appear that elite British youth soccer players are meeting current adult athlete recommendations for protein intake. Limitations of these studies are the relatively small sample sizes (*n* = 10), however when collecting data in the elite field, access to participants is usually limited. Furthermore, these data only look at two age groups; U18s and U16s, meaning there are no data currently on the nutritional habits of elite British youth soccer players outside of these age groups. As previously mentioned in this section the distribution and dose of protein are important considerations for an athlete's diet, and future research should aim to quantify this within the elite British youth soccer population.

Within youth soccer, only one research group has investigated daily protein requirements (Boisseau *et al.*, 2002, 2007). In the 2002 study, Boisseau et al. (2002) sought to determine the protein intake and nitrogen balance of two groups of adolescents; soccer players (15 ± 0 years) and non-active adolescents (15.2 ± 1.2 years). Protein intake was assessed using a 7-day food diary, and nitrogen balance was measured through 24-h urine excretion on the final day of the 7-day food record. The results reported that a positive nitrogen balance was observed with a mean protein intake of 1.57 g·kg^{-1} BM independent of group (Boisseau et al. 2002). From these findings Boisseau et al. (2002) concluded that adolescents, both active and non-active, require a higher protein intake in comparison to the current reccomendations (0.8 g·kg^{-1} BM) to meet growth and development demands. In a follow-up study, Boisseau et al. (2007) again aimed to determine the protein requirements of youth soccer athletes (13.8 ± 0.1 years old), although in this study the participant's diets were manipulated to provide three separate protein intakes;

1.4, 1.2 and 1.0 g·kg^{-1} BM. Similarly, to their previous findings, they found that the protein requirements of adolescent soccer athletes is above that of the current RDA (Boisseau *et al.*, 2007). Furthermore, a protein intake of 1.4 g·kg^{-1} BM is recommended for this population to meet their protein requirements. However, whilst classical nitrogen balance studies are suitable to identify protein requirements to prevent deficiency they perhaps are not suitable to assess protein intake for optimal training adaptation and enhanced performance (Phillips, 2012). However, these findings are in line with the current guidelines for adult athletes, 1.3 – 1.8 g·kg^{-1} BM (Phillips and Van Loon, 2011). Whilst the study from Boisseau *et al.* (2007) is a well-designed study which provides value information, the reasoning for values of the three different protein intakes (1.4, 1.2 and 1.0 g·kg^{-1} BM) is not clear. In their previous study (Boisseau *et al.*, 2002) the authors reported that it was a protein intake of 1.57 g·kg^{-1} BM that provided a positive nitrogen balance, it is perhaps surprising they choose not to use that value for the follow-up study. More research is required within this area, across a range of ages, to provide accurate guidelines for athletic adolescent populations

Table 2.2 – Adolescent soccer player protein intake

Study	**Population** (playing level, age)	**Reported Daily Intake** (g·kg^{-1} BM)
Bettonviel et al. 2016	Dutch Premier Div, ~ 17	1.7 ± 0.4
Briggs et al. 2015	EPL, ~ 16	1.5 ± 0.2
Russell and Pennock, 2011	UK Championship, ~ 17	1.7 ± 0.1
Caccialanza et al, 2007	Seria A, ~ 16	1.5 ± 0.4
Iglesias et al, 2005	Spanish 1st Div, 14 - 16	1.9

2.5.6 Dietary Fat

2.5.6.1 Performance

Dietary fat provides a vital source of energy, is an essential functional component of cellular membranes while also assisting in the absorption of fat soluble vitamins such as vitamins A, D, and E (Rodriguez, Di Marco and Langley, 2009; Thomas, Erdman and Burke, 2016). In contrast to the recommendations of CHO and protein, recommended fat intake is expressed as a percentage of TEI, with current ACSM guidelines (Rodriguez, Di Marco and Langley, 2009) suggesting a fat intake between 20 – 35%. Unlike the roles of CHO (Burke *et al.*, 2011) and protein (Phillips and Van Loon, 2011) in influencing exercise performance and recovery, there is currently no clear role of fat intake for soccer players (Bettonviel A *et al.*, 2016).

Within recent years the concept that high fat diets can benefit athletic performance has gained popularity, although it would appear that there is little evidence of such benefits within the literature. Mechanistically high-intensity exercise utilising lipids as the predominant fuel source cannot be supported (Loon *et al.*, 2001); however, the contribution of lipids as a fuel source has been shown to slightly increase during extended bouts (> 2 hr) of exercise (Romijn *et al.*, 1993) in the absence of consuming exogenous CHOs. Further evidence in performance based trials have shown no positive effect of high fat diets, but rather a potential deficiency in performance capacity (Burke, 2015).

Currently, the recommendations for soccer performance mainly focus around the intake and distribution of CHOs and protein, whilst the intake of fat is not seen as a major area of interest outside of its daily recommended intake. Due to the pressure within elite soccer to win and perform it is unlikely a study assessing the potential effect of a LCHF diet is likely to be feasible within an elite population. For now, findings from studies in other sports and laboratory controlled studies inform the recommendations, and on current available evidence there does not appear to be any performance benefit from increased dietary fat intake.

2.5.6.2 Current practices in elite youth soccer

Within elite youth soccer there is limited data of current dietary fat intake, although the three most recent studies within this population report relatively similar values of an approximate in of 1.2 – 1.5 g·kg^{-1} BM (Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015; Bettonviel A *et al.*, 2016). The values reported from a Spanish population by Iglesias *et al.* (2005), 1.95 g·kg^{-1} BM, are relatively higher than those reported in a British population by Russell and Pennock (2011), 1.5 g·kg^{-1} BM, and Briggs *et al.* (2015), 1.2 g·kg^{-1} BM. This difference may be a result of cultural differences affecting dietary intake between the two countries. Further research is required within this area, particularly in British youth soccer players < 16 years old.

Table 2.3 - Adolescent soccer player dietary fat intake

Study	**Population** (playing level, age)	**Reported Daily Intake** (g·kg^{-1} BM)
Bettonviel et al. 2016	Dutch Premier Div, ~ 17	1.2 ± 0.2
Briggs et al. 2015	EPL, ~ 16	1.2 ± 0.1
Russell and Pennock, 2011	UK Champion, ~ 17	1.5 ± 01
Caccialanza et al, 2007	Seria A, ~ 16	1.22
Iglesias et al, 2005	Spanish 1st Div, 14 – 16	1.95

2.5.7 Micronutrients

Micronutrients have many vital functions within the body, playing important roles in immune function, haemoglobin synthesis, bone health, energy production, muscle synthesis and repair, and protection against oxidative damage (Rodriguez, Di Marco and Langley, 2009). It has been suggested that through the extra demands placed on the body through exercise, greater amounts of micronutrient may be required for athletic populations (Rodriguez, Di Marco and Langley, 2009). This concern may be amplified in athletes who choose to restrict energy intake, and / or eliminate certain food groups (i.e. CHOs) from the diet. Vitamins and minerals that have received particular interest in athletes are the B vitamins, vitamins C, D and E, calcium, iron, magnesium, and zinc (Rodriguez, Di Marco and Langley, 2009), an overview of the function of these micronutrients is in table 1.4. Within adolescent athletic populations the dietary intake of iron and calcium receive particular interest (Desbrow *et al.*, 2014).

The World Health Organisation (WHO) reported that iron deficiency anemia is the most common deficiency in the world (WHO, 2012). Desbrow et al. (2014) status that when diagnosing iron status disorders, it is vital to acknowledge the progression from depleted iron stores (defined by alterations in serum ferritin), early functional iron deficiency (defined by alterations in transferring saturation), and iron deficiency anemia (defined by changes in hemoglobin and mean cell volume; Burke & Deakin, 2010). Low iron stores have been frequently observed within adolescent and youth athletes, particularly within endurance trained athletes (Gropper *et al.*, 2006; Rodenberg and Gustafson, 2007; Sandstrom, Borjesson and Rodjer, 2012) without clinical symptoms. Yet, it is unclear of what impact, if any, athletic training has on low iron stores as these observations have also been reported within nonathletic populations (Sandstrom, Borjesson and Rodjer, 2012). Current recommendations suggest although there is potential for exercise induced iron losses, there is no evidence that the adolescent athlete need consume more dietary iron than the RNI values set for the general population (Desbrow *et al.*, 2014). The current UK recommended intake of iron for adolescents is 11.3 mg·day^{-1} (Department of Health, 1991).

During maturation adolescents go through substantial physical change, and as such have differing nutritional demands in comparison to fully grown adults. A key development is skeletal bone growth, with over 90% of peak bone mass being accrued by the age of 20 (Misra, 2008). A key determinant of bone mass accrual is nutritional status, with calcium and vitamin D intake being key factors (Chan, 1991; Lehtonen-Veromaa et al., 2002) along with other external inputs such as weight bearing exercise and lean body mass (Misra, 2008). During male adolescence (11-18 years old) dietary calcium intakes of 1000 mg·day^{-1} are recommended to help support bone mass development and is higher than that of adult recommendations (700 mg·day^{-1}) (Department of health, 1991). Daily calcium requirements are amplified in adolescents compared to adults' due to the substantial development of bone during this period (Desbrow et al., 2014). It has been previously estimated that the rate of skeletal calcium accretion during adolescence is ~ 300 mg·day^{-1} (Matkovic, 1991).

Exercise has previously been shown to increase bone mineral content in adolescent populations (Nichols, Sanborn and Love, 2001; Stear *et al.*, 2003; Nogueira, Weeks and Beck, 2014). However, the observed increase in bone mineral content of those undertaking an exercise intervention is only marginally higher to that observed in the control groups within these studies. However, it has been argued that the reported small increase in bone mineral content will accumulate over time to result in significantly greater bone density in exercising compared with inactive individuals by the end of the adolescence phase (Bailey *et al.*, 1999). Desbrow et al. (2014) suggest that based on current evidence, due to this only slight increase in bone mineral accretion as a result of exercise there is no requirement substantially increase the calcium recommendations for exercising adolescents. Within the UK the current recommended intake of calcium for adolescents is 1000 mg·day^{-1} (Department of Health, 1991).

Table 2.4 – Micronutrient UK RNIs and overview of roles within the body.

	UK RNI		
Micronutrient	**RNI (≤U14s)**	**RNI (≥U15s)**	**Brief Overview of Role**
Calcium (mg)	1000	1000	Promotes bone and teeth formation, involved in muscle contraction, regulates enzyme activity
Magnesium (mg)	280	300	Component of bone, involved in DNA and protein synthesis enzyme function
Iron (mg)	11.3	11.3	Involved in oxygen transport, forms cytochromes and metalloenzymes, promotes immune support
Zinc (mg)	9	9.5	Forms metalloenzymes, promotes protein synthesis and immune function, involved with tissue repair
Vitamin B1 (mg)	0.9	1.1	Promotes CHO metabolism and central nervous system function
Vitamin B2 (mg)	1.2	1.3	Promotes CHO and fat oxidation, and help maintain healthy skin
Vitamin B6 (mg)	1.2	1.5	Promotes protein metabolism, involved in glycogenolysis and gluconeogenesis
Vitamin B12 (µg)	1.2	1.5	Promotes formation of red and white blood cells, help maintain nerve, gut and skin tissue

Adapted from Jeukendrup and Gleeson (2010)

2.5.7.1 Current Practices in elite youth soccer

The micronutrient intake and status of male adolescent / youth soccer players has received minimal attention within the literature. To the authors knowledge only a handful of studies have investigated this area (Rico-Sanz *et al.*, 1998; Leblanc *et al.*, 2002; Noda *et al.*, 2009; Hidalgo y Teran Elizondo *et al.*, 2015) with only one conducted within the UK (Russell and Pennock, 2011). With the exception of Rico-Sanz et al. (1998) and Leblanc et al. (2002) (calcium and iron only), the micronutrient data that has been collected within soccer populations to date has typically been presented in publications as RDA percentage and displayed within bar charts. This makes it difficult to compare the actual numerical data, and additionally, different countries have different RDA values. The single British based study conducted by Russell and Pennock (2011) within an U18 English Championship academy team, where they reported that adolescent was equal to or above the RDA for all micronutrients listed in table 1.4. Currently, within elite British adolescent there is no published data on the absolute micronutrient intakes, and no data whatsoever on the any micronutrient intake for age group <U16.

2.6 Assessing Dietary Intake

2.6.1 Lab Techniques vs. Field Techniques

Collecting accurate dietary intake data can be extremely challenging, and this can be of particular difficulty when investigating adolescent populations (Livingstone, Robson and Wallace, 2004). This has been evident when attempting to quantify daily energy and macronutrient intakes via self-reported methods (Briggs et al. 2015), which can result in under-reporting and a lack of detail for accurate analysis (Hill & Davies, 2001). A recent study from Briggs *et al.* (2015) highlights that the environment in which the participant is recording their data is important. Research from a laboratory based setting (Moore *et al.*, 2004; Tanofsky-Kraff *et al.*, 2007; Bozinovski *et al.*, 2009), while potentially more accurate, does not necessarily reflect an applied setting. Within athletic populations it is vital to collect habitual nutritional habits within their own environment to gain greater understanding of nutritional practices of these populaces (Russell & Pennock 2011; Briggs *et al.*, 2015; Bettonviel A *et al.*, 2016).

In a study assessing the nutritional intake of elite Italian youth soccer players (aged 15 – 17) from an elite Seria A club, the authors concluded that the essential outcome of the research is under-reporting (Caccialanza, Cameletti and Cavallaro, 2007). So strongly did the authors feel this they titled their paper '*Nutritional intake of young Italian high-level soccer players: Under-reporting is the essential outcome'* (Caccialanza, Cameletti and Cavallaro, 2007), which is a reflection of how many research groups have found the task of reporting dietary intake within soccer environments (Boisseau *et al.*, 2002; Leblanc *et al.*, 2002; Ruiz *et al.*, 2005; Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015).

Within team sports, such as soccer, and/or under free-living conditions, there are few studies which have aimed to assess daily TEE. This is in part due to the difficutity in measurement and current methods available, as traditional methods of require metabolic analysis that restricts typical activity habits and are conducted within laboratoary settings. This is particuarly problematic with team sports as it means not getting an estimation of energy expenditure for training and match play, therefore making giving nutritioanl recommendations difficult. Within free-living scernios the doubally labelled water method is considered the 'gold standard' of measuring energy expenditure (Walker *et al.*, 2016). Over the last few years this method of assessing daily TEE has been utilised within a handful of team sport based studies (Morehen *et al.*, 2016; Anderson, Orme, *et al.*, 2017). Within elite British soccer there has only been one publication which has assessed daily TEE within an adult EPL team (Anderson, Orme, *et al.*, 2017). However, the doubly labelled water technique is extremely expensive, requires a large amount of analysis and place a notable burden on the participant. However, despite the advantages of using doubly labelled water to measure energy intake, due to the expense of this technique doubly labelled water study sample sizes are often quite small, and therefore it can be difficult to extrapolate conclusions from these studies' results (Ebine *et al.*, 2000; Ekelund *et al.*, 2002; Morehen *et al.*, 2016; Anderson, Orme, *et al.*, 2017).

2.6.2 Food diaries

A prospective measure of dietary intake is the use of food diaries, and is currently the most popular method for collecting dietary intake in sport nutrition research practice (Burke, 2015a) (Burke, 2015). Food diaries typically involve requiring the participant to record the following; time of consumption, type of food / brand, cooking method (i.e. boiled, grilled, fried) and portion size. Typically, there are two types of food diary; weighed and household measures. A weighed food diary requires the athlete to weigh the individual components of a meal, while this helps to provide more accurate information it also places an increased burden on the athlete (Burke, 2015a). Due to the increased burden on the participant, they may alter food intake to food choices that they deem easier to report as opposed to their usual eating habits (Burke, 2015a). A household measure food diary places less burden on the participant, with descriptions of portion sizes using common household measures (i.e. cup, teaspoon etc.) suitable, however this potentially increases the risk of inaccurate portion assessment (Burke, 2015a). Both types of food diary are reliant on participant literacy to record their intakes methodically (Fuller *et al.*, 2017) and the level of participants literacy skills may impact on the accuracy of data obtained.

Within athletic populations, it has previously been estimated that when using food diaries there is a potential underreporting effect of up to 20% (Burke and Deakin, 2010). Which can potentially result in inaccurate conclusions leading to incorrect practical recommendations.

From a researcher/practitioner perspective the analysis of a food diary can be a laborious task, particularly when completed over a number of days (Burke, 2015a). Within the applied world, this can be a serious issue particularly within a team sport setting such as soccer. Soccer squads can contain > 16 players, and within academy settings it is likely that nutrition practitioners will have to deal with several squads. Consequently, the use of food diaries may not be best suited to those working within the applied setting unless being undertaken in the process of a research project. Within the body of research literature which has investigated adolescent soccer player nutrition, the food diary has been a repeatedly used method, with studies recording dietary intake between four to seven days (Leblanc *et al*., 2002; Ruiz *et al.*, 2005; Iglesias-Gutiérrez *et al*., 2005; Caccialanza *et al.*, 2007; Russell & Pennock 2011; Briggs *et al.*, 2015; Bettonviel A *et al.*, 2016).

Recent research within soccer has combined the traditional pen and paper food diary with another traditional method such as 24-hr recall and/or the more recently developed method remote food photographic method (RFPM) (Briggs, Cockburn, *et al.*, 2015; Anderson, Orme, *et al.*, 2017). A further breakdown is provided in Table 1.5.

2.6.3 24hr recall

A retrospective method to collect dietary intake data is the 24-hr recall. This requires the participant to provide details on their food intake from the previous 24-hr, this therefore means that the output from this method is highly dependent on the participant's ability to recall the types and quantities of foods consumed (Burke, 2015a). This method also requires a skilled practitioner/researcher to help the participant through the process and prise out accurate information. An advantage of this method is that it can be conducted relatively speedily and there is little burden placed on the participant. However, a disadvantage is that it only provides a snapshot of the participants eating habits and is likely not representative of common habits (Burke, 2015a). Within soccer settings this method has previously been used in conjunction with self-reported food diaries to supplement the information they provide (Briggs *et al.*, 2015). A further breakdown is provided in Table 2.5.

2.6.4 Dietary History

A dietary history method is commonly used to gain an initial insight into an athlete's general nutritional habits (Burke, 2015a). This is perhaps most useful when the practitioner first begins to work with an individual to give a baseline to work from. Within this assessment the practitioner will be aiming to gain an insight into patterns of meals, nutritional intake around training and competition, and any potential supplement use (Burke, 2015a). This technique requires a skilful practitioner to probe questions in with minimal bias, in order to get the most information out of the participant (Burke, 2015a). As with any retrospective dietary intake assessment, the collected data is dependent on the participants' memory and ability to provide accurate information. Tools such as pictures or models of portion sizes may be useful to assist the participant in providing more accurate information (Burke, 2015a). This technique may be useful used in tandem with food diaries or 24-hr recall, to give a fuller picture of the participants' common nutritional habits. Within the literature this technique is not typically used as it does not contribute itself to providing an accurate quantitative data (Burke, 2015a), and is perhaps best used solely within the applied setting. A further breakdown is provided in Table 1.5.

2.6.4 Food frequency questionnaires

Food frequency questionnaires (FFQ) are a useful resource as they can be employed by the researcher/practitioner or self-administered by the athlete, furthermore they can be in paper or electronic format, which can be cost and time effective (Burke, 2015a). Due to these factors, the FFQ has been used within numerous health based studies with particularly large sample sizes (> 500 participants) in several different populations (Keogh *et al.*, 2012; Jarman *et al.*, 2014; Mulligan *et al.*, 2014; Lamichhane *et al.*, 2015). An FFQ compromises of questions which ask the participant to categorise how frequently (e.g. never or less than once a month, once a week, etc.) they eat a range of food consumables. From entering this data into the relevant software packages (dependent on the FFQ chosen) a general summary of dietary intake can be produced. However, this has been criticised for tending to overestimate intake in low energy consumers, and paradoxically, underestimate intake in large eaters (Burke, 2015). The FFQ can be manipulated to focus on a particular nutrient or food group of interest, which is also validated. This has previously been achieved by Braakhuis and colleagues (2011), who developed and validated (via biomarker correlation) an FFQ for the assessment of short term antioxidant intake within an athletic population. They summarised that the FFQ offered a less labour-intensive methodology for both researchers and participants than a 7-day food diary and appeared to provide valid data (Braakhuis *et al.*, 2011). A further breakdown is provided in Table 2.5.

Table 2.5 - Traditionally used methods for collecting dietary intake information. Adapted from Burke (2015a).

	Overview of Methods	Period of Interest	Advantages	Disadvantages
Prospective				
Food diaries (written)	Weighed	1-7 days	-Provides a more accurate quantification of foods than household measures -Considered the 'gold standard for dietary assessment'	-Relies on subject's honesty & food knowledge -Time consuming for subjects to keep & researcher to process -Distorts food choice & quantity: subject alters their diet to improve intake or educe the workload of recording
	Household Measures (descriptions of cups, teaspoons, dimensions of food portions etc.)		-Improved compliance with subjects compared to weighed record -Less alteration of normal eating pattern compared to weighed or semi-weighed records	-See comments for weighed record -Requires checking by trained person -Needs standardised set of household measures -Subjective/inaccurate assessment of portion sizes
Retrospective				
24hr recall	Subject describes foods consumed over the last 24hr or a 'typical day'	24-hr	-Speedy to implement -Low burden on the participant -Interview can be structured around ail activities -Does not alter intake -Suited to epidemiological research	-Relies on subject's honesty, memory and food knowledge -Requires trained interviewer -Day for recall may be 'atypical' -Suitable for group surveys, but not representative of an individual's usual intake
Diet history	Open-ended interview concerning food use, food preparation, portion sizes, food likes/dislikes and a food checklist	Open ended or over a specified period	-Accounts for daily variation in food intake by investigating a 'typical' day -Can target contrasts between periods of interest as a sub-theme -Collects information on timing of intake & factors that influence food patterns	-Relies on subject's honesty, memory and food knowledge -Labour intensive & time consuming -Requires rained interviewer -Mostly appropriate for qualitative assessment rather than quantitative
Food frequency questionnaire (FFQ)	Subjects asked how often they eat foods from a standardised list & to estimate portion sizes often using photos or food models as a prompt	From 24-hr to open-ended	-Can be self-administered to lower burden on the investigator -Can be used to cross-check data obtained from other methods -Validated for ranking individuals -Can be modified to target certain nutrients -Can be automated to allow quick processing by investigator	-Relies on subject's honesty, literacy, memory and food knowledge -Validity dependent on the food list & the quantification method

2.6.5 Developing techniques

Over the past decade, advances in technology have promoted the development of exciting new methods in which dietary intake data can be collected. This development of technology has provided the practitioner and/or researcher with greater choices to select to assess dietary intake and nutritional habits. Some advances have been to simply upgrade the more traditional methods of dietary collection to online web-based versions, such as the 24-hr recall (Bettoniel *et al.,* 2016). Essentially, if done over an extended period of time it can also be used as on online food diary as was done by Bettoniel and colleagues (2016) to analyse nutritional intake of elite Dutch soccer players.

Furthermore, the recent advances in smartphone development, popularity and use have also helped to increase the methods of which a practitioner and/or researcher can collect dietary intake data. In a collaborative study with Dietitians of Canada, Lieffers et al., (2014) surveyed Canadian dietitians (*n* = 118) using a web-based questionnaire aimed at investigating the smartphone devices and their potential use within practice. They reported that 57% of dietitians who took part in the study stated that they used smartphone applications within practice (Lieffers, Vance and Hanning, 2014). Perhaps even more interesting, is that 54% of respondents reported that they had had questions from clients regarding nutrition based smartphone apps, and 41% of respondents had recommended a smartphone app to a client (Lieffers, Vance and Hanning, 2014). This data displaying that the clients themselves had an interest in using a smartphone app is noteworthy, as it already suggests that they may be willing to engage with this method. Lieffers, Vance and Hanning (2015) also noted that whilst the dietitians were enthusiastic about the potential of using smartphone apps, they also noted challenges with their use. Particular challenges mentioned included; content quality, accessibility, and cost. The authors concluded from their data that smartphone apps have ‘infiltrated’ practice, and suggests that it would be beneficial for dietitians to become involved in the development and evaluation of smartphone apps to help ensure their suitability for practice (Lieffers, Vance and Hanning, 2014)

Within a sporting context, Josep et al. (2015) surveyed nutritionists and dietitians (*n* = 180) working within sport across 5 countries; Australia, Canada, New Zealand, the UK and the USA, to assess the use of smartphones for dietary assessment. There results shown that just under a third (32%) of these practitioners were actively using smartphone applications (apps) as part of their practise when assessing and tracking the nutritional habits of the athletes they worked with (Jospe *et al.*, 2015). The most popular app was MyFitness Pal, which is a commercially available food log app, and this was used by 56% of the respondents who reported using apps within their practice. Furthermore, of the 32% who actively use smartphones apps 47% consider apps superior and 41% consider apps equivalent to the more traditional dietary assessment methods, such as food diaries and 24-hr recalls (Josep *et al.*, 2015). Josep and colleagues (2015) conclude by recommending the validation of commercially apps so dietitians and nutritionists can be confident in using them to track and monitor dietary intake of their athletes.

In addition to specialised food log apps, the overwhelming majority of smartphones have a built-in camera and some recent applied soccer based studies (Anderson, Naughton, *et al.*, 2017; Anderson, Orme, *et al.*, 2017) have used this camera within the RFPM. The RFPM requires the participant to capture bird’s eye images of their food choice and any plate waste, ideally using a point of reference (e.g. credit card). The RFPM was developed to record the energy and nutrient intake of participants living in free-living conditions, it’s simple to use therefore placing low burden on the participant, and cost-effective as the participant can use their own smartphone device. The data can then be analysed by the researcher or qualified practitioner (Martin *et al.*, 2012). As previously highlight this method has been used within recent applied soccer-based studies, such as those by Anderson and colleagues (2017) to help quantify the data collected through food diaries and for the subsequent analysis. The ease of this method within an athletic population may engage the athlete to engage with the process over a more burdensome method, such as the food diary.

Whilst there is no current published evidence available of the use of new technology in assessing dietary intake within elite British adolescent soccer players, there is a within the sport of rugby league (Costello *et al.*, 2017). A recent study in elite British youth (16-18 years old) rugby league players (*n* = 12) looked to assess the validity of a photography-based smartphone app named 'snap-and-send'. The 'snap-and-send' protocol required participants to take two photos of every food consumable, one prior to eating and one post, as to classify any left overs. Participants were additionally provided with an A3 1 x 1cm grid placemat and measurement shaker to help standardise the food consumable portion sizes (Costello *et al.*, 2017). Participants then were required to send the pictures to the researcher using the smartphone messaging app 'Whatsapp', and provided further details (brand labels, cooking methods, and food description) were provided by text or voice recording, also via 'Whatsapp' (Costello *et al.,* 2017). The study consisted of participants recording their dietary intake over two 4-day periods in a crossover design. For both trials the first 3-days were conducted in free-living conditions, in which participants were provided with pre-weighed consumables for *ad libitum* consumption. All left overs and packaging were re-collected and weighed by the research team. On the fourth day in both conditions, participants directly observed dietary intake over a 10-hr period within a laboratory setting where breakfast, lunch, dinner and snack were available for *ad libitum* consumption. The difference between the two conditions were that in one condition participants reported their nutritional intake via a food diary, and in the other using the novel ‘snap-and-send’. Additionally, this study also included a comprehensive behaviour change framework to help optimise the compliance to the dietary assessment methods.

