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TEAM COVERAGE - NUTRITION

Nutritional strategies to optimize performance, -training adaptation and recovery in team sports

EXERCISE IS MEDICINE

Flueck Joelle Leonie[1,2], **Kyburz Sarina Annik**[2]

[1] Swiss Sports Nutrition Society, Luzern, Switzerland

[2] Institute for Sports Medicine, Swiss Paraplegic Centre, Nottwil, Switzerland

Abstract

Team sports performance is highly demanding in terms of physiological and psychological aspects. Furthermore, the competition schedule is often time constrained and athletes need to travel between games during recovery. Therefore, it seems very important to optimize nutritional strategies around training sessions as well as while traveling or competing. This review discusses a variety of different aspects, which are important in the development of a nutritional strategy in a club. It summarizes how the medical and performance staff of a team can provide the right nutritional strategies to optimize training adaptation and recovery. Furthermore, specific nutritional aspects for female, youth and traveling athletes as well as athletes recovering from injury are discussed. Besides nutritional strategies, teams should be cautious regarding the monitoring of body composition. Choosing the right time point in the season together with selecting a reliable and valid method and measuring under standardized circumstances is essential. Furthermore, athletes need to be educated on the risks and benefits of supplement use. This can reduce the risk of a positive doping test as well as the use of unnecessary, inappropriate and ineffective

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supplements.

Zusammenfassung

Die sportlichen Belastungen im Teamsport sind aus physiologischer und psychologischer Sicht sehr anspruchsvoll. Zudem ist der Wettkampfplan oft dicht gedrängt, und die Athleten müssen zwischen den Spielen reisen und sich gleichzeitig erholen. Daher ist es entscheidend, die Ernährungsstrategien sowohl während des Trainings als auch auf Reisen oder im Wettkampf zu optimieren. Dieser Reviewartikel fasst verschiedene Aspekte zusammen, die für die Entwicklung einer Ernährungsstrategie in einem Club wichtig sind. Zuerst wird zusammengefasst, wie das medizinische und sportwissenschaftliche Team die richtigen Ernährungsstrategien zur Optimierung der Trainingsanpassung und Erholung bereitstellen kann. Ausserdem umfasst er Aspekte zur Ernährung von Sportlerinnen, Jugendlichen und reisenden Sportlern sowie während der Rehabilitation von Verletzungen. Zusätzlich befasst sich der Artikel mit der Analyse der Körperzusammensetzung von Athleten. Die Wahl des richtigen Zeitpunkts der Saison zusammen mit einer zuverlässigen, validen sowie reliablen Methode unter standardisierten Bedingungen ist zentral. Ebenfalls müssen Sportler über das Risiko und den Nutzen der Verwendung von Nahrungsergänzungsmitteln informiert werden. Dies reduziert das Risiko eines positiven Dopingtests, und die Verwendung unangemessener und unwirksamer Supplemente wird vermieden.

Physiological aspects in team sports

Team sports performance is very complex, as a player needs to present different physiological and non-physiological skills to perform at its best. Endurance as well as speed and repeated or intermittent sprinting are just a few of those physiological aspects *(Figure 1)* [1,2]. Tactical and skill-based performance may determine, whether the team will win the game [3]. Training sessions involve endurance, sprint or intermittent sprint training sessions, technical (e.g. dribbling, shooting, etc.) or tactical and resistance training. Therefore, team sports performance is highly demanding in terms of intensity, volume and impact on muscle, bone and tendons [4]. It also requires attention and concentration to optimize cognitive function. During the competition period, players might also travel to away games or playing two or more games per week. In a tournament, the situation becomes even more intense adding for example media work. Therefore, adapting the fueling requirements to the special needs of the environmental (e.g. heat, humidity) and individual conditions (e.g. female or youth athlete, religion, culture, vegetarian or vegan diet, etc.) is essential. This narrative review describes the different nutritional aspects influencing performance in team sports and translates the knowledge into practical applications.

