Journal of Science in Sport and Exercise
https://doi.org/10.1007/s42978-022-00171-3

REVIEW ARTICLE

Nutritional Considerations in High Performance Youth Soccer: A Systematic Review

Matthew North[1] · Adam L. Kelly[1] · Mayur K. Ranchordas[2] · Matthew Cole[1]

Received: 24 August 2021 / Accepted: 28 April 2022

Abstract

Purpose As players in high performance youth soccer (HYPS) environments undergo large changes in growth and maturation throughout the course of their development, they require specific nutritional intakes if they are to meet these demands. The purpose of this review was to synthesise current nutritional research conducted within HYPS players.

Methods A systematic approach, following PRISMA guidelines, was employed to capture all articles related to nutrition within HPYS using the databases MEDLINE and SPORTDiscus. Study quality and risk of bias were assessed using a Downs and Black instrument. Observational and intervention studies which investigated an element of nutritional status, knowledge, or intervention in academy aged players (U9 to U23s) within HPYS settings were included.

Results Fifty-three articles qualified assessing: current nutritional intake and energy balance ($n=21$); ergogenic aids/supplements ($n=13$); hydration status ($n=6$); the influence of Ramadan fasting ($n=4$); Vitamin D status ($n=4$); female HPYS players ($n=3$); nutrition knowledge ($n=2$). Outcomes demonstrate a large proportion of HPYS players exhibit insufficient energy and carbohydrate intake, and a lack sufficient periodisation of nutrition to account for varying training/match loads. Large variability in energy intake and expenditure exists between and within chronological age groups, indicating the potential impact on growth and maturation. Female HPYS data is lacking but indicates similar trends to male counterparts.

Conclusion HYPS players do not currently meet their energy requirements however the impact of growth and maturation is not fully understood. Furthermore, within this demographic future research is required into the barriers and enablers of players achieving adequate energy intake.

Keywords Nutrition · Youth soccer · Nutritional intake · Supplements · Hydration

Introduction

The future of sport is determined by the development of youth athletes with a large emphasis placed on talent pathways to release their potential [56]. Within the context of soccer, developmental pathways are mapped by governing bodies that begin at grassroot levels and progress towards high-performance environments like academies. These environments aim to develop players across a range of areas (i.e., technical, tactical, physical, psychological, and social), with the goal of producing first-team players [33, 56]. From a business viewpoint, one of the key aims is financial profit [89] from selling players, therefore, the development of home-grown players can provide advantages to the club from a sporting performance and business perspective. This has led to a greater emphasis on a multidisciplinary approach to develop elite environments and seek out significant change through marginal gains.

As players progress through an academy, training and match-play demands are developed to coincide with their development to avoid the risk of injury [11]. However, emerging research indicates this may not always happen, with individuals in the U18 age group actually displaying higher training loads than their adult counterparts [46]. Additionally, while in academies, players undergo rapid growth and maturational changes which result in physiological, anatomical, and biological changes [45]. Therefore,

✉ Matthew Cole
Matthew.Cole@bcu.ac.uk

[1] Research Centre for Life and Sport Sciences (CLaSS), Birmingham City University, Birmingham, West Midlands, UK

[2] Academy of Sport and Physical Activity & Advanced Wellbeing Research Centre, Sheffield Hallam University, Collegiate Crescent Campus, Sheffield, Yorkshire, UK

Published online: 06 July 2022

players exhibit increased nutritional requirements to support the energy demands of growth and performance [66], reinforcing the importance of evidence-informed nutritional support within academy settings.

There is an abundance of research documenting the importance of nutrition to optimise the performance and health of adult professional football players [24]. However, given youth athletes display differing energy requirements, and have been shown to not adjust their nutrient intake or food choices to support the demands of the training load or different training sessions [79] it is impractical to simply translate findings from adult populations. Since the shift to a more 'elite' environment, there has been a growth of research investigating nutritional strategies within HPYS players and the subsequent employment of more nutrition practitioners within this discipline. Thus, the aim of this review was to systematically evaluate and synthesise the current literature on nutrition within HPYS environments. Our emphasis was to summarise current findings for researchers and practitioners, while identifying gaps within the literature to provide directions for future research.

Methods

Protocol

The study was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) [72] guidelines for the identification, screening, eligibility, and inclusion of articles.

Search Strategy and Eligibility Criteria

Online searches of MEDLINE and SPORTDiscus electronic databases were performed in November 2020. Through the use of Boolean search function, a combination of the terms ("football" OR "soccer") AND ("Academy" OR "Youth" OR "adolescent" OR "young athlete") AND ("Nutrition" OR "energy expenditure" OR "energy Intake" OR "dietary" OR "Nutritional") were searched.

Inclusion criteria were: (a) original research (not abstract or reviews); (b) assessed academy aged (U9 to U23) players in a HPYS setting; (c) investigated an element of nutritional status, knowledge, or intervention; and (d) available in English. Research on both genders was included. Studies investigating multiple sports were excluded from the analysis. A comprehensive search of the references and citation tracking on Google Scholar was completed to identify further appropriate literature, which the lead researcher screened independently to assess adequacy for inclusion. The screening process removed articles at each stage that did not meet the inclusion and exclusion criteria comprised of: removing duplicates; assessing the title; screening the abstract; and, reviewing the full text.

Data Extraction and Analysis

Data extraction included study design, research aim, participant characteristics (i.e., gender, competitive level, and age), main assessment methods, energy intake, energy expenditure, and main findings. Due to the heterogeneity of the study design, data was not pooled together but analyzed in a qualitatively descriptive method.

Quality Assessment

Two authors (first and last author) independently assessed the methodological quality of each study using modified criteria based upon the works of Downs and Black [30]. This checklist was selected due to the ability to assess both randomised and non-randomised studies, and has been shown to have a high correlation with quality assessment scores with the more commonly used PEDro scale [3]. Importantly, this tool has also been previously used within nutritional literatures [102, 105]. As the current review included both observational studies as well as controlled trials, two adapted scales were devised. Of the original 27 criteria, only those criteria which were relevant to the study designs were applied. When assessing observational studies, criteria 1–3, 6, 7, 9–11, 16–18, 20, 21, 26, 27 were included, while controlled trials had the additional criteria 4, 14, 15, 22–24. A scoring system was applied where *yes* = *1*, *no* = *0*, and *unable to determine* = *0*, resulting in a maximum score of 19 and 24 for observational and controlled trials, respectively [30]. A percentage score was calculated to allow for direct comparison of methodological quality between all papers. Any disagreements between the two authors were resolved by consulting a third reviewer (third author).

Results

Initially, 560 studies where identified with an additional seven from reference lists (see Fig. 1), Google Scholar citation tracking, and the author's knowledge. Duplicates (96) were removed, article titles and abstracts were screened and this resulted in the exclusion of a further 370 studies. Of the 101 full texts evaluated, 53 were deemed to have met the inclusion criteria and included in the final analysis.

Study Characteristics

Of the 53 included studies, there were 35 observational designs and 18 control trials. The main themes produced by the review investigated: (a) dietary intakes and expenditures

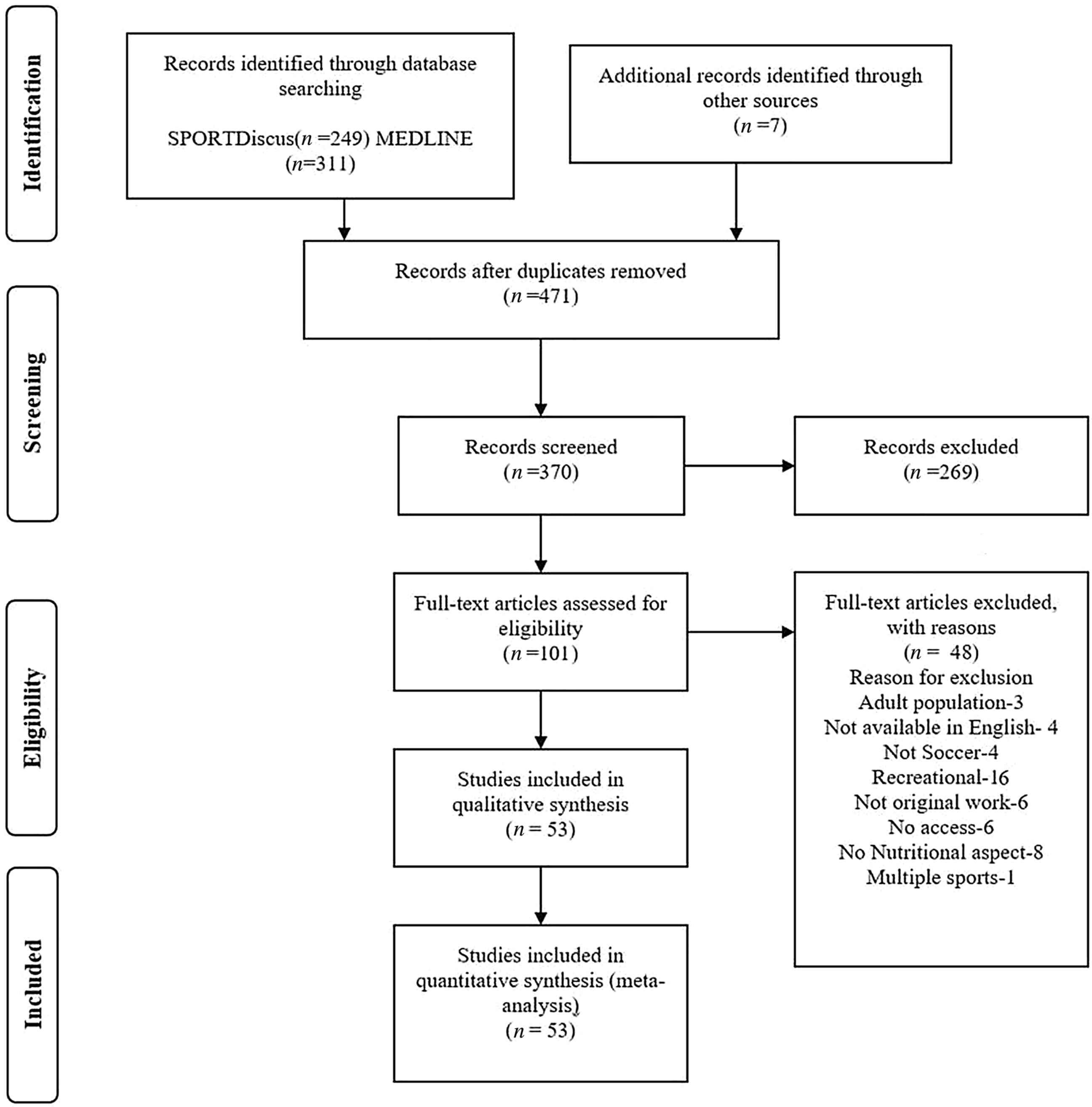

Fig. 1 Flow chart of systematic search process

(21); (b) ergogenic aid/supplements (13); (c) hydration status (6); (d) influence of Ramadan (4); (e) Vitamin D (4); (f) female studies (3); and (g) nutrition knowledge (2).