The researchers reported that the ‘snap-and-send’ methodology is a valid and reliable stand-alone method to collect dietary intake data within ecologically and internally valid environments (Costello *et al.,* 2017). Conversely, they reported that the estimated food diary was not a valid or reliable assessment of dietary intake, whether used in isolation or in combination with the 24-hr recall. The researchers concluded that the use of a comprehensive behavioural change approach together with a new innovative technology helped to improve adherence to recording their dietary intake and thus providing more valid data for assessment (Costello *et al.,* 2017). A limitation of this study is that whilst thorough in its methodology, the sample size was relatively small (n = 12), it is unknown whether the same results would be seen within larger squad sizes or across multiple squads. Currently there is no data within a soccer population, be it adult or adolescent on the potential use of this innovative smartphone based methodology.

2.7 The Use of Qualitative Research Methods to Assess Nutritional Intake

Qualitative research methodological approaches are commonly used within the studies assessing human behaviour and factors shaping behavioural processes (Harper and McCunn, 2017). These methods include one-on-one interviews and focus groups and present the researcher with opportunity to gain in-depth insight into a particular issue. Within sports science, qualitative methodologies are mainly used within psychology disciplines but are not as well utilised in other areas of sports science such as nutrition. A soccer-specific model of conducting applied research from Drust and Green (2013) recommends that researchers should initially conduct qualitative research to provide an insight to the theoretical cause of a particular problem. It is proposed that by carrying out this initial phase that the researchers can gain a useful awareness of potential barriers and issues which may arise during the research, and therefore help to sufficiently develop the research question within the applied environment (Drust and Green, 2013).

To the author's knowledge, there is only one study which analysed nutritional experience/perceptions/thought processes within adult professional soccer players, using qualitative methods (in this case one-one-one interviews) alongside quantitative data collection (Ono et al., 2012). In addition to quantifying nutritional intake through the use of a 4-day food diary, Ono et al. (2012) explored the perceptions and thoughts that perhaps influence nutritional habits through one-on-one interviews. At the time of original recruitment all players were participating within the professional English soccer leagues, with a mixture of British (n = 13) and migrant (n = 17) players taking part. Ono et al., (2012) summarised their findings by stating that a player's personal eating habits are derived from their social-economic status and national habitus which influenced their food choice during their upbringing. This however often conflicted with dietary approaches promoted within the professional clubs. The clash in player nutritional habitus with professional guidelines, could result in players struggling to adhere to their recommendation nutritional intake. No data is currently available in academy level soccer.

Chapter 3

METHODOLOGY

The aim of this chapter is to provide the details of the shared methodologies of the studies described in Chapter 4.

3.1 Participants and recruitment

Elite youth male soccer players were recruited from a local EPL club's academy. Researchers provided a presentation and participant information sheets to players and their parents, from the U13 – U18s to invite them to participate in the study. Ninety-one players were initially recruited, however due to incomplete diary entry 32 were withdrawn, leaving a sample size of *n* = 59. Incomplete diary entry was classified as having more than 1-days intake missing or not having at least three main meals (breakfast, lunch and dinner) reported on a minimum of 6-days. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All participants gave written informed consent, for those participants under 18 years of age their parents gave written informed consent on their behalf. Ethical permission was obtained from the Liverpool John Moores University Ethics Committee, REC number 14/EHC/003.

Participants were categorised into the following squads; U18s (*n* = 13), U15/16 (*n* = 25) and U13/14 (*n* = 21). The mean (± SD) body mass (determined by scale mass – Seca, Hamburg, Germany) and height (determined by stadiometry) were verified to the nearest 0.1 kg and cm respectively for all three squads and are displayed in Table 2.1 along with field and off field training frequency. Data collection occurred during the pre-season period of the 2014 – 15 season.

Table 3.1. A comparison of age, body mass, height, BMI, soccer and non-soccer training between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads. Weekly training data adapted from Brownlee *et al.* (2018).

Squad	**Age** (years)	**Body Mass** (kg)	**Height** (cm)	**BMI** (kg/m^2)	**Soccer Training** ($mins \cdot week^{-1}$)	**Non-Soccer Training** ($mins \cdot week^{-1}$)
U13/14s	12.7 ± 0.6	44.7 ± 7.2	157.8 ± 11.0	17.9 ± 1.3	436 ± 29	33 ± 28
U15/16s	14.4 ± 0.5	60.4 ± 8.1	173.1 ± 7.8	20.1 ± 1.5	212 ± 57	81 ± 39
U18s	16.4 ± 0.5	70.6 ± 7.6	180.1 ± 7.3	21.7 ± 0.9	224 ± 38	89 ± 21

Values are mean ± SD.

3.2 Recording of Dietary Intake

Participants were asked to record everything they consumed in a food diary for 7-consecutive days. This time frame was justified by previous research suggesting that 7-days provides a more accurate estimation of habitual nutritional intake than a single- or 4-day recording (Magkos and Yannakoulia, 2003). Additionally, unpublished pilot research on the current study's population displayed a high completion rate (75%) over the 7-days, in previous food diary collection by the club in question. Upon giving consent, players attended a presentation that gave detailed instructions on how to fill out the dietary diary. Parents and guardians of the U13/14s also attended, as it was evidenced from pilot research that they were likely to be responsible for completion of the diaries at this age. Participants were asked to provide as much detail as possible, including the type of day it was with respect to their soccer activity (rest, match, or training day), the commercial brand names of the food/drink, cooking/preparation methods, and time of consumption.

Supplements were defined as foods/drinks/powders that were purposefully taken to provide an additional source of any one or combination of macronutrients (e.g. Whey Protein). Participants were asked to quantify the portion of the foods and fluids consumed by using standardised household measures or, where possible, referring to the weight/volume provided on food packages, or by providing the number of items of a predetermined size. Upon return of the food diary the primary researcher checked for any cases of missing data and asked participants for clarification. To allow for subsequent analysis of energy and macronutrient distribution in Chapter 4, time of consumption was used to distinguish between meals; breakfast (main meal consumed between 0600 – 0930 hr), lunch (main meal consumed between 1130 – 1330 hr), dinner (main meal consumed between 1700 – 2000 hr), and snacks (foods consumed between main meals). Table 3.2 displays the time and frequency of snack consumption for each team.

Table 3.2. A breakdown of frequency of snack consumption for all squads.

	Percentage of snacks consumed within Time Point (%)		
Time Point	**U13/14s**	**U15/16s**	**U18s**
Morning Snack (Between Breakfast & Lunch)	24	25	6
Afternoon Snack (Between Lunch & Dinner)	40	49	59
Late Snack (After Dinner)	36	26	35

3.3 Intra-Researcher Reliability of the Methods

To assess intra-researcher reliability, the author of this thesis randomly selected a single participant's dietary intake for one day and analysed the data on two separate occasions three days apart. Comparison of energy and macronutrient values were as follows; energy = 2173 and 2244 kcal (difference of 4.2%), CHO = 305 and 321 g (difference of difference of 5.0%), protein = 92 and 87 g (difference of 5.4%), and fat = 65 and 68 g (difference of 4.4%).

3.4 Estimating Total Energy Expenditure

To estimate total energy expenditure (TEE) the following equation was used;

$$(\text{RMR x PAL score [1.75]}) + \text{TEF}$$

Resting metabolic rate was estimated by using the Schofield-HW equation for males (Schofield, 1985), which has previously been shown to be valid within adolescents (Carlsohn et al., 2011).

$$16.25 * \text{BW [kg]} + 4.65 * \text{Height [cm]} + 515.5$$

To estimate energy requirements, the estimated RMR was multiplied by a PAL score set at 1.75, which has previously been validated in adolescent athletes (Carlsohn et al., 2011). Carlsohn et al. (2011) recommended a range of 1.75 – 2.05 when trying to estimate energy requirements in adolescent athletes. For the present thesis, the lower end of this range was selected as although participants trained daily throughout the week, for the majority of the day away from training players were sedentary (Unpublished observations). Thermic effect of food was set as 10% of the estimated energy requirements, which is then added to the estimated energy required to provide an estimated TEE value (Jeukendrup and Gleeson, 2010).

Table 3.3 – Estimated daily total energy expenditure for all squads.

Squad	TEE
U13/14s	2998 ± 228
U15/16s	3568 ± 290*
U18s	3927 ± 274*#

Values are mean ± SD. *Denotes value is significantly higher than the U13/14s ($P < 0.001$). #Denotes than value is significantly higher than the U15/16s ($P = 0.001$).

3.5 Daily players' routines

The U18 players were fulltime at the club, spending approximately 8 hours in the academy on a typical training day. Players were required by the club to eat both breakfast and lunch at the academy.

Table 3.4 – Typical daily routine for U18s on training days

Time (24-hr)	Daily routine
~0830	Breakfast in the academy canteen
~1000	Injury prevention and training preparation – Gym based
~1100	Training – Soccer based
~1300	Lunch in the academy canteen
~1430	Resistance training – Gym based (x2 day·week^{-1}) or Performance Analysis work
~1600	Depart academy

(Unpublished observations)

In contrast, the schoolboy players would spend the majority of their day at school and then arrive at the academy in the late afternoon. Some snacks, such as yoghurts and toast, would be made available to the players dependent on time of arrival and in proximity to training.

Table 3.5 – Typical daily routine for schoolboy players on training days

Time (24-hr)	**Daily routine**
~0800	Report to School
~1000	Morning Break
~1230	Lunch
~1500	Finish school and taken to academy
~1600	Time for study and performance analysis
~1700	Training
~1930	Depart academy

(Unpublished observations)

3.6 Data Analysis

Food diary data was analysed using Nutritics software (version 3.74 professional edition, Nutritics Ltd., Co. Dublin, Ireland). All analyses were carried out by a single trained researcher so that potential variation of data interpretation was minimised (Deakin, 2000). Total absolute, and relative to BM, intakes of energy (measured in kcals), CHO, protein and fats were calculated. All data were assessed for normality of distribution according to the Shapiro-Wilk's test. Reported energy intake was compared to estimated TEE values using a paired-samples t-test. Statistical comparisons between squads' estimated TEE, energy macronutrient, and micronutrient intakes were performed according to a one-way between-groups analysis of variance (ANOVA) or, for non-parametric data, the Kruskal-Wallis test. Where significant differences of the ANOVA were present, Tukey post-hoc analysis was conducted to locate specific differences. For non-normal data, post-hoc analysis was performed using multiple Mann-Whitney U tests with a Bonferroni adjustment.

For free-sugar, dietary fibre and micronutrients participants reported intake were compared to their age specific UK DRVs and UK RNIs for micronutrient intake. For micronutrient intake the RNI was chosen for comparison as it is considered that this level of intake is likely sufficient to meet the requirements of 97.5% of the population (Department of Health, 1991). The micronutrients chosen for analysis were sodium, potassium, chloride, calcium, phosphorous, magnesium, iron, zinc, and vitamins A, B1, B2, B6, B9, B12 and C. This decision was made as these key micronutrients are relevant to performance (Russell and Pennock, 2011), whereas other micronutrients, while still important, are not significantly related to sports performance. To identify if players met their DRVs one-way sample *t-tests* were used. All analyses were completed using SPSS for Windows (version 21, SPSS Inc., Chicago, IL) where $P < 0.05$ is indicative of statistical significance.

For energy and macronutrient distribution across separate meals, a two-way ANOVA was employed, if a significant interaction (time x energy/macronutrient) was observed a Tukey post-hoc test was performed. Where a significant main difference for age was reported, a one-way ANOVA or, the Kruskal-Wallis test was performed, to assess at which meal the difference occurred. All analyses were completed using SPSS for Windows (version 20, SPSS Inc., Chicago, IL) where $P < 0.05$ was indicative of statistical significance.

Data is presented as mean ± SD. In the results section, *absolute* refers to the total measured daily intake and *relative* refers to when the absolute data has been normalised to each participants' BM (i.e. $g \cdot kg^{-1}$ BM).

Chapter 4

STUDY ONE: MARCO- AND MICRONUTRIENT INTAKE OF ENGLISH PREMIER LEAGUE ACADEMY SOCCER PLAYERS OVER A 7-DAY TRAINING PERIOD

Data from this chapter has been published in the following;

Naughton, R.J., Drust, B., O'Boyle, A., Morgans, R., Abayomi, J., Davies, I.G., Morton, J.P. and Mahon, E., 2016. Daily distribution of carbohydrate, protein and fat intake in elite youth academy soccer players over a 7-day training period. International Journal of Sport Nutrition and Exercise Metabolism, 26(5), pp.473-480.

And

Naughton, R.J., Drust, B., O'Boyle, A., Abayomi, J., Mahon, E., Morton, J.P. and Davies, I.G., 2017. Free-sugar, total-sugar, fibre, and micronutrient intake within elite youth British soccer players: a nutritional transition from schoolboy to fulltime soccer player. Applied Physiology, Nutrition, and Metabolism, 42(5), pp.517-522.

4.1 Thesis Studies map

The aim of this first study was to gain descriptive data of the current energy, macronutrient and micronutrient intakes of academy level soccer players spanning across a range of age groups, U13 to U18, at a single EPL club. To date there is limited data within this population, with only two studies investigating nutritional intake within academy level British soccer players (Russell and Pennock, 2011, and Briggs *et al.*, 2016). Both of these studies investigated a single team; Russell and Pennock (2011) a U18 team, and Briggs *et al.* (2016) a U16 team, with only Russell and Pennock (2011) assessing micronutrient intake. These studies took place at different academies, perhaps highlighting the difficulty of attaining access to academy level soccer players. Due to the access the researcher had with the club, it was possible to assess the nutritional intakes across multiple ages within the one single EPL academy, making this a novel dataset. In addition to collecting the total daily energy, macronutrient and micronutrient intake, the composition of CHO intake was analysed, with sugar, free-sugar and dietary fibre analysed as all have been linked to several health-related issues. Furthermore, the distribution of energy and macronutrient intake across the different meals of the day was analysed as this had yet to be conducted within academy level soccer. Recent data has suggested that the distribution of macronutrients, namely protein, might be more important than daily total in terms of potential adaptation to training stimuli (e.g. MPS for hypertrophy) (Mamerow *et al.*, 2014). Additionally, by analysing and displaying the data in this way, it provides the reader with greater detail which can perhaps be of more use to practitioners working within this area.

4.2 Abstract

Currently there is limited data on the nutritional intake within British academy level soccer players and no data currently exists on the daily distribution of energy and macronutrient intakes. Using 7-day food diaries, total daily macro- and micronutrient nutrient intake, along with energy and macronutrient distribution in academy soccer players from the EPL in U18 (*n* = 13), U15/16 (*n* = 25) and U13/14 squads (*n* = 21) were measured. All squads reported a significantly lower actual energy intake compared to their estimated TEE ($P < 0.001$, for all). Total energy (43.1 ± 10.3, 32.6 ± 7.9, 28.1 ± 6.8 kcal·kg^{-1} BM·day^{-1}), CHO (6.0 ± 1.2, 4.7 ± 1.4, 3.2 ± 1.3 g·kg^{-1} BM·day^{-1}) and fat (1.3 ± 0.5, 0.9 ± 0.3, 0.9 ± 0.3 g·kg^{-1} BM·day^{-1}) intake exhibited hierarchical differences ($P < 0.05$) such that U13/14 > U15/16 > U18 respectively. Additionally, CHO intake in U18s was lower ($P < 0.05$) at breakfast, dinner and snacks when compared with both squads but no differences were apparent at lunch. Furthermore, free-sugar intake of the U18s was significantly lower than the U13/14s and U15/16s ($P < 0.01$). Moreover, the U15/16s reported lower relative daily protein intake than the U13/14s and U18s (1.6 ± 0.3 vs. 2.2 ± 0.5, 2.0 ± 0.3 g·kg^{-1} BM). A skewed distribution ($P < 0.05$) of daily protein intake was observed in all squads, with a hierarchical order of dinner (~ 0.6 g·kg^{-1} BM) > lunch (~ 0.5 g·kg^{-1} BM) > breakfast (~ 0.3 g·kg^{-1} BM). Mean squad micronutrient values generally met the current UK RNI recommendations. However, there was large individual variability in these results with many individual's reporting micronutrient intake below that of the RNI. These data suggest that practitioners should initially focus on ensuring their athletes have a sufficient energy intake with specific attention is given to CHO intake. For micronutrients, it is vitally important for practitioners to assess on an individual basis, as high individual variation was observed. As adolescence is a critical period for the peak bone mass, ensuring adequate calcium intake (alongside energy intake) is also recommended.

4.3 Introduction

The function of soccer academies is largely to produce players who can progress to and represent the club's senior first team, and thereby reduce the requirement for clubs to buy or sell players in an attempt to achieve financial targets (Wrigley *et al.,* 2014). To support the high training loads (Wrigley *et al.,* 2012) and developmental goals such as muscle hypertrophy (Milsom *et al.*, 2015), it is essential players consume the correct quantity and type of macronutrients. Few studies have investigated habitual energy intakes and dietary habits of elite youth soccer players (Boisseau *et al.,* 2002 & 2007; LeBlanc *et al.,* 2002; Ruiz *et al.,* 2005; Iglesias-Gutierrez *et al.,* 2005) with just two in the UK (Russell and Pennock, 2011; Briggs *et al.*, 2015). These studies have typically been limited to reports of total daily energy and macronutrient intake, often concluding that elite youth soccer players habitually do not meet their energy requirements (Boisseau *et al.* 2002; LeBlanc *et al.*, 2002; Ruiz *et al.,* 2005; Russell and Pennock, 2011; Briggs *et al.,* 2015).

In addition to the quantification of daily energy and macronutrient intake, it is important to consider timing of intake in relation to training sessions (Burke, 2010; Mori, 2014) main meals (Garaulet and Gomez-Abellan, 2014; Johnston, 2014) (Garaulet and Gómez-Abellán, 2014; Johnston, 2014) and sleep (Lane *et al.*, 2015). Whilst this is well documented for CHO intake in order to fuel training and matches (Goedecke *et al.*, 2013; Jeukendrup, 2014) and promote glycogen re-synthesis (Zehnder *et al.*, 2001; Gunnarsson *et al.*, 2013) recent data suggests that the daily distribution of protein intake is critical for optimising components of training adaptations such as MPS (Areta *et al.*, 2013; Mamerow *et al.*, 2014). Recent data has highlighted the importance of quantity and timing of protein intake in elite youth soccer players. Milsom *et al.* (2015) demonstrated that such populations typically present with approximately 6 kg less lean muscle mass than adult professional soccer players. When taken together, these data suggest that dietary surveys of elite youth soccer players should not only quantify total daily energy and macronutrient intake but should also report the timing of nutrient ingestion, thereby having important practical implications for fuelling adequately, promoting training adaptations and optimising recovery.

Nutritional guidelines for soccer players, albeit in adults, encourage a diet high in CHO (6 – 10 $g \cdot kg^{-1}$ BM) (Burke et al., 2006); due to their ergogenic effect on both physical performance (Cermak & van Loon 2013; Hawley et al. 1994; Hespel et al. 2006) and the well documented improvements on soccer specific performance (Ali & Williams, 2009; Currell et al., 2009; Ostojic & Mazic, 2002; Russell et al., 2012). To support the apparent CHO demand before, during, and after training/match sessions, sugar based sports drinks are frequently consumed and recommended to soccer players in an attempt to help improve performance and recovery (Russell et al. 2014).

It is possible that as a result of these CHO recommendations, academy soccer players may consume high amounts of free-sugar. High free-sugar intake has been linked to adverse health effects particularly when consumed in excess (>5% TEI). For example, high free-sugar intake (> 5% TEI) has been associated with increased obesity (Siervo *et al.*, 2014), hypertension (Siervo *et al.,* 2014), metabolic diseases (Stanhope, 2016) and dental caries (Freeman, 2014). Therefore, the current UK guidelines have revised their recommendations for free-sugar from 10 % to 5 % TEI (SACN, 2015). Within the general UK adolescent (11 – 18 years old) population, a free-sugar intake of 15.4 ± 6.4% of TEI (Newens and Walton, 2016) has been reported, triple that of the new dietary reference value (DRV) (SACN 2015). Whilst it is clear that CHO intake has an ergogenic benefit on soccer performance, paradoxically youth players could be putting their health at risk if they over consume free-sugar based on the guidelines currently provided by the SACN (2015) which state that they should be limiting free-sugar intake to 5% TEI. However, there is a lack of evidence to support this, with no research currently available on the effect of high sugar and free-sugar intake on health within adolescent athlete populations. Furthermore, there is no current data on the free-sugar intake of elite youth British soccer players.

Another form of CHO which may be of interest is dietary fibre due to its associated health benefits and presence in foods of high nutrient value (Lairon et al. 2005; Montonen et al. 2003; Butcher et al. 2010). Current UK guidelines recommend a daily fibre intake of 25 $g \cdot day^{-1}$ for children (< 16 years old), and 30 $g \cdot day^{-1}$ for adults (SACN 2015). However, within the general population fibre intake has been reported as much lower in both children (11 – 12 g/day) and adults (14 g/day) (SACN 2015). Only one study has assessed dietary fibre intake in British youth soccer players (Russell and Pennock, 2011), reporting an intake of 16 $g \cdot day^{-1}$ in an U18s team. Currently, there is no data available in elite British soccer players ≤ U16s. Similar to free-sugar and fibre, there is limited data concerning the micronutrient intake of youth British soccer players. Calcium and iron intakes, in particular, have been identified as important for adolescent athletes (Desbrow et al. 2014), due to their important role in skeletal development and oxygen transport. Only one previous study has assessed the micronutrient intake in British soccer players (Russell and Pennock, 2011), who reported that an U18 cohort of players met the RNIs. Yet, as with fibre, there are no data for the micronutrient intake for British soccer players ≤ U16s.

Therefore, the aims of the present study were four-fold: 1) to quantify the total daily energy and macronutrient intakes of UK academy level soccer players of different ages (U13/14, U15/16 and U18 playing squads), comparing reported energy intake to estimated TEE; 2) to quantify the daily distribution of energy and macronutrient intake; 3) to quantify the free-sugar, fibre and micronutrient intake of UK academy level soccer players of different ages (U13/14, U15/16 and U18 playing squads); and 4) to compare the free-sugar, dietary fibre, and micronutrient intake against the current UK DRVs and RNIs.

In accordance with the higher absolute body masses of the U18 squads, it was hypothesised that this squad would report higher absolute daily energy and macronutrient intakes in comparison to the U13/14s and U15/16s. Furthermore, based on the habitual eating patterns of both athletic and non-athletic populations (Mamerow *et al.*, 2014), it was hypothesised that all squads would report an uneven daily distribution of macronutrient intakes, particularly for daily protein intake. Finally, due to the expected higher CHO intakes of the U18s, it is hypothesised that the U18s will have a higher absolute intake of free-sugar and dietary fibre in comparison to the U13/14s and U15/16s.

4.4 Methods

For a full description of the methods please refer to Chapter 3.

4.4.1 General Overview of Methods

Participants

Ninety-one academy level male soccer players were initially recruited from a single EPL club, although 32 participants were withdrawn due to incomplete data, leaving a sample size of *n* = 59. Participants were categorised into the following squads; U18s (*n* = 13), U15/16 (*n* = 25) and U13/14 (*n* = 21) (Table 3.1).

Recording Dietary Intake

Participants were asked to record everything they consumed in a food diary for 7-consecutive days. Participants were asked to provide as much detail as possible, including the type of day it was with respect to their soccer activity (rest, match, or training day), the commercial brand names of the food/drink, cooking/preparation methods, and time of consumption. Participants were asked to quantify the portion of the foods and fluids consumed by using standardised household measures or, where possible, referring to the weight/volume provided on food packages, or by providing the number of items of a predetermined size. Upon return of the food diary the primary researcher checked for any cases of missing data and asked participants for clarification.

4.5 Results

4.5.1 Reported daily energy intake and estimated total energy expenditure

For estimated TEE, there was a significant difference reported between all squads (*P* < 0.01, for all). Furthermore, all squads reported significantly lower energy intakes in comparison to their estimated TEE (*P* < 0.001, for all). Estimated energy deficits were as follows: U13/14s =1094 ± 421, U15/16s = 1641 ± 484, and U18s = 1968.6 ± 486 kcals (Table 4.1).

Table 4.1 – A comparison of estimated TEE and reported energy intake between EPL academy level soccer players from the U13/14s, U15/16s and U18s squads

	U13/14s	**U15/16s**	**U18s**
Estimated TEE (kcal)	2998 ± 268[a]	3568 ± 290[b]	3927 ± 274
Absolute Energy (kcal)	1903 ± 432.4*	1926.7 ± 317.2*	1958.2 ± 389.5*

[a] Denotes significant difference from both U15/16s and U18s. [b] Denotes significant difference from U18s. Values are mean ± SD. *Denotes significant difference from age matched TEE value.

4.5.1 Daily Energy and macronutrient total and relative daily intake

No significant difference was found for absolute daily energy (*P* = 0.92), CHO (*P* = 0.70) or fat (*P* = 0.18) intake between squads. However, absolute daily intake of protein showed a significant difference (*P* < 0.01) between squads, both the U13/14s and U15/16s squads reported lower intakes than the U18 squad (*P* = 0.01). In contrast to the absolute data, significant differences were observed for all variables when expressed in relative amounts (*P* < 0.05). For relative energy, CHO, and fat intake, the U13/14s values were significantly higher compared to both the U15/16s and U18s ($P < 0.01$ for all comparisons). The U13/14 and U18 squads were both significantly higher in relative protein compared to the U15/16s ($P < 0.01$). Additionally, the U15/16s had a significantly higher relative CHO intake in comparison to the U18s ($P = 0.01$) (Table 4.2).

Table 4.2. A comparison of daily energy and macronutrient intake between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads expressed as absolute and relative.

	U13/14s	U15/16s	U18s
Absolute Energy (kcal)	1903 ± 432	1927 ± 317	1958 ± 390
Relative Energy ($kcal \cdot kg^{-1}$ BM)	43 ± 10[a]	33 ± 8	28 ± 7
Absolute CHO (g)	266.3 ± 58.4	275.1 ± 61.9	223.7 ± 79.9
Relative CHO ($g \cdot kg^{-1}$ BM)	6.0 ± 1.2[a]	4.7 ± 1.4[b]	3.2 ± 1.3
Absolute Protein (g)	97.3 ± 21.0	96.1 ± 13.7	142.6 ± 23.6[c]
Relative Protein ($g \cdot kg^{-1}$ BM)	2.2 ± 0.5	1.6 ± 0.3[d]	2.0 ± 0.3
Absolute Fat (g)	56.1 ± 17.5	55.2 ± 10.6	60.0 ± 14.7
Relative Fat ($g \cdot kg^{-1}$ BM)	1.3 ± 0.5[a]	0.9 ± 0.3	0.9 ± 0.3

[a] Denotes significant difference from both U15/16s and U18s. [b] Denotes significant difference from U18s. [c] Denotes significant difference from both U13/14s and U15/16s. [d] Denotes significant difference from both U13/14s and U18s. Values are mean ± SD.

4.5.2 Supplements.

No statistical analysis was performed for supplements as intake within the U13/14 and U15/16 (n = 3) was negligible. Within the U18s mean daily intake from supplements were: Energy 78 ± 110 kcal, CHO 2.5 ± 6.5 g, Protein 15.1 ± 17.3 g, and Fat 0.8 ± 1.1 g.

4.5.3 Sugar, dietary fibre and micronutrient differences between squads

A significant difference between squads was reported for absolute total-sugar intake (*P* = 0.01) and for percentage contribution of free-sugar intake percentage contribution of TEI (*P* < 0.01). The U18s had a significantly lower intake in comparison to the U13/14s and U15/16s for both variables (*P* < 0.01) (Table 4.3). No significant difference was reported for dietary fibre intake (*P* = 0.63). For micronutrients, only phosphorus, zinc and vitamin B12 intakes were significantly different between squads (*P* < 0.01). Post-hoc analysis revealed that for zinc and vitamin B12 intake in the U18s was significantly higher than that of the U13/14s and U15/16s squads (*P* < 0.05). For phosphorus, the U18s intake was significantly higher than that of the U15/16s (*P* < 0.01) (Table 4.4).

