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Recent Nutritional Guidelines for Endurance Athletes

Aktuelle Ernährungsempfehlungen für Ausdauersportler

REVIEW

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Summary

› **Athletes may support health,** training adaptations and performance by generally adequate diets and a prudent nutrient timing. However, for endurance athletes some obsolete recommendations and dietary myths are still widespread among recreational and elite athletes, coaches and health care professionals. This includes hydration strategies as well as nutrient intake before, during and after exercise. In addition, dietary recommendations for elite endurance athletes might differ in some aspects from nutrition recommendations for the general population including recreational athletes.

› **Thus, this article aims** to summarize the recent nutritional guidelines for endurance athletes during different training periods and to distinguish between elite and recreational endurance athletes where possible. Finally, some nutrition-associated clinical issues observed in endurance athletes are presented and dietary recommendations to reduce the risks are provided.

› **To summarize,** meeting the energy requirement is the major nutritional goal in endurance athletes. Energy availability should not fall below 30-45kcal/kg fat-free mass/d. Carbohydrate requirements vary from 3-5g/kg/d during low-intensity up to 8-12g/kg/d in high-intensity, high-volume training periods. Protein requirements of elite athletes are approximately twice as high as those of sedentary people or recreational athletes, but not higher than the average protein intake of the general population in Germany (1.4-1.6g/kg/d).

› **Health care professionals** (e.g. nutritionists at the Olympic Sports Centers) may help endurance athletes to follow a healthy diet with prudent food choices and clever nutrient timing.

Zusammenfassung

› **Eine individuell bedarfsadäquate Ernährung** mit einer zeitlich auf das Training abgestimmten Nährstoffzufuhr kann die Gesundheit, die Trainingsadaptationen und die Leistungsfähigkeit von Athleten positiv beeinflussen. Jedoch sind gerade im Ausdauersportbereich veraltete Ernährungsempfehlungen (und -mythen) unter Athleten, Trainern und Betreuungspersonal verbreitet. Dies umfasst beispielsweise Trinkempfehlungen oder Fragen zur Nährstoffzufuhr vor, während und nach der Belastung. Zudem unterscheiden sich Ernährungsempfehlungen für Spitzensportler von denen der Allgemeinbevölkerung einschließlich Freizeitsportlern, was zu weiteren Unklarheiten führen kann.

› **Ziel der Übersichtsarbeit** ist es daher, aktuelle Ernährungsempfehlungen für Ausdauersportler für unterschiedliche Trainingsphasen zusammenzufassen und, wenn möglich, zwischen Spitzen- und Freizeitsportlern zu unterscheiden. Abschließend werden ausgewählte, klinisch relevante Fragestellungen im Zusammenhang mit Ausdauersport und den jeweiligen Ernährungsempfehlungen zur Risikominimierung dargestellt.

› **Es lässt sich zusammenfassen,** dass die Deckung des Energiebedarfs das wesentliche Ziel in der Ernährung von Ausdauersportlern darstellt. Die Energieverfügbarkeit sollte dabei nicht unter 30-45kcal/kg fettfreier Masse pro Tag liegen. Der tägliche Kohlenhydratbedarf variiert in Abhängigkeit der Trainingsbelastung zwischen 3-5g/kg/d während niedrig-intensiver und 8-12g/kg/d während hoch-intensiver Trainingsphasen. Der Proteinbedarf von Spitzen-Ausdauersportlern entspricht mit 1,4-1,6g/kg/d etwa dem Doppelten der Empfehlung für Nicht- und Freizeitsportler, liegt jedoch im Bereich der durchschnittlichen Proteinzufuhr der deutschen Allgemeinbevölkerung.

› **Eine professionelle Ernährungsbetreuung** (z. B. durch Ernährungsberater der Olympiastützpunkte) kann hilfreich sein, um Athleten bei einer individuell bedarfsgerechten Ernährung einschließlich der Lebensmittelauswahl und der (zeitlichen) Anpassung der Nährstoffzufuhr an das Training zu unterstützen.

KEY WORDS:
Nutritional Guidelines, Nutrient Intake, Rehydration, Endurance Athletes

SCHLÜSSELWÖRTER:
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Nutritional Demands During General Training Periods

Endurance athletes represent different sports such as running, cycling, swimming, triathlon, canoeing, skiing or walking and different disciplines within these sports. Thus, energy requirements of endurance athletes may largely vary between sports, individuals and between different training periods. The total energy expenditure (TEE) of endurance athletes depends on their body mass, body composition, age, sex, non-exercise activity and frequency, duration and intensity of exercise. ›

Table 1

Carbohydrate intake recommendations for endurance athletes during different training periods; modified from (5).