Quality Assessment [30]

Methodological quality assessment scores based upon the adapted Downs and Black [30] scale ranged from 73.7% to 100%. On average, the observational studies scored 90.2% (see Table 1), while the control trials were lower at 88.8% (see Table 2). Since HPYS environments often recruit players from aged 9 to 23, researchers deemed studies must assess more than two different age groups in order for the outcomes to be considered as representative of the whole academy population. Therefore, only 7 studies scored 'yes' to this criterion (criterion 11). All studies reported a hypothesis and stated the main outcomes to be measured.

Table 1 Observational studies quality rating

References	Reporting							External validity	Internal validity						Power	Score (%)
Criteria no.	1	2	3	6	7	9	10	11	16	17	18	20	21	26	27	
[63]	1	1	1	1	1	1	0	0	1	1	1	1	1	0	5	84.2
[92]	1	1	1	1	1	1	0	1	1	1	1	1	1	0	5	94.7
[52]	1	1	1	1	1	1	0	0	1	1	0	1	1	1	5	84.2
[73]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[9]	1	1	1	1	1	1	1	0	1	1	0	1	1	1	5	89.5
[19]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[38]	1	1	1	1	1	1	0	1	1	1	1	1	1	1	5	94.7
[58]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[96]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	73.7
[58]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	78.9
[67]	1	0	0	1	1	0	0	0	1	1	1	1	1	1	5	89.5
[51]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[97]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[94]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[39]	1	1	1	1	1	1	0	0	1	1	0	1	1	1	5	84.2
[43]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[26]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[40]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	3	78.9
[50]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	100
[86]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[14]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[15]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[48]	1	1	1	1	1	1	0	1	1	1	1	1	1	0	5	84.2
[7]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[35]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[59]	1	0	0	1	0	1	0	1	1	1	0	1	1	1	5	73.7
[75]	1	1	1	1	1	1	0	1	1	1	1	1	1	1	5	94.7
[41]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	100
[74]	1	1	1	1	0	1	0	1	1	1	1	1	1	1	5	89.5
[13]	1	1	1	1	1	1	0	1	1	1	1	1	1	1	5	94.7
[21]	1	1	1	1	1	1	1	0	1	1	1	1	1	1	5	94.7
[22]	1	1	1	1	1	1	0	0	1	1	1	1	1	1	5	89.5
[45]	1	1	1	1	1	1	0	1	1	1	1	1	1	1	5	94.7
[46]	1	1	1	1	1	1	0	1	1	1	1	1	1	1	5	94.7
[80]	1	1	1	1	1	1	0	1	1	1	1	1	1	1	5	94.7

Discussion

This review set out to systematically evaluate and synthesise the current nutritional literature within HPYS environments. Here, we summarise the current findings for researchers and practitioners, while identifying gaps within the literature to provide direction for future research in this field. As such, this section critically discusses the current categories that have been researched in HPYS, including: (a) dietary intakes and expenditures; (b) ergogenic aids/supplements; (c) hydration status; (d) Vitamin D; (e) Ramadan fasting; (f) female population; and (g) nutritional knowledge.

Dietary Intakes and Expenditures

As players undergo rapid changes in growth and maturation coupled with increasing training and match-loads, can result in extremely high energy requirements [46]. Insufficient energy intake (EI) has been shown to result in body and muscle mass loss, injury, illness, increased prevalence of overtraining, and severely impaired performance [61]. Furthermore, inadequate EI alongside increasing energy requirements may lead to low energy availability (LEA) and associated detriments [65]. Therefore, in an environment, where the focus is development of players, ensuring players

Table 2 Control trials quality rating

References	Reporting						External validity	Internal validity												Power	Score (%)
Criteria no.	1	2	3	4	6	7	9	10	11	14	15	16	17	18	20	21	22	23	24	27	
[83]	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1	0	5	75
[37]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	5	95.8
[29]	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	5	91.7
[93]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	5	95.9
[10]	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	1	5	87.5
[27]	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	5	91.7
[55]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	5	95.8
[28]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	3	87.5
[2]	1	1	1	1	1	1	0	0	0	1	0	1	1	0	1	1	1	0	0	5	75
[47]	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	4	87.5
[16]	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	4	83.3
[53]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	5	95.8
[108]	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	5	91.7
[54]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	5	91.7
[8]	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	1	0	0	5	75
[90]	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	5	95.8
[99]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	5	95.8
[100]	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	5	87.5

consume an adequate EI to support training and competition is vital for performance, growth, health, and successful progression through the age groups.

Dietary practices of HPYS players are documented within the literature (see Table 3). Studies assessing energy intakes in single age groups across differing populations have found EI is inadequate in relation to estimated energy expenditure (EE) [7, 14, 19, 52]. Findings displaying mean energy deficits of up to − 890 ± 734 kcal/day in Italian HYPS players [19]. As HPYS environments span large age ranges, it's hard to understand the extent of the issues from assessing isolated age groups. Therefore, studies have investigated multiple age groups within the same academy setting to negate possible population differences [38, 46, 50, 74, 92]. Absolute EI appears to be consistent within the same population irrespective of age between the U13s to U20s [48, 75, 92]. However, when expressed in relative terms to body weight (BW), a reduction in overall EI is observed as players grow and progress through age groups. Hannon et al. [46] displayed a stepwise reduction in EI when expressed relative to BW between U12/13 (68 ± 8 kcal/kg/day), U15 (50 ± 7 kcal/kg/day), and U18 (44 ± 7 kcal/kg/day) English Premier League (EPL) academy players. Overall, it is apparent there are large ranges in EI and EE between players of differing ages and nationalities, as well as within players of the same chronological age, indicating the possible influence of chronological age and body size on energy balance. As players progress through age groups, they do not increase their EI sufficiently to meet the increased energy requirements.

Current evidence suggests HPYS players do not periodise their EI and CHO intake to match the demands of training and competition [14]. Briggs et al. [14] assessed the EI and EE across a competitive week (including a heavy, moderate, and light/rest days and culminating in a match-day) in English U14s. Weekly mean energy deficit of − 311 ± 397 kcals/day were reported. However, findings highlighted heavy training and match days to pose the greatest risk to overall energy balance, inducing larger energy deficits of − 505 ± 539 kcal/day and − 544 ± 551 kcal/day, respectively. Similar findings in U16 Portuguese players have been reported [41], displaying larger energy deficits of − 1030 kcal/day and − 1009 kcal/day on heavy training and match days respectively. Highlighting the need for players to adjust EI to account for heavier training/competition loads. These differences may potentially be explained by methodological differences as Briggs et al. [14] accounted for the under reporting by adjusting values via a corrective equation and assessed EE via the use of accelerometry, a more sensitive measure than the predictive equations used in the previous literature [68]. Furthermore, between the U14 and U16 age groups there can be large differences in maturational status and training load [45, 46]. Therefore, although both studies investigated heavy training and match days, the exact training loads and energy requirements may differ.

Table 3 Overview of studies examining EI and/or EE in HPYS players

References	Aim	Sample size	Population (Ethnicity and Age)	Dietary assessment tool	Energy intake (kcal/day)	Energy expenditure (kcal/day)
[63]	Characterise nutritional intake in terms of energy, macro-nutrients, calcium, and iron of adolescent French soccer players		French 13–16 years	5 day food diary	Range: 2352–3395	Not measured
[52]	Accurately assess the food habits and nutritional status of high level adolescent soccer players living in their home environment during the competitive season	$N=33$	Spanish 14–16 years	6 day food diary	3003 Range: 2261–4007	2983 Range: 2705–3545
[92]	Characterise the diet of the growing soccer player and to examine how it varies during the course of adolescent development	$N=81$	Spanish U15: 14.0 ± 0.3 years U16: 14.9 ± 0.2 years U17: 16.6 ± 0.6 years	3 day food diary	U15:3456 ± 309 U15: 3418 ± 182 U17:3478 ± 223	Not measured
[19]	Assess the dietary intake of a sample of young male Italian high-level soccer players on two time points to evaluate the degree of under- reporting, using the EEI/EEE ratio	$N=43$	Italian 16 + 1 years	4 day food diary	2560 ± 636	Not measured
[94]	Investigate the dietary and activity regimes of professional soccer players who played for the youth department team (Under 18 s) of a professional club based within the United Kingdom during a 7-day period	$N=10$	English 17 ± 1 years	7 day food diary	2831 ± 164	3618 ± 61
[50]	Evaluate the nutritional intake and eating patterns of young high-level soccer players according to their playing position in the team	$N=87$	Spanish 18 ± 2 years	6 day food diary	2794 ± 526	Not measured
[14, 15]	Assess energy balance in male adolescent, academy-level soccer players over a seven day period that included four training days, one match day and two rest days	$N=10$	English 15.4 ± 0.3 years	7 day food diary with 24 h recall	2245 ± 321	2543 ± 244

Table 3 (continued)