Table 4.3. A comparison of daily total- and free-sugar intake between each squad and current UK DRVs or RNI were applicable.

	U13/14s (DRV/RNI)	**U15/16s** (DRV/RNI)	**U18s** (DRV/RNI)
Total-Sugar (% of TEI)	20.7 ± 4.7^	20.6 ± 5.1^	13.8 ± 3.3
Total-Sugar (g)	100.0 ± 36.1^	100.5 ± 34.8^	68.2 ± 23.2
Free-Sugar (% of TEI)	10.0 ± 17.7*^ (5)	11.2 ± 30.0*^ (5)	5.1 ± 12.7 (5)
Free-Sugar (g)	47.6 ± 19.2^	54.1 ± 23.8^	25.0 ± 12.4
Fibre (g)	19.0 ± 4.7* (25)	19.6 ± 8.3* (25)	17.1 ± 4.2* (30)

Values are mean ± SD. *Denotes significant difference from DRV / RNI. ^Denotes significant difference from U18s.

Footnote – TEI = Total energy intake; DRV = Dietary reference value; RNI = Reference nutrient intake

4.5.4 Total- and free-sugar and dietary fibre intake in comparison to the DRVs

4.5.4.1 U13 & U14s

A higher percentage contribution of free-sugar TEI (10.0 ± 17.7%, $P < 0.01$) was observed in comparison to the DRVs, whilst total-sugar contribution to TEI was 21 ± 5%. Dietary fibre intake was lower than that of the DRV ($P < 0.01$) (Table 4.3). The mean daily intakes of sodium, chloride, phosphorous, iron, B1, B2, B6, B9, B12, and Vitamin C daily intakes were all higher than the current UK RNIs ($P < 0.01$). Additionally, magnesium, zinc and vitamin A intake were higher than the current RNIs ($P < 0.05$). Similarly, mean daily intakes of potassium and calcium were higher than the recommended RNIs but not statistically significant ($P > 0.05$) (Table 4.4).

4.5.4.2 U15 & U16s

A higher percentage contribution of FS TEI (11 ± 30%, $P < 0.01$) in comparison to the DRV was observed, whilst total-sugar intake contribution to TEI was 21 ± 5%. Dietary fibre intake was lower than that of the DRV ($P < 0.01$) (Table 4.3). The mean daily intakes of iron, sodium, chloride, phosphorous, B2, B6, B9, B12, and vitamin C intakes were all higher when compared to the RNIs ($P < 0.01$) as was B1 ($P = 0.01$). Although calcium and zinc intake were marginally above that of their respective RNIs, no significance was reported ($P > 0.05$). In contrast, potassium intake was lower ($P < 0.01$) than that of the RNIs. Both magnesium ($P = 0.90$) and vitamin A ($P = 0.96$) intakes were slightly below the RNI value (Table 4.4).

4.5.4.3 U18s

The percentage contribution of FS intake (5 ± 13%) was not different from the DRV, whilst total-sugar intake contribution to TEI was 14 ± 3%. Conversely, dietary fibre intake was found to be lower than that of the DRV ($P < 0.01$) (Table 4.3). The mean daily intakes of iron, sodium, chloride, phosphorus, zinc, B1, B2, B6, B9, B12, and vitamin C were all ($P < 0.01$) higher than RNIs. However, magnesium ($P = 0.28$), vitamin A ($P = 0.09$), potassium ($P = 0.64$) and calcium ($P = 0.19$) intakes were not significantly different from the RNIs (Table 4.4).

Table 4.4 Comparison of micronutrient intake for all 3 squads. RNI values are in brackets. Percentage of participants under the RNI are displayed in braces.

Micronutrient (units)	U13 - U14s (RNIs) {% under RNI}	U15s – U16s (RNIs) {% under RNI}	U18s (RNIs) {% under RNI}
Sodium (mg)	2679.7 ± 779.6* (1600) {0}	3048.2 ± 553.6* (1600) {0}	2874.3 ± 800.3* (1600) {0}
Potassium (mg)	3151.2 ± 720.3 (3100) {62}	3044.1 ± 593.0 (3500) {80}	3432.5 ± 508.7 (3500) {38}
Chloride (mg)	3907.4 ± 1150.0* (2500) {0}	4240.6 ± 794.0* (2500) {4}	4074.3 ± 1366.1* (2500) {8}
Calcium (mg)	1148.2 ± 382.1 (1000) {33}	1035.4 ± 305.7 (1000) {48}	883.1 ± 305.1 (1000) {69}
Phosphorus (mg)	1625.7 ± 496.0* (775) {0}	1485.2 ± 292.8*^ (775) {0}	1874.2 ± 338.9* (775) {0}
Magnesium (mg)	323.4 ± 73.9* (280) {24}	298.0 ± 79.2 (300) {60}	320.5 ± 64.8 (300) {54}
Iron (mg)	13.2 ± 2.5* (11.3) {14}	14.3 ± 3.9* (11.3) {12}	15.0 ± 3.4* (11.3) {8}
Zinc (mg)	10.3 ± 2.3*^ (9) {24}	10.2 ± 2.5^ (9.5) {44}	12.9 ± 2.1* (9.5) {0}
Vitamin A (μg)	735.0 ± 271.9 (600) {29}	695.6 ± 425.7 (700) {64}	912.8 ± 414.8 (700) {31}
B1 (mg)	1.8 ± 0.4* (0.9) {0}	2.3 ± 2.0* (1.1) {0}	1.9 ± 0.5* (1.1) {0}
B2 (mg)	1.2 ± 0.7* (1.2) {5}	2.1 ± 0.7* (1.3) {4}	2.1 ± 0.5* (1.3) {8}
B6 (mg)	2.6 ± 0.6* (1.2) {0}	3.0 ± 0.7* (1.5) {0}	3.1 ± 0.7* (1.5) {0}
Folate (μg)	318.7 ± 84.7* (200) {0}	343.6 ± 101.0* (200) {0}	329.4 ± 60.0* (200) {0}
B12 (μg)	5.4 ± 2.4*^ (1.2) {0}	4.5 ± 1.2*^ (1.5) {0}	7.0 ± 1.7* (1.5) {0}

Vitamin C (mg)	105.7 ± 64.4* (35) {10}	114.2 ± 56.8* (40) {8}	127.5 ± 59.1* (40) {0}

Values are mean ± SD. *Denotes significant difference from DRV / RNI. ^Denotes significant difference from U18s.

4.5.5 The distribution of energy and macronutrients across separate meals

A significant main effect for meal was reported for all variables ($P < 0.05$, for all), however a significant interaction was only reported for total and relative protein and fat intake ($P < 0.01$, for all).

Protein distribution was found to be significant between all meals ($P < 0.05$) for absolute intake, and PRO at breakfast was significantly lower compared to both lunch and dinner for relative intake ($P < 0.01$). Additionally, relative protein intake at dinner was significantly higher compared to snacks ($P < 0.01$). For fat distribution, both absolute and relative intake at dinner was significantly higher ($P < 0.01$) than both breakfast and snacks ($P < 0.01$) (Figure 3.1).

A significant difference was observed between-squads for distribution of PRO intake ($P < 0.01$). Specifically, for breakfast and lunch the U18s reported a significantly higher intake of absolute PRO intake compared with the U13/14s and U15/16s ($P < 0.01$), but when considering relative protein, the U13/14s had a significantly higher ($P < 0.05$) intake at dinner and snacks compared to their older counterparts, which was also true for relative fat intake.

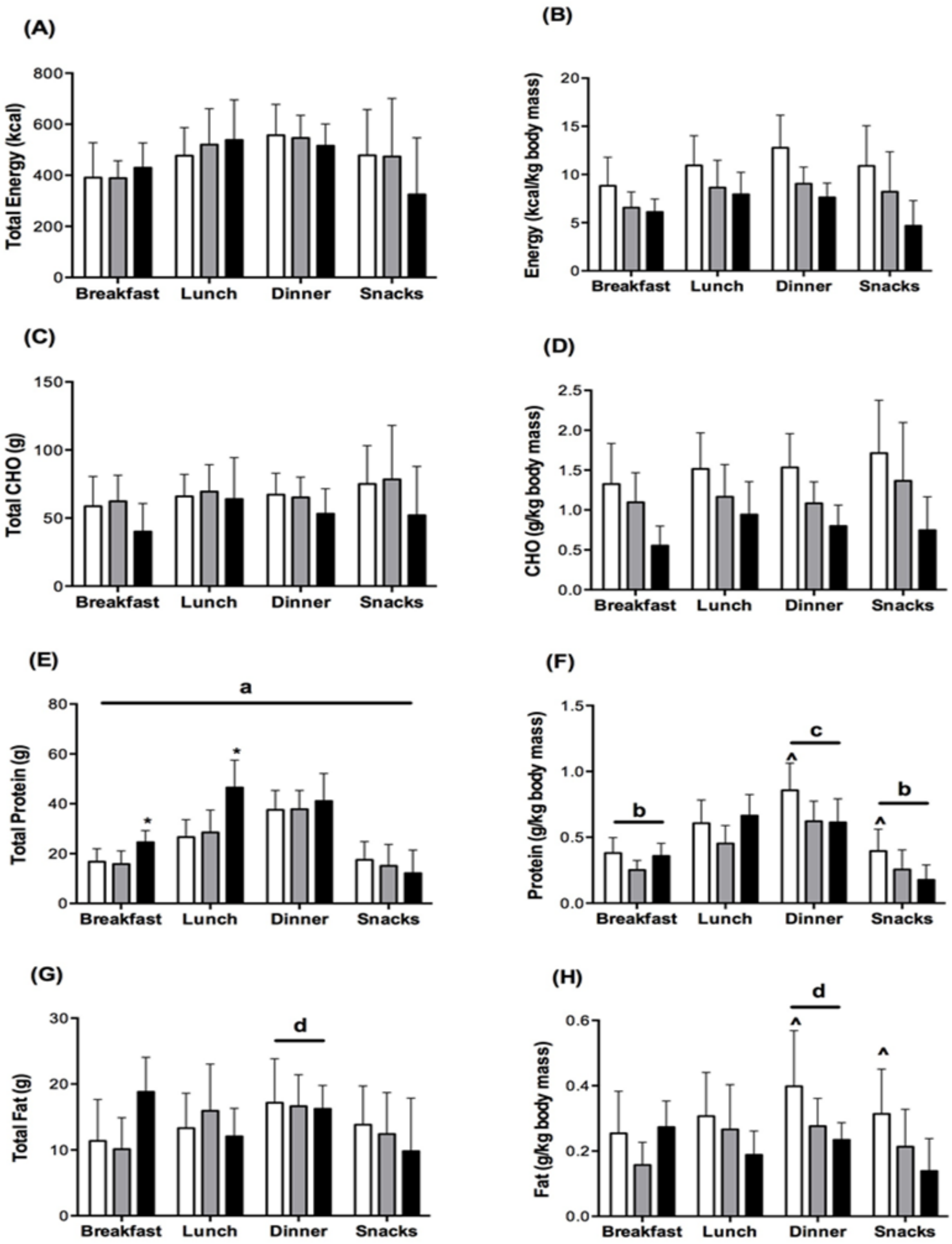

Figure 4.1. – Comparison of total and relative energy and macronutrient intake for each squad across different meals. White bars represent U13/14s, grey bars represent U15/16s and black bars represent U18s. All values are mean ± SD. [a] Denotes significant difference between all meals. [b] Denotes significant difference from both lunch and dinner. [c] Denotes significant difference from lunch. [d] Denotes that dinner is significantly different from breakfast, lunch and snacks. * Denotes significant difference from U13/14s and U15/16s. ^ Denotes significant difference from U15/16s and U18s.

4.6 Discussion

4.6.1 Aims of study and key findings

The aims of the present study were to simultaneously quantify the total daily macronutrient intake and daily distribution in academy level soccer players of differing ages. A key finding in the present study is that all squads had a significantly lower reported energy intake in comparison to their estimated TEE. In disagreement with our hypothesis, with the exception of protein, no significant difference in total absolute energy and macronutrient intake between squads were observed. However, differences in macronutrient intake were readily apparent when expressed relative to BM. We also report for the first time a skewed daily distribution of protein and fat intakes in academy level male youth soccer players (irrespective of age), an effect that was especially pertinent for protein intake.

For free-sugar and dietary fibre, the U18s have a significantly lower intake of free-sugar than the two younger age groups, and one that matches the UK DRV. However, U13/14s and U15/16s reported a significantly higher free-sugar intake in comparison to the UK DRV. Furthermore, all squads' dietary fibre intakes are significantly below that of the RNI. In regard to micronutrient intake, mean data suggests that all squads are meeting their age-specific RNIs. Yet when individual data is assessed, it appears that a large percentage of individuals across all squads are below the RNI for potassium, calcium, magnesium, iron, zinc, and vitamin A.

4.6.2 General discussion of findings

The values reported here for both total daily energy and CHO intake compare well to those previously reported for players of similar ages (Boisseau *et al.,* 2002; Ruiz *et al.,* 2007). For example, Boisseau *et al*. (2002) reported energy intakes of 38.9 ± 4.4 kcal·kg^{-1} BM·day^{-1} and Ruiz *et al.* (2007) reported CHO intakes of 5.9 ± 0.4 g·kg^{-1} BM·day^{-1}, both of which are similar to the U15/16s in the present study (Table 4.2). A consistent theme within the literature appears to be that elite youth soccer players consume, or report, lower energy intakes than daily energy requirements (Caccialanza, Cameletti and Cavallaro, 2007; Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015), thus potentially compromising performance. Firstly, the data indicates that participants should be losing body mass; secondly this may also result in reduced lean body mass; and thirdly, bone health/growth would be attenuated. The present study shows that all squads reported an energy intake which is significantly lower than their estimated TEE (Table 4.1). The estimated energy deficient for each squad was reported as U13/14s =1094 ± 421, U15/16s = 1641 ± 484, and U18s = 1968.6 ± 486 kcals. This data is concerning as having a negative energy balance, and therefore low energy availability, is a cause of attenuated bone growth (Ihle and Loucks, 2011).

Adolescence is a key time period for bone growth, with the level of bone remodelling at its greatest (MacKelvie et al., 2002) and approximately 90% of peak bone mass being achieved by the age of 20 (Misra, 2008). With such low energy intakes, in comparison to their estimated TEE, the soccer players within this study, and previous studies with similar energy intakes (Boisseau et al., 2002; Ruiz et al., 2007), may be at risk of not sufficiently developing their peak bone mass. This in turn can lead to greater risk of fracture (particularly in a contact sport) whilst young, and osteoporosis in later life (Rizzoli et al., 2010). Potential reasons for the discrepancy in estimated TEE and reported intake is the validity of the data recorded. Participants may have under reported their nutritional intake through forgetting to input the data (i.e. missing snacks), or through not reporting foods they may view as 'bad/unhealthy' (i.e. chocolate), or perhaps even through a change in eating behaviour whilst they completed the diary.

While no differences between absolute energy and CHO intake between squads were observed, large differences were apparent when expressed relative to BM. Indeed, higher CHO intakes in the U13/14 squads (6 ± 1.2 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$) compared with both the U15/16s (4.7 ± 1.4 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$) and U18s (3.2 ± 1.3 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$) were found. Carbohydrate requirements for adult athletes are an evolving topic within sports nutrition and there is debate within the literature of the optimal approach. Currently, soccer players are recommended to consume 6 - 10 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$ to support high training loads and match demands (Burke *et al.,* 2006). Conversely, recent evidence has suggested that athletes (albeit adult populations) may benefit from strategically training with lower CHO availability during carefully chosen sessions (through manipulation of CHO intake and/or timing of training) to enhance training adaptations (i.e. increased mitochondrial biogenesis) (Bartlett *et al.*, 2013; 2015).

Given the obvious developmental goals of youth soccer players and the low CHO intakes reported here and previously (Ruiz *et al.*, 2007), these data suggest that youth soccer players are likely under consuming daily CHO and do not meet current daily targets. However, given that these guidelines are for adult populations and there are currently no available CHO guidelines for elite youth athletes, further research is required. Distribution of CHO intake showed a typically lower intake at breakfast, particularly for the U18s, who would have a protein (e.g. eggs) based breakfast in comparison to the schoolboys (U13/14s and U15/U16s), who typically had cereal/toast. In the two schoolboy squads, bread and cereal were the most common CHO choices, similar to the findings of Iglesias-Gutierrez *et al.* (2012). These CHO choices were often chosen at breakfast (cereal), lunch (sandwiches) and snacks (toast). In contrast, the U18s would have cooked meals at breakfast and lunch, which they are required to attend on training days, and are therefore not relying on a school or homemade meal.

One of the novel aspects of the present study was the observation that U18 players consumed less free-sugar than their younger counterparts. Indeed, whereas the U13/14 and U15/16 squads consumed greater than the updated DRV for free-sugar, the contribution of free-sugar to TEI for the U18 players was equal to that of the RNI (i.e. 5%). Although the U18 players' choices may be reflective of adopting a more professional attitude towards dietary choices, they may also be underpinned by the fact that these players are based full-time in the soccer academy, and hence much of their daily food intake is provided by the club's catering staff. Indeed, such players receive breakfast, lunch and snacks whilst attending the academy for 5-days per week. These players are also subjected to nutritional educational material provided by the club sport science staff whilst the younger players are not yet subjected to such frequent educational exposures. It is noteworthy, however, that all squads (regardless of age) report lower free-sugar daily mean values compared to the British adolescent population (15 ± 6%) (Newens and Walton, 2016), which is an interesting finding as although the cohort within the current study are elite soccer players there are no additional social or economic factors which separate them from the general population.

However, it is unclear if the DRVs for free-sugar apply to athletic adolescents who take part in regular intense exercise. The reported health conditions that a high free-sugar intake has been associated with, obesity (Siervo et al., 2014), hypertension (Siervo et al., 2014), and metabolic diseases (Stanhope, 2016) have been observed in non-athletic populations. Carbohydrates act as an ergogenic aid for physical performance (Cermak & van Loon 2013; Hawley et al. 1994; Hespel et al. 2006), and there is strong evidence for their positive effect on soccer specific performance (Ali & Williams, 2009; Currell et al., 2009; Ostojic & Mazic, 2002; Russell et al., 2012). Data from the present study suggests all age groups are not meeting current CHO recommendations (Table 4.2), and in turn it seems that this reduced CHO intake is a main contributor to the low energy intake reported when compared to estimated TEE.

It could therefore be argued that in order to meet high CHO requirements (such as when training load is high), and subsequently help to increase energy intake, adolescent athletes should consume higher amounts of CHO and energy dense foods, which may be high in free-sugar. When energy requirements are high, products such as energy bars and drinks can provide a convenient method to consume the necessary amount of CHO (Burke et al., 2016). Although, one potential relative risk factor of a high sugar intake may be dental caries (Freeman, 2014) which has been reported in adult soccer players. More research is needed to assess if adolescent athletes should adhere to the current DRV for free-sugar as the general population, particularly when taking part in high-energy demanding sports such as soccer. However, it is not clear if the findings of Freeman (2014) were solely down to a high sugar intake or poor dental hygiene. However, the discrepancy between estimated TEE and reported energy intake with the current study suggests there has been severe under-reporting of nutritional intake. It is not clear if the encouragement of higher sugar foods is needed, or that more accurate data/methods of collection are required to give a true picture of current free-sugar intake habits within this population.

Table 4.5 – A comparison of the three most frequent sources for free-sugar and fibre intake, expressed as percentage of players, between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads.

Squad	Free-sugar (%)	Fibre (%)
U13/14s	Fruit Juices – 30 Cereals – 15 Cereal Bars – 13.3	Bread – 35 Cereals – 25 Vegetables – 21.7
U15/16s	Fruit Juice – 25.4 Cereals – 18.3 Sports Drinks – 14.1	Bread – 38 Vegetables – 26.8 Fruit – 16.9
U18s	Yoghurt Products – 20 Cereals – 15 Fruit Juice – 12.5	Vegetables – 48.7 Fruit – 17.9 Bread – 17.9

The intake of dietary fibre is also of interest, as a high intake of dietary fibre has been shown to have an inverse relationship with obesity (Lairon et al., 2005), diabetes (Montonen et al., 2003), cardiovascular disease (Butcher and Beckstrand, 2010), and bowel disease (Pituch-Zdanowska, Banaszkiewicz and Albrecht, 2015). Due to the increasing evidence of the health benefits of dietary fibre, the UK dietary guidelines have recently been raised (SACN, 2015), increasing the DRV for 11-16 year olds from 18 $g \cdot day^{-1}$ to 25 $g \cdot day^{-1}$, and for > 16 years old to 30 $g \cdot day^{-1}$ from 25 $g \cdot day^{-1}$. Within the present study, daily dietary fibre intakes were the following: U13/14s 19.0 ± 4.7 g; U15/16s 19.6 ± 8.3 g; and U18s 17.1 ± 4.2 g. These data show that all squads are consuming less than their age specific DRV (SACN, 2015) and are similar to previously reported dietary fibre intakes (16 ± 1 $g \cdot day^{-1}$) in this population (Russell and Pennock, 2011). As can be seen, dietary fibre intake across the different ages was similar (Table 4.1) and it would appear that although U18s consume less cereals and bread products, they are still consuming similar dietary fibre to the younger squads. This may be due to an increase consumption of other fibre rich foods, such as vegetables, to compensate for this loss of dietary fibre from cereal and bread products (Table 4.5). While the results suggest an increase in CHO intake (high quality CHO) would increase fibre intake, taking into consideration the discrepancy between TEE and reported energy intake this recommendation should remain in reserve until further stronger evidence on TEE and energy/food intake are available.

In relation to protein, marked differences in the total absolute daily intake were observed between squads where the U18s were higher than the U13/14s and U15/16s (142 ± 24 vs. 97 ± 21 vs. 96 ± 24 g, respectively). However, when this value was standardised for BM, the U13/14s reported higher values than the U15/16s and U18s (2.2 ± 0.4 vs. 1.6 ± 0.3 vs. 2.0 ± 0.3 $g \cdot kg^{-1}$ BM, respectively) (Table 3.1). Such absolute and relative values are comparable to previous findings in similar populations (Boisseau *et al.,* 2002; Ruiz *et al.*, 2007; Russell & Pennock, 2011; Briggs *et al.,* 2015) and are also considerably higher than current national dietary reference values of 0.8 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$ (Department of Health, 1991). The most popular source of protein for all ages was poultry, while eggs were only a main choice for the U18s. Similar to the CHO choices, this is likely a reflection of the U18s being provided with a cooked breakfast daily at the academy whereas the younger squads tended to consume cereal based breakfasts at home. To the authors' knowledge, only one research group has assessed the protein requirements of adolescent soccer players (Boisseau *et al.,* 2002 & 2007), using a nitrogen balance methodology. Results demonstrated that protein requirements of players aged 13 - 15 years range between 1.4 - 1.6 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$ (Boisseau *et al.*, 2002 & 2007), which is similar to current guidelines for adult athletes (1.3 – 1.8 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$) (Phillips and Van Loon, 2014). Therefore, in contrast to CHO, it appears that elite youth soccer players are successful in achieving daily protein requirements.

The distribution of daily protein intake may be a more important aspect of an athlete's nutritional strategy than the total daily intake. Recent data has highlighted that distorted protein intake distribution across meals (skewed to higher intake at dinner) in an adult population results in reduced MPS stimulation in comparison to a stable protein intake (~ 30 g) at each main meal (breakfast, lunch and dinner) even when total absolute intake is matched (Mamerow *et al.,* 2014). An interesting study from MacKenzie-Shalders et al. (2015) within an applied setting of young elite rugby players (~ 20 years old) analysed the potential effect of supplementing main meals (bolus condition) (i.e. breakfast, lunch and dinner) with 22 g of high biological value (HBV) protein or between main meals (frequent condition) three times a day. They reported that whilst those in the frequent condition improved their protein distribution score (which they defined as the average number of food consumptions conditioning > 20 g of protein) in comparison to the bolus condition, there was no additional benefit to lean mass gain, with both conditions gaining ~1.5 kg in lean mass (MacKenzie *et al.*, 2015). Whilst an even daily distribution of protein appears to be beneficial in improving MPS, it is not currently clear this further enhances adaptation to training stimuli.

Within the present study the distribution of protein intake at different meals was skewed for all squads in a hierarchical order of dinner > lunch > breakfast (Figure 4.1). This finding is in align with data from well-trained Dutch athletes, whom also had a protein distribution in a hierarchical order of dinner > lunch > breakfast (Gillen et al., 2017). In relation to optimal absolute protein dose, Witard *et al.* (2013) has previously reported that a single meal of ≥ 20g high quality fast-digesting protein is necessary to induce maximal rates of MPS. Therefore, it could be suggested that some players were under-consuming protein at specific meal times. For example, the U13/14s and U15/16s consumed 17 ± 5 g and 15 ± 4 g, respectively, at breakfast in comparison to the U18s who consumed 25 ± 5 g. Conversely, Murphy *et al.* (2014)

recently suggested that a protein content of 0.25 - 0.3 $g \cdot kg^{-1}$ BM per meal, that has high leucine content and is rapidly digestible, can achieve optimal MPS. Therefore, all squads would be achieving that value at each meal and consequently, the finding of < 20 g absolute doses at certain meals may be inconsequential.

Potential reasons for this difference in macronutrient intake and distribution between squads is likely related to the fact that the U18s are full-time soccer players and it is mandatory for players to consume breakfast and lunch at the academy on days they attend (5/6 $days \cdot week^{-1}$). Consequently, the club has greater control over the food and beverages the U18s can choose from. In contrast, the schoolboys will have meals provided by the school they attend or packed lunches from home, so the influence of the club is considerably reduced. When youth players are promoted to full-time U18 squad status, muscle hypertrophy is a key training goal (Milsom et al., 2015), which may result in players being encouraged to increase protein consumption to support resistance-training hypertrophy programmes (Phillips et al., 2014).

As displayed in Table 4.4, the mean values show that all squads generally met current UK RNIs for micronutrients. The exception is calcium in the U18s squad, along with potassium intakes within both the U15/16s and U18s squads. The finding that the U18s did not meet the calcium RNI is in contrast to previously reported values in an U18s soccer team population (Russell and Pennock, 2011). One potential reason for the finding that U18s did not achieve their calcium RNI, is that they have a protein based breakfast (such as eggs) as opposed to a CHO based breakfast (such as cereal and toast). Consequently, this would lead to the U18s consuming less milk which is a key source of calcium; which may explain in part the lower intake of these micronutrients in comparison to both the younger squads and the RNIs.

Although the mean data suggests all squads are generally meeting their micronutrient RNIs, if we look at the individual data a completely different picture appears (Table 4.4). Individual data shows that a large number of participants were below the RNI for potassium, calcium, magnesium, iron, zinc, and vitamin A (Table 4.4). For calcium 33% of U13/14s, 48% of U15/16s, and 69% of U18s were under the RNI, whereas mean data suggest that U13/14s and U15/16s both met the RNI, with the U18s just under. The role of calcium in the development and maintenance of bone is well established (Desbrow *et al.*, 2014). Potentially, the reported sub-optimal intake could lead to an increased risk of bone fractures and breaks as skeletal development may be compromised (Rizzoli *et al.*, 2010) therefore not allowing it to withstand the training/match load and potential impacts within training/matches. During adolescence and early adulthood, there is evidence to suggest that optimal bone mineral growth is vital to achieve a high peak bone mass to reduce the potential risk of later life osteoporosis (Rizzoli *et al.*, 2010). The mix of low energy availability and calcium intake may have detrimental consequences to the process of adolescent bone growth. The finding that the majority of U18s are not meeting their calcium RNI is of potential concern, as they are exposed to a higher training load (Wrigley *et al.*, 2012) and a more physical version of the game (Anderson *et al.*, 2016). Whilst a focus on total energy and macronutrient intake is important, it may be potentially beneficial for practitioners to educate players about the foods that provide relatively high amounts of calcium, such as milk and yoghurts, and help athletes incorporate them into their habitual diet.

