Chapter 13
Nutrition

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Abstract
The nutritional requirements of a youth rugby player are influenced by their biological growth, maturation, and physical development in addition to the demands of training and competition. Given the anatomical, physiological, and metabolic difference between youth and adult rugby players it is inappropriate to simply apply the same nutrition guidelines for senior rugby players to youth populations. The energy and macronutrient requirements of youth rugby players are dictated by their total energy expenditures which increase in conjunction with age and body size. Youth rugby players appear to meet their daily fat and protein intakes, however it is likely that many players fail to achieve optimal carbohydrate intakes. Diet quality in this population does not meet current recommendations although it does appear to improve with age. The hydration requirements of youth players do not appear to differ from those of their adult counterparts however adolescent players may have greater calcium and iron requirements. Finally, although many players regularly consume dietary supplements there is limited evidence to support their use within this population. Future research is required particularly in youth female players to establish their current practices and nutritional requirements.

Introduction

As a youth rugby player progresses from childhood through adolescence and into adulthood, they undergo many anatomical, physiological, and metabolic changes as a result of biological growth and maturation (Beall, 1993). Growth and maturation (see Chapter 2) are complex processes that are influenced by many factors including the nutritional intake of an individual. As such, ensuring an appropriate energy and macronutrient intake throughout this important period is necessary to optimise growth and maturation, physical development and body composition (Chapters 3, 8 and 9 summarise the research on the assessment and development of anthropometry, body composition and physical development of youth rugby players), while maximising sporting performance in the growing youth rugby player. Additionally, developing a positive life-long relationship with food and body image is critical for the holistic development of youth rugby players. Therefore, this chapter will review the current literature on nutrition *specifically* in youth rugby players, including energy requirements, dietary intakes, hydration, micronutrients and supplements. The chapter will conclude by discussing the limitations of the current evidence base and potential future directions.

Energy Requirements

One of the key goals for maximising health and performance of a youth rugby player is to increase fat free mass (FFM) as they progress into adulthood (Geeson-Brown et al., 2020). To achieve this, it is essential that a player *at least* matches their energy intake to their energy expenditure. Therefore, the energy expenditure of a youth rugby determines their energy intake (i.e., their energy requirements) and subsequent macronutrient requirements in line with their individualised health, physical development, and performance goals. Consequently, it is first essential to understand the energy expenditure (and its sub-components) of a youth rugby player before evaluating their dietary energy and macronutrient intakes. Resting metabolic rate (RMR; the amount of energy required to sustain homeostatic physiology in a rested state), the thermic effect of food / diet induced thermogenesis (i.e., the amount of energy required for digestion, absorption, and transport of nutrients) and activity energy expenditure (both planned and unplanned) are the three major components that contribute towards total energy expenditure (TEE). However, the assessment of both RMR and TEE is challenging, due to the measurement error inherent within practical assessments of energy expenditure. For example, validated prediction equations typically under-estimate RMR (MacKenzie-Shalders et al., 2019; Smith et al., 2016), whilst combined wearable technology (SenseWear armbands and metabolic power) has been shown to significantly under-estimate the TEE of academy male rugby league players against the criterion DLW method (Costello, Deighton, Cummins, et al., 2019). As such, youth rugby literature that employs criterion measures (indirect calorimetry or doubly labelled water; DLW) is discussed below.

Resting Metabolic Rate

The RMR of youth male rugby players appear to increase as players get older, with under (U)20 players presenting higher absolute values than U16 players (Table 1). Interesting, Smith et al. (2018) recently demonstrated that RMR was similar between players at U16, U20 and U24 age groups, with players within the U16 and U20 age groups representing greater values then U24 players (~3-4 kcal·kg.day^{-1}) when normalised for changes in player body mass (Smith et al., 2016; Smith et al., 2018). Although speculative, this suggests that once adulthood has been achieved (a fully ossified skeletal system, a fully functioning reproductive system or the attainment of adult stature), there are no further increases in the RMR of youth rugby players (Smith et al., 2016). Resting metabolic rate has been shown to be variable in response to damaging activity, with baseline values increasing by 569 ± 244 kcal·day^{-1} (~23%), 344 ± 222 kcal·day^{-1} (~14%) and 224 ± 186 kcal·day^{-1} (~9%) in the 24-, 48- and 72-hours following competitive academy male rugby league match play, respectively (Costello, Deighton, Dalton Barron, et al., 2019). In contrast, there was a non-significant change (-16 kcal·day^{-1}; -0.5 kcal·kg·day^{-1}) in the RMR of eighteen U20 rugby union players across a 14-week pre-season, despite an average increase of ~2 kg in fat-free mass across the squad (MacKenzie-Shalders et al., 2019). Finally, validated prediction equations (Schofield, Cunningham, Harris-Benedict) typically under-estimate the measured RMR of youth rugby players (MacKenzie-Shalders et al., 2019; Smith et al., 2016).