References	Aim	Sample size	Population (Ethnicity and Age)	Dietary assessment tool	Energy intake (kcal/day)	Energy expenditure (kcal/day)
[48]	Analyse anthropometric characteristics, evaluate nutritional intake and status, as well as dietary habits and finally, to evaluate pre- and post-training and game meals	$N=72$	Mexican Team A ($n=24$): 15.5 ± 0.06 years Team B ($n=24$): 16.5 ± 0.04 years Team C ($n=18$): 17.3 ± 0.04 years Team D ($n=6$): 19.3 ± 0.17 years	4 day food diary	Team A-3067 ± 151 Team B-2930 ± 73 Team C-2715 ± 131 Team D-3042 ± 117	Team A-3118 ± 41 Team B-3246 ± 55 Team C-3286 ± 39 Team D-3103 ± 56
[75]	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	$N=59$	English U13/14: 12.7 ± 0.6 years U15/16: 14.4 ± 0.5 years U18: 16.4 ± 0.5 years	7 day food diary	U13/14: 1903 ± 432 U15/16: 1927 ± 317 U18: 1958 ± 390	Not measured
[41]	Investigate the dietary intake of academy level soccer players from a Portuguese first league soccer club on match day (MD) and on the highest training load day (HTLD) during 3 consecutive weeks of the final phase of a competitive season	$N=10$	Portuguese 15.8 ± 0.4 years	2 week food diary & photographic record	MD: 2667 ± 170 Range: 2256–2810 HTLD: 2646 ± 415 Range: 2043–3234	Not measured
[45, 46]	Quantify the energy expenditure, energy intake and training loads of elite youth soccer players over a 14-day in-season period	$N=24$	English U12/13 ($n=8$): 12.2 ± 0.4 years U15 ($n=8$): 15.0 ± 0.2 years U18 ($n=8$): 17.5 ± 0.4 years	Food photography	U12/13: 2659 ± 187 U15: 2821 ± 338 U18: 3180 ± 279	U12/13: 2859 ± 265 Range: 2275–3903 U15: 3029 ± 262 Range: 2738–3726 U18: 3586 ± 487 Range: 2542–5172

EEI estimated energy intake, *EEE* estimated energy expenditure, *HTLD* heavy training load day, *MD* match day

Many of the aforementioned studies estimated EE through predictive resting metabolic rate (RMR) equations which have been shown to underestimate requirements in this population [45]. Two studies measured EE through indirect measures such as accelerometry and activity diaries [14, 94], which may still have a degree of inaccuracy. As RMR has been shown to increase by approximately 400 kcal/day between ages 12 and 16 years [45], it is important to assess total EE through more accurate measures. Hannon et al. [46] reported total EE values of 2859 ± 265 kcal/day (range: 2275–3903 kcal/day), 3029 ± 262 kcal/day (range: 2738–3726 kcal/day), and 3586 ± 487 kcal/day (range: 2542·5172 kcal/day), using indirect calorimetry and doubly-labelled water for U12/13, U15, and U18 EPL players, respectively. As with EI, large ranges are apparent within age groups and there is considerable overlap, which may be influenced by contextual factors such as playing position and training load, as well as individual constraints including growth and maturational differences. Unfortunately this method does not allow identification of EE for individual sessions or training days. Currently there are no studies investigating the impact of differing training day loads throughout an average training week on daily EE across the full academy structure. Therefore, we cannot understand the full impact of differing training sessions and matches on EE.

Few studies have assessed dietary habits and influences, aiming to identify determinants of inadequate intakes of HPYS players. Koç et al. [59] examined nutritional habits of Turkish HPYS players, finding meal frequency and overall diet quality was low. Data was analysed in a unbalanced proportion (e.g., U14s: $n = 13$ vs. U18s: $n = 105$). As outcomes were presented as a summary of the whole sample, it is difficult to distinguish whether these findings are applicable to all age groups. The investigation of different menu settings (i.e., a set menu vs. a buffet style setting), revealed a higher carbohydrate (CHO) and caloric intake in the set menu [38]. Both groups over consumed fat at the expense of adequate CHO intake. The absence of a post-exercise meal has also been identified in HPYS players by Hidalgo y Teran Elizondo et al. [48], while food preference were observed to have no influence on EI [51]. Iglesias-Gutiérrez et al. [50] found a small correlation between playing position and EI, along with an increase in CHO intake in positions that required a higher aerobic energy cost. However, findings may be irrelevant since no players met the recommended guidelines.

Protein Intake

To the authors' knowledge, only one research group has assessed protein requirements of adolescent soccer players [9]. Findings from nitrogen balance methodology in U14s showed requirements of 1.4 g/kg/day which are higher than recommend daily allowances but in-line with guidelines for adults athletes [87]. Therefore, it would appear all studies investigating nutritional intakes within this review demonstrated players met or exceeded their requirements. Daily distribution of protein is also required to maximise muscle protein synthesis (MPS) and promote recovery [1]. Naughton et al. [75] suggests EPL HPYS players do not display an even distribution of protein intake throughout the day, with protein intake greatest at dinner and higher at lunch than breakfast. Furthermore, eating habits presented may indicate protein deriving from sub-optimal leucine sources and may limit MPS. U18 players protein intake was higher at lunch and dinner than their younger counterparts. The disparity in protein intakes could potentially be due to the U18s consuming more meals at the club where staff have a greater control over food quality and options. Currently there is no study investigating impacts of food provision supplied by clubs on players protein intake.

Carbohydrate Intake

Findings of this review suggest HPYS players currently consume between 5 and 7 g/kg/day CHO daily with the majority currently around 5 g/kg/day; irrespective of age or nationality. Although differences in fuel utilization [104] and storage capacities [34], there are currently no youth specific CHO guidelines. With current recommendations for adult soccer players ranging between 5 and 10 g/kg/day [81], one may assume youth players are only *just* meeting the lower end of requirements, and therefore, may exhibit reduced recovery capabilities on heavier training days, sub-optimal fueling strategies, and limited growth. Players in EPL academies consumed inadequate daily CHO, with values as low as 3.2 g/kg/day [75]. Of further concern is the findings within the older age groups, showing CHO intake relative to body mass (BM) decreases as player age [46, 48, 75, 92].

Overall, players do not appear to be meeting their CHO and energy requirements (particularly in older age groups), thus practitioners need to implement effective interventions to combat this. Briggs et al. [15] showed an intake of pre-match breakfasts above existing CHO and calorie guidelines did not induce any gut discomfort, thus identifying one potential area in which daily CHO and EI can be increased. Low CHO intakes within HPYS players, may be influenced by a multitude of factors, including poor nutritional knowledge. Further research is required in order to fully understand the influences of dietary CHO intake.

Micronutrients

Only one paper specifically aimed to assess micronutrient intake [74]. Findings indicated U12/13, U15, and U18 players all met or exceeded the UK RNIs for the majority of micronutrients, with just a few exceptions. U18s did not meet their Calcium requirements, whilst both U15/16 s and U18s consumed inadequate intakes of Potassium. Although not the primary aim, some papers did record micronutrient intake of HPYS players. In a Mexican population, only Potassium and Vitamin D intake were below the recommended values [48]. Garrido, Webster, and Chamorro [38] also reported inadequate Calcium intakes in youth Spanish players (mean age = 16 years). Conversely, in English players of the same age group, all micronutrient intakes were sufficient [94]. In all studies micronutrient status was estimated through food diaries, rather than direct physiological assessment, and therefore may not be representative of true micronutrient status due to the associated under reporting synonymous with this method [64]. Future studies should implement direct physiological measurements in order to gain a more accurate reflection of micronutrient status.

Supplements/Ergogenic Aids

Carbohydrate

The largest proportion of goals are conceded during the latter stages of a football match [88], likely due to the onset of fatigue. Physiologically, this may be due to a reduction in muscle glycogen as this has been correlated with reduced work rate [95]. It would also seem appropriate to assume cognitive function and motor skill performance are reduced simultaneously due to the need of a glucose supply to the brain [31]. Therefore, CHO ingestion during competition may improve performance and reduce the onset of fatigue.

Research has shown ~ 59 g/h CHO to reduce detriments to soccer shooting performance even with blood glucose levels still dropping at the 60-min in U18s [93]. Players consumed the equivalent of 3.5 mL/kg via a 6% sports drink at 6 timepoints. During a competitive match, players have a reduced opportunity to consume fluids and CHO, therefore, this feeding strategy may not accurately replicate real world settings. Subsequent research [90] in Scottish U18s showed improvements to passing accuracy in both the early and latter stages, passing speed in the later half, and post-match high intensity running following the same absolute dose. However, it was administered in higher concentrations allowing the need for only two feeds (15 min prior to each half), replicating applicable strategies for real world scenarios with no gut discomfort reported. Harper et al. [47] supported CHO imporving performance in the later stages of matches in U16 players. Prior to extra-time, players consumed 0.7 g/kg CHO, which resulted in increases in dribbling precision and skill performance by 29% ± 20%.

CHO mouth-rinse has been reported to increase high intensity performance (> 75% $\dot{V}O_{2max}$) [98]. As periods of play within football exceed this exercise intensity, CHO mouth-rinsing may provide a potential strategy to improve competitive performance. Currently, the only existing study in youth soccer found no observed improvements from rinsing a 6% maltodextrin solution [10]. The testing protocol replicated a situation similar to the start of a match as players were in a euglycemic state, however the majority of CHO mouth-rinse studies present positive effects later in exercise when participants typically experience hypoglycaemia [91]. Therefore, the benefits of a CHO mouth-rinse during soccer matches cannot be ruled out and require further investigations in scenarios that replicated fatigue profile of a real-world environments.

Current literature within HPYS, suggests CHO consumption during competition may provide valuable performance improvements. As the aforementioned research was performed in conditions where players consumed at least one standardised meal in-line with current nutritional guidelines, the results may not replicate the true impact on current youth players. Large percentages of youth players are currently not meeting the CHO requirements throughout the training week and prior to competition and therefore may begin matches with already depleted glycogen stores and reduced fuel availability. Thus, the rationale for use of CHO during a match may potentially be higher than their adult counterparts.