Of concern in the present study is the large number of drop-outs (*n* = 32) from the original cohort as there is a potential risk of selection bias in the collected data, therefore leading to bias in the results and conclusions. Participants who returned full data sets may have done so because they have an active interest in their nutrition, whereas the opposite could be said for those participants who dropped out. This may lead to a misrepresentation of the squad data, particularly in the U18s where the largest percentage of drop outs occurred, which may therefore threaten the internal validity of the study.

4.6.3 Conclusions

In conclusion, the data from this study suggests that academy level soccer players from U13-18s do not meet their energy requirements. It appears that this predominantly down to low CHO intakes, which is especially prevalent in the U15/16s and U18s. In contrast, daily protein targets are achieved, but we report a skewed daily distribution in all ages such that dinner > lunch > breakfast. Additionally, this study reports for the first time the free-sugar and total sugar intake of academy level soccer players (U13-U18). Data shows an apparent nutritional transition from schoolboy to fulltime soccer player in that players approaching adulthood consume less free-sugar and total sugar than their younger counterparts. Furthermore, all players (regardless of age) consume less dietary fibre intake than current recommendations. For micronutrient intake, mean data suggest that RNI are generally met, but individual analysis shows large individual variation, with a high number of participants reporting potassium, calcium, magnesium, iron, zinc, and vitamin A intakes below the RNI.

When taken together, these data suggest that practitioners should initially focus on ensuring their athletes have a sufficient energy intake, with our data suggesting particular attention is paid to CHO intake. An increased CHO intake is likely to also increase the intake of dietary fibre, and may also result in a higher intake of free-sugar however it is not yet clear if this is of concern to adolescent athletes. For micronutrients, it is vitally important for practitioners to assess on an individual basis, as we report large individual variation. As adolescence is a critical period for the peak bone mass, ensuring adequate calcium intake (alongside energy intake) is also recommended. These recommendations are based on the reported food diary results; however, as TEE and energy intake were discordant then further research is needed before the recommendations are acted upon.

Chapter 5

STUDY TWO: A QUALITATIVE INSIGHT INTO THE NUTRITIONAL INTAKE OF ACADEMY LEVEL SOCCER PLAYERS AT A SINGLE ENGLISH PREMIER LEAGUE CLUB

5.1 Thesis Map

Chapter 4 provided a descriptive ‘snap shot’ of the current nutritional intake and habits during a single training week, the data collected and analysed were purely quantitative in nature. Whilst these data sets provided novel and informative data, they ultimately only provide the reader with numbers; essentially answering the ‘what’. In this Chapter, the aim was to provide the ‘why’, by using the qualitative method of one-to-one interviews with the players who took part in the study described in Chapter 4. This Chapter was a direct follow on from and designed around the findings in Chapters 4. The aim of this study was to provide a novel insight into the perceptions and thought processes behind the nutritional habits of elite youth soccer players. Furthermore, due to the large drop-out rates reported in Chapter 4, an additional aim was to investigate the perception and thoughts of the players on how diary intake data is collected.

5.2 Abstract

To the authors knowledge there is currently no published scientific literature that has investigated the nutritional habits of elite youth British soccer players using qualitative methodologies, such as semi-structured interviews. Fifteen participants aged 13-19 years old, (who had previously originally participated in the study described in Chapters 4), took part in a one-to-one semi-structured interview aimed at gaining insight into their perception and thought process around nutrition. Data collected was analysed using thematic analysis, and three general dimensions themes emerged; 1) Physical conditioning, 2) Soccer performance, and 3) Collection of dietary intake. Key findings from the present study were that U15 – U18s players consciously periodise their CHO intake throughout the week, with the U18s further stating that they do this to help with the management of body composition. Furthermore, players across all ages identified that they believe CHO intake is important to provide energy for their performance, particularly for matches. Finally, data also reported that whilst schoolboys generally had positive feelings towards completing a food diary, the fulltime players were more negative and expressed that a quicker, more-user friendly method would better suit. This study provides practitioners with valuable insight into the perception and thoughts of nutrition within elite youth soccer players, and emphasises the benefits of obtaining qualitative data through talking directly with players.

5.3 Introduction

Although there is currently little data regarding the nutritional intake of elite youth soccer players, published data with this area has been increasing over the last decade with published literature coming out of the UK (Russell & Pennock 2011; Briggs, Cockburn, et al. 2015) and other European countries (Iglesias et al., 2015; Caccialanze at al., 2007; Bettonviel et al., 2017). These studies have generally been descriptive in nature, focusing on quantifying the macronutrient and micronutrient nutritional intake and habits of elite youth soccer players using quantitative methods of assessment, such as food diaries. Whilst this research has provided welcome valuable insights into the current nutritional habits across a range of ages within British youth soccer, the thought process / rationale behind such eating habits are not as well understood. Establishing the understanding, reasoning and thought processes behind having certain eating habits and their understanding of the reasoning behind eating such foods (CHOs for example) is currently not available.

Historically, the use of qualitative research methodologies to investigate nutritional intake within sporting setting is not particularly common. In a brief recent editorial piece, Coutts (2016) presents an interesting conceptual model of the complementary relationship between practitioners and researchers within high performance sport (Figure 5.1). The model, according to the author, is based on the previous works of Kahnman (2011) who proposes that there are two systems that drive the thinking process. The first system is fast, emotional and intuitive, whilst the second is slower, logical and deliberate. Coutts has applied this to the relationship between the ‘fast’ practitioner and the ‘slow’ researcher, within the context of high performance sport. The practitioner is on the frontline working in the fast-paced applied environment with athlete and coaches, developing innovative methods in an attempt to ultimately improve performance (Coutts, 2016). As such it is the practitioners who are often early adopters of new technology, equipment and training practices which may yet to be investigated within the literature. A limitation of this innovative fast paced environment is that methods and/or data are not cross-examined in the same rigorous standard that a scientific research may apply (Coutts, 2016) which is likely in part due to time constraints and/or available research expertise. In contrast, the scientist is the slow-operating researcher who looks to validate new technology and equipment, and provide evidence for the verification of notion for new innovations and training methods (Coutts, 2016). It is this process which is typically slow paced due to the robust nature of the testing and the time consumed that such investigation requires (Coutts, 2016). Furthermore, the translation of this work from research to applied environments can often be a difficult hurdle to pass. Coutts proposes that by embedding the support of the slow-thinking scientist as an applied researcher working with a high-performance department can provide a conscious benefit to the applied practices utilised (Coutts, 2016).

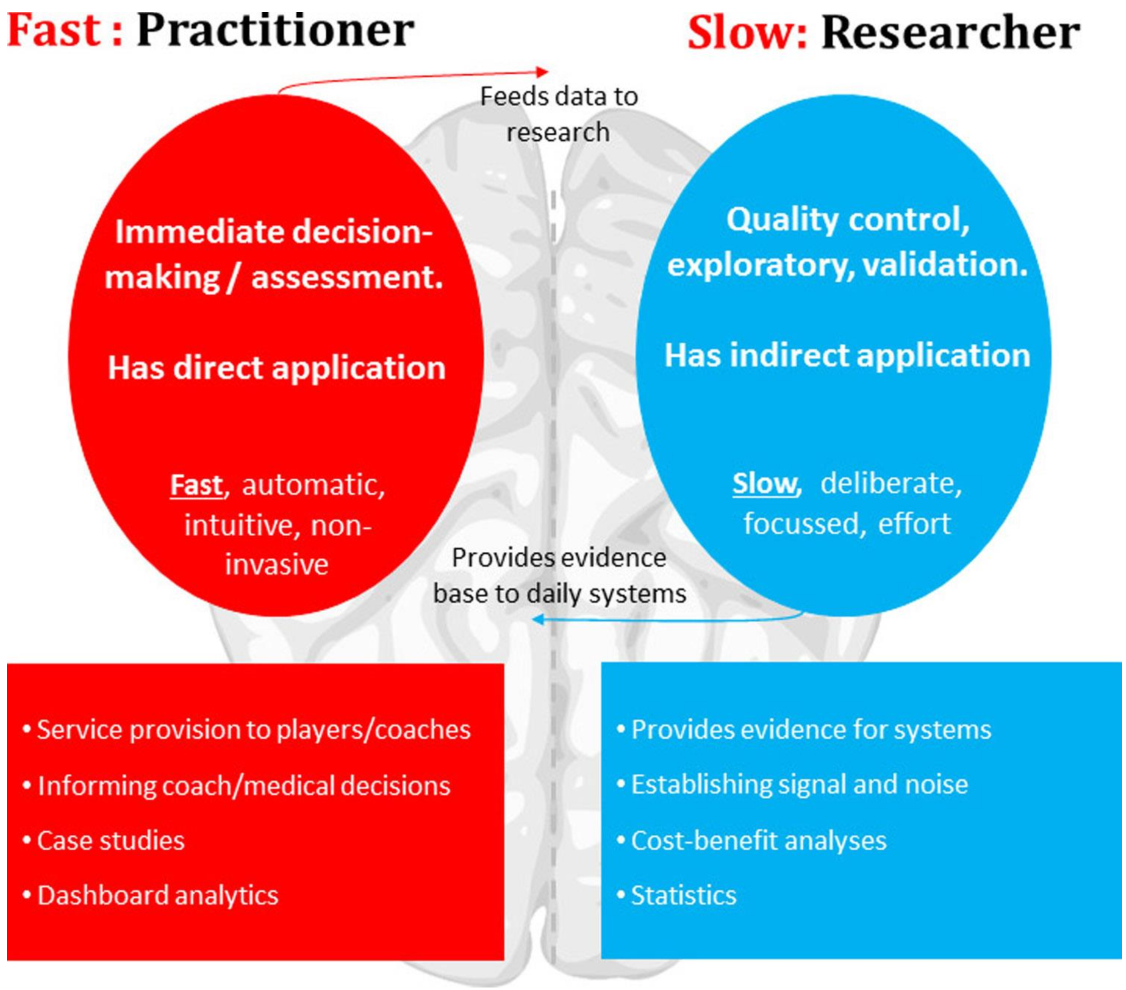

Figure 5.1 – Coutt's conceptual model for the complementary relationship between practitioners and researchers in high performance sport. Adapted from Coutts (2016).

In a follow up to the Coutts (2016) editorial, Harper and McCunn (2017) suggested that whilst the idea of having the 'fast' paced practitioner and 'slow' paced researcher working together was advantageous, it perhaps was not always practical due to logistic and economic constrictions. The authors suggest that the use of qualitative methodologies to collect data offers a valuable alternative path to combine applied practice and research within sports science (Harper and McCunn, 2017). The authors cite the 'Applied Research Model for the Sports Sciences' (Bishop, 2008) and the soccer-specific model refined by Drust and Green (2013). In Bishop's model (2008) the first stage is 'defining the problem' followed by stage two being 'descriptive research'. Harper and McCunn (2017) suggest that these two initial stages require knowledge of subject area from the researcher, and the researcher to connect with the athletes, coaches, and sports science practitioners to gather their thoughts and opinions around a particular subject area. In the soccer-specific model, Drust and Green (2013) suggest that researchers should first carry out descriptive/qualitative research to give insight to the hypothetical cause of a particular problem. This can then give valuable insight into the development of the research question by giving the researcher a more in-depth understanding of the possible barriers that will affect a particular invention and its uptake within the applied setting (Drust and Green, 2013). Harper and McCunn (2017) suggest that this approach of using qualitative methods can be a useful starting point for the development of future practically relevant research, which may include qualitative and quantitative methodologies.

Within the current sports science literature, the use of qualitative research using methods such as online questionnaires, one-on-one interviews and focus groups, has been a growing area of interest for researchers, and in some case active practitioners (Dascombe *et al.*, 2010; Walsh *et al.*, 2011; Spronk *et al.*, 2015; Trakman *et al.*, 2016; Harper and McCunn, 2017; Martin *et al.*, 2017). Previous research, in a mixture of sports, has looked to assess elite athlete perception of particular aspects of nutrition such as; general knowledge (Spronk *et al.*, 2015; Trakman *et al.*, 2016) nutritional supplements (Dascombe *et al.*, 2010) and body composition (Walsh *et al.*, 2011). However, to the authors knowledge there is no published literature that has used qualitative data, such as semi-structured interviews, to gain insight into the nutritional perceptions of elite youth British soccer players. Within a professional adult soccer player population, Ono *et al.* (2012) used a mixed method approach to assess their nutritional intake and habits. Participants were asked to complete a 4-day household measure food diary, and additionally players and staff took part in qualitative interviews to examine into the cultural factors affecting nutritional intake. From the interview outputs the authors reported that the tradition within the world of professional soccer has played an important role in the players approach to nutrition.

To the authors knowledge there is no literature regarding the perceptions and thoughts of nutrition within elite British youth soccer players using qualitative methods. The aim of the current study was two-fold; 1) to gain an insight into the perception and thought process of nutrition within elite British youth soccer players; and 2) to gain an insight into the players' perception and thoughts around nutritional habitual data collection.

5.4 Methodology

5.4.1 Participants

The current study was conducted as a follow-up to previous research study (Chapter 4). A sample size of 15 elite youth soccer players, aged 12 – 19 years were recruited, all of whom had taken part in the previous study in Chapter 4. All participants were recruited from a local EPL club's academy. All participants gave signed consent, (assent for under 18's) and parents of those participants who were U18 provided consent. Ethical permission was obtained from the Liverpool John Moores University Ethics Committee, REC number 14/EHC/003.

5.4.2 Data Collection

Semi-structured interviews were undertaken with all participants. Similar to the approach of Martin and colleagues (2017), an 'open-ended' (Gall, Gall and Borg, 2003) questioning format was implemented with all questions proposed in a conversational and informal manner (Martin *et al.*, 2017) to allow maximal voluntary contribution from the participant (Lincoln and Guba, 1985). Naturally occurring follow-up questions to gain more detailed responses were dependent on participant responses to the starting questions. The focus of the questions was based around participant's perception and knowledge of nutrition, with the topic of dietary assessment methodologies being additionally approached. Questions were developed with the results of the previous study in mind (Chapters 4).

All interviews were conducted at the academy training ground of the EPL club and recorded using a portable digital recording device (HccToo 8GB). The interviewer was familiar with the participants and soccer subculture, as they were the performance nutritionist for the previous two years at the club investigated. By being an 'insider' it is thought the researcher would draw more honest answers and reduce the ‘interaction’ effects of a researcher perceived as outside the club (Burawoy, 1998). This approach is similar to that of Martin et al. (2017).

5.4.3 Data Analysis

Upon the collection of data, a 7-stage process of thematic analysis (Clarke and Braun, 2013) was employed. This consisted of;

1. Transcription

    - Completed by a single researcher (RN)

2. Reading and familiarisation

    - Immersing in the data and taking note of items of interest through multiple readings of interview transcripts.

3. Coding

    - Initial coding taking place on individual transcripts with potential relevant content being identified

4. Searching for themes

    - The development of emergent themes from data set

5. Reviewing themes

    - Searching for possible connections across emergent themes and spawning superordinate themes, with the development of a figurative representation of analysis

6. Defining and naming themes

    - The repeat of stage 3-5 with other data sets

7. Writing the report

    - Identifying superordinate themes across dataset. Writing up to finalise analysis.

Stage two was conducted multiple times by the author of this thesis, for each manuscript at separate time points to improve the intra-observer reliability of the interpretation of the results. To check inter-observer reliability, stages two, four and five of the thematic analysis pathway were firstly conducted by the lead researcher (RN) and then replicated by a member of the supervisory team. This additionally ensures *transparency* of results, with another research acting as a ‘critical friend’ who encourages the critical analysis of data handling and interpretation (Sparkes and Smith, 2013).

5.5 Results and Discussion

Fifteen interviews were conducted, with each participant being interviewed once. The average time of each interview was approximately six minutes. Three general dimensions emerged in relation to the player's perception of nutritional intake. These themes consisted of 1) Physical conditioning, 2) Soccer performance, and 3) Collection of dietary intake. The higher order themes within these general dimensions are indicated by the use of italic text. Quotations are used to illustrate themes.

5.5.1 Physical Conditioning

This first dimension establishes that players acknowledge the effect of nutrition on their physical condition. Two higher order themes were identified; 1) *Management of body composition,* and 2) *General health and well-being.*

From the data, it seemed that the fulltime players (U18s) consistently linked the management of carbohydrate intake, and to a lesser extent protein, to improve body composition particularly body fat. When asked 'what was his biggest influence on your nutritional' intake player 8 identified protein was important and carbohydrate management:

'Think it's all about more protein, and balancing how many [carbohydrates] and when to eats carbs and obviously that will help your body fat as well – well because I have quite a high body fat at the minute, I try to eat as less [carbohydrates] as I can but I still try and eat some [carbohydrates] as obviously you need that energy but I try and eat less as possible.'

Table 5.1 - The perception and thought of the effect on nutrition on physical conditioning

Raw Data	Higher Order Theme	General Dimension
When asked if he had any particular nutritional aims at meal times *'Try and stay away from fatty foods if I can…so cheese, and chocolate and stuff like that'* P12 (U15)	Management of body composition (*n* = 9)	Effect of nutrition on physical conditioning
When asked about changes in diet since going fulltime '*During the week I don't eat much carbs… I'm trying to lose body fat – so that's why I've done it' (P3) (U18)*		
When asked if there was a particular aspect of nutrition he focused on '*I eat a lot of veg….because it helps your bones and help you recover'* P10 (U14s)	General health (*n* = 10)	
When asked do they consider nutrition important *'Yea, I think if you eat good it makes you feel good in yourself, and if you eat the right foods you get better, like energy and you're ready to train and prepare for the next day and stuff'* (P6) (U18)		

Within this higher order theme of *management of body composition*, the topic of protein intake emerged, predominantly citing their perceived requirement of protein to help build lean mass;

'[When asked if he considered anything other than CHOs important] Protein, to prepare your muscles and to develop your muscle more'

(P13 U14s)

'[When asked if he had made any changes to his diet from he became a fulltime player] Mostly protein, like chicken…I've been eating more of that and stuff. I need to eat it to gain more muscle'

(P3 U18s)

It has been previously reported by Milsom et al., (2015) that U18 soccer players present with significantly higher body fat percentage (via DXA) than first team players. It appears that this difference is not due to higher fat mass but due to significantly lower amounts of lean mass (Milsom et al., 2015). Therefore, it has been recommended that a key aim for soccer players is the development of lean tissue, which is best achieved through resistance training and protein intake (Morton, McGlory and Phillips, 2015).

For the *general health and well-being* players cited that nutrition could help them feel better from a health perspective, and after eating what they perceived as 'bad' or 'unhealthy' food they noticed it. Players often referred to feeling fit and healthy as a key determent of why they valued nutrition, with some also pointing out that by feeling good within themselves put them into a position to perform on the pitch.

'Like what you eat before training…if you eat something bad it can make you feel heavy and dead lethargic, do you know what I mean, so it makes you feel like…but you feel much better if you're eating good.'

P5 U18

'I just feel like not just fitness wise as well, but like your skin and all that…I can really tell [when I eat bad].'

P2 U18

5.5.2 Soccer Performance

This first dimension establishes that players relate their nutritional intake to soccer performance. One higher order theme was identified; 1) *Carbohydrates for performance.* Of the 15 participants, 13 players were of the opinion that CHO intake was important for their performance. Interestingly, through all ages players linked increased CHO intake to matches, but only within the fulltime players did they explicitly refer to it as 'CHO loading'. Within the younger ages they simply referred to eating more CHO based foods before and around matches (e.g. cereal, fruit, bread etc.). Within the older players the topic of CHO periodisation was frequently brought up from a performance perspective and also linking in with the higher order theme *body composition management*. Older players identified that they perceived that a lower CHO intake was preferable during the training week in comparison to a match, due to the demands of training being less than that of match.

Table 5.2 – The perception and thought of the effect on nutrition on soccer performance

Raw Data	Higher Order Theme	General Dimension
[When asked about his game preparation] 'Getting as much carbs… like say like a banana so that releases energy slow so you'll have energy for the match. [In the morning] I'd have shreddies which are wheat, a glass of milk and a bowl of fruit, and maybe sometimes an actimel yoghurt' P4 (U14)	Carbohydrates for performance (*n* = 13)	Soccer Performance
'Throughout the week I'll try and cut down on the amounts of carbs I have, but at the end of day my performance comes first so if I need to carb up…if I have 3 games in a week or the space of 10 days I'll be eating a lot of carbs so the games and training take priority of what I'm eating.' P9 (U18s)		

Carbohydrate periodisation has previously been reported in an adult EPL population (Anderson et al., 2017) through food diary analysis, but this has not been reported within an adolescent population (Briggs *et al*., 2015). Player 3 (U18) cited eating less carbohydrates during the week (see Table 4.1), but when asked what he did when approaching game day he answered;

'I'll eat more carbs for the game'

The view that carbohydrates are important for performance comes from the large body of research which shows the ergogenic effect that carbohydrate consumption has on both physical performance (Cermak & van Loon 2013; Hawley et al. 1994; Hespel et al. 2006) and on soccer specific performance (Ali & Williams, 2009; Currell et al., 2009; Ostojic & Mazic, 2002; Russell et al., 2012).

5.5.3 Collection of dietary intake data

Within this general dimension, two higher order themes were identified; 1) *The burden of the food diary*, 2) *Limited food choice affecting nutritional intake,* and 3) *Data entry.*

From the interview outputs there appears to be a difference of views between the younger players (U14s) and older players (U18s) in regard to *the burden of the food diary*. The school boy players seemed more comfortable with the idea of filling out the diary, in some instances this was likely due to parent involvement who helped the younger ages (mainly U13s and U14s) complete the data input (Unpublished observations). Furthermore, with the schoolboys still being at school it is the view of the author that the higher compliance to the data input is in part due to them potentially viewing the process as a homework task. As displayed in table 5.3, Player 13 (an U14 player) cites the learning process of completing the food diary being a factor in him engaging in the data collection.

An admission from one player (P5, U18s) was that he didn't want to report food consumed at home as he considered this 'not the best quality' (Table 5.3). This could have large ramifications for the data collected within Chapter 4. If players were being selective with their reporting of food, choosing to omit foods they deemed to be 'bad' then the reported energy intakes in Chapter 4 are likely not representative of actual nutritional intake. It is particularly interesting that this quote came from a U18 as within Chapter 4 it was this age group which had the highest energy deficit, with a difference of 1969 ± 486 kcal between their reported energy intake and estimated TEE (Table 4.1). As the fulltime players filled out the food diaries themselves, they may have chosen to exclude 'bad' foods, which are often energy dense products (i.e. a chocolate bar), in an effort to paint themselves in a better light to the researcher and coaches. Although this risk could be said of all the participants across the age groups, it is speculated to have been more prevalent within the fulltime players due to the pressures they find themselves under in trying to perform and be 'awarded' a professional contact.

Table 5.3 – The perceptions of food diaries

Raw Data	Higher Order Theme	General Dimension
'I enjoyed it, because you had to watch what you were eating and stuff, so you learn' (P13) (U14)	The burden of the food diary (n = 13)	Collection of dietary intake data
'*I would have preferred it [shorter method of data collection], I'm not the type to sit down and work and things like that…probably if it was shorter, as it was on going for a while [the 7-day food diary]'* (P5) (U18s)		
'Dinner time in schools [was a barrier], because of the choices available' (P4) (U14)	Limited food choice affecting nutritional intake (n = 8)	
'With the food diary, the food where I was [house parents] wasn't the best, so it was hard to fill it out because I didn't want to put what I had because it wasn't the best quality' (P7) (U18)		
'Meal by meal… like everything I ate I just put it in straight away' (P14) (U14s)	Data entry (n = 7)	
'I'd do it at the end of the day…just remember what I had during the day' (P3) (U18s)		

Additionally, the raw data within Table 5.3 from P13 (U14) mentions that a reason he enjoyed the food diary as he had to 'watch what you were eating'. It is unclear from this comment whether the participant was referring to the fact he felt he was forced to change his dietary habits, or that the food diary making him aware of his current nutritional practises. As he mentions that he learnt from the experience it may a case of the latter. However, a disadvantage of the food diary is that participants may alter usual behaviour, as has been reported within the U18 mentioned above. Further study in this area on this population is required.

With reference to the study discussed in Chapter 4 although there were dropouts from every age group, the largest dropout rate was from the U18s. A particular participant who dropped out of the study due to an incomplete food diary gave the following insight;

'Think it's hard for people living in digs [house parents] because sometimes you're at home [parental home], sometimes yours in digs [house parents] and you want to leave it [food diary] in a place that you're gonna be, but obviously with your timetable sometimes you're going home another day so… I think it's difficult because sometimes you forget it [food diary] and then you can't remember what you had the previous day because you have so many meals to be an athlete… so that's the only [problem with using a food diary] thing for me, why I didn't personally do it because obviously I probably left it at home one day then forgot the meals so had to make it up – and then there's no point in doing it like that.'

Player 8 (U18)

This particular player's answer perhaps offers valuable insight into the dropout rate of the fulltime players in the study discussed in Chapter 4. It seems from Player 8's insight that the sheer impracticality of having access to the food diary booklet was one potential reason for the high dropout rate within the fulltime U18s. However, this can also potentially be viewed as an excuse being offered by a player who may not prioritise nutrition and/or the monitoring of nutrition. By stating that he simply forgot the food diary due to travelling suggests that it was something that this player did not personally deem as of importance where as other players in the same situation completed it and were perhaps more engaged with the study. This points to a selection bias of the data collected in Chapter 4, in that players who valued nutrition more may have completed the food diary whereas those who didn’t, or valued it less, did not complete the food diary. The potential outcome from this is that the reported results are a misrepresentation of the nutritional values of the squad(s).

5.6 General Discussion

5.6.1 Aims of study and key findings

The aims of the current experimental chapter were twofold; 1) to gain an insight into the perception and thought process of nutrition within elite British youth soccer players; and 2) to gain an insight into the player perception and thoughts around nutritional habits data collection. Initial themes which emerged from appear to support the data reported in experimental Chapters 2 and 3 confirming CHO periodisation within the U18s and the potential reasons for the high drop-out rate recorded when using the food diaries. This study provides a unique insight into the current practices of nutritional intake of elite adolescent soccer players, and valuable information regarding the collection methodology of dietary intake.

5.6.2 General discussion of findings

Particularly within the U18s it was reported that they linked nutritional habits to their body composition, with an emphasis on the management of CHO intake (also evidenced within the soccer performance theme) and increase in protein intake to support lean mass development. From the interview data it seems that the fulltime soccer player pay particular priority at mealtime to their protein intake. Additionally, within the theme of general theme of physical conditioning, the higher order theme of the *effect on physical fitness and well-being* emerged. Players often referred to feeling fit and healthy as a key determent of why they valued nutrition, with some also pointing out that by feeling good within themselves put them into a position to perform on the pitch.

The topic of dietary collection, with particular focus on the players' view of using the 7-day food diaries used in experimental Chapters 4 provided some fascinating insights. When questioned about their thoughts on the food diary there were differences between the ages. The schoolboy players generally reacted positively often citing that it helped them think more about their nutritional habits and that they generally enjoyed the process. The fulltime players generally displayed more negative feelings towards having to complete the food diary, although they acknowledged it would likely be beneficial for them, it was the burden of time and the inconvenience of the food diary that put them off. These findings stress' the need for future research to assess the use of more time efficient and user-friendly methods within this population. The use of new technology could perhaps play a role within dietary assessment (Joseph et al., 2015; Costello et al., 2017).