DESCRIPTION OF TRAINING PERIOD	CARBOHYDRATE INTAKE RECOMMENDATION (G PER KG OF BODY MASS PER DAY)
Low-intensity training periods (< 1 hour of exercise per day)	3-5g/kg/d
Moderate volume and/or intensity (approx. 1 hour of exercise per day at moderate intensity)	5-7g/kg/d
High volume and /or intensity (1-3h of exercise per day at moderate-to-high intensity)	6-10g/kg/d
Very high volume and /or intensity (4-5h of exercise per day at moderate-to-high intensity)	8-12g/kg/d
Carbohydrate loading before competitions lasting >90min	10-12g/kg/24 h during the last 36-48 hours before the event
Recovery from exercise, when the break between two sessions is <8 hours	1.0-1.2g/kg/h or the first 4 hours post-exercise

Table 2

Protein intake recommendations for endurance athletes during different training periods; adopted from (45).

CATEGORIES OF ENDURANCE ATHLETES	PROTEIN INTAKE RECOMMENDATION (G PER KG OF BODY MASS PER DAY)
Recreational endurance athletes (exercising 4-5x/week for 30min at low intensity)	0.8-1.0g/kg/d
Competitive endurance athletes (exercising 4-5x/week for 45-60min at moderate intensity)	1.2-1.4g/kg/d
Elite endurance athletes	1.6g/kg/d
Female endurance athletes	10-20% less than males
Recovery from exercise, when the break between two sessions is <8 hours	1.0-1.2g/kg/h or the first 4 hours post-exercise

Total TEE of endurance athletes is approximately 1.8 to 2.3-fold as high as the individual's resting energy expenditure (37), but may be up to 4-fold in professional endurance athletes during short periods (48). Meeting the energy demands is the major nutritional goal in endurance athletes. Especially in females the energy intake (EI) is often observed to be considerably below the estimated TEE (3, 12). With low EI, even a high proportion of carbohydrates might be insufficient to support adequate glycogen resynthesis during intensive training periods. Nutrient recommendations should therefore be provided in absolute terms related to body mass (g/kg/d) instead of proportions relative to energy intake.

Carbohydrate-rich foods (cereals, vegetables, legumes and products thereof) should be the major source to account for elevated energy demands (25, 37). During low-intensity training periods, a carbohydrate intake of 3-5g/kg/d seems to be appropriate to meet the demands of endurance athletes, whereas requirements may rise up to 8-12g/kg/d during high-intensity training periods (5) (Table 1).

Competitive endurance athletes should aim to ingest 1.2-1.4g/kg/d of proteins (45). Elite endurance athletes might require up to 1.6g/kg/d, whereas the protein requirement of recreational endurance athletes (exercising 4-5x/week for 30min) seems not to be higher than that of sedentary people with 0.8-1.0g/kg/d (45, Table 2).

Sweat losses during exercise may considerably vary between endurance athletes and depend on individual sweat rates, type, duration and intensity of exercise, sex, fitness level and environmental factors such as heat or humidity (2). In the literature, typical sweat rates of 1.49L/h with an intra-individual range of 0.75-2.23L/h for male half-marathon runners are given (14). There is strong evidence that dehydration increases the physiologic strain and the perceived effort to perform an exercise. A dehydration >2% of body mass can adversely affect exercise performance (2, 24). Thus, athletes should aim for a regular fluid intake during exercise and support adequate hydration by regular meal consumption spread over the day (2, 24, 40). However, to reduce the risk for exercise-induced hyponatremia overdrinking (i.e. weight gain during exercise) should be avoided (2).

Sodium (~900mg/L), potassium (~200mg/L), calcium (~18mg/L), zinc (~0.6 mg/L), copper (~0,1mg/L) and magnesium (~1,4 mg/L) are the major minerals found in human sweat during exercise, with a huge intra-individual variety (43). As there is evidence that sodium loss may be linked to exercise-induced muscle cramps (27), athletes prone to heavy sodium loss ("salty sweaters") should consume sodium-containing drinks during exercise lasting >90 min (24). In case food intake is adequate, no additional electrolytes or minerals are required in the sports drink during habitual training (24, 40).

Recently, there is no rationale to assume that recommended daily allowances (RDAs) of micronutrient intake for the general population do not cover demands of athletes (17, 37), except for iron (49). For antioxidants such as vitamins C and E, an increased requirement due to exercise-induced production of reactive oxygen species has been postulated (39). However, there is no proof for detrimental effects on health or performance in case of marginal deficiencies (47). In contrast, supplementation with vitamin C and/or E may adversely affect health and training adaptation for both health-oriented and elite athletes (15, 36).

