

Nutrition: what should youth athletes be eating and drinking?

By **Marcus Hannon**, Liverpool John Moores University

OVERVIEW

Youth athletes have different nutritional requirements to adults, and to others of a similar age who are not taking part in sport. There are many factors to take into consideration when taking decisions on what to recommend: here a nutritionist helps to explain these factors and makes recommendations in all areas of nutritional intake in this group of athletes.

Introduction

Youth athletes cannot simply be considered 'mini adult athletes', and although it may be pragmatic to apply nutritional guidelines for the adult athlete to the youth athlete, it may not always be appropriate. Youth athletes undergo many anatomical and physiological changes as a result of growth and maturation, which influence their nutritional requirements (see Table 1 on next page). Nutritional recommendations for youth athletes should not only focus on sporting performance, but should also meet the requirements to support growth and development.

There are several factors that need to be considered when working with youth athletes: 1) their current maturity status and rate of growth and maturation; 2) their current physiological and metabolic capacities; and 3) their sport and exercise demands. All of these factors are interlinked and influence the nutritional requirements of a youth athlete (Figure 1 on the next page). It is essential that we gain a greater understanding of these factors and the interplay between them before we can develop sport-specific nutritional requirements for youth athletes.

Energy availability

During growth, energy is required to synthesise new tissue.¹ Highly variable rates of growth and maturation between youth athletes,² particularly around peak height velocity (PHV), will influence energy requirements. A youth athlete's energy intake is dictated by their total energy expenditure (TEE). TEE has three contributing factors: 1) basal metabolism (the energy required to maintain homeostatic physiology at rest); 2) thermic effect of food (the energy costs of digestion, absorption, transport, metabolism of food and drink); and 3) energy expenditure from planned physical activity and non-exercise activity thermogenesis. In athletes, physical activity EE (PAEE) is often the greatest contributor to TEE. Exercise type, duration and intensity, as well as an individual's anthropometrics, will all influence PAEE, resulting in a large inter-individual variability in TEE between youth athletes (Table 2). The energy requirements for non-athletic children/adolescents or for adult athletes are therefore inappropriate for youth athletes.

Although it is difficult to prescribe exact energy requirements for youth athletes, it is advised that youth athletes have sufficient

AUTHOR'S BIO



MARCUS HANNON,
BSC, MSC, rSEN

Marcus is currently the Academy performance nutritionist at a Premier League football club, having previously worked in professional rugby union. Alongside his role there, Marcus is also studying towards a PhD in applied physiology and sports nutrition at Liverpool John Moores University, investigating the energy requirements of elite youth footballers.

Table 1. The main physiological and metabolic differences between youth and adult athletes and the consequences of these factors on nutritional recommendations for youth athletes

SUMMARY OF MAIN PHYSIOLOGICAL AND METABOLIC ISSUES SURROUNDING GROWTH AND MATURATION

Greater energy cost of movement

Children and adolescents have a higher (relative) energy cost of movement compared to adults. This may be due to increased stride frequency, a greater surface area:volume ratio, a more distal distribution of mass in the legs, or because of greater levels of contraction of the antagonist leg muscles while moving⁴³

Reduced glycogen storage capacity

Children and adolescents have lower endogenous glycogen storage capacity compared to adults⁴⁴

Reduced glycolytic capabilities

Children and adolescents have reduced glycolytic capabilities, with full anaerobic capabilities developing towards the end of puberty.⁴⁵ As a result, children and adolescents have lower levels of lactate production than adults during high intensity exercise of the same relative intensity^{44,46}

Higher rates of aerobic metabolism

Higher rates of aerobic metabolism exist in children during exercise. Fat oxidation rates during sub-maximal exercise (of the same relative intensity) are greater in children and adolescents compared to adults. Less mature children have a greater reliance on fat as a fuel compared to more mature adolescents. It has been suggested that these higher fat oxidation rates in children compared to adults are the results of lower endogenous carbohydrate stores and reduced glycolytic capabilities⁴⁷

Greater reliance on exogenous carbohydrate

Children and adolescents have a greater reliance on exogenous carbohydrate as a fuel source. During exercise, exogenous carbohydrate is a greater contributor to total energy supply in children and adolescents compared to adults.⁴⁷ Exogenous carbohydrate oxidation rates are higher in less mature boys compared to more mature boys of the same chronological age; however, this is not the case in girls^{48,49}

Thermoregulatory differences

Children and adolescents generate more metabolic heat compared to adults, primarily due to their larger surface area to body mass ratio.⁵⁰ Consequently, they gain and lose more heat from the environment through conduction, convection and radiation. Adolescents who undertake regular exercise do adapt, however, improving their ability to thermoregulate through enhanced peripheral vasodilation⁵¹

Reduced sweating capacity

Children and adolescents have a lower sweating capacity compared to adults and therefore a reduced ability to lose sweat through sweat evaporation. As children mature, so too do their thermoregulation mechanisms (particularly their ability to sweat); however, these are not fully developed until late puberty⁵²