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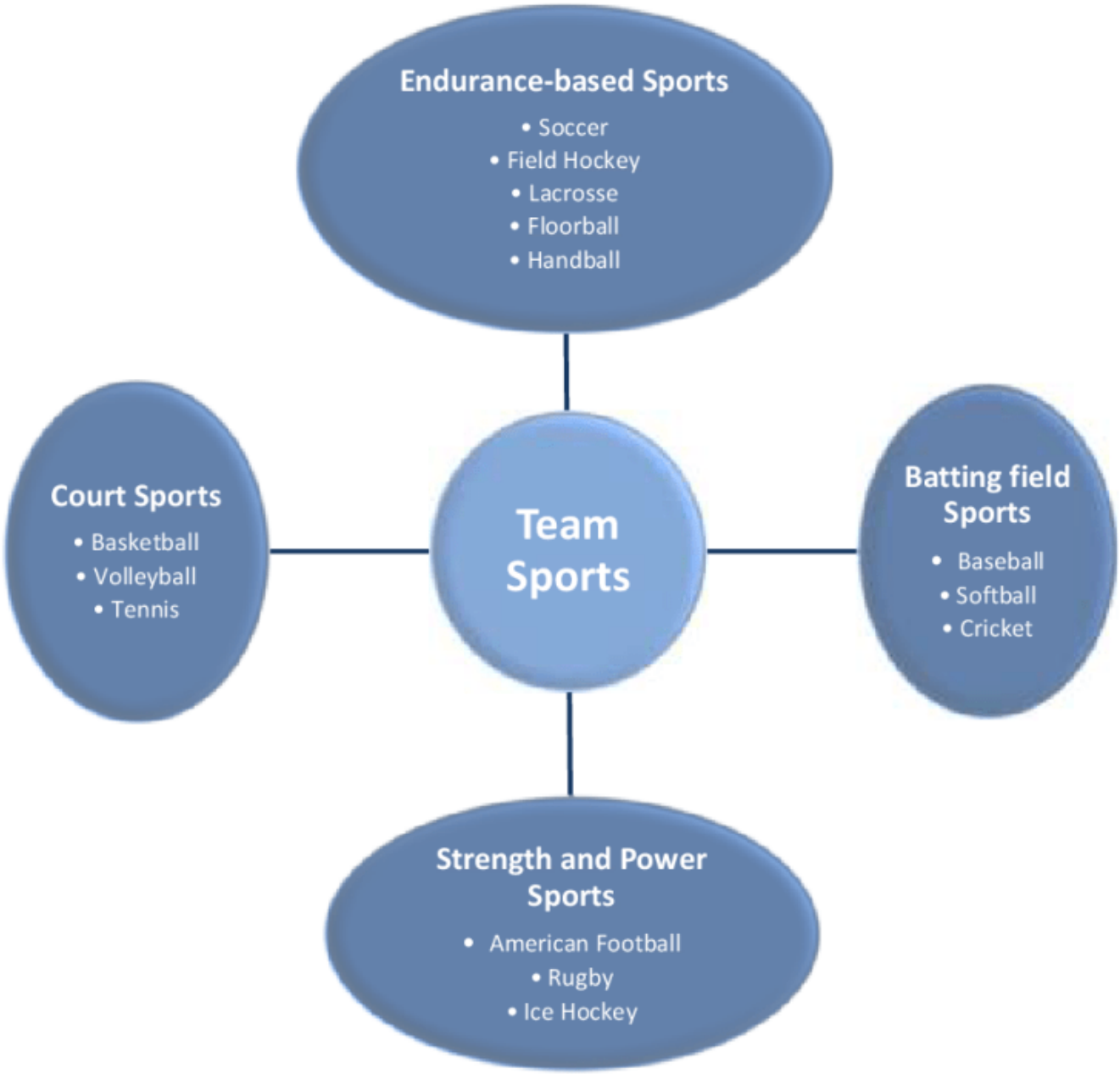