Over half the players interviewed cited limited food choices as having an effect on their intake and also what they reported, with a couple of older players (n = 3) citing this as a reason for not completing the food diary. The schoolboy players reported issues with the food choices at school, citing that this negatively impacts their nutritional intake. This is a practical issue which provides clear barriers to the nutritional intake of a youth athlete. The particular club in question had a high school which it was partnered with, and the majority of the academy schoolboy players would attend this school. The partnership of elite soccer clubs with local schools is being ever more common, as it allows the club to have greater access to players for training whilst also ensuring they are provided with the appropriate education. The finding that many of the schoolboys find the food they are provided within this environment negatively affects their nutritional intake should be of concern to the clubs, particularly those with these partnerships. The findings of the present study may encourage clubs to work more closely with the schools to ensure that the appropriate nutritional provision is provided for an elite adolescent athlete or encourage parents to provide packed lunches (with advice from a qualified nutritionist/dietitian).

5.6.3 Conclusions

In summary, this study provides a novel insight into the perceptions and thoughts of nutrition within an elite youth soccer player population. The findings from this study suggests that some players mis or under-reported data that was collected within Chapter 4 which would have resulted in inaccurate data. For the first time, this study reports that elite youth soccer players from U15-U18 consciously periodise CHO intake during to training week. The data reports that U18 players periodise their CHO intake as a reflection of their training load and for the management of body fat. Furthermore, all ages believed that CHO intake is necessary to provide energy for performance especially around matches. In relation to the collection of dietary intake data, there was an apparent difference of opinion between the schoolboy and fulltime soccer players in regard to completing a food diary. The school boys generally more positive about using food diaries, whilst the fulltime players were more negative citing that they would prefer a more user-friendly method. This study provides practitioners with insightful data into the perception and thoughts of nutrition within elite youth soccer players, and highlights the benefits of obtaining qualitative data through speaking with players. A future study should aim to assess more accessible and user-friendly methods to collect dietary data within an academy soccer setting.

Chapter 6

STUDY: A Comparison of Dietary Assessment Methods within Academy Level Soccer Players: A Place for New Technology?

6.1 Thesis Map

In Chapters 4 a high attrition of 35% was reported, with the sample size dropping from $n = 91$ to $n = 59$ when using a 7-day food diary to record dietary intake. Whilst from a research perspective this may not appear be a major issue (attrition is expected within research studies) from the practitioner perspective this is of high concern as it meant for over a third of this elite cohort there was no dietary intake data. Furthermore, within the different squads the highest drop-out rate being within the U18s, who are arguable at the most important sage of their youth career in attempting to secure a professional contact and therefore require as much support as possible. In Chapter 5, qualitative interviews revealed that the many of the U18s were not fond of the use of food diaries as a method and would prefer something less burdensome and more time-efficient. Additionally, again from an applied practitioner's perspective – analysing 7-day food diaries from multiple squads is an extremely laborious and time-consuming task.

Therefore, this current chapter focuses on currently used methodologies being utilised within applied environments to analyse nutritional intake and took inspiration from the applied practitioner to design the study. The aim of the following study was to assess time-efficient and technology based user friendly methodologies, both traditional and new technology based, in collecting dietary intake data within an elite full-time soccer setting.

6.2 Abstract

Recent advances in the use of smartphone technology as a tool to record dietary data has grown in popularity; however, no research has been conducted within an academy level soccer setting to evaluate its efficacy. To investigate, players from an EPL academy (aged 18 ± 1 years; n = 22) recorded their dietary intake using a smartphone via an app, and by RFPM on a single training day. The following day participants completed a 24-hr recall. Results displayed a compliance of > 70% when reporting main meals (breakfast, lunch, & dinner) using the smartphone methods, although this dropped to 36.4% for the app, and 18.2% for RFPM for snacks. Furthermore, we found that the 24-hr recall presented with significantly higher mean total energy (2383.2 ± 598.5 vs 1638.1 ± 858.2 & 1785.2 ± 569.4 kcal), carbohydrate (257.7 ± 94.2 vs 168.1 ± 98.4 & 177.6 ± 71.2 g) and protein (169.0 ± 39.5 vs 122.3 ± 34.9 & 131.1 ± 36.9 g) intakes compared to the app and RFPM, respectively (P < 0.05). Additionally, the combination method of 24-hr recall and pictures provided no significantly different values compared to the 24-hr recall alone, although reported energy values were slightly higher. In conclusion, the use of smartphone technology may be advantageous for certain circumstances (when approximating main meal portion sizes); however, it is advisable to use a more traditional methodology, such as 24-hr recall, concomitant with any smartphone-related methods.

6.3 Introduction

The nutritional habits of English academy level soccer players has been the subject of recent investigation (Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015). The findings of such studies suggest that youth soccer players appear to meet current guidelines for daily protein intake (Phillips and Van Loon, 2011), yet often under consume CHO, thus potentially compromising training intensity and match day performance (Burke, Loucks and Broad, 2006). To collect such data, researchers have typically used variations of a 7-day food diary methodology, although these have been limited by small sample sizes (Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015) and high dropout rates (Chapter 4). Indeed, in Chapter 4, the present author observed a high participant drop-out rate, with thirty-two participants (35% of the initial sample size) being withdrawn from the study due to incomplete data entry (Chapter 4). Common issues with using food diaries include the misreporting of the amount/type of food consumed due to incorrect estimation of portion size, reticence in reporting certain foods due to a desirability perception bias, lack of knowledge of product, and memory lapse (Jospe *et al.*, 2015).

Another traditional methodology for assessing dietary intake is the 24-hr dietary recall. Key advantages of the 24-hr dietary recall method include the simplicity and speed of the protocol (e.g. low participant burden and inexpensive; Magkos & Yannakoulia 2003). In comparison to a food diary, it places a lower burden on the participant, and takes less time for the researcher/practitioner to perform the subsequent analysis. However, only analysing a single day may not be representative of usual dietary habits, it also requires a skilled interviewer to obtain accurate results whilst relying on the participant's memory (Magkos and Yannakoulia, 2003).

Within the practical setting of elite soccer, a nutritionist/dietitian is typically required to assess multiple players, potentially from multiple squads, many of whom have diverse cultural and educational backgrounds. As such, although the use of food diaries to assess dietary intake are popular for research studies, they may not be the most appropriate methodology for the applied practitioner. Therefore, a method such as the 24-hr recall may be more suitable. Due to the ease and speed at which a 24-hr recall can be performed, it is much simpler for the practitioner to analyse and provide feedback, particularly when working with numerous players.

Subsequently, sports nutritionists and dietitians working within the applied field of youth soccer often seek an alternative methodology to assess the nutritional habits of players. The use of smartphone technology is gaining increased popularity in both the research and applied setting (Jospe *et al.*, 2015). Indeed, Jospe et al. (2015) surveyed sports dieticians (n = 180) in five countries (Australia, Canada, New Zealand, the UK and the USA) and reported that 32% of sport dietitians used smartphone applications (apps) to assess and track the dietary habits and nutritional intakes of athletes. Moreover, these researchers also reported that smartphone apps were viewed positively, with 47% and 41% considering apps to be superior or equivalent to traditional dietary assessment methods, respectively. Nonetheless, smartphone apps are still not without limitations, due to both the burden of compliance and the difficulty that athletes may experience when trying to estimate portion sizes. In this regard, many athletes may prefer to simply engage with the RFPM (Martin et al. 2012) where subsequent analyses are performed by the sports dietitian.

As such, the aims of the present study were two-fold. Firstly, this study sought to assess the compliance of elite youth soccer players EPL academy when using smartphone methodologies, an app and RFPM to record dietary intake in comparison to the 24-hr recall method. Secondly, the present study aimed to compare the dietary intake and daily distribution of energy and macronutrient intake collected through the three different methods. The practical aim is to inform practising nutritionists/dietitians on the most efficient method of dietary assessment when working in the field.

6.4 Methodology

6.4.1 Participants

Elite youth soccer players (age: 17.7 ± 1.2 years; height: 180.3 ± 7.4 cm; weight: 71.5 ± 6.9 kg; sum of 7 skinfolds, 49.4 ± 11.4 mm) were recruited from a local EPL club's academy. Researchers provided a participant information sheet to invite fulltime players from the U18s and U21s to participate in the study. Twenty-two players were recruited, all participants gave informed consent and for those under 18, parental consent was obtained. Ethical permission was obtained from the Liverpool John Moores University Ethics Committee, REC number 15/EHC/085.

6.4.2 Design

Diet was assessed for each participant over 24-hr on a training day, which was held at the club's academy training ground. Participants were informed that the study was aimed at assessing energy and macronutrient intake; however, participants were not informed that their ability to use the different methods and compliance was also being analysed. The methods of assessing dietary intake were a popular commercially available self-reporting smartphone app ('*My Fitness Pal'*), RFPM (using their smartphone), and a subsequent 24-hr dietary recall. Data was collected in-season over a six-week period over the months of January and February during the 2015-2016 English football season. All participants were required to have a mobile device which had a camera and could remotely access the internet (iPhone, iPod Touch, Android, or Blackberry) to participate in the study. Time of consumption was used to distinguish between meals; breakfast (main meal consumed between 0600 – 0930 hr), lunch (main meal consumed between 1130 - 1330 hr), dinner (main meal consumed between 1700 – 2000 hr), and snacks (foods consumed between main meals). Additionally, snacks were broken down into morning snacks (consumed between breakfast & lunch), afternoon snacks (consumed between lunch and dinner), and pre-bed snacks (consumed after dinner).

6.4.3 Dietary Intake

6.4.3.1 Smartphone App

Upon agreeing to participate, participants were asked to download the free smartphone app *'My Fitness Pal'* to their smartphone, and create a profile which required a name, date of birth, and email address. The primary researcher then gave each participant an individual tutorial on how to use the app to record their dietary data. Thereafter, participants were instructed to record everything they consumed over a 24-hr period. Participants could search for the consumable via the app database by typing in a description or via scanning the products barcode (if available). It was then up to the participant's discretion which database product to select. If the product was not listed, or the participant could not find an appropriate match, the participant could submit the food details (energy and macronutrient quantities) manually. Once the consumable was selected, participants were then required to quantify the portion of the foods and fluids consumed by: using standardised household measures, referring to the weight/volume provided on food packages, or by providing the number of items of a predetermined size. If the participant could not find an appropriate match within the app's database, they could manually enter a value. Inputted data was collected from participants by having the participants 'screenshot' their inputted data from the app send to the lead author on the day following data input via text message.

6.4.3.2 Remote Mobile Photography

Upon agreeing to participate, the primary researcher then gave each participant an individual tutorial on how to correctly photograph their food / drink intake. Participants were requested to take a bird's eye view picture of their plate / bowl (if applicable) or food product, additionally if they had leftovers they were asked to take an additional photograph of this. When taking a picture of a plate / bowl participants were asked to place a piece of cutlery next to it to provide a scale. A piece of cutlery was chosen as it was believed that this was easily accessible for all participants and likely to be close to hand when consuming food products. Upon analysis the food atlas was used to aid with the interpretation of food quantities on the plate. Photographs were collected from participants by having the participants send, via text message, to the researcher on the day following data collection.

6.4.3.3 24-hr Recall

On the day following app, and RFPM data collection participants completed an individual face-to-face 24-hr recall with a single trained researcher at the academy training ground, using the two-pass method (Rumbold *et al.*, 2011) which has been used in similar populations (Briggs et al. 2015).

6.4.3.4 Combination of 24-hr recall and RFPM

Data collected from both the 24-hr recall and the RFPM where used in combination to analyse each participant's nutritional intake. This method was assessed to see if a combination of methods would provide further insight for the researcher. This method will hence forth be referred to as the 'combination' method.

6.4.4 Comparisons between methods

Within this study, the compliance levels and intakes for the 24-hr recall were established as the set standard used to compare the app and RFPM. Our data present that all (n = 22) participants reported having breakfast, lunch and dinner.

6.4.5 Data Analysis

Dietary intake data from all three methods was analysed using Nutritics software (version 3.74 professional edition, Nutritics Ltd., Co. Dublin, Ireland). All analyses were carried out by a single trained researcher so that potential variation of data interpretation was minimised (Deakin, 2000). Total absolute, and relative to BM, intakes of energy (measured in kcals), CHO, protein and fats were calculated. All data were assessed for normality of distribution according to the Shapiro-Wilk's test. Data which was not normally distributed was log transformed, and re-assessed using the Shapiro-Wilk's test. If this subsequent data was still not normally distributed non-parametric analysis was performed. Statistical comparisons between methods for total energy and macronutrient intakes were performed according to a one-way between-groups ANOVA or, for non-parametric data, the Kruskal-Wallis test. Where significant differences of the ANOVA were present, Tukey post-hoc analysis was conducted to locate specific differences. For non-normal data, post-hoc analysis was performed using multiple Mann-Whitney U tests with a Bonferroni adjustment. For energy and macronutrient distribution across separate meals, a two-way ANOVA was employed and a Tukey post-hoc analysis was conducted where appropriate. Where a significant main difference for age was reported, a one-way ANOVA or, the Kruskal-Wallis test was performed, to assess at which meal the difference occurred. All analyses were completed using SPSS for Windows (version 20, SPSS Inc., Chicago, IL) where $P < 0.05$ was indicative of statistical significance. Data are presented as mean ± SD.

6.5 Results

6.5.1 Compliance

Compliance data is presented in Table 6.1. In comparison to the 24-hr recall, high compliance for main meals but not for recorded snacks was found for both the smartphone app and RFPM.

Table 6.1. Participant compliance to the three dietary recording methodologies. Values are expressed as a percentage relative to that of reported 24-hr recall values.

	24 hr Recall (%)	**Smartphone App** (%)	**Smartphone Pictures** (%)
Breakfast	100 (*n* = 22)	81.8 (*n* = 18)	86.4 (*n* = 19)
Lunch	100 (*n* = 22)	72.7 (*n* = 16)	81.8 (*n* = 18)
Afternoon Snacks	100 (*n* = 16)	37.5 (*n* = 6)	18.8 (*n* = 3)
Dinner	100 (*n* = 22)	68.2 (*n* = 15)	59.1 (*n* = 13)
Pre-Bed Snacks	100 (*n* = 17)	35.3 (*n* = 6)	17.6 (*n* = 3)

6.5.2 Reported total and relative daily energy and macronutrient intake difference between methodologies

There was a significant difference between dietary analysis methods for total daily absolute and relative energy, CHO, protein intake (all $P < 0.01$), but not for total daily absolute fat intake ($P < 0.05$; Table 6.2). Specifically, intakes were greater when using the 24-hr recall and combination method compared with smartphone app and the RFPM for absolute and relative energy CHO and protein (all $P < 0.05$). However, there was no difference for any of the variables when comparing the 24-hr recall and combination methodologies ($P > 0.05$). Similarly, no differences were observed when comparing all variables between the smartphone app and RFPM (P > 0.05). No significant differences were observed for total absolute and relative energy and macronutrient intakes at individual meals between methodologies (Figure 6.1).

Table 6.2 – Participant total and relative daily intake for the different dietary recording methodologies

	24 hr Recall	**Smartphone App**	**Smartphone Pictures**	**24-hr Recall & Smartphone Pictures**
Total Energy Intake (kcal)	2383 ± 599*	1638 ± 858	1785 ± 569	2460 ± 641*
Relative Energy Intake ($kcal \cdot kg \cdot BM^{-1}$)	33 ± 9*	23 ± 12	25 ± 9	34 ± 10*
Total CHO Intake (g)	257.7 ± 94.2*	168.1 ± 98.4	177.6 ± 71.2	242.0 ± 83.3*
Relative CHO Intake ($g \cdot kg \cdot BM^{-1}$)	3.6 ± 1.3*	2.3 ± 1.3	2.5 ± 1.0	3.4 ± 1.2*
Total Protein Intake (g)	169.0 ± 39.5*	122.3 ± 34.9	131.1 ± 36.9	179.9 ± 51.3*
Relative Protein Intake ($g \cdot kg \cdot BM^{-1}$)	2.3 ± 0.6*	1.7 ± 0.5	1.8 ± 0.6	2.5 ± 0.8*
Total Fat Intake (g)	80.6 ± 26.9	67.2 ± 35.8	65.7 ± 31.2	83.3 ± 30.4
Relative Fat Intake ($g \cdot kg \cdot BM^{-1}$)	1.1 ± 0.4	0.9 ± 0.5	0.9 ± 0.5	1.2 ± 0.4

*Denotes significant difference from smartphone app and pictures (P<0.05).

6.5.3 The distribution of energy and macronutrients across separate meals

A significant difference for distribution across meals was found for all variables for both absolute and relative intake (P < 0.01). Both absolute and relative energy intakes at breakfast, lunch and dinner were greater compared to afternoon and pre-bed snack (all P < 0.01). For CHO, both absolute and relative lunch intake was greater than that at breakfast, afternoon snack, and pre-bed snack (all P < 0.01), whilst breakfast and dinner were also higher than both snacks ($P < 0.01$). Absolute and relative protein intake at breakfast, lunch and dinner was significantly higher than intakes for both snacks (all $P < 0.01$). Additionally, lunch intakes were greater than breakfast and dinner ($P < 0.01$). Furthermore, absolute and relative protein intake for afternoon snack was greater compared with pre-bed snack ($P < 0.01$). For fat, both absolute and relative breakfast intake was greater compared with all other meals (all $P < 0.01$). Absolute and relative intakes at lunch and dinner were also greater compared to both snacks ($P < 0.01$, for both).

A significant difference was observed between-methods for distribution of absolute and relative energy, CHO, protein (all $P < 0.01$) and fat ($P = 0.03$, and 0.05, respectively). Specifically, for absolute and relative energy intake at lunch, afternoon snack and dinner was greater for 24-hr recall when compared to the app (all $P \leq 0.03$). Absolute and relative CHO intake was significantly higher at lunch, afternoon snack, dinner, and pre-bed snack for 24-hr recall in comparison to the app (all $P < 0.02$). For absolute and relative protein intake, greater values for 24-hr recall were reported for afternoon snack and dinner compared to the app (all $P \leq 0.01$). Additionally, absolute ($P = 0.04$) and relative ($P = 0.05$) fat intake at dinner was higher for 24-hr recall compared to the app. Furthermore, absolute and relative energy, CHO and protein intake at dinner, and at both snack-times were greater for 24-hr recall compared to RFPM (all $P < 0.05$,). Absolute fat intake was significantly greater for dinner ($P = 0.04$), while both absolute and relative pre-bed snack (both $P < 0.01$) were greater for 24-hr recall compared to RFPM.

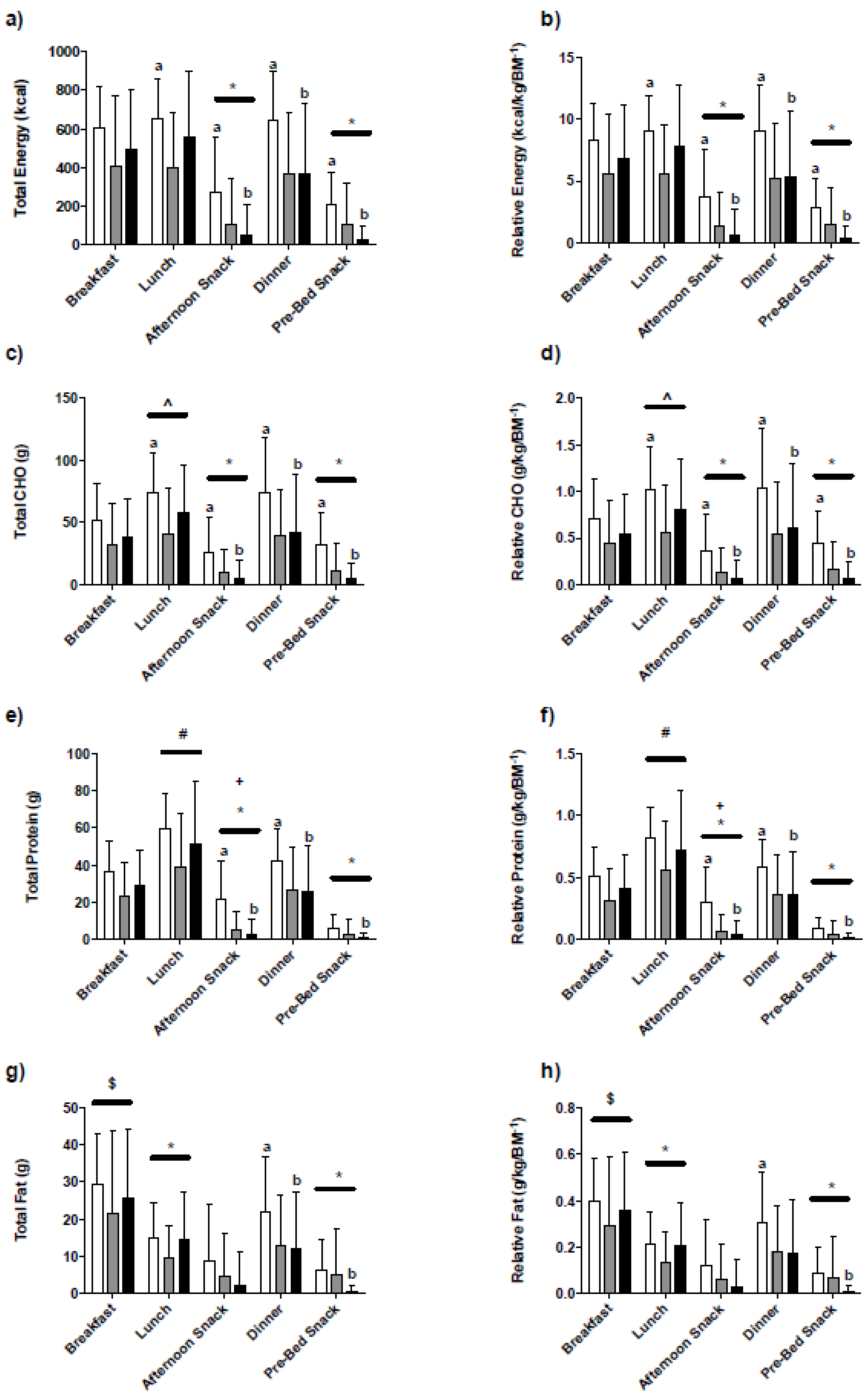
a)
Total Energy (kcal)
0
200
400
600
800
1000
b)
Relative Energy (kcal/kg/BM-1)
0
5
10
15
c)
Total CHO (g)
0
50
100
150
d)
Relative CHO (g/kg/BM-1)
0.0
0.5
1.0
1.5
2.0
e)
Total Protein (g)
0
20
40
60
80
100
f)
Relative Protein (g/kg/BM-1)
0.0
0.5
1.0
1.5
g)
Total Fat (g)
0
10
20
30
40
50
h)
Relative Fat (g/kg/BM-1)
0.0
0.2
0.4
0.6
0.8
Breakfast
Lunch
Afternoon Snack
Dinner
Pre-Bed Snack
a
b
*
^
#
+
$

Figure 6.1 – Comparison of total and relative energy, CHO, protein and fat intake across the three different methods. White bars represent 24-hr recall data, grey bars represent SP app data and black bars represent RPM data. All value are mean ± *SD.* [a] Denotes significant difference from app. [b] Denotes significant difference from 24-hr recall. * Denotes significant difference from breakfast, lunch and dinner. ^ Denotes significant difference from breakfast, afternoon snack and pre-bed snack. [#] Denotes significant difference from breakfast and dinner. [+] Denotes significant difference from pre-bed snack. [$] Denotes significant difference from lunch, dinner, afternoon snack and pre-bed snack.

6.6 Discussion

6.6.1 Aims of study and key findings

The aims of the present study were to simultaneously quantify the compliance of academy level British youth soccer players to using smartphone-derived methods to record dietary intake, and to compare the total and relative daily intake of energy and macronutrient and its distribution across different meals. The present study provides novel data on the use of smartphone technology to assess dietary intake in academy level British youth soccer players. This data reports that players display a high compliance when using the smartphones methodologies for main meals (breakfast, lunch and dinner) but not for snacks (afternoon and pre-bed snacks). Furthermore, we report that upon analysis, the smartphone methods significantly underestimate total daily energy and macronutrient intake in comparison to a 24-hr dietary recall, which appears to be mainly a result of the low compliance to reporting snacks. Additionally, no difference was found between 24-hr recall and combination methods for any variables. When looking at the absolute and relative distribution of energy and macronutrients across different meals, 24-hr recall repeatedly reported significantly greater values in comparison to the app and RPFM for the variables tested. Our findings suggest that assessing dietary habits using smartphone technology within youth soccer has potential. It is perhaps of best use to practitioners when completed in tandem with a more traditional dietary assessment method such as the 24-hr recall.

6.6.2 General discussion of findings

The primary goal of any dietary assessment is to achieve accurate information of the nutritional intake of the participant and to achieve this, the compliance of the participant is key. In this regard, it was observed that players complied relatively well (> 70%) when reporting main meals using the app and RPFM compared with the 24-hr recall (Table 6.1). However, we observed a substantial decrease in the reporting of snacks using the app and RPFM compared to the 24-hr recall (Table 6.1). Having established athlete compliance, further analysis assessed the reported total energy and macronutrient intake from each method. We observed that 24-hr recall presented significantly higher total and relative energy, protein and CHO intakes than the app and RPFM methods, but not for fat intake (Table 6.2). This data is unsurprising given the low levels of compliance when using the smartphone methodologies for the reporting of snacks (Table 6.1). Additionally, the combination method (24-hr recall and pictures) provided a slightly higher energy intake (~80 kcal) than the 24-hr recall, though no significant difference was reported between any of the variables analysed. It is noteworthy that our 24-hr recall and combination approach disagrees with the previous findings of daily energy and macronutrient intakes using a 7-day food diary methodology in a similar cohort which is summarised in Chapter 4. We previously reported daily energy and macronutrient intakes of: energy - 1958 ± 390 kcal, CHO - 223.7 ± 79.9 g, protein - 142.6 ± 23.6 g, and fat - 60.0 ± 14.7 g (Chapter 4). These values are lower by over 400 and 500 kcal respectively, for 24-hr recall alone and combination methods (Table 6.2). This may confirm the suspected issue of under-reporting in the data collected in Chapter 4. These data may suggest that performing a 24-hr recall or a combination methodology may provide a more time efficient method to collect dietary data in the field.

The finding that the 24-hr recall methodology provided superior data is potentially a result of the interview process, and that the interviewer can probe the participant on their nutritional intake (Burke, 2015). Whereas the app and picture methods require the participant to consciously and independently provide the data, and perhaps this can in part explain why there is a lack of compliance particularly for snacks when using the smartphone methods (Table 6.1). Potentially, snacks where considered as not important by participants and therefore didn't consciously report them, and only because they were asked by the researcher did they then report this intake.

In addition to assessment of total daily energy and macronutrient intake, sport nutritionists are now beginning to appreciate the role of meal and energy distribution in modulating components of training adaptation (Murphy et al. 2014; Bettonviel et al. 2016). Indeed, in Chapter 4 a skewed distribution of protein across main meals in youth soccer players (U13-U18s) with a hierarchical order of dinner > lunch > breakfast. Within the present study, lunch (58.6 g) had the highest reported protein intake across all methods, followed by dinner (41.4 g) then breakfast (33.0 g; Figure 6.1). The finding within the present study that protein intake at lunch is higher than that of dinner is likely due to the participants being provided their breakfast and lunch at the academy, and this particular club prioritises quality protein (meat, fish, dairy etc.) intake when providing meals (Unpublished Observations).