Total Energy Expenditure

The TEE of youth rugby players also appear to increase as players get older, with U20 players presenting higher values than U16 players (Table 13.1). Recently, Smith et al. (2018) demonstrated that TEE increased in a hierarchal manner across U16, U20 and U24 age groups, which coincided with an increase in player body mass and FFM. Interestingly, when expressed relative to player body mass, TEE was similar between age-groups (~50 kcal·kg·day^{-1}; (Smith et al., 2018). However, absolute TEEs varied by up to ~4,000 kcal·day^{-1}, highlighting a large inter-individual variability between players, even amongst those competing within the same rugby code(Smith et al., 2018). Total energy expenditure has been shown to be elevated in response to damaging activity, with a collision-based training session (inclusive of 10 tackles and 10 hit-ups) significantly increasing the TEE (1185 ± 232 kcal; 5%) of academy male rugby league players (Costello, Deighton, et al., 2018).

INSERT TABLE 13.1 HERE

Physical Activity Levels

Physical activity level (PAL) represents activity energy expenditure, which is expressed as a magnitude of the RMR of an individual (PAL = TEE / RMR). This value enables direct comparison between athletes, while also permitting estimation of TEE if RMR is known (Westerterp, 2013) Considering both RMR and TEE are required to calculate PAL there are limited studies that have measured this value in youth rugby players (Table 13.1). Recently, Smith et al. (2018) demonstrated identical PALs between U16 and U20 rugby league and union players, with an increase of 0.3 arbitrary units (AU) highlighted in the U24 age group (Smith et al., 2018). The PALs reported by Smith and colleagues (2018) are 0.2 and 0.3 AU higher than PALs observed in U19 male rugby league players across a 14-day pre-season (Costello, Deighton, et al., 2018; Costello, McKenna, et al., 2018) and 7-day in-season microcycle (inclusive of one competitive match), respectively (Costello et al., *unpublished observations*). Interestingly, the PALs of senior professional male rugby players range from 2.1-2.9 AU (Morehen et al., 2016; Smith et al., 2018), compared to the range of 1.5 – 1.9 seen in youth players demonstrating a marked increase in activity energy expenditure from youth to senior age groups within elite rugby. This may be due to adult players experiencing a higher exercise intensity and/or an increased number of collisions during training and match play compared to youth players.

Dietary Intake

The dietary intakes of youth male rugby players by age, position and code are shown in Table 13.2. The self-reported energy and macronutrient intakes of youth male rugby players appear to increase with age (i.e., U20 greater than U16). For example, Smith et al. (2016) reported a significantly greater energy (+371 kcal$\cdot$day^{-1}), protein (+57 g$\cdot$day^{-1}) and fluid (+1084 ml$\cdot$day^{-1}) intake in U19 compared to U16 rugby league and rugby union players across a four-day pre-season period (Smith et al., 2016). For positional comparisons, U20 male rugby union forwards reported consuming more energy (+616 kcal·day^{-1}), carbohydrate (CHO, +100 g·day^{-1}), protein (+13 g·day^{-1}) and fat (+15 g·day^{-1}) than backs from a university team in Japan (Imamura et al., 2013). However, when normalised for changes in player body mass, the dietary energy and macronutrient intakes of youth rugby players are similar across age and positional groups. This suggests that an increased body size (particularly body mass) results in greater absolute differences in dietary intake self-reported across age groups and positions.

Dietary Energy

The energy intakes of youth male rugby players typically fail to achieve recommendations or requirements, although these are subject to measurement error. The average self-reported energy intakes of youth male rugby players range from 37.9-40.5 kcal·kg^{-1}·day^{-1} (3009-3269 kcal·day^{-1}) and ~29-65.0 kcal·kg^{-1}·day^{-1} (2378-5855 kcal·day^{-1}) across U16 and U19 age groups, respectively (Table 13.2). Considering that elite youth male rugby players expend ~ kcal·kg^{-1}·day^{-1} on average (Smith et al., 2018), current youth rugby literature suggests that players are under fuelling (Bouhlel et al., 2006; Burrows et al., 2016; Costello, Deighton, et al., 2018; Imamura et al., 2013; MacDougall et al., 2015; MacKenzie-Shalders et al., 2019; MacKenzie et al., 2015; Petri et al., 2016; Smith et al., 2016) . However, consideration is required for the measurement error inherent within the assessment of energy intake across some studies. For example, twenty-five elite U20 rugby union players self-reported an average energy deficit of -1,200 kcal·day^{-1} across a seven-day pre-season period, despite gaining 1.7 ± 1.6 kg of lean mass and 1.1 ± 2.5 kg of overall body mass across a fourteen-week pre-season (MacKenzie et al., 2015). Clearly, the accurate assessment of energy intake is challenging for youth rugby players (Costello et al., 2017) with substantial measurement error of up to 1,030 kcal·day^{-1} reported amongst individuals against a DLW criterion (version of the remote food photography method; (Costello, Deighton, Dalton Barron, et al., 2019). Conversely, nine national U20 rugby union players in Tunisia self-reported a large average negative energy balance of -1,123 kcal·day^{-1} during Ramadan (range: -48 to -1911 kcal·day^{-1}), which corresponded in an average body mass loss of 1.8 kg (Bouhlel et al., 2006).