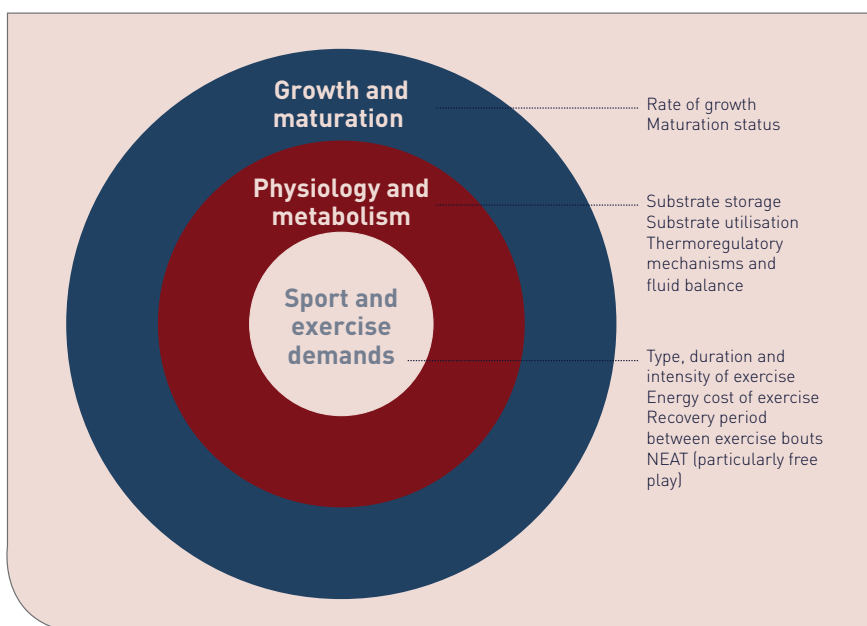


Figure 1. Factors which influence nutritional requirements of youth athletes

energy availability (EA) for growth and development. EA is the amount of energy left for homeostatic physiological functions, thermoregulation and growth, once PAEE has been deducted from energy intake ($EA = \text{energy intake} - PAEE$).³ Chronic low EA ($<30 \text{ kcal.kg FFM}^{-1}.\text{day}^{-1}$) may result in impaired growth and maturation of tissues and organs, reduced skeletal bone mineral accrual, and an increased risk of stress fractures and osteoporosis in later life, as well as delayed sexual maturation, disruption or cessation of menstruation and a suppression of the immune system.³ Not only is this likely to have a negative effect on a youth athlete's performance, but it also impacts on long-term physical and psychological health. An EA of $\geq 45 \text{ kcal.kg FFM}^{-1}.\text{day}^{-1}$ is recommended for adult athletes to maintain normal physiological function.³ Considering youth athletes have greater relative energy demands than adults, $\geq 45 \text{ kcal.kg FFM}^{-1}.\text{day}^{-1}$ is likely to be the minimum a youth athlete would require;

Table 2. Energy intakes and expenditures of youth athletes in different sports

SPORT	TRAINING & COMPETITION LOAD	AGE (YEARS)	SEX	EI METHOD	EI (KCAL.DAY ⁻¹)	MACRONUTRIENTS (G.DAY ⁻¹)	EE METHOD	EE (KCAL.DAY ⁻¹)
Active adolescents [53]	-	~15	M & F	-	-	-	DLW	M: 3361 ± 557 F: 2546 ± 392
TEAM SPORTS								
Basketball [54]	> 10 hours per week	~17	M & F	24-hour recall	M: 2895 ± 479 F: 1807 ± 46	M C: 365.5 ± 64.4 M F: 93.5 ± 20.7 M P: 135.4 ± 23.5 F C: 218.8 ± 1.8 F F: 64.1 ± 1.2 F P: 64.1 ± 1.2	DLW	M: 4626 ± 682 F: 3497 ± 242
Rugby [55]	-	~15	M	-	-	-	DLW	4010 ± 744
Soccer [56]	5 days per week	~15	M	Weighed food diary 24-hour recall	2245 ± 321	C: 318 ± 24 F: 70 ± 7 P: 86 ± 10	Accelerometry	2552 ± 245
Soccer [57]	~85 minutes per day	13-17	F	Food diary	2262 ± 368 (range: 1702 – 3194)	C: 303 ± 62 F: 78 ± 19 P: 77 ± 11	Activity diary	2403 ± 195 (range: 1946 – 2753)
Volleyball [58]	6-8 times per week	12-17	M & F	24-hour recall	M: 3725 ± 753 F: 2786 ± 529	M C: 520 ± 98 M F: 127 ± 39 M P: 124 ± 17 F C: 356 ± 91 F F: 106 ± 29 F P: 100 ± 38	-	-
STRENGTH & POWER SPORTS								
Speed skating [59]	-	~18	M	-	-	-	DLW	4013 ± 908 (range: 3057 – 5971)
Sprinters [60]	-	13-19	M & F	Food diary	2569 ± 508	-	Activity diary SenseWear armband	3196 ± 590
AESTHETIC SPORTS								
Gymnastics [61]	4 hours per day	6-8	M & F	Weighed food diary	1744 ± 444	-	DLW	2004 ± 258
ENDURANCE SPORTS								
Endurance runners [62]	>30-40 weeks per year	10-19	M & F	-	-	-	Activity diary	M: 3609 ± 928 F: 2467 ± 426
Swimmers [63]	~5-6 hours per day	~19	F	Food diary	3129 ± 239	-	DLW	5589 ± 502
MISCELLANEOUS SPORTS								
Modern pentathlon [64]	3 times per week	10-18	M & F	FFQ 24-hour recall	M: 2749 ± 1024 F: 2558 ± 808	M C: 6.3 ± 2.5 (g/kg) M F: 31.4 ± 8.4 (%EI) M P: 1.6 ± 0.5 (g/kg) F C: 6.6 ± 2.2 (g/kg) F F: 30.3 ± 6.6 (%EI) F P: 1.7 ± 0.6 (g/kg)	-	-
Table Tennis [65]	~3 hours per day	~19	M	Food diary Photos via phones	3211 ± 566	-	DLW	3695 ± 449
Youth athletes* [66]	≤5 times per week	~15	M & F	-	-	-	Activity diary	M: 3635 ± 828 F: 3100 ± 715
Youth athletes** [67]	≥5 h per week	11-18	M & F	24-hour recall	M (11-13): 2745 M (14-18): 2905 F (11-13): 2159 F (14-18): 2177	M (11-13) C: 386 M (11-13) F: 92 M (11-13) P: 114 M (14-18) C: 353 M (14-18) F: 108 M (14-18) P: 123 F (11-13) C: 264 F (11-13) F: 72 F (11-13) P: 94 F (14-18) C: 281 F (14-18) F: 79 F (14-18) P: 97	-	-