Creatine

Creatines (Cr) potentitial to increase strength, power, FFM, and recovery is well documented within the literature making it one of the most utilised ergogenic aids [60]. Its popularity in soccer specifically, is due to its impact on training adaptation and also the potential to provide substrate for the anaerobic processes required [101] for high intensity bouts in matches. A recent review by Mielgo-Ayso et al. [71] showed Cr supplementation elicited positive effects on physical performance related to anaerobic metabolism and power in adult soccer players.

Within HPYS, Cr has been shown to increase total body water [28], with similar performance benefits as their adult counterparts. Yáñez-Silva et al. [108] showed a 5% and 4% greater increase in peak and mean power output in Brazialian U18s following Cr supplementation compared to the placebo counterparts (see Table 4). Total workload of players, assessed via a Wingate test, also increased by 7%, although fatigue was similar between groups. Ostojic et al. [83] showed similar performance benefits in Yugoslavian players following Cr supplementation, whereby

Table 4 Overview of studies examining supplement/ergogenic aid use in HPYS players

References	Population (Ethnicity and Age)	Sample size (*N*)	Supplement/Ergogenic aid	Protocol	Main outcome
[83]	Yugoslavian 16.6 ± 1.9 years	20	Creatine	3 × 10 g for 7 days	↑ Soccer specific skill ↑ Sprint-power ↑ Vertical Jump
[27]	Brazilian U20s-17.1 ± 1.4 years	25	Creatine	0.3 g/kg for 7 days	↑ Sprint Performance No effect on oxidative stress
[28]	Brazilian U20s-18.2 ± 0.8 years	13	Creatine	0.3 g/kg for 7 days	↑ TBW ↑ BM
[108]	Brazilian U18s- 17 ± 0.5 years	19	Creatine	0.03 g/kg for 14 days	↑ PPO ↑ MPO ↑ Total Workload
[99]	English 17.4 ± 1.6 years	25	Creatine	0.3 g/kg for 7 days 5 g/day for 7 weeks	Mild ↓ lung health in asthmatic players
[93]	English 18 ± 1 years	15	CHO-electrolyte fluid	6% Sucrose solution = ~ 59 g/h	↓ fatigue induced reductions to shooting
[10]	Brazilian U15s- 15.0 ± 1.5 years	12	CHO Mouth Rinse	~ 100 mL 6% maltodextrin solution	No observed improvements
[47]	English 16 ± 1 years	8	CHO-electrolyte gel	46 g glucose and maltodextrin prior half time	↑ Blood glucose ↑ Skill performance No changes to physical performance
[90]	Scottish 18 ± 2 years	18	CHO	500 mL 12% sucrose and maltodextrin solution = 60 g	↑ Passing accuracy in early and late stages ↑ Passing speed during later stages No impact on gut comfort
[55]	American 14.1 ± 0.5 years	17	Caffeine	6 mg/kg 1 h pre (Tablet form)	↑ Faster reaction time of non-dominant foot No sig diff to time trial performance
[37]	Brazilian 18.4 ± 1.1 years	9	Glutamine	2.5 g glut/ 50 g CHO 30 min prior	↓ Fatigue ↑ Distance covered ↑ Time to failure
[29]	Serbian 18.1 ± 0.7 years	32	Astaxanthin	4 mg for 90 days	No improvements to oxidative stress observed
[2]	Italian 18.42 ± 0.5 years	26	L-Carnitine	3 mg or 4 mg 1 h pre	↑ Antioxidant action following 3 mg

CHO carbohydrate, *PPO* peak power output, *MPO* mean power output, *BM* body mass, *TBW* total body water

sprint, power, and vertical jump performance all increased by 21.5%, 18.5%, and 12%, respectively.

Due to the high intensity bouts present within soccer, training and competition can result in oxidative stress and an increased inflammatory response. Cr has been suggested to protect against this [5, 62], however, limited research has been shown within human studies and more specifically in soccer. Deminice et al. [27] showed in U18s Cr may lead to benefits in sprint performance, as well as inducing a protective effect against oxidative stress. Results indicated a suppression of tumour necrosis factor alpha (TNF-α), C-Reative protein (CRP) levels, and lactate dehydrogenase (LDH) suggesting an anti-inflammatory effect. The dosing strategy of 0.3 g/kg/day for seven days significantly increased Cr plasma levels.

Potential negative effects to lung inflammation, airway remodeling, and airway hyperresponsiveness (AHR) have been shown in an animal studies, suggesting creatine may have deleterious effects in individuals with asthma [106]. Simpson et al. [99] investigated the impact of Cr on respiratory health in English U18s and U21s. Following an initial loading period of 7 days (0.3 g/kg/day), 5 g was administered for 7 weeks. No significant effects were observed to BM or fat free mass, whilst those in the Cr group displayed mild unfavourable respiratory health. This was more pronounced in atopic players. Until further research is performed in this area, Cr supplementation should be carefully considered in youth players displaying allergic or asthmatic conditions. This review demonstrates there are currently no studies investigating Cr supplementation in ≤ U16s, thus implementation cannot be recommended to these age groups at this time.

Caffeine

Caffeine has potential adverse effects to sleep, general toxicity, cardiovascular function, bone status, and calcium balance (even with consumption of adequate calcium) [76]. Within the youth population use is often limited, although some will consume it through coffee and energy drinks [103]. The investigation of caffeine as an ergogenic aid in HPYS is limited to one study [55], which found supplementation of 6 mg/kg of BM administered in pill form 1 h before exercise produced a significant improvement in the reaction time by 11% on the players non-dominant side. It is suggested this may improve skill development and performance. The findings of this study should be taken with caution when applying it to the population in question (U15s). Although some small benefits were observed, the required dose was on the upper end of what has been found to be effective in older counterparts (3–6 mg/kg), and thus require large quantities for any ergogenic effect. Furthermore, ethical considerations around use of caffeine in adolescents should be carefully considered especially among younger age groups whom are classed as highly sensitive [76]. Thus, the use of caffeine in HPYS players should be implemented on an individual and age-specific basis.

Antioxidant

Findings have reported up-regulated oxidative stress following soccer matches [57], which may potentially lead to impaired recovery capabilities, increased delayed onset of muscle soreness, and increased injury risk [23]. High training and competition loads can result in reduced antioxidant expression [85], and since micronutrient intake may be lacking in the current population [38, 74], antioxidant supplementation may prove beneficial to recovery. Limited studies have investigated the use of antioxidants with HPYS players. Astaxanthin, an antioxidant present in certain marine animals and plants such as fish, shrimps, and algae, was shown to have no real effect to recovery in HPYS players following supplementation of 4 mg daily for 90 days showed [29]. Conversely, acute L-carnitine supplementation in U20 players showed a strong antioxidant action at a 3 g dose [2]. This may potentially reduce associated muscle damage with strenuous exercise, and therefore improve a player's ability to train and perform. Antioxidant supplementation should be carefully considered as soccer-specific adaptations following training are triggered by the inflammatory response and may act as a defence for future exposure to elevations in oxidative stress. Due to differing physiology and training load exposures, the response to exercise may differ in the youth population when compared to adult counterparts. Future studies are encouraged to investigate the inflammatory response produced following training and matches at the differing stages of the academy to identify and understand whether antioxidant supplementation is warranted.

Peptide Glutamine

Glutamine, an intermediate metabolite in the Krebs cycle, acts in gluconeogenesis by saving phosphocreatine (CP) deposits and glycogen in muscle fibres, thereby potentially improving exercise tolerance [37]. However, evidence is lacking supporting its benefits to soccer performance. Favano et al. [37] suggested it may improve performance when acutely administered with CHO (2.5 glutamine, 50 g CHO). Reduced feelings of fatigue, increased distanced covered (+ 3155 m), and greater time to volitional failure (+ 15.6 ± 15.6 min) were all observed. It was also suggested athletes who received glutamine and maltodextrin supplementation presented a higher aerobic capacity for submaximal effort. Nevertheless, further investigation should look into the chronic use during training and competition in a larger sample size and across diverse age groups.

Hydration Status

Youth athletes display lower sweat rates than adults however, data suggests they can dehydrate to similar levels as adults if no fluid is ingested [70]. Lower sweat rates, coupled with higher metabolic cost of locomotion, can make thermoregulation harder in children [36]. Thus, hydration is key when since the onset of dehydration can result in greater increases in core temperature [4].

Due to the adverse impact of heat on hydration status, the majority of research in youth soccer has been performed in tropical conditions (~ 30 °C and > 50% relative humidity). Three studies investigating hydration in Brazilian U18s [26, 43, 97] observed findings with varying outcomes; however, all agreed fluid intake did not match fluid losses. As expected, higher temperatures posed a greater risk to hydration status even with an increased self-selected fluid intake as sweat rate increased, with six of 20 players losing more than 3 L [97]. Findings displayed an average BM loss across three training days of − 1.21 ± 0.46 kg, equivalent to dehydration of − 1.77% ± 0.70%. It is important to recognise that although dehydration was less than the critical level (− 2% BM loss) [32], in the present study, players arrived to training in a hypo-hydrated state and thus may still exhibit detriments to performance from smaller magnitudes of BM losses. In similar conditions, dehydration has been found to occur during matches [26]. Weight loss varied widely between players ranging from minimal (− 0.40 kg; − 0.59%) to substantial (− 2.10 kg; − 3.15%) with mean values of − 1.08 ± 0.55 kg (− 1.62% ± 0.78%).

Guttierres et al. [43] reported lower values of dehydration (− 1.00 ± 0.39 kg; − 1.35% ± 0.87% BM). Similar to the work of Silva et al., players attended the match in a hypo-hydrated state, whereby ~ 45% of the players started the match with a moderate dehydration status (USG = 1.010–1.020 g/mL); ~ 50% of the players presented a significant level of dehydration (USG = 1.021–1.030 g/mL); and ~ 5% presented a condition of serious dehydration (USG > 1.030 g/mL) in the pre-match period. Therefore, starting the match in a sub-optimal hydration status, and even with an increased fluid intake that was in excess of players sweat losses, ~ 65% of the players reached significant dehydration levels, while ~ 17% presented a serious dehydration condition. Despite players perceiving conditions as a warm environment, ~ 55% of the players finished the match with either 'no thirst' or with a 'slight degree of thirst', indicating thirst may not be an appropriate measure of hydration status for HPYS players. This is in agreement with previous findings that suggest the sensation of thirst typically lags behind the fluid deficit [42].