Dietary Carbohydrate (CHO)

The CHO intakes of youth male rugby players typically fail to achieve daily recommendations, potentially providing insufficient substrate for glycolytic and oxidative metabolism during training and competition, in addition to requirements for overall energy for growth and maturation. Although there are no CHO guidelines specific to youth rugby players, CHO recommendations range from 6-10 g·kg·day^{-1} for athletes engaged in one to three hours of high-intensity exercise (Burke et al., 2011), 5-7 g·kg·day^{-1} for one-hour moderate exercise programs (Thomas et al., 2016), or 6-8 g·kg·day^{-1} around team sport match-play (i.e., soccer) (Collins et al., 2021). Intriguingly, the self-reported CHO intakes of youth rugby players typically fall below 5 g·kg·day^{-1} (Table 13.2), suggesting that current intakes are typically insufficient. Interestingly, Walsh et al. (2011) depicted that 123 youth rugby players in Ireland (over two-thirds of the investigated sample) were unaware that some form of CHO should be consumed during match-play, while 62% thought steak and salad (a meal containing negligible CHO) was a good refuelling meal (Walsh et al., 2011). It is perhaps unsurprising then that sub-optimal CHO intakes have been reported by U18 national rugby union players on match (4.4 ± 1.7 g·kg·day^{-1}), training (4.3 ± 1.4 g·kg·day^{-1}) and rest (3.9 ± 1.6 g·kg·day^{-1}) days (Petri et al., 2016). Finally, consideration is required for the dietary practices of youth rugby players around religious events, with nine national U20 rugby union players in Tunisia self-reporting a decrease of ~245 g·day^{-1} (~2.9 g·kg·day^{-1}) of CHO during the holy month of Ramadan in comparison to baseline (Bouhlel et al., 2008).

INSERT TABLE 13.2 HERE

Dietary Protein

The protein intakes of youth male rugby players typically exceed daily recommendations. Although there are no protein guidelines specific to youth rugby players, protein intakes of 1.2-2.0 $g \cdot kg \cdot day^{-1}$ are recommended within athletic populations (Thomas et al., 2016). Greater protein intakes are only advised during periods of player injury (1.6-2.5 $g \cdot kg \cdot day^{-1}$) or weight loss (1.8-2.7 $g \cdot kg \cdot day^{-1}$) (Egan, 2016). Therefore, protein intakes of >2.0 $g \cdot kg \cdot day^{-1}$ are potentially excessive within injury-free, eucaloric or hypercaloric youth rugby cohorts (Costello, Deighton, et al., 2018; Costello, McKenna, et al., 2018; MacKenzie-Shalders et al., 2019; MacKenzie et al., 2015; Smith et al., 2016). Of note, youth rugby players from Tunisia, Japan and Italy reported protein intakes of <1.6 $g \cdot kg \cdot day^{-1}$ (Bouhlel et al., 2008; Imamura et al., 2013; Petri et al., 2016), potentially highlighting cultural differences in dietary protein practices or beliefs in comparison to the United Kingdom (Costello, McKenna, et al., 2018; Smith et al., 2016) or the Southern Hemisphere (MacKenzie-Shalders et al., 2019; MacKenzie et al., 2015). Interestingly, U20 rugby union players in Australia have been shown to consume moderate to large protein intakes regularly throughout the day (protein distribution score^{20g}: 3.8 ± 0.9), although often failed to consume a high-quality protein source prior to sleep (MacKenzie et al., 2015). However, purposefully increasing protein distribution from four to six eating occasions, while maintaining total protein intake, in a cross-over design did not significantly increase lean mass gains in twenty-four elite developing rugby union players across a rugby union pre-season (MacKenzie-Shalders et al., 2019).

Dietary Fat

The fat intakes of youth male rugby players typically fall within the upper limit of daily recommendations, however saturated fat intakes exceed guidelines. Although there are no fat guidelines specific to youth rugby players, dietary fat recommendations for athletes replicate public health guidelines, which should fall between 20-35% of total energy intake (Thomas et al., 2016). Consequently, the daily fat intakes of youth rugby players appear largely appropriate, ranging from 23-34% of total energy intake (Table 13.2). Alternatively, consumption of saturated fats typically exceeds recommendations (<10% of total energy intake) with youth players in Australia, England and America surpassing recommendations by 5%, 2% and 3%, respectively (Burrows et al., 2016; MacDougall et al., 2015; Smith et al., 2016). Interestingly, Thivel et al. (2015) demonstrated that adolescent rugby players prioritised meals containing greater amounts of fat following exercise sessions that they deemed more difficult, potentially providing evidence for a hedonic control of energy intake following intensive exercise (Thivel et al., 2015). Collectively, it is possible that the increased energy content and palatability of foods high in saturated fat drives the intakes currently self-reported in youth rugby players (Burrows et al., 2016; Thivel et al., 2015). Finally, fasting during the holy month of Ramadan resulted in a significant increase in the total energy intake from dietary fat (33 to 44%) (Bouhlel et al., 2008). As a result, lipids were more readily available (e.g., plasma triglycerides and high density lipoproteins cholesterol), and used to a greater extent as an energy source than prior to Ramadan (Bouhlel et al., 2008).