Figure 1: Classification of different team sports

Energy requirements

The activity level between players varies depending on the type of sport, training quantity and quality, body mass as well as playing position. Total daily energy expenditure of elite soccer players varied between 3000 and 4000 kcal/day [5], whereas energy intake (EI) ranged in between 2400 and 4300 kcal/day in team sports athletes in general [6]. In soccer, EI during a match day was higher compared to a normal training day (3790 vs. 2960 kcal/day) [5]. During a match, distance covered, speed, number of sprints and total intensity showed a high variability depending on playing position as well as type of sport. The energy expenditure of male outfield football players during a match has been estimated at 1300–1600 kcal [5].

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Research on female players is sparse, but available evidence highlights that they cover approximately the same average total distance as their male counterparts, however at a lower average speed, which lowers the exercise energy expenditure [7]. Carbohydrate (CHO) ingestion before and during a game seemed to have the greatest impact in intermittent sports performance [8] *(Table 1)*. To avoid or minimize gastrointestinal side effects during games, all match nutrition strategies should be practiced during training sessions to develop individual protocols [7]. Moreover, rinsing the mouth with CHO-solution during breaks could potentially enhance performance when CHO consumption is limited by gastrointestinal concerns [9]. Performance enhancing supplements such as caffeine or creatine display strong scientific evidence *(Table 2)*, but also a high individual variability [7,10]. Athletes should be educated on the risks and benefits of supplements before its application. Third-party testing programs for supplements (e.g. Kölnerliste, Informed Sports, NSF) allows players to make a safe choice regarding contamination with prohibited substances [11]. Two examples of a nutrition plan during a training and a game day are provided in Table 3.

Situation		Carbohydrate	Protein
Daily needs			
Minimal	Light training program (e.g. skill-based or low intensity)	3 to 5 g per kg per day	1.6 to 2 g per kg per day
Moderate	Moderate exercise program (e.g. 1 h per day)	5 to 7 g per kg per day	4 to 5 meals with 20 to 25 g
High	Endurance program (e.g. 1 to 3 h per day of moderate to high intensity)	6 to 10 g per kg per day	1.6 to 2 g per kg per day 4 to 5 meals with 20 to 25 g
Very high	Extreme exercise (e.g. >4 h per day of moderate to high intensity)	10 to 12 g per kg per day	30 to 50 g of casein 1-2 h before sleep
Game Day			
Pre game day	Glycogen storage loading 24 h prior to game day	7 to 12 g per kg for 24 h	
Pre-game	Before the game	1 to 4 g per kg 1-4 h before exercise	
During game	Short game duration (e.g. 30 to 60 min)	Small amounts of carbohydrate	
	Longer game duration (e.g. 60 to 90 min)	30 to 60 g per h	
Refueling	Refilling glycogen stores Muscle protein synthesis Replacement of lost fluids (150% of body mass loss)	1 to 1.2 g per kg immediately after the first session or after game	20 to 25 g immediately after session or after game

Tab. 1: Nutritional guidelines to optimize and adapt fueling for training sessions and games (adapted from Mujika and Burke (2010)