*those engaged in either athletics, soccer, handball, rowing, canoeing, swimming or triathlon. ** those engaged in endurance, intermittent, aesthetic or strength/power sports.
M = males. F = females. EI = energy intake. EE = energy expenditure. DLW = doubly labelled water. FFQ = food frequency questionnaire.

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however, further research is required. Koehler et al⁴ reported a mean EA of 28.5 and 29.4 kcal.kg FFM⁻¹.day⁻¹ in a group of male and female youth athletes respectively (11-25 years old), who competed in a range of sports (aesthetic, ball, endurance, racquet, water sports) at national or international level.

Carbohydrate recommendations

Carbohydrate is stored in the body as muscle and liver glycogen. Given glycogen depletion is a major cause of fatigue during exercise, it is essential that youth athletes consume sufficient carbohydrate in their diet for performance and recovery from training and competition. Exercise type, intensity and duration dictate an athlete's carbohydrate requirements: as intensity or duration increases, so does an athlete's carbohydrate requirements.

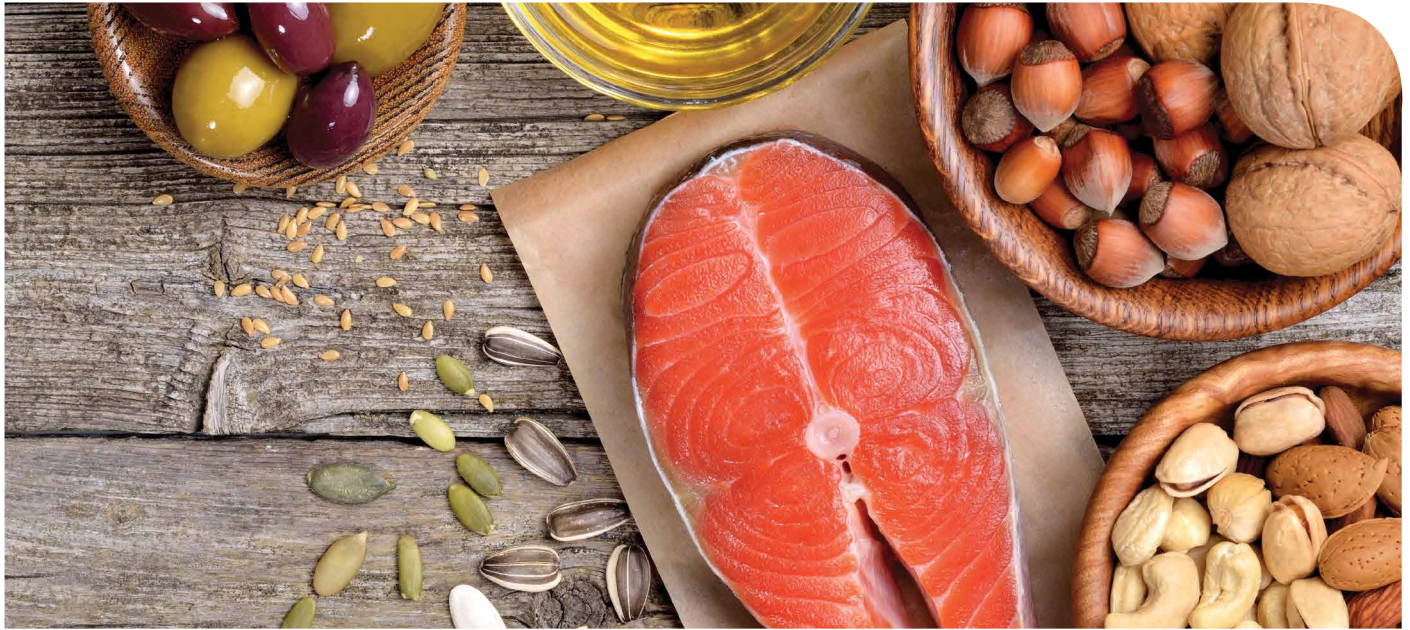
Carbohydrate foods can be categorised according to their glycaemic index (GI). The GI is a numerical scale (1-100) which ranks carbohydrate foods/drinks on their ability to raise blood glucose concentrations: high GI (>70), moderate GI (55-70) or low GI (<55).⁵ Low GI sources typically contain more fibre than higher GI sources and include wholegrain breads and pasta, rice and oats. High GI sources include white bread, rice and potatoes, sports drinks and high sugar-containing breakfast cereals.⁵