The aforementioned studies investigated hydration status during the period immediately prior to, during, and post training and thus the outcomes may have been impacted by acute hydration strategies. Phillips, Sykes, and Gibson [86] assessed hydration using morning urine samples, which mitigated the impact of acute fluid ingestion [82], in European environments across three training sessions of varying conditions (12.9 ± 0.7 °C; 8.9 ± 0.3 °C; and 17.2 ± 0.1 °C). Findings indicated the majority of European HPYS players appear hypo-hydrated at first in the morning, and subsequently replaced approximately 71% of their sweat losses during training, resulting in hypo-hydration of < − 1% BM. These findings were supported by Ersoy et al. [35] who found player's voluntary hydration strategies in moderate conditions only resulted in a mean dehydration of − 0.5% BM. However, the authors believed that due to their young age, players paid greater attention to consuming adequate fluid because of the concern that the study would be an assessment of their performance. Therefore, interventions need to be implemented for pre-training and match hydration strategies in order to ensure players attend training and matches in a euhydrated or hyper-hydrated state, with further emphasis placed on ensuring adequate fluid intake in hot conditions. Furthermore, tropical natives are typically heat-acclimated and may present improved thermoregulatory responses in comparison non-tropical natives [17]. Therefore, the effect of more tropical conditions should be investigated in HPYS players habituated to more temperate conditions in order to provide accurate recommendations when exposed to these conditions through travel and seasonal variation.

Vitamin D

Vitamin D is vital for bone health, immunological function, cell differentiation, and muscle development and repair is well-documented [84]. Large percentages of people display low Vitamin D concentrations (< 30 nmol/L), therefore, it is common practice for sports teams to routinely supplement all players during winter months. Prevalence of Vitamin D deficiencies and potential performance benefits have been investigated in HPYS. Russian youth soccer players (mean age: 15.6 ± 2.4 years) were assessed in winter for Vitamin D levels (25(OH)D). Those identified to be deficient (< 52.5 nmol/L) or insufficient (52.5–72.5 nmol/L) were supplemented with 5000 IU per day for 60 days [8]. Vitamin D supplementation increased both groups to normal levels within 60 days, although effectiveness decreased over time. As both groups (deficient and insufficient) were treated with the same dose, the findings do not allow for identification of a minimum effective dose. Skalska et al. [100] found similar results in Polish U18s with supplementation (5000 IU per day) increasing serum 25(OH)D from 48.5 ± 8.6 to 106.3 ± 26 nmol/L. However no significant differences in performance were observed.

In contrast, a later study found Vitamin D (5000 IU) supplementation during 8 weeks of high intensity interval training increased serum 25(OH)D and improved aerobic capacity by 7% more in the Vitamin D group versus the control group [54]. Therefore, it would appear supplementation with 5000 IU per day of Vitamin D during winter months may be beneficial to adolescent soccer players with reduced sunlight exposure. Some individuals and ethnicities may require varied dosage due to darker skin requiring greater sunlight exposure to synthesise Vitamin D [107]. However, even with this greater risk to Vitamin D deficiency, they may exhibit lower risks to the associated negative effects to bone health [20]. Therefore, where possible, baseline measurement should be actioned to quantify the level of deficiency before supplementation.

Influence of Ramadan

During Ramadan, Muslims abstain from consuming food or liquid during daylight for 30 days. Given the well-documented influence that nutrient and fluid consumption pre, during, and/or post-exercise can have on adaptation, recovery, and performance in training and competition [18], it is important to consider the influence of such events. According to the Qur'an [44], an individual is not required to observe the fast until they reach the age of maturity;

although some individuals choose to observe from early childhood and thus it is important to understand the impact this may have on youths in a HPYS environment.

Maughan et al. [67] investigated the effect of Ramadan on dietary intake and body composition in U18s, by observing a fasting and non-fasting group. Those not observing the fast increased their EI over the month, resulting in a 1.6 kg weight gain, whereas the fasting group showed no significant weight change. This increase may be attributed to a net positive energy balance as a consequence of increased EI in the non-fasting players, who consumed their regular diet throughout the day while also joining the evening Ramadan celebrations. Water and salt balance was also investigated during the third week of fasting in this population [96]. No substantial change in total body water was found. The fasting group displayed a greater fluid deficit, even with a reduced sweat rate (Fasting 1.41 L/h vs. Non-fasting 1.61 L/h), which may impair performance in training whilst not impacting overall hydration status across the day. The effect of fasting appeared to have little effect on performance as, after a short period adjusting at the start of the month, the players reverted to or superseded performance noting very little change to perceived difficulty, mood, and alertness [58]. Meckel et al. [69] investigated a younger population (aged 14–16 years) who exhibited a small increase in of 228 kcals/day while fasting; although no changes in BW occurred and only a very small increase in sum of four skinfold measurements was observed (+ 0.2 mm). Fasting appeared to have a detrimental effect to performance with a reduction in intense physical activity (− 30%), aerobic endurance (− 1%), vertical jump (− 1.8%), and speed endurance performance (− 5.3%). It appears Ramadan has a small influence on EI and has the potential to influence performance despite player perceptions being unaffected. Therefore, the timing and frequency of meals and fluid intake could be a limiting factor, highlighting the need for players and support staff to be aware of any impact upon training outputs.

Female Population

Female representation within existing sport science literature is significantly under reported [25]. Given females have diverse physiology and differing requirements [49], one should not simply transfer the results and recommendations for male soccer players across both genders. This is even more apparent in the youth population, with females on average reaching maturity approximately 2 years earlier than their male counterparts [66]. Currently, there is a shortage of scientific research investigating the nutritional status of youth female soccer players. Of those studies that have been undertaken, Gibson et al. [39] reported a mean daily energy deficit of ~ 500 kcal/day in Canadian HPYS female players between the ages of 14–17 years, showing a similar trend to the earlier reporting findings in male athletes. Of concern was one individual whom consumed a mean EI of only ~ 1292 kcal/day. This would indicate a large energy deficit and potentially low EA. This is supported by research that also found inadequacies in EI, CHO, and protein intake in female HPYS players [13]. With smaller mean daily energy deficits (~ 141 kcal/day), yet over fifty percent of participants exhibited LEA (< 30 kcal/kg lean BM). During both studies, EE was estimated and thus may not be totally valid; although due to the known detrimental effects of LEA to health [65], further research needs to be performed in this population to confirm these findings. Sub-optimal intakes of Vitamin D and Calcium, as well as low serum Hydroxyvitamin-D, were recorded further highlighting this population as a key area to address.

Hydration status has also been assessed in the U15, U16, and U18 female population during a training session [40]. Players experienced mild dehydration and low sodium losses (48 ± 12 mmol/L) in cool conditions (9.8 ± 3.3 °C) and mean sweat − 0.69 ± 0.54 L. However, there was a large individual variability in fluid balance and sodium loss. Due to lack of sweating only two of five sites measured produced sodium loss data. Over the 90 min training session 63.6% consumed less than 250 mL; however, only 12.1% of participants hit the critical level of − 2% of the BM [32]. These results are most likely due to mild conditions and athletes attending the session in a hypo-hydrated state; therefore, future studies should look to investigate hydration in female HPYS players in more tropical conditions. In the meanwhile, female players should look to follow recommendations of 0.4–0.8 L/h outlined by Holtzman and Ackerman [49].

Nutrition Knowledge

Nutrition knowledge is perceived as a key barrier to achieving appropriate nutritional intake therefore, it is common practice within sporting environments to implement education programmes [6]. However, research would suggest this may not be the only influencing factor [73]. Through the combination of a seven-day food diary, interview, and multiple choice knowledge questionnaires, it is apparent there is a poor correlation between nutritional knowledge and appropriate EI, especially with regards to CHO intake. Indicating other barriers influence adequate nutrition and HPYS players may require assistance with transferring knowledge into practice. Conversely, Noronha et al. [80] found there was a correlation between better nutritional knowledge and the appropriate dietary intake of some key nutrients. One of the main barriers was 'lack of willpower'; however, as nutrition knowledge was low some athletes may be unaware they needed to improve their dietary intake. Specifically, CHO intake (3.9 g/kg) was far below recommended values. Both studies assessed nutritional knowledge via differing questionnaires, neither of which have been validated as an appropriate measure of nutrition knowledge. It is clear further research is required to investigate the influence of nutrition knowledge and other barriers to adequate EI in order to develop effective interventions.

Strengths and Limitations

One of the main strengths of this review is it is the first review to present all current nutritional research performed within HPYS players. However, this also posed a key limitation as it was not feasible to pool data and perform a meta-analysis due to the comprehensive array of research areas investigated within this review. Furthermore, due to the limited amount of research in certain areas (e.g., caffeine; antioxidants; and female HPYS players) it is difficult to draw robust conclusions in these topic areas. The review was not registered to PROSPERO and this acknowledged as a limitation. Finally, it is acknowledged that the rapidly evolving field of sports nutrition research within HPYS causes some challenges when trying to capture the most contemporary evidence. To the authors' knowledge two papers have been published since the time of our systematic search of the literature [77, 78] therefore we recommend a subsequent review to be completed within the next five years to explore any future findings within this population.

Conclusion and Future Directions

This review demonstrates current HPYS players display high inter-individual variability in EE and EI across and within all chronological age groups within these environments, indicating a potential impact of growth and maturation of players. Future studies should look to follow the developing concept of 'bio-banding' within academy soccer [12] and assess nutritional requirements and intakes based upon biological age of players, to better consider the impact of growth and maturation on energy requirements. Furthermore, to understand whether nutritional periodisation is required, methodology should be implemented that will allow distinction of individual training sessions and daily EE. This will allow understanding of which days pose key threats to players achieving energy balance at each biological age group and inform practitioners of the need to implement nutritional interventions to periodise EI.