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Supplement	Type of sport	Mechanism	Protocol	Side effects
Caffeine	Performance enhancing benefits for endurance-based, short-term, supramaximal or repeated-sprint exercise	Increased catecholamine levels, improved concentration and alertness	3-6 mg/kg of BM 60 min prior to exercise, lower doses during exercise	Nausea, anxiety, insomnia, restlessness possible with larger caffeine doses (> 9 mg/kg BM)
Creatine	Acute performance enhancement in repeated high-intensity exercise, enhancing lean mass, strength and recovery	Increased muscle creatine stores, enhanced short-term, high-intensity exercise capacity	loading phase with 20 g/day for 5-7 days, maintenance phase with 3-5 g/day for supplementation period (8 weeks), stop 2 weeks before main competition	Possible increase in body mass (1-2 kg)
Nitrate	Benefits for prolonged submaximal exercise and high-intensity, intermittent, short-duration efforts	Enhanced nitric oxide bioavailability, increased mitochondrial efficiency, increased blood flow to the muscle	5-9 mmol of nitrate or beetroot juice 2-3 hours before exercise, or chronic loading (> 3 days) prior competition	Gastrointestinal upset in susceptible athletes
Beta-Alanine	Beneficial effects on sustained high-intensity exercise performance	Enhancing intracellular buffer capacity (i.e. carnosine shuttle)	Daily consumption of 800-1600 mg ingested via split dose (every 3-4 hours) over 10-12 weeks	Skin rashes, paresthesia
Sodium Bicarbonate	Beneficial effects on sustained high-intensity exercise performance	Enhancing extracellular blood buffer capacity	Single acute dose of 0.2-0.4 g/kg BM 60-150 min prior exercise or Chronic loading (> 2 days) of 3-4 smaller doses per day	Nausea, vomiting, diarrhea, bloating, flatulence

Tab. 2: Performance supplements with good scientific evidence to be used in certain sport-specific situations (adapted from Maughan et al. (2018)

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Nutrition plan for an intense training day of a 50 kg female soccer player			Nutrition plan for a game day of a 90 kg male rugby player		
Breakfast (7.30 am)	3 slices of wholegrain bread, 2 eggs, butter and jam, green tea	70 g CHO, 20 g protein	**Breakfast (8 am)**	Bowl of porridge with milk, fruit and nut butter, 2 eggs, coffee	110 g CHO, 30 g protein
Training (9.30 am)	90 min gym session (strength training) Water during the session		**Training (10 am)**	30 min flexibility and core session (easy), banana, water	25 g CHO
Post-training (11 am)	Whey protein powder with milk 1 Banana	40 g CHO, 20 g protein	**Lunch (12 pm)**	Bowl of rice with vegetables and sliced chicken (100 g), water	110 g CHO, 25 g protein
Lunch (12.30 pm)	Bowl of rice with vegetables and sliced chicken (80 g)	70 g CHO, 20 g protein	**Snack (2.30 pm)**	2 slices of wholegrain bread with ham, yogurt with granola, water	100 g CHO, 25 g protein
Training (4 pm)	120 min moderate game training 1 Liter sports drink	90 g CHO (45 g/h)	**Dinner (5.00 pm)**	Pasta with tomato sauce and cheese, water	110 g CHO, 25 g protein
Post-training (6.15 pm)	Self-made smoothie with milk, curd cheese or greek joghurt, fruits and oats	50 g CHO, 15 g protein	**Game (8.00 pm)**	1 Liter sports drink, water 1 CHO gel	100 g CHO
Dinner (7.30 pm)	1 piece of salmon, potatoes cooked in salty water, vegetables, fruit + chocolate as a dessert	80 g CHO, 20 g protein	**Recovery-meal (10 pm)**	Recovery shake (CHO + protein) with milk, big sandwich, water	110 g CHO, 35 g protein
Daily consumption		400 g CHO = 8 g CHO / kg BM / d 95 g protein = 1.9 g / kg BM / d	**Daily consumption**		665 g CHO = 7.4 g CHO / kg BM / d 142 g protein = 1.6 g / kg BM / d

Table 3: Example of a nutrition plan for an intense training day and a game day Note: CHO = carbohydrate, BM = body mass

Micronutrient intake

During the winter months, most Swiss athletes and especially athletes training indoors have a vitamin D deficiency [12]. As vitamin D is linked to bone health, neuromuscular and immune function, monitoring of serum vitamin D is recommended [13]. Iron is closely linked to oxygen-transport capacity and, therefore, an iron deficiency might negatively influence performance [10]. Iron status should be regularly monitored. Furthermore, an athlete's diet should further include a sufficient calcium intake provided through dietary sources [14]. If needed, supplementation must be prescribed by a sports physician and should meet specific health goals.