Dietary Alcohol

Alcohol intakes are rarely reported in youth rugby populations, but if they are included in the study, alcohol is typically concentrated in post-match periods where optimal recovery should be prioritised. Youth rugby players typically self-report low intakes of dietary alcohol (Table 13.2. For example, U19 academy rugby league players from the United Kingdom reported consuming 0.4% and 1.5% of total energy intake from alcohol per day across a ten-day pre-season (Costello, Deighton, et al., 2018) and seven-day in-season microcycle (Costello et al., *unpublished observations*), respectively. Such intakes appear appropriate in comparison to guidelines for adults within the general population (<5% of total energy intake) (Committee on Medical Aspects of Food and Nutrition Policy, 1991). However, intakes occurred in a youth population where several players were under the legal drinking age of 18 years. Moreover, in-season intakes were solely concentrated within post-match periods, with five of the seven players investigated drinking after the competitive game (Costello et al., *unpublished observations*). Consequently, post-match alcohol intakes were large (average: 55 ± 62 g or 7 ± 8 units; range: 0-154 g or 0-19 units), with similar findings also reported in South African Varsity Cup university students (~7 units·person^{-1} following match-play)(Potgieter et al., 2014). Considering public health guidelines state weekly alcohol intakes of 14 units spread over at least three days for adults, such intakes could be considered excessive within youth rugby populations (Department of Health, 2016). Finally, Walsh et al. (2011) outlined that a high prevalence for underage drinking in youth rugby players in Ireland (83.1% of 16-year-olds), although dietary patterns and quantities of intake were not investigated (Walsh et al., 2011).

Diet Quality

The diet quality of youth male rugby players can be improved, although are in alignment with their non-rugby peers. Youth rugby players typically report low intakes of fruits (MacDougall et al., 2015; Smith et al., 2016), vegetables (Burrows et al., 2016; Imamura et al., 2013; MacDougall et al., 2015; Smith et al., 2016) and dairy (Burrows et al., 2016; Smith et al., 2016) For example, non-elite players in Australia reported consuming 1.1 servings of vegetables per day, while U20 rugby union players in the United States of America reported consuming 0.8

servings of fruit per day (MacDougall et al., 2015). As expected, youth rugby players have consistently reported consuming more foods than recommended from the fats and sugars food groups (Burrows et al., 2016; Imamura et al., 2013; MacDougall et al., 2015; Smith et al., 2016). For example, sweetened drinks (soft drinks, cordials, sports drinks, juice), confectionary (chocolates, candy) and takeout meals (included hamburgers, fries, pies, sausage rolls) represented 4.4%, 5.4% and 8.1% of total energy intake for youth players in Australia, respectively (Burrows et al., 2016). Interestingly, Smith et al. (2016) highlighted an improvement in dietary quality with age, with U19 rugby league players consuming greater servings of fruit and vegetables, non-dairy proteins and lower intakes of fats and sugars in comparison to U16 players (Smith et al., 2016). Finally, the dietary behaviours of youth rugby players are influenced by their peers and role models (Stokes et al., 2018).

Hydration

There is limited research investigating the dietary fluid intakes of youth rugby players, especially in warmer climates. Although there are no fluid guidelines specific to youth rugby players, dietary fluid recommendations for athletes range from 30-35ml.kg^{-1} (Thomas et al., 2016). Youth male U16 and U19 mixed rugby union and rugby league players have self-reported consuming 3.1 ± 1.0 and 4.2 ±1.3 litres of fluid per day across a four-day pre-season period, inclusive of a weekend, respectively (Smith et al., 2016). There was no significant difference in fluid intake across rugby code (Smith et al., 2016). Although there is limited comparative fluid intakes for youth rugby players, reported intakes were within recommendations and likely adequate to maintain fluid balance given losses were similar to those previously reported in senior rugby union (Jones et al., 2015; Smith et al., 2016) and rugby league players (O'Hara et al., 2010) in the northern hemisphere. Irish school rugby players had good knowledge of correct hydration practices (mean score: 76.3%), with 99% of players following recommendations to consume fluid during exercise (Walsh et al., 2011). Finally, there was a significant decrease of 1.1 litres in fluid intake during Ramadan (3.7 ± 0.7 *vs.* 2.6 ± 0.9 l), which resulted in a significant decrease of 9.6% in plasma volume (Bouhlel et al., 2008).