Anecdotally, participants within the present study generally favoured the 24-hr recall method due to the ease and small burden it placed on them. Which is in contrast to previous findings reporting that smartphone dietary assessments were more popular with participants compared with more traditional methods such as the 24-hr recall (Sharp and Allman-Farinelli, 2014). Within the present study, players cited the ease of the 24-hr recall and that they enjoyed talking through their habits for reasons of preference for the 24-hr recall. However, the use of a smartphone app may potentially help educate players into the energy and macronutrient content of foods along with better understanding portion sizes. A practical limitation of the 24-hr recall is that the researcher/practitioner is dependent on the memory and accuracy of the participants' portion sizes. Subsequently, by incorporating the RFPM along with the 24-hr recall a more complete picture can be created.

Collecting dietary intake data within free-living conditions is considered as one of the most problematic measurements to accurately and reliably obtain (Hackett, 2007), due to issues such as participant memory/compliance/knowledge, and variation in food products. There is no official gold standard of assessing energy intake (Hackett, 2009), although many consider the weighed food diary to be the closest method to this (Burke, 2015a). With each method, there are multiple advantages and disadvantages (see Table 2.5, Chapter 2), and consideration needs to be given when deciding the most appropriate method to use. When choosing which methodology to employ, it is important to consider the population being assessed and the practicality of implementing the chosen method. Within academy level soccer, research has typically used a self-reported food diary (Russell and Pennock, 2011; Briggs et al., 2016) although it is currently not clear which methods soccer nutrition practitioners commonly use. Practitioners are likely to have different considerations to those of researchers when reflecting which method of dietary assessment is best for them, such as time and the number of players they are working with, although the reliability and validity of method should still be a key concern.

6.6.3 Conclusions

In conclusion, the findings of the present study provide novel data on the use of smartphone technologies to collect dietary intake data within an EPL academy. The data reports that players display a high compliance when using the smartphone methodologies for main meals (breakfast, lunch and dinner) but not for snacks (afternoon and pre-bed snacks). Furthermore, it was found that smartphone methods significantly underestimate total daily energy and macronutrient intake in comparison to a 24-hr dietary recall and combination method, and lower than previously reported values in this population (Chapter 4). These findings suggest that assessing dietary habits using smartphone technology within academy level soccer has potential and it is perhaps of most use to practitioners when synchronised with a more traditional dietary assessment method such as the 24-hr recall.

Chapter 7

General Discussion

7.1 Synopsis of findings

The aim of this project was to:

1. To investigate the nutritional habits of EPL academy level soccer players

The PhD project had the following objectives:

1. Quantify the current energy, macronutrient, and micronutrient intake within EPL academy level soccer players – Chapter 4
2. Quantify the distribution of energy and macronutrient intake across the course of a day within EPL academy level soccer players – Chapter 4
3. To investigate the perceptions and thought process around nutritional intake within EPL academy level soccer players – Chapter 5
4. To assess the use of new smartphone technology in collecting dietary intake data within EPL academy level soccer players – Chapter 6

Prior to this research, limited scientific literature was available on the dietary intake and practices of academy level youth British soccer players. Furthermore, no previous study had assessed the collection of dietary information within an applied setting with this population across a range of age groups. This research was needed to provide further data to the previous studies done in similar cohorts (Russell and Pennock, 2011; Briggs et al., 2016), and to also provide new data on the nutritional intake of British academy level soccer players within teams ≤U15s for which previously there was no data. Furthermore, this thesis provides the first dataset which analysed energy and macronutrient distribution over the day, as well as the first reports of free-sugar intake within academy level soccer players. This data will provide a baseline for other researchers to compare against, whilst also potentially helping to further identify issues for which further attention and research is needed i.e. energy intake and availability. This thesis has also provided insight into the thought processes and perception around nutrition from academy-level soccer players in relation to their nutritional intake. This data may be useful for researchers aiming to study this population and help with future study design. Additionally, this data can provide practitioners with insight when working with this cohort in the field. The final study of the thesis aimed to assess the use of modern technology in collecting dietary intake data within the field. The findings indicated that new smartphone methods, when used in isolation, do not provide a valid measure of nutritional intake in comparison to 24-hr recall. Although, the combination of smartphone methods (i.e. pictures) in tandem with a traditional method, such as the 24-hr recall, may provide the researcher and/or practitioner with greater detail for subsequent analysis.

Chapter 4 focused on the energy, macronutrient (both absolute and relative to body weight), and micronutrient intake as well as the distribution of energy and macronutrients across the different meals of the day. This study provided novel data in academy level youth British soccer players aged from U13s to U18s. The results found that all squads reported a significantly lower energy intake than their estimated TEE, which each squad having large estimated energy deficits: U13/14s =1094 ± 421, U15/16s = 1641 ± 484, and U18s = 1968.6 ± 486 kcals. This would be of major concern, as sustained periods of negative energy balance/low energy availability can result in overall weight/lean mass loss, and the attenuation of peak bone mass accrual, which is critical during adolescence (Misra, 2008). Poor BMD can result in increased risk of fracture (particularly in a contact sport) whilst young, and osteoporosis in later life (Rizzoli et al., 2010). Additionally, with results showing such high energy deficits, it could also be possible that under reporting of nutritional intake was a particular issue with this data set.

For CHO, results showed that relative intake decreased as age increased (U13/14s - 6.0 ± 1.2, U15/16s - 4.7 ± 1.4, and U18s - 3.2 ± 1.3 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$), with the 15/16s displaying intakes similar to those previously reported in age matched participants (Caccialanza et al., 2007, Briggs et al., 2015). However, the intake of the U18s was considerably lower than the values of 5.9 ± 0.4 and 6.0 ± 1.5 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$ which have been previously reported in a similar aged cohort by Russell and Pennock (2011) and Bettonviel et al., (2016), respectively. Current recommendations for soccer suggest a CHO intake of 5-7 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$during moderate intensity training periods and 7-12 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$during heavy training periods (e.g. sustained intense training and/or training twice daily). The U15/16s reported values just below this, but the U18s are particularly low in comparison to either of the recommendations, and would imply that players are 'under fuelling' their performance and recovery. It appears that this low reported CHO is predominantly responsible for the low reported energy intake. Conversely, daily protein intake for all squads (U13/14s 2.2 ± 0.5, U15/16s 1.6 ± 0.3, and U18s 2.0 ± 0.3 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$) met current recommendations (Phillips and Van Loon, 2011), and similar to those previously reported from other age-matched similar studies (Table 2.2).

For micronutrients, the findings support previous literature analysing an U18 academy level British soccer team (Russell and Pennock, 2011), who also reported no significant intakes lower than the UK RNIs. However, when the individual data is analysed a different story unfolds, with a high proportion of participants reporting potassium, calcium, magnesium, iron, zinc, and vitamin A below the RNI. Of particular concern would be the percentage of participants below the RNI for calcium: U13/14s – 33%, U15/16s – 48%, and U18s – 69%. Calcium intakes below the RNI coupled with the low energy intake and availability may further the risk of attenuated bone mineralisation, resulting in poor BMD. This large individual variation perhaps stresses the point that it is important to look at individual data sets and not only the mean data.

This thesis generated the first data reporting the free-sugar intake of academy level youth soccer players, with the results showing that school boy squads (U13/14s and U15/16s) were over the current UK DRV of 5% of TEI with intakes of 10.0 ± 17.7 and 11.2 ± 30.0% of TEI reported (Table 4.3), respectively. However, the U18s meet current recommendations with a reported free-sugar intake of 5.1 ± 12.7 % of TEI. The daily intake of dietary fibre is a concern, with all squads significantly lower than that of their age-matched RNI (Table 4.3). Previous research regarding dietary fibre in this population is scant, with only Russell and Pennock (2011) publishing data from an U18s squad, finding that they also were significantly lower (16 ± 1 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$) than UK RNIs which supports the findings from the current study. However, as mentioned above there is a risk that significant underreporting occurred within this dataset, specifically for CHO intakes which would likely have a meaningful effect on the reported free-sugar and dietary fibre intakes. This data appeared to suggest a change in eating habits from the transition of schoolboy to fulltime soccer player specifically with free-sugar intake. Furthermore, this study provides novel data that academy level youth British soccer players consume less free-sugar than their general population adolescent counterparts whom report daily intakes of 15 ± 6% of TEI (Newens and Walton, 2016). Yet, the current free-sugar guidelines are not athlete specific, and it is unclear currently what guidelines should be given to adolescent athletes.

The distribution of macronutrients was skewed for all squads, but particularly noticeable for protein intake (Figure 4.1). Protein distribution across meals presented with a hierarchical order of dinner > lunch > breakfast, which has previously been observed in other athletic populations

(Gillen *et al.*, 2017), and has been reported to result in a sub-optimal stimulus of MPS in comparison to an even distribution (Mamerow *et al.*, 2014). The reported sub-optimal CHO intake (Burke, Loucks, and Broad, 2006) in the U15/16s and U18s may imply that players are 'under fuelling' their performance, although there was no data collected to assess the potential effect on performance. Furthermore, total daily protein intake was found to be in line with current, albeit adult, guidelines but a skewed distribution was reported. It would be beneficial for future research to aim to develop age-specific nutritional guidelines for soccer, along with athlete specific free-sugar guidelines (Collins *et al.*, 2017).

Following on from the descriptive data collected in Chapters 4, Chapter 5 focused on gaining a qualitative insight into the reported nutritional intake within the same population sample previously used. For this study, one-on-one interviews using an open-ended questioning format were used to gain insight into the perceptions and thoughts of nutrition from a range of ages within academy level youth soccer. This study approach provided unique data, with several common themes derived by the participants, such as: associating CHOs with fuel for performance, nutrition strategies to improve physical conditioning, and the collection of dietary intake data. The data collected in this Chapter can provide meaningful insight for practitioners working within academy level soccer, by providing player perceptions of nutrition and moreover, their perceived barriers. Potentially, this can help the practitioner to devise approaches to communicate nutritional strategies to their athletes based on the responses here. This data also highlights the benefits of conducting qualitative research within nutrition, and can thereby provide understanding around particular issues.

The study described in Chapter 6, was designed with the findings from Chapters 4 and 5 in mind. The methodological approach of using 7-day food diaries in Chapter 4 had a high dropout rate (35%) which is an important finding, particularly from a practitioner perspective. Additionally, the qualitative data collected in Chapter 5 revealed that whilst the full-time players understood the importance of collecting dietary data, they felt that the food diary was a negative burden and would prefer a simpler/quicker method to provide such data. With this in mind, the study aimed to evaluate the acute (single day) collection of dietary intake within the applied setting using a range of different methods; Smartphone app (MyFitness Pal), smartphone pictures, and a 24-hr recall. It was observed that in comparison to a 24-hr dietary recall, self-reporting through a smartphone app or using the RFPM does not provide a valid measure of dietary intake. This finding is in disagreement with the work of Costello et al. (2017), who reported that using a smartphone app to track dietary intake was valid with an academy level league youth team. The present study identified that smartphone methods result in lower reported energy and macronutrient intakes in comparison to a 24-hr dietary recall and combination method, this however appears to be heavily due to reduced participant compliance and therefore under-reporting. Consequently, the results from this study suggest that using smartphone methodologies in isolation will likely lead to an under reporting of energy and macronutrient intake. That said, if used in tandem with the 24-hr recall the app and/or RFPM may provide an extra tool for the collection of dietary intake for the practitioner.

7.2 Limitations

Firstly, all data was collected from a single EPL club academy and is therefore not representative of British academy level soccer players. Training philosophies can vary between clubs and consequently, this may impact on the nutritional intake of players based at different academies. Furthermore, for multiple reasons (i.e. financial, infrastructure etc.) the amount of nutrition support provide at academy level is likely to differ between clubs which again would impact on player nutritional intake. Another major limitation of the current thesis is that the measurement of TEE comes from an estimation equation. Whilst the equation used has been validated within male adolescent athletes (Carlsohn et al., 2011) is has not been validated in soccer specific athletes. Ideally, doubled labelled water would have been used to provide a more accurate measure of TEE, which has been implemented previously within elite adult soccer (Anderson, Orme, *et al.*, 2017). This option has not previously been used within adolescent soccer but due to economic limitations it was not feasible for this study. Likewise, the use of accelerometers (as used in Briggs, Cockburn, et al. 2015) was unavailable due to financial reasons and also at the request of the club in question, who stipulated minimal disturbance to the players involved, therefore it was decided against attempting this on a sub-sample of the participants involved.

Within Chapter 4, the food diary methodology used has limitations. Previous research has shown a potential under-reporting effect of up to 20% (Burke *et al.,* 2001), and from the data obtained within this study, it is likely that significant underreporting occurred. In comparison to estimated TEE the reported energy intake from the food diaries has an estimated under-reporting of 45% which has clear implications for the findings. Self-reported food diaries are dependent on the subjects' honesty of reporting what they have consumed and the knowledge that they have of the food eaten (i.e. cooking method). Furthermore, there is a risk that by having a participant track their dietary habits they may alter their intake to make their habits seem more favourable to the researcher, and/or to reduce the task of reporting their intake. This issue was raised within Chapter 5, with players alluding to a change in nutritional habits during data collection, and also avoiding adding foods they deemed ‘bad’, such factors would likely have led to a misrepresentation of nutritional intake within academy level soccer players. The food diary timeframe employed (7-days) places a considerable burden on the participant, which potentially results in incomplete data or participants withdrawing from the study, which was cited by players in Chapter 5. Likewise, the analysis process for the researcher can be a time-consuming and laborious task. The reporting of micronutrient intake is not necessarily indicative of micronutrient status. Ideally, alongside self-reported intake of micronutrients, blood samples would also be taken and screened to provide a more objective reflection of micronutrient status.

The large dropout rate from Chapter 4 (35%) is another limitation, as the risk of selection bias increases potentially leading to data which is non-representative of the original cohort. On reflection, it may have been wiser to focus on a specific age group at a time, therefore having a smaller number of participants to monitor while trying to ensure they use the food diary correctly. However, there were two main concerns around this approach. Firstly, training and match load can change on a weekly basis, therefore the nutritional intakes may also change which would make it impossible to compare data within squads (if the approach was to break up squads into smaller samples and repeat) and between squads. At the time, it was deemed that 7-day period where a full training week (no matches) was scheduled would provide the best opportunity to collect data from the different age groups. Secondly, from a general research and practical perspective, the soccer environment is ever changing particularly within the competitive season with training day and games often being rescheduled last minute

(Unpublished observations). This potentially could have resulted in a discontinuation of data collection, and subsequently an incomplete data set.

In Chapter 5, a major obstacle is that the sample size is relatively small (n = 15) and that the interviews themselves were quite brief (~6 minutes). These limitations were in part due to restricted access to players during the time of data collection. Larger sample sizes would allow for more viewpoints, which could potentially lead to new themes being brought up. Longer interviews with a skilled interviewer would lead to greater detail being obtained and better exploration of content with the participant. As interviews were all conducted solely with players, only one view point was analysed. Interviews with parents/guardians and academy staff might therefore also be beneficial in gaining a more holistic viewpoint. Additionally, within the one-on-one interview environment some participants appeared nervous and did not fully engage with the content and questions. The use of focus groups may have been more appropriate to try and encourage greater engagement.

In Chapter 6, a relatively small sample size was used (n = 22) again from a single EPL academy, and the dietary intake data was only collected for a single 24-hr period on a training day. Therefore, results cannot be generalised and further research is needed to assess the use of new technology to collect dietary intake data within this population. Additionally, due to the nature of the 24-hr recall, the collected data may be influenced by factors such the relationship between the participant and nutritionist/dietitian (in this case also the primary researcher), and the skill-set of the practitioner to interpret dietary intake data. Consequently, the analysis from the various methods are likely specific to the primary researcher of this study. More research is thus required on larger sample sizes, different clubs and with the involvement of different practitioners.

7.3 Practical Recommendations

The main aim of a soccer academy is to develop players to progress to first team soccer for the club in question, and therefore lessen the requirement for incoming transfers and/or sell those developed players to help meet financial targets (Wrigley et al. 2014). Whilst the development of soccer specific skills is vital, physical development also is a key factor in players making the step up to senior soccer (Milsom *et al.,* 2015). Furthermore, due to the large training loads players are exposed to (both soccer and non-specific training) it is important that players meet training demands to help with their progression (Wrigley et al., 2014). Nutrition therefore can have a major role in the progression of youth soccer players, be this through providing appropriate fuelling for physical performance (Hawley, Dennis and Noakes, 1994), aiding in muscle strength/hypertrophy (Phillips and Van Loon, 2011), or supporting immune function (Gleeson, Nieman and Pedersen, 2004).Within this thesis the nutritional habits of academy level youth soccer players across a range of ages were the focus, with specific attention on quantifying and exploring current habits, and assessing methods of collection in the field. This area was important to investigate as to date, there is limited research within this population with only the works of Russell and Pennock (2011) and Briggs et al., (2015), who quantified nutritional intake in U18 and U16 populations respectively.

The findings of this thesis may assist with the future development of soccer-specific practical guidelines, to contribute to the toolbox at the practitioners' disposal with the over-riding aim of improving player development and performance. From the findings within this thesis, the author has summarised several practical recommendations for youth soccer nutrition practitioners which is presented in Table 7.1.

Table 7.1 – Practical recommendations for youth soccer practitioners

Novel Finding	Practical Implication
1) Players across squads reported significantly lower energy intakes in comparison to estimated energy expenditure.	Practitioners should firstly aim to ensure that players are consuming enough energy. Ideally aiming for an energy availability of ~45 $kcal \cdot kg^{-1}$ $FFM \cdot day^{-1}$
2) Fulltime U18 players appear to consume low amounts of CHO, which has a negative effect on energy availability and potentially attenuate performance and recovery. In part, it seems this comes from attempting to maintain/lose body fat.	Practitioners should aim to educate players about the role of CHO intake as an energy source which has effects on performance and health. Additionally, players should be educated about strategies to maintain and/or lose body fat (if actually necessary) appropriately and safely.
3) There is a large variability in individuals' micronutrient intake, with many players not meeting RNIs although mean squad data may suggest players are meeting these targets. Of particular interest is that of calcium intake due to its role in the development of bone growth. Our data shows that approximately 50% of academy players do not meet their calcium RNI.	When providing energy and macronutrient requirements, practitioners should consider providing recommendations of food sources which also help provide micronutrient intakes, particularly those that are key during adolescences such as calcium. For example, choosing milk as a recovery drink to provide protein, carbohydrates, electrolytes and calcium.
4) The use of smartphone technology in isolation to collect dietary intake data led to a significant under-reporting of energy and macronutrient intake when compared to 24-hr recall or a combination of 24-hr recall and pictures. This was predominantly due to an apparent low compliance with the reporting of snacks between meals, although the reporting of main meals using smartphone methods also decreased as the day went on.	A combination of the 24-hr recall and smartphone pictures may be a time efficient method for a practitioner to use. The supplementary pictures can be used to help with portion sizes and perhaps identify foods which the participant may have retrospectively not reported.

7.4 Conclusions

In conclusion, the work completed in this thesis has quantified the weekly energy, macronutrient, and micronutrient intake in academy level British soccer players from aged from U13s to U18s. The distribution of energy and macronutrients was also analysed providing original data for this population. Additionally, novel qualitative data on the role of nutrition in academy level soccer has been collected providing valuable insight into the nutritional habits of this cohort. Finally, the collection of dietary data in free-living conditions using new smartphone technologies were assessed for the first time in a British academy soccer setting. These data can provide insight into current nutritional practises within academy level soccer players, whilst additionally identifying areas practitioners should monitor closely (specifically energy intake). Further research is now needed to accurately quantify the energy demands of training and match play across the different ages in academy level soccer.

7.5 Recommendations for Further Work

From the research conducted within the present thesis, through reviewing the literature, and from time spent working within the field, the researcher proposes the following directions for future investigation in the field of youth soccer nutrition. As guidelines for youth soccer as based on those from adult guidelines, research should look to assess if these guidelines are appropriate and if not, what the specific guidelines for the different academy age groups should be. To start, research should firstly aim to accurately quantify energy expenditure across a range of ages (U12-U18) within academy level soccer during an in-season training and match day week. An approach to this could be to use double labelled water in a sub-group (*n* dependent on finances) of players within each age group, whilst simultaneously quantifying internal and external training/match load. During this time self-reported food diaries, along with 24-hr recalls, would be used to gain a measure of nutritional intake and to compare against energy expenditure. In addition, player weight could be monitored at set points during the season, perhaps in line with the physical performance testing (typically four testing bouts a season) to assess physical development. If possible, RMR and body composition via DXA scan would additionally be measured to firstly provide baseline measures for this population, and secondly to assess any potential relationship between the two. Ideally this study would run across a number of academies, to get a large sample size and to be comparable against potentially differing training methodologies. With the developments of the EPPP, it could potentially be co-ordinated by the EPL and/or the FA.

Anecdotally, from the authors experience of working within the applied environment, coaches and sports scientist are taking an increased interest of maturation status to help give players an opportunity to develop. For example, players in the U14s may play in games an age either side depending on their maturation status. It would also be of interest to potentially investigate this from a ‘bio-banding’ categorisation. The use of ‘bio-banding’ within soccer is becoming increasingly more popular, with the EPL now designing tournaments around players biological age as opposed to their chronological age. Furthermore, this change has been positively received by players for their holistic development as soccer players (Cumming *et al.*, 2017). If this is to be the future of academy team organisation than it is perhaps important for nutritional researchers to investigate nutritional requirements via biological age as opposed to chronological.

The use of qualitative research within sport nutrition, specifically soccer, is sparse. Within this thesis, the use of interviews provided interesting insights and more in-depth interviews would likely provide a greater understanding of the perceptions and thought processes around nutrition in academy level soccer players. To build on the findings of Chapter 5, a study which uses focus-groups with academy level players would perhaps lead to greater interaction with the interviewer and content. A weakness of the study in Chapter 5 was that certain players, typically the younger pages (≤U15s) seemed nervous and did not fully engage with the interviewer or the questions. For this potential study, using an independent and/or an interviewer unknown to the players, as opposed to an imbedded researcher (as was the case for this thesis), would attempt to minimise any risk of influencing the participants. Furthermore, the collection of data from parents, coaches, kitchen staff, and sports scientists may also be beneficial to provide differing viewpoints.

Anecdotally, the nutrition provision within academies can hugely vary between home and away games, with the length of travel and quality of hotel likely having the most significant impact. Whether this potential change has a meaningful effect on energy and macronutrient intake is not clear, though the author would hypothesise that a detrimental effect would be observed.

Secondly, again from the authors experience from the field it would appear that the use of supplements within soccer differs from the recommendations in the literature, such as those recently published for team sports (Heaton *et al.*, 2017). The author believes it would be of interest to survey the use of different nutritional supplements that practitioners use, but also enquire about the brand, dose, and timing of supplements and how practitioners decide on these variables – from the literature, experience, or potentially a mixture of the two. It could be interesting to compare the difference between adolescents and adult, but also between countries. The author would hypothesise that the prescription of supplements would deviate away from the recommendations within the literature (Heaton *et al.*, 2017). This hypothesis is in part supported by the suggestion of Coutts (2016), in that within the applied world practitioners are often forced into developing novel approaches to improve performance, with the research catching up/investigating afterwards. To follow on from the findings of this initial study, researchers could test out supplementation protocols currently used within the field through a mixture of laboratory and, preferably, field-based studies.

Chapter 8

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8.1 References

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Chapter 9

Appendices

Appendix 1 – Parent / Guardian consent form

LIVERPOOL JOHN MOORES UNIVERSITY
PLAYER CONSENT FORM
Under 18

Investigating the nutritional intake of elite youth academy soccer players across different ages.

R. Naughton - LJMU

1. I and my son have read and understood the information provided for the above study and had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. The player understands that his participation is voluntary and that he is free to withdraw at any time, without giving a reason and that this will not affect his legal rights. ☐

3. The player understands that any personal information collected during the study will be anonymous and remain confidential. ☐

4. The player agrees to take part in the brief interview, in which he will be audio recorded anonymously, and knows that the recording will destroyed upon completion of the study. ☐

5. The player agrees to allow the researcher to access current data held by LFC ☐

Name of Participant

Name of Person giving consent (if under 18) Date Signature

Name of Researcher Date Signature

Appendix 2 – Participant information sheet

LIVERPOOL JOHN MOORES UNIVERSITY PARTICIPANT INFORMATION SHEET

Investigating the nutritional intake of elite youth academy soccer players across different ages

Robert Naughton: School of Education, Health and Community

You are being invited to take part in a research study. Before you decide it is important that you understand why the research is being done and what it involves. Please take time to read the following information. Ask us if there is anything that is not clear or if you would like more information. Please take your time to decide if you want to take part or not.

1. What is the purpose of the study?

This study has been set up to gain an understanding of your nutrition; this is really interesting as the knowledge gained can potentially help improve your performance in training and on match day. To gain this understanding we will be asking participants to take part in a brief (~3 minute) interview regarding their views on nutrition.

2. Do I have to take part?

No. It is up to you to decide whether or not to take part. If you do you will be given this information sheet and asked to sign a consent form. You are still free to withdraw at any time and without giving a reason. A decision to withdraw will not affect your rights/any future treatment/service you receive.

3. What will happen to me if I take part?

If you agree to participate you will be asked to do the following;

- *Complete a 7 day food diary*
- *Take part in a brief informal interview (~3 mins) with the club nutritionist*

4. Are there any risks / benefits involved?

If you do choose to participate you will be able to receive individual feedback on your current diary practises and help enhance the knowledge and understanding of nutrition within soccer that we currently have.

5. Will my taking part in the study be kept confidential?

Yes, your participation will be strictly confidential.

This study has received ethical approval from LJMU's Research Ethics Committee *(14/EHC/003)*

Contact Details of Researcher - Robert Naughton R.Naughton@2008.ljmu.ac.uk

Contact Details of Academic Supervisor - *Elizabeth* Mahon E.Haywood@ljmu.ac.uk

Appendix 3 – Consent form

LIVERPOOL JOHN MOORES UNIVERSITY
PLAYER CONSENT FORM

Investigating the quality of 'practical' methods to assess the nutritional intakes in elite youth soccer players
R. Naughton - LJMU

1 I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2 I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights.

3 I understand that any personal information collected during the study will be anonymous and remain confidential.

4 I agree to allow the researcher to access current data held by LFC

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Appendix 4 – Participant information sheet

LIVERPOOL JOHN MOORES UNIVERSITY
PARTICIPANT INFORMATION SHEET

Investigating the quality of 'practical' methods to assess the nutritional intakes of elite youth soccer players

Robert Naughton: School of Education, Health and Community

You are being invited to take part in a research study. Before you decide it is important that you understand why the research is being done and what it involves. Please take time to read the following information. Ask us if there is anything that is not clear or if you would like more information. Please take your time to decide if you want to take part or not.

1 What is the purpose of the study?

This study has been set up to gain an understanding of what is the most appropriate method to assess dietary intake of elite youth soccer players in a practical / real-world environment; as the knowledge gained can potentially help improve your performance in training and on match day. To gain this understanding we will be asking participants to take part in a single day dietary assessment using several methods.

2 Do I have to take part?

No. It is up to you to decide whether or not to take part. If you do you will be given this information sheet and asked to sign a consent form. You are still free to withdraw at any time and without giving a reason. A decision to withdraw will not affect your rights/any future treatment/service you receive.

