POSITION STAND

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Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Minerals and Vitamins in Sports Nutrition

Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung (DGE): Minerale und Vitamine in der Sporternährung

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Summary

- **An adequate intake** of minerals and vitamins is essential for health and performance of athletes. Depending on the type of sport and the intensity and scope of physical performance, as well as individual factors (such as dietary behavior, perspiration rate and composition of perspiration), athletes may be at increased risk of suboptimal micronutrient supply.
- **This position paper** will provide an overview of the potential causes of deficient micronutrient supply in athletes, such as increased requirements as a result of enhanced energy metabolism, higher losses associated with physical activity, and special diets associated with sport in general or particular types of sport. This position statement will also present the proven effects of insufficient micronutrient supply on the health and performance of athletes, and the effects on their supply situation.
- **In summary,** it can be concluded that with a balanced diet that covers energy requirements, the D-A-CH reference values for micronutrients can usually be attained without any problems. However, in certain situations (such as strenuous endurance exercise or weight reduction, or in the case of lopsided eating habits or hypocaloric diets), iron, calcium, sodium and vitamin D may be critical nutrients for athletes.
- **A diet that is adapted to** the individual and covers all requirements is achievable even in the case of high metabolic demands, and such a diet can reduce the risk of nutrient deficiencies.

Zusammenfassung

- **Eine bedarfsdeckende Zufuhr** an Mineralstoffen und Vitaminen ist für die Gesundheit und Leistungsfähigkeit von SportlerInnen essenziell. In Abhängigkeit von der Sportart, der Intensität und des Umfangs der Belastung sowie von individuellen Faktoren (z. B. Ernährungsverhalten, Schweißrate und -zusammensetzung) können SportlerInnen ein erhöhtes Risiko für eine suboptimale Versorgung mit einigen Mikronährstoffen aufweisen.
- **Das Positionspapier** gibt einen Überblick über potenzielle Ursachen (z. B. energieumsatzabhängig gesteigerte Bedarfe, sportassoziiert erhöhte Verluste, sport(art)spezifische Ernährungsweisen) für eine defizitäre Versorgung von AthletInnen mit Mikronährstoffen. Zudem werden belegte Auswirkungen einer unzureichenden Mikronährstoffversorgung auf Gesundheit und Leistungsfähigkeit von SportlerInnen sowie deren Versorgungslage dargestellt.
- **Zusammenfassend** lässt sich feststellen, dass SportlerInnen bei ausgewogener, energiebedarfsdeckender Ernährungsweise die D-A-CH-Referenzwerte für Mikronährstoffe in der Regel problemlos erreichen. Jedoch lassen sich Eisen, Calcium, Natrium in besonderen Situationen (z. B. während Langzeitausdauerbelastungen oder Gewichtsreduktionen, bei einseitiger oder hypokalorischer Ernährung) und Vitamin D als möglicherweise für SportlerInnen kritische Nährstoffe identifizieren.
- **Eine individuell bedarfsgerechte Ernährung** kann auch bei hoher metabolischer Beanspruchung erreicht werden und reduziert das Risiko von Nährstoffdefiziten.

KEY WORDS:
Micronutrients, Requirements of Athletes, Health, Exercise Performance

SCHLÜSSELWÖRTER:
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Introduction

An intake of minerals and vitamins that covers individual requirements is essential for health and performance in athletes. For athletes, it is of interest to determine whether they have increased micronutrient requirements as a result of increased energy consumption or micronutrient loss due to sporting activities, and whether increased intake may influence performance. Because anthropometric, physiological, training and sex-specific parameters vary within and between individuals, it is very difficult to quantify any potential additional micronutrient requirements in athletes. Nevertheless, in order to identify types of sport, training periods or situations that may represent a risk of deficient micronutrient supply, this position paper will consider sport-associated micronutrient losses (e.g. losses through perspiration), increased requirements associated with sport (e.g. in the context of training adaptation) and critical supply periods (e.g. due to restricted nutrition during weight reduction).

Table 1

Overview of estimated average mineral losses through perspiration. Data according to (49) (for calcium, sodium, potassium, copper, magnesium and zinc) and according to (18) (for iron). *according to (64) for a person weighing 70 kg with a running pace of 10 km/h (outdoor temperature 15°C).