Nutritional Competition Preparation

Depletion of glycogen stores are a major cause of fatigue during endurance exercise (29). Therefore, glycogen status should be optimized before competition. Performance benefits (i.e. maintaining the speed at the end of the race) from carbohydrate loading seem to persist even when carbohydrates are consumed during competition (34, 50). Increased carbohydrate intake and tapered exercise or rest are prerequisites for glycogen storage (18). Although there a different carbohydrate loading protocols available, a carbohydrate intake of 10-12g/kg/d for 36-48 hours combined with 1-2 days of rest before competitions lasting >90 min is recently recommended (5, 7).

The pre-exercise meal should provide sufficient fluids to ensure euhydration before exercise, be low in fat and fibre to reduce gastrointestinal complaints and improve gastric emptying and should be familiar to the athlete (37). Depending on the individual needs and palatability, 1-4g of carbohydrate per kg body mass 1-4 hours before exercise are recommended (5).

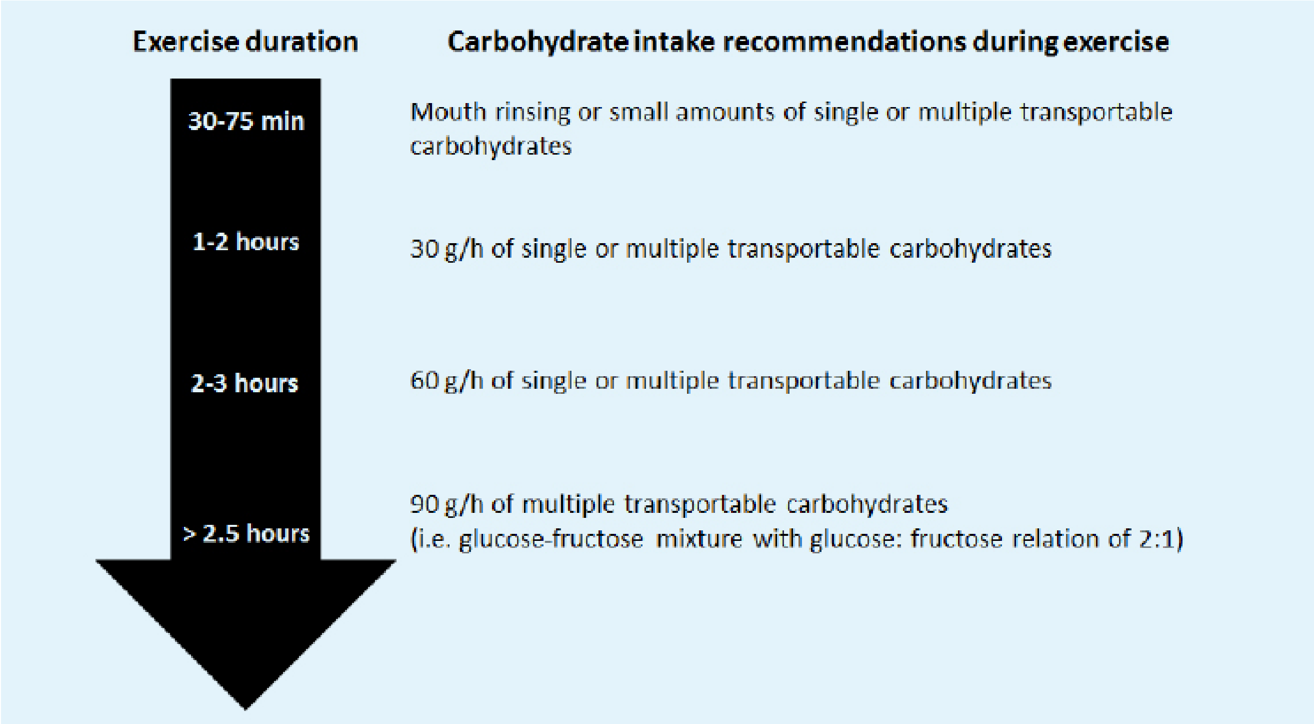

Figure 1

Carbohydrate intake recommendations during endurance exercise; adopted from (20).

Nutritional Intake During Competition

During endurance events, carbohydrates, fluids and sodium should be ingested depending on the exercise duration, intensity and environmental conditions. There is strong evidence for performance benefits when endurance athletes consume 0.7g/kg/h carbohydrates (~30-60g/h) during exercise (37). This recommendation takes into account that the oxidation rate from exogenous glucose is ~1g/min, even at higher rates of intake.