Data from adult studies show that pre-training/competition, low GI carbohydrates may confer a metabolic advantage over high GI sources as they increase lipid oxidation, maintain more stable blood glucose and spare muscle glycogen utilisation during exercise.⁶ As such, low GI sources are advisable choices in the pre-training/competition meal and on rest days. Considering youth athletes do not have the same ability to store glycogen as adult athletes and their competition is likely to be shorter in duration, carbohydrate loading prior to competition may not be necessary, although currently no data on youth athletes exist.

Youth athletes also have a greater reliance on exogenous carbohydrate (as a fuel source) during exercise, and therefore carbohydrate consumption during exercise is advised. Not only does carbohydrate consumption during exercise spare endogenous carbohydrate stores in adolescent boys,⁷ but it has also been shown to reduce perception of effort during exercise and benefit performance across different types of exercise. Phillips et al⁸ demonstrated that consumption of a 6% carbohydrate solution (500ml) during intermittent high intensity exercise improved exercise capacity in 12-14-year-old boys compared to placebo. Similarly, Riddell et al⁹ reported a 40% improvement in time to exhaustion performed on a cycle ergometer following consumption of a 6% glucose and fructose solution (25 ml.kg⁻¹) in 10-14-year-old boys.

Peak exogenous carbohydrate oxidation rates are similar between adult and youth athletes;⁷ therefore during exercise youth athletes should consume around 1 g.min⁻¹ of carbohydrate. Liquid forms of high GI carbohydrates are recommended due to the additional benefits on fluid consumption. This should be in the form of a 6% carbohydrate drink (ie, a commercial sports drink), as drinks with a higher carbohydrate content (8%) have been shown to increase gastrointestinal discomfort in both male and female adolescents.¹⁰ Competition rules and regulations may dictate when carbohydrate (and fluid) consumption can occur. Athletes and practitioners should make carbohydrates (and fluids) easily accessible (eg, side of a pitch) for when competition rules allow.

The purpose of post-exercise carbohydrate ingestion is to replenish glycogen stores; however, no data in youth athletes exists. Data from adults have shown that the greatest rates of glycogen re-synthesis occur in the first hour after exercise, and by delaying carbohydrate intake by two hours, glycogen re-synthesis is attenuated.¹¹ Therefore, youth athletes should consume 1.2 g.kg⁻¹.h⁻¹ of high GI carbohydrate in the two hours immediately post-exercise. High GI carbohydrates are preferred



post-exercise because of their ability to rapidly elevate blood glucose and promote glycogen re-synthesis.¹² The precise amount of carbohydrate to be consumed post-exercise is dependent on the recovery period until the next competition time-point. Short recovery periods will require a more aggressive approach, whereas youth athletes who compete once a week may not require such a high intake.

Fat recommendations

Dietary fat is required to promote absorption of fat-soluble vitamins and also to supply essential fatty acids (Omega 3 and 6 fatty acids) which cannot be synthesised by the body and therefore must be obtained through the diet.¹³ Fats are also required as an energy source during exercise, particularly when exercise exceeds 60-90 minutes. Fats are generally classified as saturated or unsaturated, based on their chemical structure. Unsaturated can be further subdivided into mono-unsaturated or poly-unsaturated.

Traditionally saturated fats have been classed as 'bad' fats, whereas unsaturated fats have been classified as 'good' fats. Inclusion of unsaturated fats (contained in oily fish, avocados, nuts, seeds) in the diet has been shown to have health benefits. Furthermore, individual saturated fatty acids have differing effects on blood lipid levels depending on their composition. For example, lauric acid (found in high concentrations in coconut oil), actually decreases total-to-HDL cholesterol ratio, due to an increase in HDL cholesterol.