Fluid loss and hydration

The risk for hypohydration is the greatest in soccer and rugby [15]. Sweat rate ranged in all team sports between 0.3 and 2.6 L/h [15] whereas fluid balance (i.e. % change of body mass) ranged from +0.4 to -4.3%. It needs to be mentioned, that sweat rate and the risk for hypohydration is influenced by the limited fluid

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intake or drinking availability, the frequent high intensity efforts and different environmental conditions (e.g. heat, clothing and body protection) [15]. Nuccio et al. (2017) concluded, that the impact of hydration status on team sports performance showed mixed results. However, it seems likely, that cognitive performance as well as sport-specific skills are becoming more impaired with a higher fluid loss (e.g. >3 to 4%). Such large losses of fluid have been rarely reported in team sports. Nevertheless, it would be valuable to monitor sweat rate and fluid loss *(Figure 2)* by measuring pre- and post-session body mass and by recording of fluid intake in order to define an individual drinking strategy [6]. Hydration status should be monitored by determination of urine specific gravity *(Table 4)*. Together with the urine color, this provides a practical tool to enhance knowledge and awareness of a sufficient hydration status. The measurements could be repeated on a regular basis during training sessions as well as during tournaments in humid and hot conditions to ensure sufficient fluid intake and prevent hypohydration, overdrinking and hyponatremia. Athletes should be encouraged to start exercise well hydrated and to make use of drinking opportunities during training and games [16]. It seems reasonable to remind players to drink at sidelines (e.g. soccer), on the bench (e.g. ice hockey) and during quarter or halfway breaks [17].

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Figure 2: Different techniques to implement nutritional strategies over a long-term perspective

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Topic	Recommendations
Energy intake	• Carbohydrate periodization according to training load and intensity • Chose a food-first approach with a wide variety of foods, vegetables and fruits • Choose protein-rich sources and distribute them into 4 to 5 meals per day to reach 1.5 to 2.0 g per kg per day
Hydration	• Provide sufficient drinking opportunities during training and game situations (e.g. sideline, bench, halfway, before and after) • Monitor individual sweat rate during training and game, especially in different environmental conditions • Monitor hydration status by using urine specific gravity (e.g. hand-held refractometer), pre/post body weight measurement and urine color (e.g. visual scale) • Educate the athlete for optimal fluid status • Develop individual drinking protocols and test them in training before applying to game situations
Supplement Use	• Educate the athletes on the risk and benefits of taking supplements • Educate the athlete on how to choose a "safe" supplement • Develop a supplementation strategy for the team with individual protocols for each player (e.g. to avoid gastrointestinal symptoms)
Body Composition	• Use a standardized measurement to track body composition (e.g. DXA scan or skinfold) • Use a standardization of the procedure including hydration status and nutritional status (e.g. glycogen storage) • Take seasonal variation into account • Do not use body composition to compare individuals, use it as an individual monitoring tool
Travelling	• Pack sufficient food for travel and new location to ensure adequate energy intake • "Buffet-style" is most convenient to meet individual requirements • Consider using probiotic supplements two weeks prior and during the stay
Youth Athletes	• Plan nutritional intake according to the daily schedule • Consider energy requirements for maturation and growth • Consider an altered thermoregulatory response in youth athletes and provide sufficient hydration and cooling opportunities • Check vitamin D levels, calcium and iron intake
Female Athletes	• Education on risk and consequences of RED-S • Provide a good atmosphere to openly talk about menstrual function, contraception and individual women-specific problems • Check vitamin D levels, calcium and iron intake • Verify an adequate nutrient intake (macro- and micronutrients) especially in vegetarian or vegan athletes
Recovery from injury	• Provide adequate energy and protein intake • Ingest vegetables and fruits to provide micronutrients • Consider using supplements depending on evidence, type of sport and injury