3 What will happen to me if I take part?

If you agree to participate you will be asked to do the following;

- *Complete a one day food diary via a smart-phone app*
- *Take pictures of all food consumed for one day (same day as food diary)*
- *Complete a food frequency questionnaire (~10 mins)*
- *Complete a 24hr dietary recall with the primary researcher (~10 mins)*

4 Are there any risks / benefits involved?

If you do choose to participate you will be able to receive individual feedback on your current diary practises and help enhance the knowledge and understanding of nutrition within soccer that we currently have.

5 Will my taking part in the study be kept confidential?

Yes, your participation will be strictly confidential.

This study has received ethical approval from LJMU's Research Ethics Committee *(14/EHC/003)*

Contact Details of Researcher - Robert Naughton R.Naughton@2008.ljmu.ac.uk

Contact Details of Academic Supervisor - *Elizabeth* Mahon E.Haywood@ljmu.ac.uk

Appendix 5 – Chapter 3 publication

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Daily distribution of carbohydrate, protein and fat intake in elite youth academy soccer players over a 7-day training period

Robert J. Naughton[1], Barry Drust[2,3], Andy O'Boyle[3], Ryland Morgans[3], Julie Abayomi[1], Ian G. Davies[1], James P. Morton[2] and Elizabeth Mahon[1]

[1]School of Sports Studies, Leisure and Nutrition

Liverpool John Moores University

Liverpool

L17 6BD

UK

[2]Research Institute for Sport and Exercise Sciences

Liverpool John Moores University

Tom Reilly Building

Byrom St Campus

Liverpool

L3 3AF

UK

[3]Liverpool Football Club

Melwood Training Ground

Deysbrook Lane

Liverpool

L12 8SY

UK

Running head: Nutrition, youth soccer, exercise metabolism

Word Count: 3250

Address for correspondence:

Robert Naughton

[1]School of Sports Studies, Leisure and Nutrition

Liverpool John Moores University

Liverpool

L17 6BD

United Kingdom

Email: R.Naughton@2008.ljmu.ac.uk

Abstract

While traditional approaches to dietary analysis in athletes have focused on total daily energy and macronutrient intake, it is now thought that daily distribution of these parameters can also influence training adaptations. Using seven-day food diaries, we quantified the total daily macronutrient intake and distribution in elite youth soccer players from the English Premier League in U18 (*n*=13), U15/16 (*n*=25) and U13/14 squads (*n*=21). Total energy (43.1±10.3, 32.6±7.9, 28.1±6.8 $kcal \cdot kg^{-1} \cdot day^{-1}$), CHO (6±1.2, 4.7±1.4, 3.2±1.3 $g \cdot kg^{-1} \cdot day^{-1}$) and fat (1.3±0.5, 0.9±0.3, 0.9±0.3 $g \cdot kg^{-1} \cdot day^{-1}$) intake exhibited hierarchical differences ($P<0.05$) such that U13/14>U15/16>U18. Additionally, CHO intake in U18s was lower ($P<0.05$) at breakfast, dinner and snacks when compared with both squads but no differences were apparent at lunch. Furthermore, the U15/16s reported lower relative daily protein intake than the U13/14s and U18s (1.6±0.3 vs. 2.2±0.5, 2.0±0.3 $g \cdot kg^{-1}$). A skewed distribution ($P<0.05$) of daily protein intake was observed in all squads, with a hierarchical order of dinner (~0.6 $g \cdot kg^{-1}$) > lunch (~0.5 $g \cdot kg^{-1}$) > breakfast (~0.3 $g \cdot kg^{-1}$). We conclude elite youth soccer players do not meet current CHO guidelines. Although daily protein targets are achieved, we report a skewed daily distribution in all ages such that dinner>lunch>breakfast. Our data suggest that dietary advice for elite youth players should focus on both total daily macronutrient intake and optimal daily distribution patterns.

Introduction

The function of soccer academies is largely to produce players who can progress to and represent the club's senior first team, and thereby reduce the requirement for clubs to buy or sell players in an attempt to achieve financial targets (Wrigley *et al.,* 2014). To support the high training loads (Wrigley *et al.,* 2012) and developmental goals such as muscle hypertrophy (Milsom *et al.,* 2015), it is essential players consume the correct quantity and type of macronutrients. Few studies have investigated habitual energy intakes and dietary habits of elite youth soccer players (Boisseau *et al.,* 2002 & 2007; LeBlanc *et al.,* 2002; Ruiz *et al.,* 2005; Iglesias-Gutierrez *et al.,* 2005) with just two in the UK (Russell and Pennock, 2011; Briggs *et al.,* 2015). These studies have typically been limited to reports of total daily energy and macronutrient intake, often concluding that elite youth soccer players habitually don't meet their energy requirements (Boisseau *et al.* 2002; LeBlanc *et al.*, 2002; Ruiz *et al.,* 2005; Russell and Pennock, 2011; Briggs *et al.,* 2015).

In addition to the quantification of daily energy and macronutrient intake, it is important to consider timing of intake in relation to training sessions (Burke, 2010; Mori, 2014), main meals (Garaulet and Gomez-Abellan, 2014; Johnston, 2014) and sleep (Lane *et al.,* 2015). Whilst this is most well documented for carbohydrate (CHO) intake in order to fuel training and matches (Goedecke *et al.,* 2013; Jeukendrup, 2014) and promote glycogen re-synthesis (Zehnder *et al.,* 2001; Gunnarsson *et al.,* 2013), recent data suggests that the daily distribution of protein intake is critical for optimizing components of training adaptations such as muscle protein synthesis (MPS) (Areta *et al.,* 2013; Mamerow *et al.,* 2014). Recent data has highlighted the importance of quantity and timing of protein intake in elite youth soccer players. Milsom *et al.* (2015) demonstrated that such populations typically present with approximately 6 kg less lean muscle mass than adult professional soccer players. When taken together, these data suggest that dietary surveys of elite youth soccer players should not only quantify total daily energy and macronutrient intake but should also report the timing of nutrient ingestion, thereby having important practical implications for fuelling adequately, promoting training adaptations and optimizing recovery.

Therefore, the aims of the present study were two-fold: 1) to quantify the total daily energy and macronutrient intakes of elite youth UK academy players of different ages (U13/14, U15/16 and U18 playing squads) and 2) to quantify the daily distribution of energy and macronutrient intake. In accordance with the higher absolute body masses and training loads of the U18 squads (Wrigley *et al.*, 2012), we hypothesised that this squad would report higher absolute daily energy and macronutrient intakes in comparison to the U13/14s and U15/16s. Furthermore, based on the habitual eating patterns of both athletic and non-athletic populations (Mamerow *et al.*, 2014), we hypothesised that all squads would report an uneven daily distribution of macronutrient intakes, particularly for daily protein intake.

Methodology

Participants

Elite youth soccer players were recruited from a local English Premier League (EPL) club's academy. Researchers provided a presentation and participant information sheets to invite players from the U13-18s to participate in the study. Ninety-one players were initially recruited, however 32 were withdrawn due to incomplete diary entry, leaving a sample size of 59. All participants gave informed consent and ethical permission was obtained from the Liverpool John Moores University Ethics Committee.

Participants were subsequently categorised into the following squads; U18s (*n*=13), U15/16 (*n*=25) and U13/14 (*n*=21). The mean (±SD) body mass (determined by scale mass – Seca, Hamburg, Germany) and height (determined by stadiometry) were recorded to the nearest 0.1kg and cm, respectively, for each squad and are displayed in Table 1, along with habitual training time albeit collected 2-3 weeks after this study period (Brownlee *et al.* Unpublished Data). Data collection occurred during a 7 day training period of the 2014-15 season, during which no competitive matches took place.

Dietary Intake

Participants were asked to record everything they consumed in a food diary for 7-consecutive days. This time frame was justified by previous research suggesting that 7-days provides a more accurate estimation of habitual nutritional intake than a single- or 4-day recording (Magkos & Yannakoulia, 2003). Additionally, unpublished pilot research on the current study's population displayed a high completion rate (75%) over the 7-days. To promote high ecological validity, researchers made no attempt to influence the player's diets. Upon giving consent, players attended a presentation that gave detailed instructions on how to fill out the dietary diary. Parents and guardians of the U13/14s also attended, as it was evidenced from pilot research that they were likely to be responsible for completion of the diaries at this age. Participants were asked to provide as much detail as possible, including the type of day it was with respect to their soccer activity (rest, match, or training day), the commercial brand names of the food/drink, cooking/preparation methods, and time of consumption. Time of consumption was used to distinguish between meals; breakfast (main meal consumed between 6-9.30am), lunch (main meal consumed between 11.30-1.30pm), dinner (main meal consumed between 5-8pm), and snacks (foods consumed between main meals). Additionally in table 2 the time and frequency of snack consumption for each team is displayed. Supplements were defined as foods/drinks/powders that were purposefully taken to provide an additional source of any one or combination of macronutrients (e.g. Whey Protein). Participants were asked to quantify the portion of the foods and fluids consumed by using standardised household measures or, where possible, referring to the weight/volume provided on food packages, or by providing the number of items of a predetermined size. Upon return of the food diary the primary researcher checked for any cases of missing data and asked participants for clarification.

Data Analysis

Food diary data was analysed using Nutritics software (version 3.74 professional edition, Nutritics Ltd., Co. Dublin, Ireland). All analyses were carried out by a single trained researcher so that potential variation of data interpretation was minimised (Deakin, 2000). Total absolute, and relative to body mass (BM), intakes of energy (kcal), CHO, protein and fats were calculated. All data were assessed for normality of distribution according to the Shapiro-Wilk's test. Statistical comparisons between squads' total energy and macronutrient intakes were performed according to a one-way between-groups analysis of variance (ANOVA) or, for non-parametric data, the Kruskal-Wallis test. Where significant differences of the ANOVA were present, Tukey post-hoc analysis was conducted to locate specific differences. For non-normal data, post-hoc analysis was performed using multiple Mann-Whitney U tests with a Bonferroni adjustment. For energy and macronutrient distribution across separate meals, a two-way ANOVA was employed and a Tukey post-hoc analysis was conducted where appropriate. Where a significant main difference for age was reported, a one-way ANOVA or, the Kruskal-Wallis test was performed, to assess at which meal the difference occurred. All analyses were completed using SPSS for Windows (version 20, SPSS Inc., Chicago, IL) where $P<0.05$ was indicative of statistical significance.

Data is presented as mean±SD. In the results section, *absolute* refers to the total absolute daily intake and *relative* refers to when the absolute data has been normalized to each participants' BM (i.e. $g{\cdot}kg^{-1}$ BM).

Results

Daily Energy and macronutrient total and relative daily intake

No significant difference was found for absolute daily energy (*P*=0.92), CHO (*P*=0.70) or fat (*P*=0.18) intake between squads. However, absolute daily intake of protein showed a significant difference (*P*<0.01) between squads, both the U13/14s and U15/16s squads reported lower intakes than the U18 squad (*P*=0.01). In contrast to the absolute data, significant differences were observed for all variables when expressed in relative amounts (*P* <0.05). For relative energy, CHO and fat intake, the U13/14s values were significantly higher compared to both the U15/16s and U18s (*P*<0.01 for all comparisons). The U13/14 and U18 squads were both significantly higher in relative protein compared to the U15/16s (*P*<0.01). Additionally, the U15/16s had a significantly higher relative CHO intake in comparison to the U18s (*P*=0.01) (Table 3).

The distribution of energy and macronutrients across separate meals

A significant difference for distribution across meals was found for all variables for both absolute and relative intake (*P*<0.01). For energy, both absolute and relative intake at breakfast was significantly lower than intake at lunch and dinner (*P*<0.01). Dinner was significantly higher (*P*<0.01) than snacks whether expressed as absolute or relative. CHO intake at breakfast was significantly lower than lunch and snacks for both absolute and relative intake (*P*<0.05), and for absolute dinner intake (*P*=0.03), but not for relative intake (*P*=0.06) (Figure 1).

Protein distribution was found to be significant between all meals (*P*<0.05) for absolute intake, and PRO at breakfast was significantly lower compared to both lunch and dinner for relative intake (*P*<0.01). Additionally, relative protein intake at dinner was significantly higher compared to snacks (*P*<0.01). For fat distribution, both absolute and relative intake at dinner was significantly higher (*P*<0.01) than both breakfast and snacks (*P*<0.01) (Figure 1).

A significant difference was observed between-squads for distribution of absolute CHO and PRO intake (*P*<0.01). Specifically, for breakfast and lunch the U18s reported a significantly higher intake of absolute PRO intake compared with the U13/14s and U15/16s (*P*<0.01), but when considering relative protein, the U13/14s had a significantly higher (*P*<0.05) intake at dinner and snacks compared to their older counterparts, which was also true for relative fat intake. Furthermore, a significantly lower intake of both absolute and relative CHO in comparison to the U15/16s at breakfast was observed (*P*<0.01), and with dinner and snacks but only for relative intake compared to the younger groups (Figure 1). The U13/14s have a significantly higher intake of relative energy for every meal compared to the U15/16s and U18s (*P*<0.05).

Supplements.

No statistical analysis was performed for supplements as intake within the U13/14 and U15/16 (*n*=3) was negligible. Within the U18s mean daily intake from supplements were: Energy 89.2±110.4 kcal, CHO 2.5±6.5 g, Protein 15.1±17.3 g, and Fat 0.8±1.1 g.

Discussion

The aims of the present study were to simultaneously quantify the total daily macronutrient intake and daily distribution in elite youth soccer players of differing ages. With the exception of protein, we observed no significant difference in total absolute energy and macronutrient intake between squads. However, differences in macronutrient intake were readily apparent when expressed relative to BM. We also report for the first time a skewed daily distribution of macronutrient intakes in elite male youth soccer players (irrespective of age), an effect that was especially pertinent for protein intake. Given the requirement for young soccer players to gain lean muscle mass, such data may have practical implications for helping to promote training adaptations.

The values reported here for both total daily energy and CHO intake compare well to those previously reported for players of similar ages (Boisseau *et al.,* 2002; Ruiz *et al.,* 2007). For example, Boisseau *et al*. (2002) reported energy intakes of 38.9±4.4 kcal·kg^{-1}·day^{-1} and Ruiz *et al.* (2007) reported CHO intakes of 5.9±0.4 g·kg^{-1}·day^{-1}, both of which are similar to the U15/16s in the present study (Table 3). A consistent theme within the literature appears to be that elite youth soccer players consume lower energy intakes than likely daily energy requirements, thus potentially compromising performance. While no differences between absolute energy and CHO intake between squads were observed, large differences were apparent when expressed relative to BM. Indeed, higher CHO intakes in the U13/14 squads (6±1.2 g·kg^{-1}·day^{-1}) compared with both the U15/16s (4.7±1.4 g·kg^{-1}·day^{-1}) and U18s (3.2±1.3 g·kg^{-1}·day^{-1}) were found. Carbohydrate requirements for adult athletes are an evolving topic within sports nutrition and there is debate within the literature of the optimal approach. Currently, soccer players are recommended to consume 6-10 g·kg^{-1}·day^{-1} to support training and match demands (Burke *et al.,* 2006). Conversely, recent evidence has suggested that athletes (albeit adult populations) may benefit from strategically training with lower CHO availability during carefully chosen sessions (through manipulation of CHO intake and/or timing of training) to enhance training adaptations (i.e. increased mitochondrial biogenesis) (Bartlett *et al.,* 2013; 2015). Given the obvious developmental goals of youth soccer players and the low CHO intakes reported here and previously (Ruiz *et al.*, 2007), these data suggest that youth soccer players are likely under consuming daily CHO and do not meet current daily targets. However, given that these guidelines are for adult populations and there are currently no available CHO guidelines for elite youth athletes, further research is required.

Distribution of CHO intake showed a typically lower intake at breakfast, particularly for the U18s, who would have a protein (e.g. eggs) based breakfast in comparison to the schoolboys (U13/14s and U15/U16s), who typically had cereal/toast. In the two schoolboy squads, bread and cereal were the most common CHO choices, similar to the findings of Iglesias-Gutierrez *et al.* (2012). These CHO choices were often chosen at breakfast (cereal), lunch (sandwiches) and snacks (toast). In contrast, the U18s would have cooked meals at breakfast and lunch, therefore not relying on a school / homemade meal.

In relation to protein, marked differences in the total absolute daily intake were observed between squads where the U18s were higher than the U13/14s and U15/16s (142±24 vs. 97±21 vs. 96±24 g, respectively). However, when this value was standardised for BM, the U13/14s reported higher values than the U15/16s and U18s (2.2±0.4 vs. 1.6±0.3 vs. 2.0±0.3 $g·kg^{-1}$, respectively) (Table 3). Such absolute and relative values are comparable to previous findings in similar populations (Boisseau *et al.,* 2002; Ruiz *et al.,* 2007; Russell & Pennock, 2011; Briggs *et al.,* 2015) and are also considerably higher than current national dietary reference values of 0.8 $g·kg^{-1}·day^{-1}$ (Department of Health, 1991). The most popular source of protein for all ages was poultry while eggs were only a main choice for the U18s. Similar to the CHO choices, this is likely a reflection of the U18s being provided with a cooked breakfast daily at the academy whereas the younger squads tended to consume cereal based breakfasts at home. To the authors' knowledge, only one research group has assessed the protein requirements of adolescent soccer players (Boisseau *et al.,* 2002 & 2007), using a nitrogen balance methodology. Results demonstrated that protein requirements of players aged 13-15 years range between 1.4-1.6 $g \cdot kg^{-1} \cdot day^{-1}$ (Boisseau *et al.,* 2002 & 2007), which is similar to current guidelines for adult athletes (1.3–1.8 $g \cdot kg^{-1} \cdot day^{-1}$) (Phillips and Van Loon, 2014). Therefore, in contrast to CHO, it appears that elite youth soccer players are successful in achieving daily protein requirements.

The distribution of daily protein intake may be a more important aspect of an athlete's nutritional strategy than the total daily intake. Recent data has highlighted that distorted protein intake distribution across meals (skewed to higher intake at dinner) in an adult population results in reduced MPS stimulation in comparison to a stable protein intake (~30 g) at each main meal (breakfast, lunch and dinner) even when total absolute intake is matched (Mamerow *et al.,* 2014). The distribution of protein intake at different meals was skewed for all squads in a hierarchical order of dinner>lunch>breakfast (Figure 1). In relation to optimal absolute protein dose, Witard *et al.* (2013) has previously reported that a single meal of ≥20g high quality fast-digesting protein is necessary to induce maximal rates of MPS. Therefore, it could be suggested that some players were under-consuming protein at specific meal times. For example, the U13/14s and U15/16s consumed 17±5 g and 15±4 g, respectively, at breakfast in comparison to the U18s who consumed 25±5 g. Conversely, Murphy *et al.* (2014) recently suggested that a protein content of 0.25-0.3 $g \cdot kg^{-1}$ BM per meal, that has high leucine content and is rapidly digestible, can achieve optimal MPS. Therefore, all squads would be achieving that value at each meal and consequently, the finding of <20 g absolute doses at certain meals may be inconsequential. However, a caveat to this paper is that the sources of habitual protein intakes for some squads would likely result in sub-optimal leucine contents. For example, whereas the U18s consume a protein based breakfast (i.e. eggs), the U13/14s and U15/16s intake of protein at breakfast was largely derived from adding milk to a predominantly CHO based breakfast (e.g. cereals, bread). Such pattern of breakfast choices in these squads is also in accordance with breakfast choices of children from the general population (Alexy *et al.,* 2010). Therefore, the schoolboys have not yet adopted a more sports specific diet. Similar to breakfast, the U18s have a significantly higher absolute protein intake at lunch in comparison to their younger counterparts (46±11 vs. 27±7 vs 29±9 g, respectively), but CHO intake was similar across all squads for lunch and dinner (Figure 1).

Potential reasons for this difference in macronutrient intake and distribution between squads is likely related to the fact that the U18s are full-time soccer players and it is mandatory for players to consume breakfast and lunch at the academy on days they attend (5/6 days·week^{-1}). Consequently, the club has greater control over the food and beverages the U18s can choose from. In contrast, the schoolboys will have meals provided by the school they attend or packed lunches from home, so the influence of the club is considerably reduced. When youth players are promoted to full-time U18 squad status, muscle hypertrophy is a key training goal (Milsom et al., 2015), which may result in players being encouraged to increase protein consumption to support resistance-training hypertrophy programmes (Phillips et al., 2014).

Distribution of snacks differed between squads (Table 2) and it would appear that this is consequence of differing training times between squads. The fulltime U18s trained in the morning (~10.30am) and only consumed 6% of their snacks during this period. In comparison, the school boy squads habitually train in the evening (~5pm) and consumed ~25% of their snacks during the morning period. This disparity of snack distribution across squads in the morning period may simply be due to the U18s being out training and are therefore restricted in what they can consume.

A limitation of the current study is the use of food dairies to analyze nutritional habits, and indeed, previous research has shown a potential under-reporting effect of up to 20% (Burke *et al.*, 2001). However, even when accounting for potential under-reporting effects, it would appear that the current populations would still be under-fueling for performance in accordance with current literature (Burke *et al.*, 2006). To address this hypothesis, future research should accurately quantify the energy expenditure within elite youth soccer players through a variety of techniques such as doubly labeled water and accurate monitoring of training load through GPS technology. Additionally, the sample population for the present study was taken from a single EPL academy, and therefore may not be truly representative of elite players based at other clubs.

In conclusion, we provide novel data by simultaneously reporting both the total and daily distribution of macronutrient intakes in elite youth soccer players of differing ages. In agreement with previous authors, we report that soccer players are not meeting current CHO guidelines (especially U18s) though daily protein targets are readily achieved. However, we also report a skewed daily macronutrient distribution in all ages, an effect that was particularly evident for daily protein targets. In this regard, the smallest protein intakes were typically reported at breakfast and snacks whereas the largest intakes were reported in the evening meal. Given the requirement for both optimal energy availability and protein intake to support muscle hypertrophy, our data have important practical implications and suggest that key dietary goals for elite youth players should focus on both total daily macronutrient intake and optimal daily distribution patterns.

Acknowledgments

All authors contributed to the design of the study; RN collected and analyzed all data; RN, JA, IGD, JPM, & EM drafted the manuscript; All authors critically revised the manuscript; All authors approved the final manuscript for publication. There are no conflicts of interest to disclose.

Table 1. A comparison of age, body mass, height, BMI, soccer and non-soccer training between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads. Training data adapted from Brownlee *et al.* (Unpublished data).

Squad	Age (years)	Body Mass (kg)	Height (cm)	BMI (kg/m^2)	Soccer Training (mins)	Non-Soccer Training (mins)
U13/14s	12.7 ± 0.6	44.7 ± 7.2	157.8 ± 11.0	17.9 ± 1.3	436 ± 29	33 ± 28
U15/16s	14.4 ± 0.5	60.4 ± 8.1	173.1 ± 7.8	20.1 ± 1.5	212 ± 57	81 ± 39
U18s	16.4 ± 0.5	70.6 ± 7.6	180.1 ± 7.3	21.7 ± 0.9	224 ± 38	89 ± 21

Values are mean ± SD.

Table 2. A breakdown of frequency of snack consumption for all squads.

Time Point	Percentage of snacks consumed within Time Point (%)		
	U13/14s	U15/16s	U18s
Morning Snack (Between Breakfast & Lunch)	24	25	6
Afternoon Snack (Between Lunch & Dinner)	40	49	59
Late Snack (After Dinner)	36	26	35

Table 3. A comparison of daily energy and macronutrient intake between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads expressed as absolute and relative.

	U13/14s	**U15/16s**	**U18s**
Absolute Energy (kcal)	1903 ± 432.4	1926.7 ± 317.2	1958.2 ± 389.5
Relative Energy ($kcal \cdot kg^{-1}$)	43.1 ± 10.3[a]	32.6 ± 7.9	28.1 ± 6.8
Absolute CHO (g)	266.3 ± 58.4	275.1 ± 61.9	223.7 ± 79.9
Relative CHO ($g \cdot kg^{-1}$)	6.0 ± 1.2[a]	4.7 ± 1.4[b]	3.2 ± 1.3
Absolute Protein (g)	97.3 ± 21.0	96.1 ± 13.7	142.6 ± 23.6[c]
Relative Protein ($g \cdot kg^{-1}$)	2.2 ± 0.5	1.6 ± 0.3[d]	2.0 ± 0.3
Absolute Fat (g)	56.1 ± 17.5	55.2 ± 10.6	60.0 ± 14.7
Relative Fat ($g \cdot kg^{-1}$)	1.3 ± 0.5[a]	0.9 ± 0.3	0.9 ± 0.3

[a] Denotes significant difference from both U15/16s and U18s. [b] Denotes significant difference from U18s. [c] Denotes significant difference from both U13/14s and U15/16s. [d] Denotes significant difference from both U13/14s and U18s. Values are mean±SD.

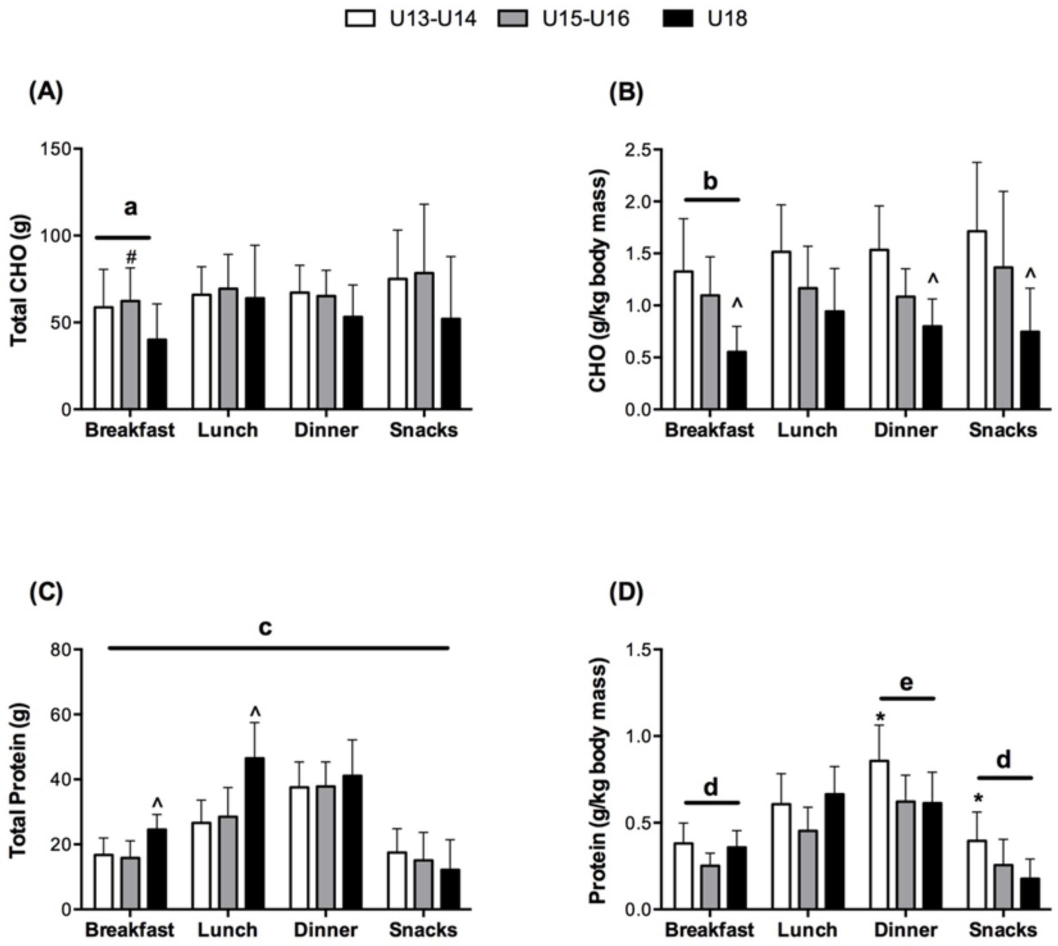

Figure 1. – Comparison of total and relative CHO and protein intake for each squad across different meals. White bars represent U13/14s, grey bars represent U15/16s and black bars represent U18s. All values are mean ± SD. [a] Denotes significant difference from lunch, dinner and snacks. [b] Denotes significant difference from both lunch and snacks. [c] Denotes significant difference from all meals. [d] Denotes significant difference from both lunch and dinner. [e] Denotes significant difference from lunch. # Denotes significant difference from U18s. ^ Denotes significant difference from U13/14s and U15/16s. * Denotes significant difference from U15/16s and U18s.