MINERAL	MINERAL CONCENTRATION IN SWEAT WITH APPROX. 60 MIN OF PHYSICAL EXERCISE [MG/L] (VARIATION BETWEEN INDIVIDUALS STATED AS A RANGE IN MG/L)	ESTIMATED LOSS DURING 45 MIN OF TRAINING AT A PERSPIRATION RATE OF 0.8 L/HOUR* [MG/HOUR]
Calcium	18 (11-36)	11
Iron	0.56 (0-1.12)	0.34
Sodium	874 (175-1512)	524
Potassium	196 (167-236)	117
Copper	0.11 (0.04-0.22)	0.07
Magnesium	1.43 (0.84-2.36)	0.86

Sport-Associated Micronutrient Losses

Micronutrients can be lost through perspiration, urine or feces. The composition of sweat and the amount of minerals that athletes lose through perspiration both depend on factors such as the duration and intensity of physical exercise, environmental factors and factors specific to the individual (e.g. sex, training status, body mass) (64). In the literature, the reported perspiration rates for endurance athletes are between 0.4 and 1.8 l per hour (64). The concentration of minerals in sweat varies greatly between individuals. With regard to sodium, it varies by about a factor of 10 (49). As the duration of physical activity as well as acclimatization to heat increase, the concentration of minerals in sweat decreases (18). In the case of an average perspiration rate and a moderate level of work load for the particular sport in question, significant quantities of the minerals sodium, copper and zinc can be lost through perspiration (Table 1). Loss of iron through perspiration can—in combination with other exercise-induced losses or increased requirements—contribute significantly to the development of iron deficiency. As for the other minerals, losses through perspiration can be disregarded for the most part (Table 1).

The question of whether mineral losses in urine and feces are increased by physical activity is currently the subject of debate. Such losses may depend on the intensity of exertion and the scope of training. For instance, older studies found significant excretions of magnesium (21, 54) and zinc (20). However, more recent studies were unable to confirm these findings. For example, male cyclists were found to have no elevated excretion of magnesium, iron, zinc or copper during high-intensity training (25).

Exercise-Associated Hyponatremia

Given that the sodium intake of the general population in Germany is far above the reference values (40, 69), sport-associated sodium loss may be seen in a positive light in terms of health—as the elimination of an oversupply of sodium. Therefore, loss of sodium through perspiration should generally not be viewed as problematic. However, in the case of "salty sweaters" (who can be identified through visible salt marks on sports clothing), high sodium losses (Table 1) during long periods of physical performance (elevated risk for sporting activities taking longer than four hours or more) can lead to clinical symptoms of exercise-associated hyponatremia (1, 16). A reduction in the sodium concentration of the blood to below 135 mmol/l (hyponatremia) is observed in 3-22% of the participants in endurance sports events (16). The cause of exercise-associated hyponatremia (apart from individual predisposing factors) is the combination of increased sodium loss through perspiration and increased intake of low-sodium drinks. Those affected are predominantly inexperienced participants, athletes performing more than four hours (e.g. marathon, triathlon or ultra-endurance events), women, and athletes with a low body mass index (BMI) and excessive (low-sodium) fluid intake (1). Inexperienced athletes are liable to interpret the initially non-specific symptoms—such as nausea, headache, or reduced performance—as the symptoms of dehydration. Additional consumption of low-sodium drinks can lead to a further reduction in sodium concentration. In the literature, there are many reports of cases of severe hyponatremia during sports events, some of which have been fatal (1, 16). Despite the importance of adequate sodium supply in endurance exercise, about one third of marathon runners are unaware of the risks of exercise-associated hyponatremia (32). Outdated recommendations about fluid intake ("as much as tolerable") are still widespread among the sporting population. According to current recommendations, for the prevention of exercise-associated hyponatremia during endurance exercise, moderate amounts of fluid with a sodium concentration of 400-1,100 mg/l should be consumed (see also the position statement of the sports nutrition working group of the German Nutrition Society (DGE): fluid management in sport (51)) (41, 72). This data is also in line with the health claims of the European Food Safety Authority (EFSA) for carbohydrate-electrolyte drinks (460-1,150 mg/l) (26).

Organizers of marathons and other endurance events should pay particular attention to the provision of suitable food and drinks (e.g. provision of bouillon, sodium-rich sports drinks, salty snacks). In the case of adequate fluid intake, the use of sodium-rich drinks or snacks is not necessary because a normal diet usually provides sufficient sodium (40) and an excessive fluid intake is considered a key risk factor for hyponatremia (35).

Increased Micronutrient Requirements Associated with Exercise

Vitamins Involved in Energy Metabolism

Due to increased energy metabolism, it can be assumed that requirements for certain vitamins increase in line with increasing energy requirements as a result of sporting activities compared to the moderately physically active general population. Some of the vitamins to which this applies are thiamine (vitamin B1), riboflavin (vitamin B2) and niacin (Table 2). However, in the case of a diet that covers energy requirements, these increased vitamin requirements are usually covered by the increased intake levels. The D-A-CH reference values for these vitamins are based on the guiding values for energy supply, which means › that the relevant reference value for vitamin intake can still be calculated based on these values even in the case of increased energy metabolism as a result of athletic activity (22). Therefore, for athletes, the reference values that should be taken into account are not age and sex-specific reference values, but rather values based on energy metabolism (Table 2).