Table 4: Practical application of nutritional strategies in team sports Note: DXA = Dual-energy x-ray absorptiometry; RED-S = relative energy deficiency in sports

Monitoring body composition

Body composition and other anthropometric characteristics (e.g. height, body mass) might depend on the type of sport and playing position [7]. Whereas an endurance-based field athlete (e.g. soccer) presents himself much leaner, a strength-based athlete (e.g. rugby) shows a high amount of fat-free mass. Thus, comparing athletes within different sports or within different playing positions is not reasonable. Furthermore, the variability of body mass and body composition throughout a sporting year or career needs to be taken into consideration [18]. Therefore, monitoring body composition (Figure 2, Table 4) over

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different training phases (e.g. off-, pre- and on-season) or over a career are helpful to track individual changes [7]. This is especially valuable during nutritional interventions (e.g. during weight loss) or after a major injury (e.g. to monitor fat-free mass). Athletes are very sensitive to measurements concerning body mass. Hence, choosing an adequate method to monitor minor changes is important. Dual energy x-ray absorptiometry (DXA) is a reliable and valid method with the least error, but it is expensive with limited use [18,19]. Moreover, a standardization of the procedure regarding the device, software, technician, hydration and nutritional status [20] is needed to provide a reliable measurement. An easier way to track body composition in the field is by skinfold measurements using a caliper [21], though this method requires some expertise and the amount of fat-free mass is indirectly estimated. Nevertheless, tracking the sum of skinfold over time is a cost-effective way to monitor fluctuations in body composition.

Travelling

Domestic and international travel for games and training camps is happening on a regular basis in elite teams. Strategies to ensure appropriate catering “on the go” and at the venue are needed. Limited food options may not provide the required nutrient intake. It is important to pack non-perishable food items and fluids [22]. On destination, buffet-style food service is the most suitable and convenient to nourish athletes on an individual basis. The menu should be adapted to the nutritional requirements, cultural considerations, special needs (i.e. allergies, intolerances) and diets (e.g. vegetarian, vegan, cultural, religious) of the athletes [23]. The athletes should be educated on their nutritional goals and know how to choose food accordingly. It can be valuable to consult a sports dietitian for specific advice or to develop a nutritional strategy (Table 4, Figure 2) for the whole team travelling [23]. Due to altered conditions (e.g. time zone, environmental conditions) and dietary habits, there is an enhanced risk for traveler’s diarrhea or upper respiratory tract infections [23,24]. The intake of probiotics two weeks before and during a trip appears to have a marginal protective role in reducing the incidence and severity of travel-specific problems [23].

Young athletes

Nutritional support is key to ensure that junior players can meet the requirements for their daily school routine, training, games, growth, maturity, health and recovery. Mostly, energy demands are higher compared to adults due to growth and changes in body composition. A severe chronic energy deficit may impair growth and maturity, develop menstrual irregularities and enhance injury and illness risk [7,25]. Players should be monitored periodically to examine changes in height-for-weight, weight-for-age, BMI-for-age and body composition [7]. In male soccer players, total energy expenditure increased from 2800 up to 3500 kcal/d between the age of 12 to 18 years and is then comparable to adult players [26]. Therefore, daily CHO recommendations by body mass are similar to adult players [25]. Additional CHO intake during trainings and games may be beneficial [7]. Regarding protein consumption, a daily intake of up to 1.6 g/kg body mass and a balanced distribution of protein over the whole day is appropriate [27]. Compared to adults, youth athletes are less effective in regulating body temperature and have lower heat tolerance [25]. Due to the greater surface area-to-body mass ratio than adults and a lower sweating capacity, junior players have an increased risk of hypohydration [25]. With their daily training schedules and school commitments, hydration is not a priority. Many youth athletes arrive for trainings and games

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hypohydrated [28]. They should be encouraged to ensure euhydration before commencing exercise [25]. Furthermore, a food-first approach is essential when educating junior players [29]. Generally, adolescent athletes would benefit from sports nutrition education that enhances food selection skills for their daily schedule, general health and sport performance [29].