Whilst the hydration requirements (in addition to fluid and electrolyte balance) of adult rugby players in both training and match-play scenarios are well documented (Cosgrove et al., 2014; Love et al., 2018; Meir & Halliday, 2005) there is limited research in youth rugby players. Bargh et al., (2017) investigated fluid losses and intake in ten academy male rugby league players (17 ± 1 years old) during rugby training, which consisted of 6 x 6-minute bouts of intermittent non-contact small-sided games (interspersed with 2 minutes passive rest; ~46 mins in total (Bargh et al., 2017). During training *ad libitum* drinking of fluids was permitted. Interestingly, 50% of players arrived for training in a hypohydrated state (>295 $mOsmol{\cdot}kg^{-1}$) and these players consumed significantly less fluid during training compared to players who arrived in a euhydrated state. During training players consumed 0.88 ± 0.38 kg of fluid (range: 0.41–1.38 kg) and had net fluid losses of 1.02 ± 0.31 kg (range: 0.49–1.51 kg). Players sweat rate was 1.15 ± 0.35 $L{\cdot}h^{-1}$ which resulted in a decrease of –0.17 ± 0.59 % in body mass. It should be noted that there was a large range in both sweat rate and fluid intake between players, highlighting the need for an individualised approach to hydration strategies. Muth et al. (2019) also reported that male and female university players consumed enough water during training to prevent a >2% decrease in body mass and maintain a euhydrated state (Muth et al., 2019). Taken together these data demonstrate that youth rugby players consume enough fluid to prevent performance decrements associated with dehydration during training. During match-play, fluid losses of 2.1 ± 0.7 kg (equating to -2.5 ± 0.7 % decrease in body mass) in South African university players in hot conditions (24-25 ˚C) were observed (Goodman et al., 1985)

Micronutrients

Iron and calcium are often targeted as key micronutrients in youth populations (Desbrow et al., 2014), and intakes have been found to be higher in Australian youth players compared to age matched non-rugby players (Burrows et al., 2016), but lower than the national Recommended Dietary Allowances in Japanese and Italian samples (Imamura et al., 2013; Petri et al., 2016). Low iron intakes have not been found to be associated with poorer clinical outcomes (Imamura et al., 2013). One study found intakes of Vitamin E, potassium and magnesium intakes were below recommended values (MacDougall et al., 2015) but these were correlated with poor dietary quality around low vegetable intake. Micronutrient requirements are difficult to determine in growing athlete populations and to the authors knowledge no studies have been done in youth rugby to evaluate the prevalence or treatment of micronutrient deficiencies. Any dietary exclusions (e.g., vegetarian or vegan, lactose or dairy free, gluten free, allergies, texture or taste aversions) should be referred to nutrition professionals in order to ensure that there are no further micronutrient concerns.

Supplements

Research investigating the need and efficacy for supplementation in youth sport is sparse. However, supplement intake ranges from 8% (Burrows et al., 2016), 26% (Imamura et al., 2013), 42% (Duvenage et al., 2015), 65% (Walsh et al., 2011), up to 74% (Smith et al., 2016) across Australian, Japanese, South African, Irish and English youth male rugby players respectively. Supplemental protein and multivitamin products were most popular, and usage tended to increase with age (Smith et al., 2016). Protein supplements contributed 33% of daily protein intake in university players, where daily intakes from food were already meeting standard requirements (Potgieter et al., 2014). Advice on supplementation was most often sourced from coaches, not qualified nutrition professionals (Duvenage et al., 2015; Walsh et al., 2011). The majority of players reported via questionnaires that protein supplements are necessary for their growth and strength development, or convenient and better quality compared to food, illustrating gaps in the fundamental ‘food first’ principles (Duvenage et al., 2015; Stokes et al., 2018; Walsh et al., 2011). Studies in U16 players found poor nutrition knowledge in general but this was no different between those who supplemented and those who did not (Duvenage et al., 2015; Walsh et al., 2011).

To date, there are three studies evaluating supplement interventions in youth populations. Creatine usage (loading and maintenance phase) was shown to improve dihydrotestosterone to testosterone ratio in college-aged rugby players (Merwe et al., 2009). This may promote muscle mass accrual but the supplements were not batch tested, leading to concerns about supplement contamination. Another study in collegiate rugby players (21 ±1.6 years) showed no advantage of adding β-hydroxy β-methylbuterate to creatine over the course of a season (Mangine et al., 2020). Unfortunately, there was no control group to show the impact of the creatine alone. In a separate study, montmorency cherry juice did not reduce markers of muscle soreness or inflammation in response to a rugby league match in youth players (Morehen et al., 2021). There have been no other intervention studies in U18 rugby players evaluating the impact of any supplement. As there is limited research investigating the need for, or the efficacy of supplements in a growing youth rugby population, all current position stands advocate a food first approach, with only clinically necessitated supplementation provided under professional supervision (Claassen, 2011; Desbrow et al., 2019; Desbrow et al., 2014). Consideration is required for unwarranted supplementation being a potential additional risk factor towards doping behaviours (Backhouse et al., 2013), especially within a sport that prioritises size and FFM.