Antioxidants

Physical activity is associated with an increased production of reactive oxygen and nitrogen species (RONS), also known as free radicals, as a result of various mechanisms (19, 66). This means that athletes require an adequate supply of nutrients with antioxidant effects (e.g. vitamin C, vitamin E, beta-carotene). However, due to the body's own antioxidative mechanisms (see below), it is unclear whether the intake recommendations for the general population cover antioxidant nutrient requirements for athletes. Various studies have demonstrated an increased endogenous antioxidative capacity (17, 28) and increased antioxidative enzyme activity (e.g. glutathione peroxidase, superoxide dismutase, catalase) (39, 58, 71). The significance of reactive species (RONS) for muscular training adaptation and mitochondrial biogenesis has now been scientifically demonstrated (2, 53, 57, 60). Increased antioxidative defense mechanisms can already be observed after just a few training sessions (62, 70) and can also be observed in young athletes (12).

Some studies have shown that the use of antioxidant supplements alongside training may have a detrimental effect on training adaptation and on increasing performance (31, 57), or a detrimental effect on surrogate parameters of health benefits in amateur athletes (63).

According to current scientific knowledge therefore, a balanced selection of antioxidant-rich foods is advisable so that the D-A-CH reference values for vitamin C, vitamin E and beta-carotene can be reliably reached. Athletes who opt for antioxidant supplementation for personal reasons should not exceed the maximum daily doses for food supplements: 30 mg for vitamin E and 250 mg for vitamin C (77).

Vitamin D

Both the general population (22) and athletes (34, 44, 78) are considered to have a season-dependent insufficient vitamin D supply. Due to the role that vitamin D plays in bone metabolism (34) and its various other effects (for instance in the skeletal muscle), optimal supply of vitamin D is essential for athletes (37, 44). At present, it is unclear whether administration of vitamin D affects performance, but at a minimum, athletes with a deficiency appear to benefit from vitamin D supplementation (65).

Since vitamin D supply from food only covers about 10% of requirements, athletes with an inadequate vitamin D intake from food may still have a good vitamin D supply if they have adequate UV exposure (e.g. during training) (14). However, athletes who do indoor sports (such as swimming or gymnastics), and those with a dark skin color, a high percentage of body fat, or who take significant measures to protect against UV radiation are at an increased risk of suboptimal vitamin D supply (30 to ≤ 50 nmol/l 25-hydroxyvitamin D in serum) or vitamin D deficiency (<30 nmol/l) (72). Although the optimum value for hydroxyvitamin D in the serum in the general population is ≥50 nmol/l, some authors consider a value between 80 and 125 nmol/l optimal for athletes (10, 14). Currently, there is no scientific consensus regarding this (72).

Iron and Iron Deficiency Anemia

Athletic training, which leads to changes such as increased vascularization (formation of new blood vessels) increased red blood cell concentration (increase in hematocrit) and increased hemoglobin concentration in the blood can increase iron requirements (3). High-intensity exercise or (regular) use of non-steroidal anti-inflammatory drugs (NSAIDs), as is frequently observed in athletes (9, 74), can lead to hemorrhages, gastrointestinal blood loss, and/or bleeding in the urinary tract, which can in turn lead to the loss of iron (76). Iron requirements are estimated to be 70% higher in athletes compared to non-athletes (72).

The prevalence of iron deficiency among athletes is comparable to the prevalence in the general population, but there are some increased risks for population groups involved in certain types of sports or who have certain diets (11). These groups include endurance athletes, vegetarians, and athletes with a restrictive energy intake (e.g. in the case of aesthetic sports). Iron deficiency anemia (hematocrit and hemoglobin concentrations that are below the normal values) reduces performance by reducing oxygen transport. It is also possible that iron deficiency without anemia is also associated with detrimental effects on athletic performance (72). For iron deficiency without anemia, the focus should initially be on nutritional therapy and/or an iron-rich diet. The relevant recommendations for an iron-rich diet in the context of sport have been presented elsewhere (15).

Iron deficiency in athletes should always be diagnosed and treated by a physician, relevant standards having been published elsewhere, too (29). Due to the health risks of long-term oversupplementation with iron (e.g. gastrointestinal symptoms, pro-oxidative effects, and the potential risks of cardiovascular diseases and cancer associated with iron overload that are currently the subject of discussion), athletes should be discouraged from independent iron supplementation without medical supervision (59).