Therefore, instead of recommending types of fat, recommending types of food is more appropriate.¹⁴ Youth athletes should choose natural sources of fat, particularly those high in Omega 3 (including oily fish, nuts and seeds). Processed sources of fat such as trans-fats (contained in processed foods such as margarine, pastry and biscuits) should be limited as they increase LDL cholesterol and lower HDL cholesterol, increasing risk of cardiovascular disease.¹⁴

There is no evidence to suggest a youth athlete's fat requirements should differ from their non-athletic peers. Considering this, youth athletes should have a greater absolute fat intake compared to their non-athletic peers because of their higher EI (a consequence of their higher EE). As fat is the most energy dense macronutrient, youth athletes competing in weight-making sports may choose to limit their fat intake. This should be avoided to prevent deficiencies in certain fat-soluble vitamins (vitamins A, E and K), Omega 3 and 6 fatty acids and potentially iron and calcium.

Protein recommendations

Protein is an essential macronutrient to support turnover of tissues and tissue growth in youth athletes. Furthermore, proteins have a variety of functions that far extend beyond the mere requirement to build muscle. Proteins provide the building blocks (amino acids) to make many thousands of enzymes that are required in order to provide energy from the breakdown of carbohydrate and fat. The amino acids leucine, isoleucine and valine are collectively

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known as branched chain amino acids and are especially required to facilitate muscle protein synthesis, particularly leucine.¹⁵

Children and adolescents have increased dietary protein requirements, due to the additional protein required for the growth of

new tissues.¹ However, protein requirements of youth athletes are not further increased during periods of growth spurts.¹⁶ Protein requirements are prescribed per kilogram of body mass, to account for individual differences in body size. A number of studies have measured nitrogen balance (intake

Table 3a. Major fat and water-soluble vitamins, their physiological role, typical food sources, and recommended nutrient intake (RNI) for children and adolescents. Data taken from reference 68. It is important to note that RNIs vary for different countries, so the numbers provided here may not be precise for all countries

VITAMIN	PHYSIOLOGICAL ROLE	FOOD SOURCE	RECOMMENDED MALES (AGES)	NUTRIENT INTAKE FEMALES (AGES)
FAT SOLUBLE VITAMINS				
A	Antioxidant. Eye function, cell growth and division	Oily fish, liver, egg yolk, milk, butter, carrots, and apricots	7-10: 500 µg 11-14: 600 µg 15-18: 700 µg	7-10: 500 µg 11-14: 600 µg 15-18: 600 µg
D	Facilitates the utilisation of calcium, cell differentiation, immunity, skin cell development and muscle function	Oily fish, eggs and fortified food	NO DRVs because of sun related synthesis Safe upper limit set at 4,000iU per day	
E	Major fat-soluble antioxidant. Growth and development	Almonds, peanuts, shrimp, sunflower seeds, corn oil	No DRVs but 4 mg for males and 3mg for females considered adequate	
K	Essential for blood clotting and formation of some proteins	Broccoli, cabbage, liver, cauliflower, spinach	No DRVs but 1 µg/kg body weight considered adequate	
WATER SOLUBLE VITAMINS				
C	Major water-soluble antioxidant. Iron absorption. Important in skin, gum and blood vessel health	Asparagus, grapefruit, limes, oranges, lemons, broccoli, sprouts	7-10: 30 mg 11-14: 35 mg 15-18: 40 mg	7-10: 30 mg 11-14: 35 mg 15-18: 40 mg
B ₁ (Thiamin)	Important in carbohydrate and amino acid metabolism (energy)	Almonds, liver, peanuts, whole grain bread and cereals, green peas	7-10: 0.7 mg 11-14: 1.0 mg 15-18: 1.0 mg	7-10: 0.7 mg 11-14: 0.8 mg 15-18: 0.8 mg
B ₂ (Riboflavin)	Important in carbohydrate metabolism (energy)	Asparagus, broccoli, spinach, banana, mushrooms, tuna, dairy products	7-10: 1.0 mg 11-14: 1.2 mg 15-18: 1.3 mg	7-10: 1.0 mg 11-14: 1.1 mg 15-18: 1.1 mg
B ₃ (Niacin)	Important in carbohydrate, fat, amino acid metabolism (energy)	Liver, meat and fish, milk, eggs, avocados, tomatoes, legumes, carrots	7-10: 12.0 mg 11-14: 16.5 mg 15-18: 16.5 mg	7-10: 11.2 mg 11-14: 13.2 mg 15-18: 13.2 mg
B ₅ (Pantothenic acid)	Needed to synthesise co-enzyme A and important in carbohydrate, fat and amino acid metabolism (energy)	Chicken, beef, potatoes, liver, egg yolk, broccoli, whole grains, tomatoes	No DRV but 3-mg considered safe	
B ₆ (Pyridoxine)	Haemoglobin formation and important in carbohydrate metabolism (energy)	Banana, fish, spinach, tuna, egg yolk, chicken	7-10: 1.0 mg 11-14: 1.2 mg 15-18: 1.5 mg	7-10: 1.0 mg 11-14: 1.0 mg 15-18: 1.2 mg
B ₁₂ (Cobalamine)	Haemoglobin formation and prevention of anaemia. Carbohydrate metabolism (energy). Plays role in nervous system	Beef, dairy products, chicken, egg yolk, tuna	7-10: 1.0 µg 11-14: 1.2 µg 15-18: 1.5 µg	7-10: 1.0 µg 11-14: 1.2 µg 15-18: 1.5 µg
Folic acid	Cell division and important in the production of some proteins	Meat, liver, green leafy vegetables, legumes, fruit	7-10: 150 µg 11-14: 200 µg 15-18: 200 µg	7-10: 150 µg 11-14: 200 µg 15-18: 200 µg
Biotin	Important in carbohydrate, fat and amino acid metabolism (energy)	Egg yolk, liver, kidney, meat	No DRV but 10-200 µg considered safe and adequate	