Limitations

Research in youth populations can be challenging due to ethical and safe-guarding constraints. Unfortunately, this is reflected in large gaps in the youth sport literature, including in youth rugby. Much of the current research in youth rugby focuses on the chronological age of players (i.e. age-group) but often fails to account for biological age (i.e. maturity status) too. Given the potentially large differences between a players chronological and biological age, these should both be included to provide more context to the data. Whilst it is acknowledged there are more youth males that play rugby compared to youth females, there is a distinct paucity of research investigating female players so very little is known this population. Finally, it is also widely reported that dietary intake studies in youth populations are confounded by similar limitations to those in adult athletes. Self-reported dietary intake is subject to under-reporting and also errors in both validity and reliability.

Future Research Directions

The above limitations of the youth rugby literature should help guide future research. More studies are needed in female populations and future research should include the biological age of players in addition to their chronological age. Considering the distinct differences in thermoregulation mechanisms between adult and youth athletes (Hannon et al., 2021), further research investigating fluid balance and hydration requirements in youth rugby players is warranted. A greater understanding of players nutrition knowledge and skills in different countries and age-groups is required and also whether nutrition knowledge translates into behaviour. Given the increasing presence of social media and its influence on food choices research specifically within this population is warranted. Finally, collaborative projects that can draw on larger sample sizes should be prioritised, to elucidate inter and intra player variation to provide practitioners with more accurate requirements.

Conclusion

The nutritional requirements of a youth rugby player are influenced by their biological growth and maturation, the demands of training and competition, alongside a requirement to significantly increase FFM and overall BM in line with senior populations. The energy intakes of youth rugby players increase in conjunction with age and body size and align to increases in energy expenditures and subsequent energy requirements. Whilst most players appear to meet their daily fat and protein intakes, it is likely that many players fail to achieve optimal carbohydrate intakes for performance. Diet quality in this population does not meet current recommendations although it does appear to improve with age. Acknowledging that research is limited, the hydration requirements of youth players do not appear to differ from those of their adult counterparts however adolescent players may have a greater need for calcium and iron. Finally, although many players regularly consume dietary supplements there is limited evidence to support their use within this population.

Table 13.1. Resting metabolic rate, total energy expenditure and physical activity level of youth rugby players spilt by age and code. Data is reported as mean ± standard deviation (table continues onto the next page).

Reference	Population	Demographics	Assessment period	Assessment Method	RMR (kcal·day⁻¹) (kcal·kg·day⁻¹) (kcal·kg·FFM·day⁻¹)	TEE (kcal·day⁻¹) (kcal·kg·day⁻¹) (kcal·kg·FFM·day⁻¹)	PAL
U16s (mixed)							
Smith et al. (2018)	10 elite male players, United Kingdom	*Rugby Union* N = 5 16 ± 1 years 85.4 ± 17.3 kg *Rugby League* N = 5 15 ± 1 years 79.3 ± 17.1 kg	14-days In-season	RMR: Indirect calorimetry TEE: DLW PAL: TEE/RMR	2168 ± 353 26 ± 5 33 ± 4	4010 ± 744 50 ± 8 62 ± 8	1.9 ± 0.2
U20s (rugby union)							
MacKenzie-Shalders et al. (2019)	18 elite male players, Australia	20 ± 2 years 101.2 ± 14.5 kg	Star & end of a 14-week period Pre-season	RMR: Indirect calorimetry	Start: 2389 ± 263 ~23 ~29 End: 2373 ± 270 ~23 ~28	-	-
U20s (rugby league)							
Costello et al. (2018a)	6 academy male players, United Kingdom	17 ± 1 years 87.3 kg	14-days Pre-season	RMR: Indirect calorimetry TEE: DLW PAL: TEE/RMR	2657 ± 537 30 ± 3 -	4388 ± 728 50 ± 3 -	1.7 ± 0.2