However, more recent studies have shown that the carbohydrate oxidation rate may be increased up to 1.75 g/min, when multiple transportable carbohydrates using different intestinal transporters are ingested (10). A mixture of glucose (using sodium-dependent glucose transporter-1 [SGLT-1]) and fructose (using glucose transporter 5 [Glut5]) at a ratio of 2:1 in amounts of 1.8g/min (i.e. up to 70g of glucose +35g of fructose per hour) seems to be most effective (10). The administration form of carbohydrates does not influence the oxidation rate, thus athletes may combine beverages, carbohydrate bars or gels during long-distance events (32, 33). To achieve an optimal balance between the requirements for carbohydrate absorption and fluid delivery, carbohydrate concentration should range between 5-10% in fluids, with the lower concentration when fluid delivery is more important than carbohydrate absorption (i.e. in hot and humid environments) (2).

For endurance competitions of shorter duration (30-75min), mouth rinsing with carbohydrate solutions was shown to improve exercise performance, although the potential mechanisms are not fully understood yet (9, Fig. 1). Nutrient receptors in the oral cave seem to mediate central nervous effects and activate brain regions associated with reward and motor control and thus promote performance (6).

Nutrition to Promote Post-Exercise Recovery

Adequate nutrition may support recovery from endurance events, especially rehydration and glycogen resynthesis. Shirreffs et al. analysed the effect of differently concentrated sodium solutions in varying amounts on fluid restoration and found that high-sodium solutions (~1330mg/L) at amounts of 150% of body mass loss are most effective in rehydration (41). Thus, expert panels recommend to ingest 1.5L of a sodium-containing fluid for each kg of body mass lost during exercise to support rapid recovery from dehydration (2). Voluntary drinking after exhausting exercise may be supported by adding palatable flavour and carbohydrates (40).

Immediate consumption of carbohydrates following glycogen-depleting exercise can enhance glycogen resynthesis rates (26). Adequate glycogen resynthesis may promote recovery, ensure high carbohydrate availability during subsequent exercises and thus promote exercise performance (26). In addition, post-exercise carbohydrate ingestion was shown to reduce exercise-induced immune function impairment by reducing the exercise-induced rise of plasma catecholamines and cytokines (13). A carbohydrate ingestion of 1.0-1.5g/h per kg body mass during the first few hours following exercise, was shown to significantly increase glycogen restoration (4, 5, 26). In case a high carbohydrate intake cannot be achieved, a reduced carbohydrate ingestion (~0.8g/kg/h) is effective, when ~0.2-0.4g/kg/h of protein is co-ingested (4, 26). Co-ingestion of protein may also have beneficial effects on parameters of muscle damage and soreness (42) with chocolate milk being as effective as commercial recovery beverages (22). Protein supplementation alone seems not to promote recovery of muscle function, parameters of muscle damage or perceived muscle soreness following endurance exercise (30). To achieve these nutritional targets, athletes may consume beverages or non-liquid foods that are rich in carbohydrates, spread over smaller dosages every 15-20min (for examples, see Table 3; online revised version, January 26th 2016).

Table 3

Examples of carbohydrate and protein sources suitable for endurance athletes with particular carbohydrate contents; *note that serving sizes in athletes´ diets may largely vary.
Online revised version, 26th January 2016.