of dietary nitrogen [from protein] versus output of urinary nitrogen) in adolescent sprinters and soccer players.^{16,17} A positive nitrogen balance was achieved with protein intakes between 1.4-1.6 g.kg⁻¹.day⁻¹ in both male and female youth athletes, substantially higher than the reported 0.8 g.kg⁻¹.day⁻¹. Aerenhouts et al,¹⁶ however, did report that in two of the youth athletes, a negative nitrogen balance still occurred despite a protein intake of 2 g.kg⁻¹.day⁻¹. Based on this information, minimum daily protein intakes of 1.4-2 g.kg⁻¹ are recommended for youth athletes.

Studies in active children have also shown that timing of protein intake influences whole-body protein balance (WBPB). Protein should be consumed at breakfast to shift WBPB from a negative into a positive state¹⁸ and intake should be evenly spaced throughout the day (every 3-4 hours) in moderate doses (0.22-0.33 g.kg⁻¹ per meal/snack).¹⁹ This is particularly important prior to exercise (to increase amino acid availability) and also post-exercise.

Volterman et al⁹ found that WBPB remains negative in the absence of post-exercise protein consumption in active 9-13-year-olds. However, consumption of only 5 grams (0.12 g.kg⁻¹) post-exercise promotes a positive WBPB, suggesting that children have an increased sensitivity (relatively) to protein feeding in the three hours post-exercise compared to adults. Intakes of 10 and 15 grams (0.22 and 0.33 g.kg⁻¹) post-exercise further increased WBPB, in a

dose-dependent manner.¹⁸ Protein (eg, a large glass of milk) should also be consumed prior to sleep to provide a supply of amino acids to the muscle overnight to promote increases in muscle mass.²¹

Protein should ideally come from sources high in leucine including meat, poultry, fish, eggs and dairy products. Non-animal sources of protein include beans, pulses, lentils and nuts, but it should be noted that these sources lack a number of essential amino acids including leucine. Practitioners working with vegetarian athletes should closely monitor their protein intake to ensure they are consuming enough.

Micronutrient recommendations

Micronutrients are compounds that are required in small quantities (<1g) to maintain normal physiological function. Although micronutrients do not directly supply energy for human performance, they play essential roles in many metabolic pathways. Broadly speaking, micronutrients can be divided into vitamins and minerals (Table 3). Although it is essential that youth athletes consume adequate amounts of all micronutrients, there are certain vitamins and minerals that are of paramount importance for youth athletes.

CALCIUM AND VITAMIN D RECOMMENDATIONS

Calcium and vitamin D are two key micronutrients that influence skeletal bone mineral content (BMC) accrual and skeletal

Table 3b. Common minerals that athletes may be deficient in, their physiological role and typical food sources.
Data taken from ref 68

MINERAL	PHYSIOLOGICAL ROLE	FOOD SOURCE	RECOMMENDED NUTRIENT INTAKE	
			MALES (AGES)	FEMALES (AGES)
Calcium	Important in muscle contraction and transmission of nerve impulses. Involved in developing and maintaining strong bones	All dairy products including milk, cheese and yoghurt. Small fish with bones (eg, sardines), beans and broccoli	7-10: 550 mg 11-14: 1000 mg 15-18: 1000 mg	7-10: 550 mg 11-14: 800 mg 15-18: 800 mg
Iron	Important in the transport of oxygen	Red meat, liver, broccoli, spinach, fortified cereals, eggs, dried fruits, nuts and seeds	7-10: 8.7 mg 11-14: 11.3 mg 15-18: 11.3 mg	7-10: 8.7 mg 11-14: 14.8 mg 15-18: 14.8 mg
Magnesium	Muscle contraction and transmission of nerve impulses	Meats and dairy. Vegetables and potatoes, bread and cereals, nuts (brazil, almonds and cashews), mushrooms	7-10: 200 mg 11-14: 280 mg 15-18: 300 mg	7-10: 200 mg 11-14: 280 mg 15-18: 300 mg
Zinc	Assists immune function and is an antioxidant. Helps protein digestion and assists in some energy pathways	Liver, kidney, red meat, seafood, poultry, milk, whole grain, leafy and root veg.	7-10: 7.0 mg 11-14: 9.0 mg 15-18: 9.5 mg	7-10: 7.0 mg 11-14: 9.0 mg 15-18: 7.00 mg

‘It is advised that youth athletes consume a calcium-rich snack/meal prior to exercise to attenuate bone resorption’

maintenance. Vitamin D is a key regulator of calcium homeostasis, with sufficient levels required for calcium absorption. Around 26% of adult BMC is accrued during peak BMC velocity (~12.5 and ~14 years old in girls and boys respectively).²² Ensuring maximal BMC accrual is of paramount importance for youth athletes, to maximise peak bone mass and to help reduce the risk of skeletal injuries (eg, stress fractures) and osteoporosis in adulthood.