Micronutrients for the Prevention of Infection in Athletes

For diseases of the upper respiratory tract (e.g. viral infections, the common cold), a J-shaped dose-response relationship has been repeatedly observed between athletic activity and the risk of contracting the relevant illness (50, 52). Both low and high levels of physical activity in terms of scope and intensity increase the risk of infection. However, it may be that athletes with less training are more likely to be affected (52). In the case of competitive sport, it is thought that it is mainly a subgroup of susceptible athletes that is contributing to this observed association (75).

Vitamin C and zinc are often marketed as effective micronutrients for the prevention and treatment of colds. A Cochrane analysis shows that a daily intake of 200 mg vitamin C has no effect on the incidence, severity or duration of the illness (relative risk [RR]: 0.97) (33). Under extreme conditions (e.g. Arctic expeditions, marathon running), an appropriate vitamin C intake can help to reduce self-reported symptoms that are typical of infection (RR: 0.48) (33). However, it remains unclear whether vitamin C actually has a beneficial effect on the course of a viral infection. Nevertheless, the objective of a vitamin C supply that covers requirements for athletes is in line with the results from the relevant EFSA panel, according to which vitamin C can contribute to the maintenance of normal immune defenses (27).

Table 2

Intake values for vitamins B1, B2 and niacin as a function of energy intake for athletes. Calculations according to the German Nutrition Society (DGE) (22).

VITAMIN	D-A-CH REFERENCE VALUES FOR MEN/WOMEN AGED 25 TO <51 YEARS	CALCULATIONS FOR ATHLETES WITH A BODY WEIGHT OF 60 KG AND ENERGY INTAKE OF E.G. 2,000 KCAL/DAY	CALCULATION FOR ATHLETES WITH A BODY WEIGHT OF 70 KG AND ENERGY INTAKE OF E.G. 2,500 KCAL/DAY	CALCULATION FOR ATHLETES WITH A BODY WEIGHT OF 80 KG AND ENERGY INTAKE OF E.G. 3,500 KCAL/DAY
Vitamin B1 [mg/d]	1.2 / 1.0	1.1	1.4	1.9
Vitamin B2 [mg/d]	1.4 / 1.1	1.2	1.5	2.1
Niacin [mg/d]	15.0 / 12.0	13.2	16.5	32.1

The use of zinc preparations in pharmacological doses (≥75 mg/day) appears to reduce the incidence and duration of the common cold in the general population, but not the severity (67). However, in the intervention groups (zinc intake well above the tolerable intake level), unfavorable effects occurred much more frequently than in the placebo groups. In addition, the quality of the evidence was assessed by the authors as low to very low (67).

In the case of supplementation, the possibility of side effects and the recommended maximum daily doses for food supplements (vitamin C: 250 mg/day; zinc: 6.5 mg/day) should be taken into account (77). The D-A-CH reference values for the aforementioned micronutrients can be achieved through food: for instance with a medium sweet pepper (approx. 190 mg vitamin C) and two slices of wholegrain bread with cheese and one serving of broccoli (approx. 9 mg zinc).

In general, in the case of a balanced diet that meets energy requirements, nutrient intake increases with increased food and energy intake, which means that athletes are also able to cover their (possibly elevated) micronutrient needs under these conditions without problems (45).

Critical Micronutrient Supply due to Sport-Specific Diets

Due to sport-specific, sometimes periodically varying nutrition aims (e.g. weight reduction, carbohydrate loading or train low techniques), athletes are not always able to meet all of their nutritional needs through their diet. In the case of athletes participating in sports where body weight is crucial (e.g. endurance, aesthetic, or technical sports), restrictive nutritional behavior with insufficient iron and calcium supply is often observed (72). In addition, the range of foods that athletes consume may be temporarily restricted (e.g. during training or competition trips, during high altitude training camps, or due to weight reduction) or permanently restricted (e.g in the case of intolerances, for ethical or religious reasons, or due to avoidance of certain foods for other reasons). Nutrition counseling from professionals with sport-specific qualifications may be advisable in such cases so that custom solutions can be developed.

Vegetarian diets should be viewed as unproblematic even for athletes as long as they are composed of a balanced variety of foods and are combined with regular screening for critical nutrients (e.g. iron supply) (32). It is not currently possible to determine whether a vegan diet increases the risk of nutrient deficiencies or whether it is associated with beneficial or detrimental effects in terms of health and performance due to the low prevalence of competitive athletes who are vegan and due to insufficient evidence from scientific studies. In principle, it should be assumed that vegan athletes and the general population will derive similar health benefits from sport and will have similar critical nutrients (61).