Reference	**Population**	**Demographics**	**Assessment period**	**Assessment Method**	**RMR** (kcal·day^{-1}) (kcal·kg·day^{-1}) (kcal·kg·FFM·day^{-1})	**TEE** (kcal·day^{-1}) (kcal·kg·day^{-1}) (kcal·kg·FFM·day^{-1})	**PAL**
			U20s (rugby league continued)				
Costello et al. (2018c)	1 academy male player, United Kingdom	18 years 84.4 kg	14-days Pre-season	RMR: Indirect calorimetry TEE: DLW PAL: TEE/RMR	3513 42 -	5353 63 -	1.5
Costello et al. (*unpublished observations*)	7 academy male players, United Kingdom	18 ± 1 years 88.5 ± 9.7 kg	7-days In-season	RMR: Indirect calorimetry TEE: DLW PAL: TEE/RMR	2464 ± 353 28 ± 2 -	3861 ± 184 44 ± 3 -	1.6 ± 0.2
			U20s (mixed)				
Smith et al. (2018)	9 academy male players, United Kingdom	*Rugby Union* N = 4 18 ± 1 years 85.1 ± 8.3 kg *Rugby League* N = 5 18 ± 1 years 87.6 ± 8.8 kg	14-days In-season	RMR: Indirect calorimetry TEE: DLW PAL: TEE/RMR	2318 ± 335 27 ± 4 35 ± 5	4414 ± 688 51 ± 9 66 ± 10	1.9 ± 0.3

Note: Resting metabolic rate (RMR). Total energy expenditure (TEE). Physical activity level (PAL). Doubly labelled water (DLW). Fat-free mass (FFM). '~' denotes an estimation from the available data. '-' denotes data not available.

Table 13.2. Dietary energy and macronutrient intakes of youth rugby players spilt by age and code. Data is reported as mean ± standard deviation or median (interquartile range) (table continues over the next three pages).

Reference	Population	Demographics (Age: years) (Body mass: kg)	Assessment style and period	Energy (kcal·day^{-1}) (kcal·kg^{-1}·day^{-1})	CHO (g·day^{-1}) (g·kg^{-1}·day^{-1})	Protein (g·day^{-1}) (g·kg^{-1}·day^{-1})	Fat (g·day^{-1}) (g·kg^{-1}·day^{-1})	Alcohol (g·day^{-1}) (g·kg^{-1}·day^{-1})
U16s (rugby union)								
Smith et al. (2016)	31 elite male players, United Kingdom	16 ± 1 83.9 ± 12.0	4-day FD (Fri to Mon) Pre-Season	3269 ± 766 37.9 ± 10.4	392 ± 108 4.8 ± 1.1	155 ± 56 1.9 ± 0.6	112 ± 34 1.4 ± 0.5	-
U16s (rugby league)								
Smith et al. (2016)	22 elite male players, United Kingdom	16 ± 1 75.2 ± 9.6	4-day FD (Fri to Mon) Pre-Season	3009 ± 804 40.5 ± 11.3	395 ± 107 5.3 ± 1.6	145 ± 46 1.9 ± 0.6	105 ± 32 1.4 ± 0.4	-
U20s (rugby union)								
Bouhlel et al. (2006)	9 national male players, Tunisia	19 ± 2 80.4 ± 16.6	7-day FD (Before Ramadan) 28-day FD (During Ramadan)	*Before Ramadan*				
				4028 ± 722 ~50	559 ± 91 ~6.9	116 ± 19 ~1.4	148 ± 34 ~1.8	-
				During Ramadan				
				2890 ± 898 ~37	315 ± 102 ~4.0	84 ± 26 ~1.1	144 ± 56 ~1.8	-
Imamura et al. (2013)	34 university male players, Japan	*Backs* 20 ± 1 72.6 ± 7.4	FFQ and dietary questionnaire Pre-season	*Backs*				
				2963 ± 111 ~41	457 ± 192 6.3 ± 2.8	80 ± 31 1.1 ± 0.4	77 ± 31 ~1.1	3.8 ± 3.9 ~0.0
		Forwards 20 ± 1 87.3 ± 8.9		*Forwards*				
				3579 ± 848 ~41	567 ± 160 6.5 ± 1.9	93 ± 22 1.1 ± 0.3	92 ± 25 ~1.1	1.9 ± 3.6 ~0.0
MacKenzie et al. (2015)	25 elite male players, Australia	20 ± 2 years 100.2 ± 13.3 kg	7-day FD Pre-season	3251 ± 869 33.4 ± 10.7	352 ± 115 3.6 ± 1.3	211 ± 62 2.2 ± 0.7	101 ± 34 1.1 ± 0.5	-
Macdougall, Balilionis and Svetlana (2015)	15 collegiate male players, USA	20 ± 1 years 81.9 ± 16.5 kg	3 x 24-hour recall (2 week, 1 weekend) Off-season	2378 ± 126 ~29.0	~278 3.4 ± 1.1	~139 1.7 ± 0.80	~90 ~1.1	-