Female athletes

In the past few years, the term relative energy deficiency in sports (RED-S) has emerged and describes the risk of an inadequate EI in athletes [30]. Energy availability is calculated from the daily EI minus exercise energy expenditure related per kg fat-free mass [30-32]. A state of low energy availability is defined as an intake below 30 kcal per kg fat-free mass per day. Such a low intake further increases the risk for secondary health consequences like low bone mineral density, menstrual and hormonal dysfunction, depression, gastrointestinal disturbances and cardiovascular disease. Furthermore, physical and cognitive performance reduce whereas injury and illness risk increase. The risk for low energy availability is increased in endurance, body weight sensitive and esthetic sports as well as in female athletes in general [33-36]. Female soccer players displayed this issue of inadequate nutritional support [7,37,38]. Therefore, it seems highly important to educate female team sport athletes properly in terms of risks and consequences of RED-S [35], even though they are not part of a weight-sensitive, esthetics or endurance sport.
Moreover, the risk for micronutrient deficiencies such as iron [39], vitamin D and calcium might be increased in female athletes [27,34]. Also, numerous female athletes often stick to a vegan, vegetarian or low-CHO diet, which represents an additional risk for low energy availability and deficiencies [3].
Therefore, it is important to educate female athletes properly in terms of risks and consequences of RED-S [35] and to provide nutritional support to those athletes
(Figure 2) to verify an adequate macro- and micronutrient intake as well as to optimize training adaptation and performance [40]. Due to the scarce scientific literature on the special requirements of female athletes, to date, no differentiated recommendations regarding CHO intake before, during or after exercise can be given for the female athletes [34].

Recovery from injury

Adequate EI should be the first nutritional consideration as negative energy balance accelerates muscle loss especially in immobility period [41]. Intake should be higher than 30 kcal/kg body mass, however, providing excess energy does not further attenuate muscle loss, but rather results in an increased fat deposition [41]. In conditions of sudden inactivity as a result of surgery or injury, elevating protein intakes to 1.6-2.0 g/kg/day may be advantageous to prevent the loss of fat-free mass [7,42]. Including leucine-rich protein and pre-sleep protein to the diet helps to achieve the protein target values [7]. Several different supplements like omega-3 fatty acids, creatine, vitamin D, collagen/gelatin, curcumin and antioxidants [22] has been suggested to have a beneficial effect during the rehabilitation of injury and illness (e.g. anti-inflammatory, collagen, etc.), nutritional considerations for the rehabilitation of bone and tendon are similar to those for muscle after injury [3]. They might play a role in the management and rehabilitation of different injuries, but the different phases of stage and duration of injury provide a continuum of varied nutritional needs [3]. Literature is scarce and further studies are needed to establish nutritional guidelines. By providing an adequate energy and protein intake, the first step for a successful rehabilitation is made

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[41]. The further intake of micronutrients through vegetables and fruits might support the healing process.

Practical implications

The key nutritional considerations (Table 4):

- Use different techniques (Figure 2) to induce a long-term change in nutritional practices on an individual, gender- and age-specific level.
- Nutrition should be tailored to individual needs (e.g. load, intensity, sweat rate, environmental conditions)
- Education (e.g. general healthy eating, RED-S, nutritional needs for youth or female athletes, risk and benefit of supplement use) is important in the development and should be implemented in the early stages of the career.

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Corresponding author

Dr. sc. nat. Joëlle Flück
Guido A. Zäch Strasse 1,
6207 Nottwil
Tel: +41 939 66 17
Email: joelle.flueck@sportmedizin-nottwil.ch

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