Athletes frequently do not achieve the recommended fruit and vegetable intakes for the general population due to the “amount vs. time problem” (i.e. high energy requirements and little time to prepare, ingest and digest sufficient amounts of food prior to training) and due to the high volume of food consumed combined with limited tolerability prior to training (36). This may be associated with an inadequate supply of folate for instance, and with low supply of secondary plant compounds (7). Individual nutrition counselling with regard to suitable alternatives (e.g. integration of vegetable and fruit juices into the meal plan, consumption of vegetable or fruit purees, enrichment of meals with nuts, etc.) is advisable.

Current Micronutrient Supply Situation in Athletes

Based on the D-A-CH reference values (i.e. without taking account of any increased requirements) it can be assumed that the micronutrient supply situation among athletes is roughly as good as in the general population (4, 5, 48). In the case of (competitive) athletes who have increased energy requirements, the international literature clearly shows that intake recommendations are exceeded through food alone (120-365% of nutrient-based Recommended Daily Intake [RDI]) (45).

Therefore, additional supplementation should be called into question, and it may be associated with various risks (45, 46).

However, it is not possible to draw conclusions about the supply situation of an individual athlete based on groups of people. In individual cases, particularly in young athletes, but also in athletes with the aforementioned risk constellations (hypocaloric diets, restricted range of foods, travel, etc.), micronutrient supply may be below the recommended intake levels. Current data from young German footballers shows, for instance, that the majority of female players did not achieve the D-A-CH reference values for calcium supply (59%), iron supply (69%), folate supply (75%) and vitamin D supply (100%) (7). The picture is similar for young German athletes in different types of sport for calcium (47% of boys and 63% of girls did not achieve the D-A-CH reference values), iron (9% and 65%), vitamin D (86% and 93%) and vitamin E (38% and 34%) (13). However, it should be noted that not achieving the D-A-CH reference values for nutrient intake is not the same as a deficiency.

Micronutrients as Food Supplements in Sport

The use of food supplements is associated with risks for athletes in terms of health, performance, and doping (e.g. as a result of impurities or deliberate addition of prohibited substances) (30, 42, 47). Based on recent research, it is estimated that 6-9% of doping cases are attributable to food supplements (55). In athletes with an adequate supply of micronutrients, an additional supply beyond requirements does not lead to an increase in athletic performance. However, the prevalence of food supplement use is significantly higher among athletes than in the general population (6, 23, 24, 73). In the area of junior sports in Germany, prevalence varies between 16% (43) and 91% (6), › depending on the cohort studied (e.g. age, type of sport and squad status) and depending on how foodstuffs are classified: as either food supplements or enriched foods (e.g. in the case of sports drinks). Senior athletes also use relevant preparations (68). Among athletes in general, the most commonly used food supplements are vitamin and mineral preparations (56). The most frequent reasons given for the use of these preparations are expectations of improved regeneration, optimization of health condition, and improved performance (47). Other athletes use food supplements to prevent illness or because they do not have sufficient time to prepare balanced meals (56). Measures such as appropriate, action-focused nutritional training for athletes and the provision of health-promoting catering services tailored to the needs of athletes in top German sports facilities therefore have the potential to reduce the food supplement consumption among athletes by strengthening their food literacy. The current expert consensus of the International Olympic Committee (IOC) emphasizes that food supplements cannot compensate for an inadequate diet or for poor food choices (38). Athletes who, after a thorough risk-benefit analysis, still opt for micronutrient supplementation should adhere to maximum recommended intakes for food supplements, for instance the maximum intake recommendations of the German Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung) (77, 79).

Conclusion

In summary, it can be concluded that the D-A-CH Reference Values for Nutrient Intake are also suitable for use in healthy athletes as a basis for an adequate nutrient intake. In the case of a balanced diet that covers energy requirements, on average, athletes meet or exceed the D-A-CH reference values for micronutrients. However, in certain situations (such as endurance exercise), iron, calcium, sodium and vitamin D may be critical nutrients for athletes, particularly in at-risk groups (athletes with permanent or recurrent food restrictions). With the support of nutrition professionals, a diet that is adapted to the individual and covers all requirements is achievable even in the case of high metabolic demands, and such a diet can reduce the risk of nutrient deficiencies. Due to risks in terms of health, performance and doping, supplementation with the support of nutrition professionals should only be considered in the case of a relevant medical diagnosis and/or unsuccessful nutritional therapy.

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Conflict of Interest

The authors have no conflict of interest.

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