Research has shown that boys and girls who partake in weight-bearing physical activity during their adolescent years have greater rates of BMC accrual compared to non-active controls.²² However, there is a lack of data to suggest that calcium requirements are higher for youth athletes who partake in weight-bearing exercise. Calcium requirements of adolescents are increased as a result of the higher accrual of BMC. A number of studies, however, have reported low calcium intakes in both male and female youth athletes from a range of sports, which are significantly below the recommended daily amounts.²³

Current calcium recommendations for male and female adolescents in the UK are 1000 and 800mg per day respectively;²⁴ however, these are lower than the American and Australian daily recommendations of 1300mg. The best dietary sources of calcium are dairy products including milk, yogurt and cheese. Sardines, mackerel and green leafy vegetables and oranges also contain a moderate amount of calcium. It is advised that youth athletes consume a calcium-rich snack/meal prior to exercise to attenuate bone resorption.²⁵

In addition to its involvement in calcium homeostasis, vitamin D is also involved in supporting immune function and skeletal muscle regeneration.²⁶ Vitamin D is a unique micronutrient, as it is primarily obtained through dermal synthesis following exposure to ultraviolet-B (UVB) radiation. Small, yet suboptimal quantities, however, can be obtained from certain foods including liver and eggs. From October-March in the UK (locations >35° latitude) there is a lack of UVB radiation and supplementation is advised to prevent deficiency (serum 25(OH)D <30nmol.L⁻¹). Current vitamin D3 supplementation recommendations for adolescents in the UK are 400-4000iU a day.²⁷ Youth athletes who train/compete indoors all year should take supplements towards the higher end of these recommendations, although >4000iU of vitamin D3 a day is not advised due to possible health concerns associated with vitamin D toxicity. Although there is limited evidence for vitamin D supplementation having an ergogenic effect on performance, it is clear that deficiency impairs musculo-skeletal health and increases risk of injury.

IRON RECOMMENDATIONS

Iron is a mineral involved in many different biological processes, including oxygen transport and energy metabolism. Around 60% of iron in the body is in the form of haemoglobin (in the red blood cell), a protein responsible for oxygen transport around the body.²⁸ During childhood and adolescence, iron requirements are increased as a result of growth of tissues. The onset of menstruation in females results in iron losses, increasing their requirements further.²⁹ Daily recommendations for iron



for adolescent boys and girls are 11.3 and 14.8mg respectively.²⁴ This can be obtained from two types of iron in the diet: haem and non-haem iron. Although levels of iron absorption depend on the body's iron stores, absorption of haem-iron (15-35%) is greater than that of non-haem iron (2-20%). Haem-iron is provided mainly from meat sources (particularly red meat) and non-haem from pulses, legumes and green leafy vegetables. Vitamin C promotes absorption of non-haem iron, whereas calcium, polyphenols and phytates reduce absorption of non-haem iron.³⁰ Considering vegetarian athletes will consume primarily non-haem iron sources, iron bioavailability may be an issue resulting in iron deficiency, so monitoring of iron status is advised.

Thermoregulation and fluid recommendations

Thermoregulation is a homeostatic process which regulates body temperature. There are several physiological differences in thermoregulation between youth and adult athletes (Table 1), which can make exercising in very hot and humid conditions dangerous for youth athletes.

Youth athletes should aim to start exercise in a euhydrated state (ie, a state of normal hydration), with normal plasma electrolyte concentrations to offset possible decrements in performance associated with dehydration. Youth athletes should sip 5-7 ml.kg⁻¹ of fluids in the four hours preceding exercise and consume ~20-50 mEq.L⁻¹ of sodium.³¹ During exercise, excessive dehydration (through sweat loss) should be avoided. The disruption of electrolyte balance can impair optimal muscle function and dehydration of 2-3% can increase cardiovascular stress, accelerate glycogen utilisation, and increase subjective perception of effort during exercise; it can also increase core temperature which can lead to heat illness.³¹ Dehydration of ~2% (of body mass) has also been reported to reduce basketball skill-based performance³² and also time to exhaustion cycling performance³³ in young boys. Despite this, many youth athletes from a range of sports voluntarily dehydrate while exercising by not consuming enough fluids.³⁴ Adding flavouring to water, such as squash, has been shown to increase voluntary drinking of youth athletes, most probably because of increased palatability.³⁵ Consequently, it is recommended that youth athletes bring and consume flavoured drinks during training and competition. Youth athletes should drink from their



‘Milk or flavoured milk has been shown to be an effective post-exercise rehydration drink because of its high water and electrolyte content, but milk also contains carbohydrate and protein and so consequently promotes recovery’

own bottles, so that fluid consumed can be assessed and the possible spreading of infection reduced. In addition to fluid intake, electrolyte replacement is also imperative considering the loss during exercise. Milk has been shown to be effective in replacing electrolytes post-exercise.³⁶

Due to the large differences in sweat rates among youth athletes, a blanket approach for hydration recommendations is unwise and individualised hydration strategies are advised.³⁷ Individualised strategies should aim to prevent excessive dehydration (>2% body mass reductions from pre-exercise body mass).³¹ Since change in body mass is an effective assessment of fluid loss, one way for youth athletes to gauge fluid requirements for rehydration is to weigh themselves pre- and post-training/competition. However, a strict protocol should be followed: for example, complete towelling off of sweat and any urine passing collected and included in assessment.