Appendix 6 – Chapter 4 publication

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Free-sugar, total-sugar, fibre and micronutrient intake within elite youth British soccer players: a nutritional transition from schoolboy to fulltime soccer player

Robert J. Naughton[1,2], Barry Drust[3,4], Andy O'Boyle[3,4], Julie Abayomi[2], Elizabeth Mahon[2], James P. Morton[3] and Ian G. Davies[2]

[1]School of Human and Health Sciences

University of Huddersfield

Queensgate

Huddersfield

HD1 3DH

[2]School of Sports Studies, Leisure and Nutrition

Liverpool John Moores University

Liverpool

L17 6BD

UK

[3]Research Institute for Sport and Exercise Sciences

Liverpool John Moores University

Tom Reilly Building

Byrom St Campus

Liverpool

L3 3AF

UK

[4]Liverpool Football Club

Melwood Training Ground

Deysbrook Lane

Liverpool

L12 8SY

UK

Address for correspondence:

[1]School of Human and Health Sciences

University of Huddersfield

Queensgate

Huddersfield

HD1 3DH

Email: R.Naughton@hud.ac.uk

Co-corresponding author

Dr Ian Davies

[2]School of Sports Studies, Leisure and Nutrition

Liverpool John Moores University

Liverpool

L17 6BD

United Kingdom

Email: I.G.Davies@ljmu.ac.uk

Shortened Title: Sugar intake in elite adolescent soccer

Abstract

It is recommended that soccer players consume a high carbohydrate (CHO) diet to augment performance. However, growing evidence suggests that there is a link between high free-sugar (FS) intake (>5% total energy intake; TEI) and metabolic diseases. Furthermore, foods that are often high in sugar, such as processed foods, are typically lacking in nutrient quality. We therefore analysed total- and FS, dietary fibre and micronutrient intake of players from an English Premier League academy under(U) 18 (n=13); U15/16 (n=25); U13/14 (n=21) using a 7-day food diary. Data was compared to current UK dietary reference value (DRV) for free-sugar via a t-test. The U13/14s (10±18 %) and U15/16s (11±30 %) both consumed higher amounts of free-sugar in comparison to the UK DRV of 5% TEI 5% (*P*<0.01), conversely, the U18s did not exceed the DRV (5±13 %). Furthermore, FS intake of the U18s was significantly lower than the U13/14s and U15/16s (*P*<0.01). Dietary fibre was below the DRV (25g/d for U13/14 & U15/16s; 30g/d for U18s) for all squads (19.0±4.7; 19.6±8.3; 17.1±4.2 g/d, respectively), but not different between squads. Additionally, micronutrient reference intakes were generally met. In conclusion, we provide novel data on dietary sugar, fibre and micronutrient intake within elite youth soccer players. We report an apparent 'nutritional transition' from schoolboy to fulltime soccer player, with U18s showing a significantly lower intake of sugar in comparison to younger squads, and a similar intake of FS to the UK DRVs. Practitioners should target improving player education around sugar and fibre consumption.

Keywords: Sugar, Micronutrient, Fibre, Soccer, Nutrition, Adolescent, UK

Introduction

Whilst the research into youth soccer has markedly rose over the last decade, relatively little is currently known about the nutritional intake and habits of elite British adolescent soccer players. To the author's knowledge, only three studies have been conducted within this area (Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015; Naughton *et al.*, 2016), with these investigations mainly concentrating on energy and macronutrient intakes. Nutritional guidelines for soccer players, albeit in adults, encourage a diet high in carbohydrate (CHO) (6-10 g·kg·Body Mass $(BM)^{-1}$·day^{-1}) (Burke et al., 2006); due to their ergogenic effect on both physical performance (Cermak & van Loon 2013; Hawley et al. 1994; Hespel et al. 2006) and the well documented improvements on soccer specific performance (Ali & Williams, 2009; Currell et al., 2009; Ostojic & Mazic, 2002; Russell et al., 2012). To support the apparent CHO demand before, during, and after training/match sessions, sugar based sports drinks are frequently consumed and recommended to soccer players in an attempt to help improve performance and recovery (Russell et al. 2014).

As a result of these CHO recommendations, particularly frequent intake of sugar based sports drinks, it is possible that youth soccer players are consuming high amounts of free-sugar (FS). High FS intake has been linked to adverse health effects particularly when consumed in excess. High FS intake (>5% Total Energy Intake [TEI]) has been associated with increased obesity (Siervo *et al.*, 2014), hypertension (Siervo *et al.*, 2014), metabolic diseases (Stanhope, 2016) and dental caries (Freeman, 2014). Therefore, the current UK guidelines have revised their recommendations for FS from 10% to 5% TEI (SACN, 2015). Within the general UK adolescent (11-18 years old) population, a FS intake of 15.4 ± 6.4% of TEI (Newens and Walton, 2016) has been reported, triple that of the new dietary reference value (DRV) (SACN 2015). Whilst it is clear that CHO intake has an ergogenic benefit on soccer performance, paradoxically youth players could be putting their health at risk if they over consume FS. Currently there is no data on the FS intake of elite youth British soccer players.

Another form of CHO which may be of interest is dietary fibre due to its associated health benefits and presence in foods of high nutrient value (Lairon et al. 2005; Montonen et al. 2003; Butcher et al. 2010). Current UK guidelines recommend a daily fibre intake of 25g/day for children (<16 years old), and 30g/day for adults (SACN 2015). However, within the general population fibre intake has been reported as much lower in both children (11-12 g/day) and adults (14 g/day) (SACN 2015). Only one study has assessed dietary fibre intake in British youth soccer players (Russell and Pennock, 2011), reporting an intake of 16 g/day in an U18s team. Currently, there is no data available in elite British soccer players ≤U16s.

Similar to FS and fibre, there is limited data concerning the micronutrient intake of youth British soccer players. Calcium and iron intakes, in particular, have been identified as important for adolescent athletes (Desbrow et al. 2014), due to their important role in skeletal development and oxygen transport. Only one previous study has assessed the micronutrient intake in British soccer players (Russell and Pennock, 2011), who reported that an U18 cohort of players met the Reference Nutrient Intakes (RNIs). Yet, as with fibre, there is no data for the micronutrient intake for British soccer players ≤U16s.

Therefore, the aims of the present study were twofold: 1) to quantify and compare daily FS, total sugar, dietary fibre and micronutrient intake amongst 3 different age groups (U13/14s, U15/16s and U18s) of elite youth soccer academy players, and 2) to compare against UK DRVs and reference nutrient intakes (RNIs). We hypothesise that due to the previously reported higher intake of CHOs in the U13/14 and U15/16s in comparison to the U18s (Naughton *et al.*, 2016), the U18s will have a lower contribution of FS to TEI.

Methodology

Participants

Elite youth male soccer players were recruited from a local English Premier League (EPL) club's academy. Researchers provided a presentation and participant information sheets to players and their parents, from the U13-18s to invite them to participate in the study. Ninety-one players were initially recruited, however due to incomplete diary entry 32 were withdrawn, leaving a sample size of 59. Incomplete diary entry was classified as having more than 1 days intake missing or not having at least 3 main meals (breakfast, lunch and dinner) reported on a minimum of 6 days. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All participants gave written informed consent, for those participants under 18 years of age their parents gave written informed consent on their behalf. Ethical permission was obtained from the Liverpool John Moores University Ethics Committee.

Participants were categorised into the following squads; U18s (n=13), U15/16 (n=25) and U13/14 (n=21). The mean (±SD) body mass (determined by scale mass – Seca, Hamburg, Germany) and height (determined by stadiometry) were verified to the nearest 0.1 kg and cm respectively for all 3 squads and are displayed in Table 1 along with field and off field training frequency. Data collection occurred during the pre-season period of the 2014-15 season.

Dietary Intake

Participants were asked to record everything they consumed in a dietary diary for 7-consecutive days. Each participant was asked to provide as much detail as possible, including the type of day it was in respect to their soccer activity (rest, match, or training day), the commercial brand names of the food/drink, the cooking/preparation methods, and time of consumption. Additionally, each participant was requested to quantify the portion of the foods / fluids consumed using standardised household measures or, if possible, referring to the weight/volume provided on food packages, or by providing the number of items of a determined size. Upon the return of the dietary diary the primary researcher checked for any cases of missing data and, if necessary, asked participants to clarify. Total CHO and energy intakes are displayed in Table 2 as reported by Naughton *et al.* (Naughton *et al.*, 2016). For a full overview of methodology please refer to Naughton *et al.* (Naughton *et al.*, 2016).

Data Analysis

Food diary data was analysed using Nutritics software (version 3.74 professional edition, Nutritics Ltd., Co. Dublin, Ireland). All analyses where carried out by a single trained researcher so that potential variation of food diary data interpretation was minimised (Deakin, 2000). Any foodstuff that wasn't present within the software package, was manually added by the same researcher from the packaging information available. From this program's analysis comprehensive information on the intake of the different micronutrients was obtained. All data were initially assessed for normality of distribution according to the Shapiro-Wilk's test. Participant's FS and DF were compared to their age specific UK DRVs and UK RNIs for micronutrient intake. For micronutrient intake the RNI was chosen for comparison as it is considered that this level of intake is likely sufficient to meet the requirements of 97.5% of the population (Department of Health, 1991). To identify if players met their DRVs one-way sample *t-tests* were used. All analyses were completed using SPSS for Windows (version 21, SPSS Inc., Chicago, IL) where $P < 0.05$ is indicative of statistical significance. Statistical comparisons between squads were performed according to a one-way between-groups analysis of variance (ANOVA) or the Kruskal-Wallis test where data were not normally distributed. Where significant main effects of the ANOVA were present, Tukey post hoc analysis was conducted to locate specific differences. For non-normal data post hoc analysis was performed using multiple Mann-Whitney U tests with a Bonferroni adjustment. All data are presented as mean (± SD).

Results

Participant Characteristics

Participant characteristics are displayed in Table 1.

Sugar, dietary fibre and micronutrient differences between squads

A significant difference between squads was reported for absolute total-sugar intake ($P = 0.01$) and for percentage contribution of FS intake percentage contribution of TEI ($P < 0.01$). The U18s had a significantly lower intake in comparison to the U13/14s and U15/16s for both variables ($P < 0.01$) (Table 3). No significant difference was reported for dietary fibre intake ($P = 0.63$). For micronutrients, only phosphorus, zinc and vitamin B12 intakes were significantly different between squads ($P < 0.01$). Post-hoc analysis revealed that for zinc and vitamin B12 intake in the U18s was significantly higher than that of the U13/14s and U15/16s squads ($P < 0.05$). For phosphorus, the U18s intake was significantly higher than that of the U15/16s ($P < 0.01$) (Table 4).

Total- and free-sugar and fibre intake in comparison to the DRVs

U13 & U14s

A higher percentage contribution of FS TEI (10.0 ± 17.7%, $P < 0.01$) was observed in comparison to the DRVs, whilst total-sugar contribution total-sugar to TEI was 21 ± 5%. Dietary fibre intake was lower than that of the DRV ($P < 0.01$) (Table 3). The mean daily intakes of sodium, chloride, phosphorous, iron, B1, B2, B6, B12, Vitamin C and folic acid mean daily intakes were all higher than the current UK RNIs ($P < 0.01$). Additionally, magnesium, zinc and vitamin A intake were higher than the current RNIs ($P < 0.05$). Similarly, mean daily intakes of potassium and calcium were higher than the recommended RNIs but not statistically significant ($P > 0.05$) (Table 4).

U15 & U16s

A higher percentage contribution of FS TEI (11 ± 30 %, $P < 0.01$) in comparison to the DRV was observed, whilst total-sugar intake contribution to TEI was 21 ± 5%. Dietary fibre intake was lower than that of the DRV ($P < 0.01$) (Table 3). The mean daily intakes of iron, sodium, chloride, phosphorous, B2, B6, B12, folic acid and vitamin C intakes were all higher when compared to the RNIs ($P < 0.01$) as was B1 ($P = 0.01$). Although calcium and zinc intake were marginally above that of their respective RNIs, no significance was reported ($P > 0.05$). In contrast, potassium intake was lower ($P < 0.01$) than that of the RNIs. Both magnesium ($P = 0.90$) and vitamin A ($P = 0.96$) intakes were slightly below the RNI value (Table 4).

U18s

The percentage contribution of FS intake (5 ± 13%) was not different from the DRV, whilst total-sugar intake contribution to TEI was 14 ± 3%. Conversely, dietary fibre intake was found to be lower than that of the DRV ($P < 0.01$) (Table 3). The mean daily intakes of iron, sodium, chloride, phosphorus, zinc, B1, B2, B6, B12, folic acid, and vitamin C were all (P < 0.01) higher than RNIs. However, magnesium ($P = 0.28$), vitamin A ($P = 0.09$), potassium ($P = 0.64$) and calcium ($P = 0.19$) intakes were not significantly different from the RNIs (Table 4).

Discussion

We provide novel data on the dietary FS and total sugar intake within elite youth soccer players. Our data reports that U18s reported a similar intake of FS to the new UK DRVs whilst the U13/14s and U15/16s reported a significantly higher FS intake in comparison to the UK DRV (SACN, 2015). With respect to sugar, we see a ‘‘nutritional’’ transition from schoolboy to fulltime soccer player, with fulltime players consuming less total- and FS than the schoolboy squads. All squads' dietary fibre intakes are significantly below that of the RNI; however, it would appear that all squads are generally meeting their micronutrient intakes.

One of the novel aspects of the present study was the observation that U18 players consumed less FS than their younger counterparts. Indeed, whereas the U13/14 and U15/16 squads consumed greater than the updated DRV for FS, the contribution of FS to TEI for the U18 players was equal to that of the RNI (i.e. 5%). Although the U18 players' choices may be reflective of adopting a more professional attitude towards dietary choices, they may also be underpinned by the fact that these players are based full-time in the soccer academy, and hence much of their daily food intake is provided by the club's catering staff. Indeed, such players receive breakfast, lunch and snacks whilst attending the academy for 5 days per week. These players are also subjected to nutritional educational material provided by the club sport science staff whilst the younger players are not yet subjected to such frequent educational exposures. It is noteworthy, however, that all squads (regardless of age) report lower FS daily mean values compared to the British adolescent population (15 ± 6%) (Newens and Walton, 2016). This is an interesting finding as although the cohort within the current study are elite soccer players there are no clear additional social or economic factors which separate them from the general population. It could be speculated therefore that the mere exposure to a professional sport environment steers such individuals towards better food choices than that consumed by the non-athlete adolescent UK population. Future studies employing larger sample sizes are now required to verify this relationship.

For all squads, fruit-juice and cereals were amongst the top sources of FS (Table 5). Fruit juice, such as pure orange or apple juice, are perceived as a ‘healthy’ options due to the high amount of vitamins and minerals they are believed to contain and that they can contribute to daily fruit and vegetable intake (Clemens et al., 2015). Whilst that may be true of 100% freshly squeezed fruit juices, evidence shows processed fruit juices are deficient in several nutrients in comparison (Clemens *et al.*, 2015). Due to this perception, soccer players may be consuming fruit juice in place of sugar sweetened beverages in the belief that it is a healthier alternative without realising that they are consuming high amounts of FS. Within the UK, it has been reported that breakfast cereals significantly contribute to the micronutrient intake of the general population (Holmes et al., 2012) due to the cereals being fortified, with iron for example. Many of the breakfast cereals available in the UK are relatively high in FS (LoDolce et al., 2013), and within this study cereals were not only consumed at breakfast but as a snack choice at other times in the day. As such, the high use of cereal intake may help to achieve daily CHO and micronutrient requirements but paradoxically, may also contribute to the relatively high FS intakes.

The intake of dietary fibre is also of interest, as higher intakes of dietary fibre has been shown to have an inverse relationship with obesity (Lairon *et al.*, 2005), diabetes (Montonen et al., 2003), cardiovascular disease (Butcher and Beckstrand, 2010), and bowel disease (Pituch-Zdanowska, Banaszkiewicz and Albrecht, 2015). Due to the increasing evidence of the benefits to health dietary fibre the UK dietary guidelines have recently been raised (SACN, 2015), increasing the DRV for 11-16 year olds from 18 g/day to 25 g/day, and for >16 years old to 30 g/day from 25 g/day. Within the present study, daily dietary fibre intakes were the following; U13/14s 19.0 ± 4.7g; U15/16s 19.6 ± 8.3g; and U18s 17.1 ± 4.2g. These data show that all squads are consuming less than their age specific DRV (SACN, 2015) and are similar to previously reported dietary fibre intakes (16 ± 1 g/day) in this population (Russell and Pennock, 2011). As can be seen, dietary fibre intake across the different ages was similar (Table 3) and it would appear that although U18s consume less cereals and bread products (Naughton *et al.*, 2016), they are still consuming similar dietary fibre to the younger squads. This may be due to an increase consumption of other fibre rich foods, such as vegetables, to compensate for this loss of dietary fibre from cereal and bread products (Table 4). The observation of a low daily fibre intake in the U18 players may also be reflective of a habitually low daily CHO diet, as previously reported (Naughton *et al.*, 2016).

As displayed in Table 4, all squads met and generally exceeded the current UK RNIs for micronutrients. The exception is calcium in the U18s squad, along with potassium intakes within both the U15/16s and U18s squads. The finding that the U18s did not meet the calcium RNI is in contrast to previously reported values in an U18s soccer team population (Russell and Pennock, 2011). One potential reason for the finding that U18s didn't achieve their calcium, is that they have a protein based breakfast (such as eggs) as opposed to a CHO based breakfast (such as cereal and toast) (Naughton *et al.*, 2016). Consequently, this would lead to the U18s consuming less milk which is a key source of calcium; which may explain in part the lower intake of these micronutrients in comparison to both the younger squads and the RNIs. Although not statistically significant, the finding that the U18s are not meeting their calcium RNI is of potential concern, as they are exposed to a higher training load (Wrigley et al., 2012) and a more physically demanding version of the game (Anderson *et al.*, 2016). The role of calcium in the development and maintenance of bone is well established (Desbrow *et al.*, 2014). The reported suboptimal intake could potentially lead to an increased risk of bone fractures and breaks as skeletal development may be compromised (Rizzoli et al., 2010) and not be able to withstand the training / match load and potential impacts within training /

matches. During adolescence and early adulthood, there is evidence to suggest that optimal bone mineral growth is vital to achieve a high peak bone mass to reduce the potential risk of later life osteoporosis (Rizzoli *et al.*, 2010). Furthermore, it may be potentially beneficial for practitioners to educate players about the foods that provide relatively high amounts of calcium, such as milk and yoghurts, and help athletes incorporate them into their habitual diet.

Previous research from our group have shown that the population investigated in the present study have higher protein diets (>1.5 g/kg/BM^{-1}) (Naughton *et al.*, 2016) in comparison with the current RNI (0.8 g/kg/BM^{-1}). A higher protein diet has been suggested to result in greater intake of micronutrients (Phillips *et al.*, 2015). It is proposed that foods that are high in quality protein (such as eggs, poultry, beef, dairy products etc.) are also high in important micronutrients – such as iron in beef, and calcium in dairy. Thus, due to the previous findings of the current authors, it is perhaps unsurprising that the majority of micronutrients RNIs are surpassed in the current study. This apparent additional benefit of dietary protein has perhaps been overlooked and potentially could be a method to increase micronutrient intake within adolescents; however, more research is required within this population. As new guidelines have only recently been published, it could also be potentially viewed that the schoolboy squads simply need an updated education on sugar consumption, which may help players understand how to decrease their FS intake through simple dietary alterations, such as decreasing the consumption of fruit juice and sports drinks.

A limitation of the current study is the use of food diaries to analyze nutritional habits, and indeed, previous research has shown a potential under-reporting effect of up to 20% (Burke and Deakin, 2010). Therefore, it is possible that we may have under-estimated the FS, fibre and micronutrient intakes reported here. However, this method is often used within this population (Russell and Pennock, 2011; Briggs, Cockburn, *et al.*, 2015; Naughton *et al.*, 2016), additionally, unpublished pilot research on the current study's population displayed a high completion rate (75%) over the 7-days (Naughton *et al.*, 2016). Furthermore, reporting micronutrient intake is not necessarily indicative of micronutrient status, therefore future research should aim to analyze blood samples to gain a more objective reflection of micronutrient status. Additionally, the sample population for the present study was taken from a single EPL academy based in the North-West of England, and therefore may not be fully representative of elite players based at other clubs in other regions or countries. Nonetheless, given that our macronutrient intake data reported previously (Naughton et al., 2016) is similar to other UK based EPL soccer academies (Russell and Pennock 2011; Briggs et al. 2015), we suggest that our data is indeed reflective of the UK adolescent soccer player.

In summary, we provide novel data by reporting the dietary FS and total sugar intake within elite youth soccer players. We report for the first time an apparent nutritional transition from schoolboy to fulltime soccer player in that players approaching adulthood consume less FS and total sugar than their younger counterparts. Importantly, all players (regardless of age) consume less dietary fibre intake than current recommendations though all squads generally met and exceeded micronutrient intakes, potentially due to high daily protein intakes. When taken together, these data suggest that nutritional educational packages for youth soccer players should also focus on strategies to reduce sugar and increase fibre consumption so as to promote both health and performance.

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Conflict of Interest

None

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Conflict of interest

None

Authorship

All authors contributed to the design of the study; RN collected and analyzed all data; RN, JA, EM, JPM, & IGD drafted the manuscript; All authors critically revised the manuscript; All authors approved the final manuscript for publication. There are no conflicts of interest to disclose.

Table 1. A comparison of age, body mass, height, BMI, soccer and non-soccer training between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads. Weekly training data adapted from Brownlee *et al.* (Unpublished data).

Squad	**Age (years)**	**Body Mass (kg)**	**Height (cm)**	**BMI (kg/m^2)**	**Soccer Training (min/week)**	**Non-Soccer Training (min/week)**
U13/14s	12.7 ± 0.6	44.7 ± 7.2	157.8 ± 11.0	17.9 ± 1.3	436 ± 29	33 ± 28
U15/16s	14.4 ± 0.5	60.4 ± 8.1	173.1 ± 7.8	20.1 ± 1.5	212 ± 57	81 ± 39
U18s	16.4 ± 0.5	70.6 ± 7.6	180.1 ± 7.3	21.7 ± 0.9	224 ± 38	89 ± 21

Values are mean ± SD.

Table 2. Total daily CHO and energy intake of all 3 squads. Adapted from Naughton *et al.* (2016) with permission.

Squad	Total carbohydrate intake (g/day)	Total energy intake (Kcal/day)
U13/14s	266.3 ± 58.4	1903 ± 432.4
U15/16s	275.1 ± 61.9	1926.7 ± 317.2
U18s	223.7 ± 79.9	1958.2 ± 389.5

Values are mean ± SD.

Table 3. A comparison of daily total- and free-sugar intake between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads and current UK DRVs or RNI were applicable.

	U13/14s (DRV/RNI)	**U15/16s** (DRV/RNI)	**U18s** (DRV/RNI)
Total-Sugar (% of TEI)	20.7 ± 4.7^	20.6 ± 5.1^	13.8 ± 3.3
Total-Sugar (g)	100.0 ± 36.1^	100.5 ± 34.8^	68.2 ± 23.2
Free-Sugar (% of TEI)	10.0 ± 17.7*^ (5)	11.2 ± 30.0*^ (5)	5.1 ± 12.7 (5)
Free-Sugar (g)	47.6 ± 19.2^	54.1 ± 23.8^	25.0 ± 12.4
Fibre (g)	19.0 ± 4.7* (25)	19.6 ± 8.3* (25)	17.1 ± 4.2* (30)

Values are mean ± SD. *Denotes significant difference from DRV / RNI. ^Denotes significant difference from U18s.

Footnote – TEI = Total energy intake; DRV = Dietary reference value; RNI = Reference nutrient intake

Table 4. Comparison of micronutrient intake for all 3 squads. RNI values are in brackets.

Micronutrient (units)	U13 - U14s (RNIs)	U15s – U16s (RNIs)	U18s (RNIs)
Sodium (mg)	2679.7 ± 779.6* (1600)	3048.2 ± 553.6* (1600)	2874.3 ± 800.3* (1600)
Potassium (mg)	3151.2 ± 720.3 (3100)	3044.1 ± 593.0 (3500)	3432.5 ± 508.7 (3500)
Chloride (mg)	3907.4 ± 1150.0* (2500)	4240.6 ± 794.0* (2500)	4074.3 ± 1366.1* (2500)
Calcium (mg)	1148.2 ± 382.1 (1000)	1035.4 ± 305.7 (1000)	883.1 ± 305.1 (1000)
Phosphorus (mg)	1625.7 ± 496.0* (775)	1485.2 ± 292.8*^ (775)	1874.2 ± 338.9* (775)
Magnesium (mg)	323.4 ± 73.9* (280)	298.0 ± 79.2 (300)	320.5 ± 64.8 (300)
Iron (mg)	13.2 ± 2.5* (11.3)	14.3 ± 3.9* (11.3)	15.0 ± 3.4* (11.3)
Zinc (mg)	10.3 ± 2.3*^ (9)	10.2 ± 2.5^ (9.5)	12.9 ± 2.1* (9.5)
Vitamin A (μg)	735.0 ± 271.9 (600)	695.6 ± 425.7 (700)	912.8 ± 414.8 (700)
B1 (mg)	1.8 ± 0.4* (0.9)	2.3 ± 2.0* (1.1)	1.9 ± 0.5* (1.1)
B2 (mg)	1.2 ± 0.7* (1.2)	2.1 ± 0.7* (1.3)	2.1 ± 0.5* (1.3)
B6 (mg)	2.6 ± 0.6* (1.2)	3.0 ± 0.7* (1.5)	3.1 ± 0.7* (1.5)

Folate (µg)	$318.7 \pm 84.7^{*}$ (200)	$343.6 \pm 101.0^{*}$ (200)	$329.4 \pm 60.0^{*}$ (200)
B12 (µg)	$5.4 \pm 2.4^{*\wedge}$ (1.2)	$4.5 \pm 1.2^{*\wedge}$ (1.5)	$7.0 \pm 1.7^{*}$ (1.5)
Vitamin C (mg)	$105.7 \pm 64.4^{*}$ (35)	$114.2 \pm 56.8^{*}$ (40)	$127.5 \pm 59.1^{*}$ (40)

Values are mean ± SD. *Denotes significant difference from DRV / RNI. $^{\wedge}$Denotes significant difference from U18s.

Table 5. A comparison of the three most frequent sources for free-sugar and fibre intake, expressed as percentage of players, between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads.

Squad	**Free-sugar (%)**	**Fibre (%)**
	Fruit Juices – 30	Bread – 35
U13/14s	Cereals – 15	Cereals – 25
	Cereal Bars – 13.3	Vegetables – 21.7
	Fruit Juice – 25.4	Bread – 38
U15/16s	Cereals – 18.3	Vegetables – 26.8
	Sports Drinks – 14.1	Fruit – 16.9
	Yoghurt Products – 20	Vegetables – 48.7
U18s	Cereals – 15	Fruit – 17.9
	Fruit Juice – 12.5	Bread – 17.9