As highlighted by this review, players display insufficient energy and CHO intakes across multiple chronological age groups within HPYS environments however, the key barriers and enablers to players achieving appropriate intakes are not currently understood. Future studies should assess the influences and barriers behind EI, availability of adequate nutrition provision, and eating habits across the full academy pathway.

Findings in female HPYS players mirror their male counterparts in consuming insufficient energy and CHO intake. Even in the limited number of female-specific studies presented in this review, a large percentage of female players exhibit LEA which is particularly concerning given the detrimental health, growth and performance issues associated with this [13]. Thus, further research is required in this population, across multiple age groups, to ensure appropriate interventions are implemented to minimize the risk of LEA.

Practical Considerations

The practical considerations of this review suggest that practitioners and coaches should:

- Implement strategies to promote more optimal dietary behaviours to help ensure that HPYS players consume sufficient energy intakes to meet their energy requirements.
- Aim to identify scenarios which pose a significant threat to the energy demands of HPYS players (e.g., heavier training days; match-days; tournaments; fixture congestion etc.) and encourage increased energy and carbohydrate intakes around these periods.
- Seek to understand the various enablers and barriers to achieving optimal dietary intake in HPYS players and develop appropriate interventions where necessary.

Acknowledgements Not applicable.

Author Contributions MN and MC carried out the systematic review with support from AK. MN wrote the manuscript with support from MC, AK, and MR. All authors read and approved final manuscript.

Funding No funding sources were received for this work.

Availability of Data and Materials Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethics Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

References

1. Areta JL, Burke LM, Ross ML, Camera DM, West DWD, Broad EM, Jeacocke NA, Moore DR, Stellingwerff T, Phillips SM. Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. J Physiol. 2013;591(9):2319–31. https://doi.org/10.1113/jphysiol.2012.244897.
2. Ataley-Guzel N, Erikoglu Orer G, Sezen Bircan F, Coskun Cevher S. Effects of acute l carnitine supplementation on nitric oxide production and oxidative stress after exhaustive exercise in young soccer players. J Sports Med Phys Fitness. 2015;55(1–2):9–15.
3. Aubut J-AL, Marshall S, Bayley M, Teasell RW. A comparison of the pedro and downs and black quality assessment tools using the acquired brain injury intervention literature. NeuroRehabilitation. 2013;32(1):95–102. https://doi.org/10.3233/NRE-130826.
4. Bar-Or O. Climate and the exercising child-a review. Int J Sports Med. 1980;1(02):53–65.
5. Bassit RA, Curi R, Rosa LC. Creatine supplementation reduces plasma levels of pro-inflammatory cytokines and pge 2 after a half-ironman competition. Amino Acids. 2008;35(2):425–31.
6. Bentley MRN, Patterson LB, Mitchell N, Backhouse SH. Athlete perspectives on the enablers and barriers to nutritional adherence in high-performance sport. J Sports Sci. 2021;52:101831. https://doi.org/10.1016/j.psychsport.2020.101831.
7. Bettonviel AEO, Brinkmans NYJ, Russcher K, Wardenaar FC, Witard OC. Nutritional status and daytime pattern of protein intake on match, post-match, rest and training days in senior professional and youth elite soccer players. Int J Sport Nutr Exerc Metab. 2016;26(3):285–93. https://doi.org/10.1123/ijsnem.2015-0218.
8. Bezuglov E, Tikhonova A, Zueva A, Khaitin V, Waśkiewicz Z, Gerasimuk D, Żebrowska A, Rosemann T, Nikolaidis P, Knechtle B. Prevalence and treatment of vitamin d deficiency in young male Russian soccer players in winter. Nutrients. 2019;11(10):2405.
9. Boisseau N, Le Creff C, Loyens M, Poortmans JR. Protein intake and nitrogen balance in male non-active adolescents and soccer players. Eur J Appl Physiol. 2002;88(3):288–93.
10. Bortolotti H, Pereira LA, Santos Oliveira R, Serpeloni Cyrino E, Altimari LR. Carbohydrate mouth rinse does not improve repeated sprint performance. Braz J Kineanthr & Hum Perf. 2013;15(6):639–45.
11. Bowen L, Gross AS, Gimpel M, Li F-X. Accumulated workloads and the acute: chronic workload ratio relate to injury risk in elite youth football players. Br J Sports Med. 2017;51(5):452–9.
12. Bradley B, Johnson D, Hill M, McGee D, Kana-Ah A, Sharpin C, Sharp P, Kelly A, Cumming SP, Malina RM. Bio-banding in academy football: player's perceptions of a maturity matched tournament. Ann Hum Biol. 2019;46(5):400–8. https://doi.org/10.1080/03014460.2019.1640284.
13. Braun H, von Andrian-Werburg J, Schänzer W, Thevis M. Nutrition status of young elite female German football players. Pediatr Exerc Sci. 2018;30(1):157–67. https://doi.org/10.1123/pes.2017-0072.
14. Briggs MA, Cockburn E, Rumbold PLS, Rae G, Stevenson EJ, Russell M. Assessment of energy intake and energy expenditure of male adolescent academy-level soccer players during a competitive week. Nutrients. 2015;7(10):8392–401. https://doi.org/10.3390/nu7105400.
15. Briggs MA, Rumbold PL, Cockburn E, Russell M, Stevenson EJ. Agreement between two methods of dietary data collection in male adolescent academy-level soccer players. Nutrients. 2015;7(7):5948–60. https://doi.org/10.3390/nu7075262.
16. Briggs MA, Harper LD, McNamee G, Cockburn E, Rumbold PL, Stevenson EJ, Russell M. The effects ofan increased calorie breakfast consumed prior to simulated match-play in Academy soccer players. Eur J Sport Sci. 2017;17(7):858–66. https://doi.org/10.1080/17461391.2017.1301560.
17. Buono MJ, Heaney JH, Canine KM. Acclimation to humid heat lowers resting core temperature. Am J Physiol. 1998;274(5):1295–9. https://doi.org/10.1152/ajpregu.1998.274.5.R1295.
18. Burke L. Practical sports nutrition. Champaign, Illinois: Human Kinetics; 2007.
19. Caccialanza R, Cameletti B, Cavallaro G. Nutritional intake of young Italian high-level soccer players: under-reporting is the essential outcome. J Sports Sci Med. 2007;6(4):538–42.
20. Cauley JA, Lui L-Y, Ensrud KE, Zmuda JM, Stone KL, Hochberg MC, Cummings SR. Bone mineral density and the risk of incident nonspinal fractures in black and white women. JAMA. 2005;293(17):2102–8. https://doi.org/10.1001/jama.293.17.2102.
21. Cherian KS, Shahkar F, Sainoji A, Balakrishna N, Yagnambhatt VR. Resting metabolic rate of Indian Junior Soccer players: testing agreement between measured versus selected predictive equations. Am J Hum Biol. 2018;30(1):e23066. https://doi.org/10.1002/ajhb.23066.
22. Cherian KS, Sainoji A, Nagalla B, Yagnambhatt VR. Energy balance coexists with disproportionate macronutrient consumption across pretraining, during training, and posttraining among Indian junior soccer players. Pediatric Exer Sci. 2018;30(4):506–15. https://doi.org/10.1123/pes.2017-0276.
23. Close GL, Ashton T, McArdle A, Maclaren DPM. The emerging role of free radicals in delayed onset muscle soreness and contraction-induced muscle injury. Comp Biochem Physiolo A Mol Integr Physiol. 2005;142(3):257–66. https://doi.org/10.1016/j.cbpa.2005.08.005.
24. Collins J, Maughan RJ, Gleeson M, Bilsborough J, Jeukendrup A, Morton JP, Phillips SM, Armstrong L, Burke LM, Close GL. Uefa expert group statement on nutrition in elite football. Current evidence to inform practical recommendations and guide future research. Br J Sports Med. 2020;55(8):416–416.
25. Costello JT, Bieuzen F, Bleakley CM. Where are all the female participants in sports and exercise medicine research? Eur J Sport Sci. 2014;14(8):847–51. https://doi.org/10.1080/17461391.2014.911354.
26. Da Silva RP, Mündel T, Natali AJ, Bara Filho MG, Alfenas RCG, Lima JRP, Belfort FG, Lopes PRNR, Marins JCB. Pregame hydration status, sweat loss, and fluid intake in elite Brazilian young male soccer players during competition. J Sports Sci. 2012;30(1):37–42. https://doi.org/10.1080/02640414.2011.623711.
27. Deminice R, Rosa FT, Franco GS, Jordao AA, de Freitas EC. Effects of creatine supplementation on oxidative stress