Post-exercise/competition, aggressive rehydration strategies may be required if there is a short recovery period. For each 1kg of body mass lost during exercise, 1.5 litres of fluids should be consumed. If there is not a short recovery period, a less aggressive approach may be used. Consumption of a carbohydrate-containing meal/snack/drink with plain water is sufficient.³¹ Considering 1g of carbohydrate binds 3g of water, carbohydrate consumption will promote rehydration. Milk or flavoured milk has been shown to be an effective post-exercise rehydration drink because of its high water and electrolyte content, but milk also contains carbohydrate and protein and so consequently promotes recovery.³⁶ Flavoured milk is a popular recovery drink with many youth athletes.

Supplements

It is recommended that youth athletes adopt a ‘food-first’ approach, as all macro and micronutrients (with the exception of vitamin D3 in the winter) can be obtained through diet alone. Individuals may choose

certain supplements (carbohydrate gels/protein powders) for convenience reasons, or to help meet their nutritional targets if they struggle to meet these through food sources, as might be the case in larger athletes. However, practitioners should focus their education on the importance of a food-first approach and emphasise the risks associated with consuming supplements.

Laws and legislation surrounding the production and quality control of supplements are not as strictly regulated as those surrounding the pharmaceutical industry.³⁸ Consequently, these supplements may contain harmful ingredients (often undeclared),³⁹ or contaminated ingredients.⁴⁰ There is therefore the potential for inadvertent doping, which can have significant repercussions for youth athletes who undergo testing.³⁸ The World Anti-Doping Agency’s (WADA) code operates the policy of ‘strict liability’, in which an athlete is solely responsible for any substance present in their body, or any banned method used.⁴¹ Doping (inadvertently or not) can lead to an adverse analytical finding (failed drugs test), and consequently lead to the athlete facing up to a four-year ban from their sport.

Informed Sport is a quality-assurance testing programme, which tests supplements, raw ingredients and manufacturing facilities for banned substances. By choosing an Informed Sport batch-tested supplement, a youth athlete can minimise the risk of inadvertent doping; however, there is no guarantee that the supplement is 100% free of a banned substance.⁴² Youth athletes considering taking any supplements should therefore seek advice from a SENr-accredited sports dietician/nutritionist.

Practical considerations

Interpreting the science and putting the current macro- and micro-nutrient, fluid and supplement recommendations into practice is imperative for the success of youth athletes. Table 4 provides an example of how to do this on a typical school and training day.

Table 4. An example of a day's nutrition for a 50 kg football player attending school and 90 minutes of training aiming to achieve >3000 kcal

TIME (MEAL/SNACK)	FOOD / FLUIDS	NUTRITIONAL CONTENT
07:00 (b/fast)	Large bowl of muesli with 250ml of full-fat milk, honey and a banana	Kcal: 778 C: 109g - F: 30g - P: 18g F&V: 1 Fluids: 300ml Comments: low GI source of C
10:00 (mid-morn snack)	1 large full-fat Greek yogurt pot 1 cereal bar 1 apple 300ml water with squash	Kcal: 437 C: 57g - F: 15g - P: 18g F&V: 1 Fluids: 300ml Comments: good source of calcium
13:00 (lunch)	Spaghetti bolognese (minced beef, onion, canned tomatoes, garlic, mixed herbs) with whole-wheat spaghetti 300ml carton of orange juice (not from concentrate)	Kcal: 620 C: 96g - F: 14g - P: 28g F&V: 3 Fluids: 300ml Comments: good source of iron (with vitamin C)
16:00 (pre-training snack)	Sandwich (2 slices of wholegrain bread with butter, two slices of ham, cheese and lettuce) 300ml water with squash	Kcal: 368 C: 35g - F: 17g - P: 19g F&V: 1 Fluids: 300ml
17:00 – 18:30 (during training)	500ml sports drink	Kcal: 140 C: 33g - F: 0g - P: 0g F&V: 0 Fluids: 500ml Comments: high GI C and fluid source
19:00 (post-training meal/dinner)	300ml pineapple juice 1 small salmon fillet with pesto, medium portion of white rice and green beans 1 packet of sweets	Kcal: 786 C: 119g - F: 24g - P: 24g F&V: 2 Fluids: 300ml Comments: good source of omega 3
		DAILY TOTAL Kcal: 3129 C: 449g - F: 100g - P: 107g C: 9.0g.kg ⁻¹ F: 2.0g.kg ⁻¹ P: 2.1g.kg ⁻¹ F&V: 8 Fluids: 2000ml (from fluids)

C: carbohydrate. F: fat. P: protein. F&V: portions of fruit and/or vegetables



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