Reference	Population	Demographics (Age: years) (Body mass: kg)	Assessment style and period	Energy (kcal·day^{-1}) (kcal·kg^{-1}·day^{-1})	CHO (g·day^{-1}) (g·kg^{-1}·day^{-1})	Protein (g·day^{-1}) (g·kg^{-1}·day^{-1})	Fat (g·day^{-1}) (g·kg^{-1}·day^{-1})	Alcohol (g·day^{-1}) (g·kg^{-1}·day^{-1})
U20s (rugby union continued)								
{Smith, 2016 #253}Smith et al. (2016)	21 academy male players, United Kingdom	18 ± 1 years 92.4 ± 13.4 kg	4-day FD (Fri to Mon) Pre-Season	3412 ± 670 38.2 ± 9.8	416 ± 107 4.7 ± 1.4	211 ± 47 2.3 ± 0.5	112 ± 35 1.3 ± 0.5	-
Burrows et al. (2016)	25 non-elite male players, Australia	14-18 76.5 ± 10.0	FFQ Pre-season	2481 (1189) ~32.0	317 ± 153 3.5 (2.4)	108 (761) 1.5 (0.8)	88 (54) ~1.1	-
Petri et al. (2016)	22 youth national male RU players, Italy	*Backs* 18 ± 1 years 79.6 ± 11.1 kg	3 x 24 hour recall (1 training, 1 MD, 1 rest day) In-season	*Backs*				
				2438 ± 559 ~30.6	~350-374 4.4-4.7	~103-143 1.3-1.8	~72-88 0.9-1.1	-
		Forwards 18 ± 1 years 101.3 ± 9.6 kg		*Forwards*				
				3078 ± 698 ~30.3	~365-446 3.6-4.4	~142-182 1.4-1.8	~91-111 0.9-1.1	-
Nagayama et al. (2018)	11 youth male national-level RU players, Japan	17 ± 1 69.3 ± 7	4-day weighed FD with pictures Training camp	3546 ± 408 ~51.0	~547 7.9 ± 1.1	~118 1.7 ± 0.2	~97 1.4 + 0.1	-
U20s (rugby league)								
Smith et al. (2016)	13 academy male players, United Kingdom	18 ± 1 years 85.3 ± 8.5 kg	4-day FD (Fri to Mon) Pre-Season	3432 ± 714 40.8 ± 8.6	444 ± 102 5.3 ± 1.3	189 ± 50 2.2 ± 0.5	111 ± 26 1.3 ± 0.3	-
Costello et al. (2018a)	6 academy male players, United Kingdom	18 ± 1 years 85.2 ± 8.3 kg	5-day RFPM x 2 (Mon to Fri) Pre-Season	3998 ± 73 46.7 ± 8.3	445 ± 64 5.2 ± 1.2	224 ± 48 2.6 ± 0.8	149 ± 25 1.8 ± 0.3	1.5 ± 3.7 0.0 ± 0.0
Costello et al. (2018c)	1 academy male players, United Kingdom		4-day RFPM x2 Pre- and post-intervention. (Fri to Mon)	Pre-intervention				
				3991 47.2	440 5.2	142 1.6	142 1.6	18 0.2
		18 years 84.4 kg		Post-intervention				
				5855 65.0	645 7.1	331 3.6	213 2.3	0 0.0
Costello et al. (*unpublished observations*)	7 academy male players, United Kingdom	18 ± 1 years 88.5 ± 9.7 kg	7-day RFPM (Thurs to Wed) In-Season	3692 ± 341 41.9 ± 4.5	420 ± 60 4.7 ± 1.0	188 ± 28 2.1 ± 0.3	172 ± 25 1.5 ± 0.1	8 ± 9 0.0 ± 0.0

Reference	**Population**	**Demographics** (Age: years) (Body mass: kg)	**Assessment style and period**	**Energy** ($kcal \cdot day^{-1}$) ($kcal \cdot kg^{-1} \cdot day^{-1}$)	**CHO** ($g \cdot day^{-1}$) ($g \cdot kg^{-1} \cdot day^{-1}$)	**Protein** ($g \cdot day^{-1}$) ($g \cdot kg^{-1} \cdot day^{-1}$)	**Fat** ($g \cdot day^{-1}$) ($g \cdot kg^{-1} \cdot day^{-1}$)	**Alcohol** ($g \cdot day^{-1}$) ($g \cdot kg^{-1} \cdot day^{-1}$)
U20s (mixed)								
MacKenzie-Shalders et al. (2016)	24 elite male RU and RL players, Australia	*Group 1* N = 12 20 ± 1 years 102.4 ± 13.0	X6 24 hour recall across 6 weeks Pre-season	*Group 1 (bolus protein condition)*				
				3768 ± 877 37 ± 10	363 ± 113 3.6 ± 1.3	272 ± 45 2.7 ± 0.6	125 ± 36 1.3 ± 0.4	-
		Group 2 N = 12 20 ± 2 100.8 ± 10.6		*Group 2 (frequent protein condition)*				
				3772 ± 785 37 ± 10	372 ± 93 3.7 ± 1.1	262 ± 45 2.6 ± 0.6	128 ± 41 1.3 ± 0.5	-

Note: Carbohydrate (CHO). Food frequency questionnaire (FFQ). Food diary (FD). Remote Food Photography Method (RFPM) (Costello et al., 2017). '~' denotes an estimation from the available data.

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