and inflammatory markers after repeated-sprint exercise in humans. Nutrition (Burbank, Los Angeles County, Calif). 2013;29(9):1127–32. https://doi.org/10.1016/j.nut.2013.03.003.
28. Deminice R, Rosa FT, Pfrimer K, Ferrioli E, Jordao AA, Freitas E. Creatine supplementation increases total body water in soccer players: a deuterium oxide dilution study. Int J Sports Med. 2016;37(2):149–53. https://doi.org/10.1055/s-0035-1559690.
29. Djordjevic B, Baralic I, Kotur-Stevuljevic J, Stefanovic A, Ivanisevic J, Radivojevic N, Andjelkovic M, Dikic N. Effect of astaxanthin supplementation on muscle damage and oxidative stress markers in elite young soccer players. J Sports Med Phys Fitness. 2012;52(4):382–92.
30. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998;52(6):377–84. https://doi.org/10.1136/jech.52.6.377.
31. Duelli R, Kuschinsky W. Brain glucose transporters: relationship to local energy demand. Physiology. 2001;16(2):71–6. https://doi.org/10.1152/physiologyonline.2001.16.2.71.
32. Edwards AM, Mann ME, Marfell-Jones MJ, Rankin DM, Noakes TD, Shillington DP. Influence of moderate dehydration on soccer performance: physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests. Br J Sports Med. 2007;41(6):385–91. https://doi.org/10.1136/bjsm.2006.033860.
33. Elferink-Gemser MT, Huijgen BCH, Coelho-E-Silva M, Lemmink KAPM, Visscher C. The changing characteristics of talented soccer players–a decade of work in Groningen. J Sports Sci. 2012;30(15):1581–91. https://doi.org/10.1080/02640414.2012.725854.
34. Eriksson O, Saltin B. Muscle metabolism during exercise in boys aged 11 to 16 years compared to adults. Acta Paediatr Belg. 1974;28:257–65.
35. Ersoy N, Ersoy G, Kutlu M. Assessment of hydration status of elite young male soccer players with different methods and new approach method of substitute urine strip. J Int Soc Sports Nutr. 2016;13:1–6. https://doi.org/10.1186/s12970-016-0145-8.
36. Falk B, Dotan R. Children's thermoregulation during exercise in the heat—a revisit. Appl Physiol Nutr Metab. 2008;33(2):420–7. https://doi.org/10.1139/H07-185.
37. Favano A, Santos-Silva PR, Nakano EY, Pedrinelli A, Hernandez AJ, Greve JMDA. Peptide glutamine supplementation for tolerance of intermittent exercise in soccer players. Clinics (Sao Paulo, Brazil). 2008;63(1):27–32. https://doi.org/10.1590/S1807-59322008000100006.
38. Garrido G, Webster AL, Chamorro M. Nutritional adequacy of different menu settings in elite Spanish adolescent soccer players. I Int J Sport Nutr Exerc Metab. 2007;17(5):421–32. https://doi.org/10.1123/ijsnem.17.5.421.
39. Gibson JC, Stuart-Hill L, Martin S, Gaul C. Nutrition status of junior elite Canadian female soccer athletes. Int J Sport Nutr Exerc Metab. 2011;21(6):507–14. https://doi.org/10.1123/ijsnem.21.6.507.
40. Gibson JC, Stuart-Hill LA, Pethick W, Gaul CA. Hydration status and fluid and sodium balance in elite Canadian junior women's soccer players in a cool environment. Appl Physiol Nutr Metab. 2012;37(5):931–7. https://doi.org/10.1139/h2012-073.
41. Granja DS, Cotovio R, Pinto R, Borrego R, Mendes L, Carolino E, Macedo P, Ferreira D, Caetano C, Mendes B. Evaluation of young elite soccer players food intake on match day and highest training load days. J Hum Sport Exerc. 2017;12(4):1238–47. https://doi.org/10.14198/jhse.2017.124.10.
42. Greenleaf J. Problem: thirst, drinking behavior, and involuntary dehydration. Med Sci Sports Exer. 1992;24(6):645–56. https://doi.org/10.1249/00005768-199206000-00007.
43. Guttierres APM, Natali AJ, Vianna JM, Reis VM, Marins JCB. Dehydration in soccer players after a match in the heat. Biol Sport. 2011;28(4):249–54.
44. Haleem MAA. The Qur'an. Oxford: OUP; 2005.
45. Hannon MP, Carney DJ, Floyd S, Parker LJF, McKeown J, Drust B, Unnithan VB, Close GL, Morton JP. Cross-sectional comparison of body composition and resting metabolic rate in premier league academy soccer players: implications for growth and maturation. J Sports Sci. 2020;38(11/12):1326–34. https://doi.org/10.1080/02640414.2020.1717286.
46. Hannon MP, Parker LJF, Carney DJ, McKeown J, Speakman JR, Hambly C, Drust B, Unnithan VB, Close GL, Morton JP. Energy requirements of male academy soccer players from the English premier league. Med Sci Sports Exerc. 2020;53(1):200–10.
47. Harper LD, Briggs MA, McNamee G, West DJ, Kilduff LP, Stevenson E, Russell M. Physiological and performance effects of carbohydrate gels consumed prior to the extra-time period of prolonged simulated soccer match-play. J Sci Med Sport. 2016;19(6):509–14.
48. Hidalgo y Teran Elizondo R, Martín Bermudo FM, Peñaloza Mendez R, Berná Amorós G, Lara Padilla E, Berral de la Rosa FJ. Nutritional intake and nutritional status in elite Mexican teenagers soccer players of different ages. Nutr Hosp. 2015;32(4):1735–43.
49. Holtzman B, Ackerman KE. Recommendations and nutritional considerations for female athletes: health and performance. Sports Med. 2021;51:43–57. https://doi.org/10.1007/s40279-021-01508-8.
50. Iglesias-Gutiérrez E, García A, García-Zapico P, Pérez-Landaluce J, Patterson AM, García-Rovés PM. Is there a relationship between the playing position of soccer players and their food and macronutrient intake? Appl Physiol Nutr Metab. 2012;37(2):225–32. https://doi.org/10.1139/h11-152.
51. Iglesias-Gutiérrez E, García-Rovés PM, García A, Patterson AM. Food preferences do not influence adolescent high-level athletes' dietary intake. Appetite. 2008;50(2–3):536–43. https://doi.org/10.1016/j.appet.2007.11.003.
52. Iglesias-Gutiérrez E, García-Rovés PM, Rodríguez C, Braga S, García-Zapico P, Patterson ÁM. Food habits and nutritional status assessment of adolescent soccer players. A necessary and accurate approach. Can J Appl Physiol. 2005;30(1):18–32. https://doi.org/10.1139/h05-102.
53. Jastrzebska M, Kaczmarczyk M, Suárez AD, Sánchez GFL, Jastrzebska J, Radziminski L, Jastrzebski Z. Iron, hematological parameters and blood plasma lipid profile in vitamin D supplemented and non-supplemented young soccer players subjected to high-intensity interval training. J Nutritional Sci Vitaminol. 2017;63(6):357–64. https://doi.org/10.3177/jnsv.63.357.
54. Jastrzębska M, Kaczmarczyk M, Michalczyk M, Radzimiński Ł, Stępień P, Jastrzębska J, Wakuluk D, Suárez AD, López Sánchez GF, Cięszczyk P, Godlewski P, Król P, Jastrzębski Z. Can supplementation of vitamin d improve aerobic capacity in well trained youth soccer players? J Hum Kin. 2018;61(1):63–72. https://doi.org/10.2478/hukin-2018-0033.
55. Jordan JB, Korgaokar A, Farley RS, Coons JM, Caputo JL. Caffeine supplementation and reactive agility in elite youth soccer players. Pediat Exerc Sci. 2014;26(2):168–76. https://doi.org/10.1123/pes.2013-0134.
56. Kelly AL, Williams CA, Wilson M. Developing a football-specific talent identification and development profiling concept–the locking wheel nut model. Appl Coach Res J. 2018;2:32–41.
57. Kingsley MI, Wadsworth D, Kilduff LP, McEneny J, Benton D. Effects of phosphatidylserine on oxidative stress following intermittent running. Med Sci Sports Exerc. 2005;37(8):1300–6. https://doi.org/10.1249/01.mss.0000175306.05465.7e.

58. Kirkendall DT, Leiper JB, Bartagi Z, Dvorak J, Zerguini Y. The influence of Ramadan on physical performance measures in young Muslim footballers. J Sports Sci. 2008;26(Suppl 3):S15–27. https://doi.org/10.1080/02640410802422199.
59. Koç MC, Saritaş N, Kirbaş Ş, Bülbül H. Examining nutritional habits of soccer players at youth development teams. Ovidius Univ Ann Ser Phys Educ Sport/Sci Mov Health. 2016;16:576–84.
60. Kreider RB, Kalman DS, Antonio J, Ziegenfuss TN, Wildman R, Collins R, Candow DG, Kleiner SM, Almada AL, Lopez HL. International society of sports nutrition position stand: safety and efficacy of creatine supplementation in exercise, sport, and medicine. J Int Soc Sports Nutr. 2017;14(1):1–18. https://doi.org/10.1186/s12970-017-0173-z.
61. Kreider RB, Wilborn CD, Taylor L, Campbell B, Almada AL, Collins R, Cooke M, Earnest CP, Greenwood M, Kalman DS. ISSN exercise & sport nutrition review: research & recommendations. J Int Soc Sports Nutr. 2010;7(1):1–43. https://doi.org/10.1186/1550-2783-7-7.
62. Lawler JM, Barnes WS, Wu G, Song W, Demaree S. Direct antioxidant properties of creatine. Biochem Biophys Res Commun. 2002;290(1):47–52. https://doi.org/10.1006/bbrc.2001.6164.
63. Leblanc JC, Le Gall F, Grandjean V, Verger P. Nutritional intake of French soccer players at the clairefontaine training center. Int J Sport Nutr Exerc Metab. 2002;12(3):268–80. https://doi.org/10.1123/ijsnem.12.3.268.
64. Livingstone MB, Prentice AM, Coward WA, Strain JJ, Black AE, Davies PS, Stewart CM, McKenna PG, Whitehead RG. Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. Am J Clin Nutr. 1992;56(1):29–35. https://doi.org/10.1093/ajcn/56.1.29.
65. Loucks AB. Low energy availability in the marathon and other endurance sports. Sports Med. 2007;37(4–5):348–52. https://doi.org/10.2165/00007256-200737040-00019.
66. Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity. Human Kinetics. 2004. https://doi.org/10.5040/9781492596837.
67. Maughan RJ, Leiper JB, Bartagi Z, Zrifi R, Zerguini Y, Dvorak J. Effect of Ramadan fasting on some biochemical and haematological parameters in Tunisian youth soccer players undertaking their usual training and competition schedule. J Sports Sci. 2008;26(S3):S39–46. https://doi.org/10.1080/02640410802491368.
68. McMinn D, Acharya R, Rowe DA, Gray SR, Allan JL. Measuring activity energy expenditure: accuracy of the gt3x+ and actiheart monitors. Int J Exerc Sci. 2013;6(3):5.
69. Meckel Y, Ismaeel A, Eliakim A. The effect of the Ramadan fast on physical performance and dietary habits in adolescent soccer players. Eur J Appl Physiol. 2008;102(6):651–7. https://doi.org/10.1007/s00421-007-0633-2.
70. Meyer F, Bar-Or O. Fluid and electrolyte loss during exercise. Sports Med. 1994;18(1):4–9. https://doi.org/10.2165/00007256-199418010-00002.
71. Mielgo-Ayuso J, Calleja-Gonzalez J, Marqués-Jiménez D, Caballero-García A, Córdova A, Fernández-Lázaro D. Effects of creatine supplementation on athletic performance in soccer players: a systematic review and meta-analysis. Nutrients. 2019;11(4):757. https://doi.org/10.3390/nu11040757.
72. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma G. Preferred reporting items for systematic reviews and meta-analyses: the Prisma statement. PLoS med. 2009;6(7): e1000097. https://doi.org/10.1371/journal.pmed.1000097.
73. Murphy S, Jeanes Y. Nutritional knowledge and dietary intakes of young professional football players. Nutr Food Sci. 2006;36:343–8. https://doi.org/10.1108/00346650610703199.
74. Naughton RJ, Drust B, O'Boyle A, Abayomi J, Mahon E, Morton JP, Davies IG. Free-sugar, total-sugar, fibre, and micronutrient intake within elite youth British soccer players: a nutritional transition from schoolboy to fulltime soccer player. Appl Physiol Nutr Metab. 2017;42(5):517–22. https://doi.org/10.1139/apnm-2016-0459.
75. Naughton RJ, Drust B, O'Boyle A, Morgans R, Abayomi J, Davies IG, Morton JP, Mahon E. Daily distribution of carbohydrate, protein and fat intake in elite youth academy soccer players over a 7-day training period. Int J Sport Nutr Exerc Metab. 2016;26(5):473–80. https://doi.org/10.1123/ijsnem.2015-0340.
76. Nawrot P, Jordan S, Eastwood J, Rotstein J, Hugenholtz A, Feeley M. Effects of caffeine on human health. Food Addit Contam. 2003;20(1):1–30. https://doi.org/10.1080/0265203021000007840.
77. Nobari H, Cholewa JM, Pérez-Gómez J, Castillo-Rodríguez A. Effects of 14-weeks betaine supplementation on pro-inflammatory cytokines and hematology status in professional youth soccer players during a competition season: a double blind, randomized, placebo-controlled trial. J Int Soc Sports Nutr. 2021;18(1):42. https://doi.org/10.1186/s12970-021-004415.
78. Nobari H, Kargarfard M, Minasian V, Cholewa JM, Pérez-Gómez J. The effects of 14-week betaine supplementation on endocrine markers, body composition and anthropometrics in professional youth soccer players: a double blind, randomized, placebo-controlled trial. J Int Soc Sports Nutr. 2021;18(1):20. https://doi.org/10.1186/s12970-021-00417-5.
79. Noll M, de Mendonça CR, de Souza Rosa LP, Silveira EA. Determinants of eating patterns and nutrient intake among adolescent athletes: a systematic review. Nutr J. 2017;16(1):46. https://doi.org/10.1186/s12937-017-0267-0.
80. Noronha DC, Santos MIAF, Santos AA, Corrente LGA, Fernandes RKN, Barreto ACA, Santos RGJ, Santos RS, Gomes LPS, Nascimento MVS. Nutrition knowledge is correlated with a better dietary intake in adolescent soccer players: a cross-sectional study. J Nutr Metab. 2020;2020:1–7. https://doi.org/10.1155/2020/3519781.
81. Oliveira CC, Ferreira D, Caetano C, Granja D, Pinto R, Mendes B, Sousa M. Nutrition and supplementation in soccer. Sports. 2017;5(2):28. https://doi.org/10.3390/sports5020028.
82. Oppliger RA, Bartok C. Hydration testing of athletes. Sports Med. 2002;32(15):959–71. https://doi.org/10.2165/00007256-200232150-00001.
83. Ostojic SM, Mazic S. Effects of a carbohydrate-electrolyte drink on specific soccer tests and performance. J Sports Sci Med. 2002;1(2):47.
84. Owens DJ, Sharples AP, Polydorou I, Alwan N, Donovan T, Tang J, Fraser WD, Cooper RG, Morton JP, Stewart C. A systems-based investigation into vitamin d and skeletal muscle repair, regeneration, and hypertrophy. Am J Physiol Endocrinol Metab. 2015;309(12):E1019–31. https://doi.org/10.1152/ajpendo.00375.2015.
85. Packer L. Oxidants, antioxidant nutrients and the athlete. J Sports Sci. 1997;15(3):353–63. https://doi.org/10.1080/026404197367362.
86. Phillips SM, Sykes D, Gibson N. Hydration status and fluid balance of elite European youth soccer players during consecutive training sessions. J Sports Sci Med. 2014;13(4):817.
87. Phillips SM, Van Loon LJC. Dietary protein for athletes: from requirements to optimum adaptation. J Sports Sci. 2011;29(Sup 1):S29–38. https://doi.org/10.1080/02640414.2011.619204.
88. Reilly T. Motion analysis and physiological demands. Sci Soccer. 2003;2:59–72.
89. Relvas H, Littlewood M, Nesti M, Gilbourne D, Richardson D. Organizational structures and working practices in elite European professional football clubs: understanding the relationship

between youth and professional domains. Eur Sport Manag Q. 2010;10(2):165–87. https://doi.org/10.1080/16184740903559891.

90. Rodriguez-Giustiniani P, Rollo I, Witard OC, Galloway SDR. Ingesting a 12% carbohydrate-electrolyte beverage before each half of a soccer match simulation facilitates retention of passing performance and improves high-intensity running capacity in academy players. Int J Sport Nutr Exerc Metab. 2019;29(4):397–405. https://doi.org/10.1123/ijsnem.2018-0214.
91. Rollo I, Cole M, Miller R, Williams C. Influence of mouth rinsing a carbohydrate solution on 1-h running performance. Med Sci Sports Exerc. 2010;42(4):798–804. https://doi.org/10.1249/MSS.0b013e3181bac6e4.
92. Ruiz F, Irazusta A, Gil S, Irazusta J, Casis L, Gil J. Nutritional intake in soccer players of different ages. J Sports Sci. 2005;23(3):235–42. https://doi.org/10.1080/02640410410001730160.
93. Russell M, Benton D, Kingsley M. Influence of carbohydrate supplementation on skill performance during a soccer match simulation. J Sci Med Sport. 2012;15(4):348–54. https://doi.org/10.1016/j.jsams.2011.12.006.
94. Russell M, Pennock A. Dietary analysis of young professional soccer players for 1 week during the competitive season. J Strength Cond Res. 2011;25(7):1816–23. https://doi.org/10.1519/JSC.0b013e3181e7fbdd.
95. Saltin B. Metabolic fundamentals in exercise. Med Sci Sports. 1973;5(3):137–46. https://doi.org/10.1249/00005768-197323000-00010.
96. Shirreffs SM, Maughan RJ. Water and salt balance in young male football players in training during the holy month of Ramadan. J Sports Sci. 2008;26(Suppl 3):S47–54. https://doi.org/10.1080/02640410802428097.
97. Silva R, Mündel T, Natali A, Bara Filho M, Lima JP, Alfenas RG, Lopes PNR, Belfort F, Marins JB. Fluid balance of elite Brazilian youth soccer players during consecutive days of training. J Sports Sci. 2011;29(7):725–32. https://doi.org/10.1080/02640414.2011.552189.
98. Silva T, Di Cavalcanti Alves de Souza M, De Amorim JF, Stathis CG, Leandro CG, Lima-Silva AE. Can carbohydrate mouth rinse improve performance during exercise? A systematic review. Nutrients. 2014;6(1):1–10.
99. Simpson AJ, Horne S, Sharp P, Sharps R, Kippelen P. Effect of creatine supplementation on the airways of youth elite soccer players. Med Sci Sports Exerc. 2019;51(8):1582–90. https://doi.org/10.1249/MSS.0000000000001979.
100. Skalska M, Nikolaidis PT, Knechtle B, Rosemann TJ, Radzimiński Ł, Jastrzębska J, Kaczmarczyk M, Myśliwiec A, Dragos P, López-Sánchez GF, Jastrzębski Z. Vitamin d supplementation and physical activity of young soccer players during high-intensity training. Nutrients. 2019;11(2):349. https://doi.org/10.3390/nu11020349.
101. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer. Sports Med. 2005;35(6):501–36.
102. Sánchez-Díaz S, Yanci J, Castillo D, Scanlan AT, Raya-González J. Effects of nutrition education interventions in team sport players. A systematic review. Nutrients. 2020;12(12):3664.
103. Temple JL. Caffeine use in children: what we know, what we have left to learn, and why we should worry. Neurosci Biobehav Rev. 2009;33(6):793–806. https://doi.org/10.1016/j.neubiorev.2009.01.001.
104. Timmons BW, Bar-Or O, Riddell MC. Oxidation rate of exogenous carbohydrate during exercise is higher in boys than in men. J Appl Physiol. 2003;94(1):278–84. https://doi.org/10.1152/japplphysiol.00140.2002.
105. Trakman GL, Forsyth A, Devlin BL, Belski R. A systematic review of athletes' and coaches' nutrition knowledge and reflections on the quality of current nutrition knowledge measures. Nutrients. 2016;8(9):570. https://doi.org/10.3390/nu8090570.
106. Vieira RP, Duarte ACS, Claudino RC, Perini A, Santos ABG, Moriya HT, Arantes-Costa FM, Martins MA, Carvalho CRF, Dolhnikoff M. Creatine supplementation exacerbates allergic lung inflammation and airway remodeling in mice. Am J Respir Cell Mol Biol. 2007;37(6):660–7. https://doi.org/10.1165/rcmb.2007-0108OC.
107. Weishaar T, Rajan S, Keller B. Probability of vitamin d deficiency by body weight and race/ethnicity. J Am Board Fam Med. 2016;29(2):226–32. https://doi.org/10.3122/jabfm.2016.02.150251.
108. Yáñez-Silva A, Buzzachera CF, Piçarro IDC, Januario RSB, Ferreira LHB, McAnulty SR, Utter AC, Souza-Junior TP. Effect of low dose, short-term creatine supplementation on muscle power output in elite youth soccer players. J Int Soc Sports Nutr. 2017;14(1):1–8. https://doi.org/10.1186/s12970-017-0162-2.