FOOD (AVERAGE SERVING SIZE*)	CARBOHYDRATES (G) PER SERVING	PROTEIN (G) PER SERVING
Side Dishes		
Potatoes, peeled and cooked (200 g)	30	3
Smashed potatoes (200 g)	20	4
Pasta, cooked (70 g dry weight)	45	9
Parboiled rice (70 g dry weight)	55	6
Cereals and products thereof		
Oats (75 g)	45	10
Granola with dried fruits (75 g)	46	4
Granola with dried nuts (75 g)	42	6
Couscous (70 g dry weight)	48	8
Whole-grain bread, rye (1 slide/60 g)	20	3
Rusk (5 slides/50 g)	36	5
Shortbread (5 pieces/25 g)	16	3
Plain/marble cake (1 piece, 50 g)	24	3
Fresh fruits and vegetables		
Apple (1 piece, 150 g)	21	0,5
Banana (1 piece, 120 g)	24	1,5
Grapes (200 g)	31	2
Pineapple (200 g)	25	1
Rockmelon (200 g)	25	2
(Kidney) beans (200 g)	32	18
Peas (200 g)	14	11
Corn (200 g)	22	6
Dairy products		
Skimmed milk (250 g)	12	9
Buttermilk (250 g)	10	9
Skimmed chocolate milk (250 g)	18	9
Plain yogurt (150 g)	10	6
Fruit yogurt (150 g)	20	5
Cottage cheese, skimmed curd (50 g)	1,5	6
Semi-hard cheese, average (30 g)	0,5	8
Meat, fish and eggs		
Chicken breast (150 g)	1	35
Beef (150 g)	0	28
Pork (150g)	0	33
Salmon (150 g)	0	31
Scrambled eggs (150 g)	3	16
Fluids and beverages		
Smoothie (100% fruits, 250 g)	28	1
Apple or orange juice (100% juice, 250 g)	28	0,3
Apple juice spritzer (60% fruit juice, 250 g)	16	0
Grape juice (100% juice, 250 g)	40	0
Snacks/others		
Fruit bar (20 g)	13	0,5
Cereal bar (20 g)	15	1
Raisins (20 g)	14	0,5
Trail mix (20 g)	6	4
Blancmange (chocolate/vanilla) (150 g)	27	5

Clinical Issues Concerning the Nutrition of Endurance Athletes

Hyponatremia

Exercise-induced hyponatremia (EIH) was reported in endurance events and is characterized by a plasma-sodium level below 135mmol/L (1). Incidence of hyponatremia in ultra-endurance events ranges from 0.3% to 27% (16). EIH is a life-threatening condition that may be taken for symptoms of hypoglycaemia, heat stroke, exercise exhaustion or exercise-associated collapse when laboratory assessment is not available (16). A hot and humid environment, events lasting >4 hours, female sex, slower finishing times and the use of nonsteroidal anti-inflammatory drugs are considered as risk factors for EIH (16). To prevent EIH, athletes should follow a moderate hydration regime (~500mL per exercise hour or less) with carbohydrate-electrolyte solutions instead of drinking as much (water) as tolerable (2, 19).

Weight Management, Female Athlete Triad and Eating Disorders

Reducing body mass and body fat is often seen as an competitive advantage by athletes (44). However, the purpose to reduce body mass may result in dieting, disordered eating or eating disorders. An eating disorder prevalence of 10 % was reported in endurance athletes (38). Long-term restricted eating or low energy availability may adversely affect both health and performance, including cardiovascular, endocrine, reproductive, gastrointestinal and renal disturbances (28). The prevalence of the female athlete triad (disordered eating, amenorrhea, osteoporosis, or subclinical presentations thereof) varies between 4-27% in elite athletes (11, 28, 46). Long-term health consequences (impairment of reproductive function, premature osteoporosis) may not be excluded. Similar health problems (e.g. osteopenia) may occur in male endurance athletes with restricted diets (35). To reduce the risk of detrimental effects on health and performance, athletes should follow a diet and training regime that ensures an energy availability of 30-45kcal per kg fat-free mass per day (21). Energy availability denotes the remaining energy from dietary intake for the body after subtracting exercise-related energy expenditure (21).

Iron Deficiency and Iron Deficiency Anaemia

Risk factors for iron depletion in endurance athletes include poor iron intake, poor iron availability (e.g. due to high cereal intake to meet elevated carbohydrate requirements), foot strike haemolysis, increased iron loss, altered intestinal absorption, vegetarian diets, altitude training and female sex (37). Iron requirements in endurance athletes (esp. runners) may be increased by approximately 70% (49). It is non-controversial that iron deficiency anaemia adversely affects endurance performance. The effect of iron deficiency without anaemia on exercise performance remains equivocal, at least at early stages of iron depletion (31, 51). Athletes at risk should be individually counselled how to increase dietary iron intake and iron availability from food (8). A regular screening for iron deficiency in endurance athletes accompanied by a supervised iron supplementation to correct for iron depletion is recommended (23, 37).

Conclusion

Meeting the energy requirement is the major nutritional goal in endurance athletes. Carbohydrate needs to avoid glycogen depletion vary from 3-5g/kg/d during low-intensity up to 8-12g/kg/d during high-intensity training. During endurance events, a carbohydrate intake of 30-60g/h or higher is recommended. Avoiding a dehydration >2 % of body mass by regular ingestion of sodium beverages during and/or proper hydration before exercise is required.

Recovery from exercise is supported by proper rehydration and glycogen resynthesis. Rehydration is most effective when

1.5L of sodium beverages for each kg of body mass lost during exercise are consumed. For the first 2-4 hours post-exercise, ingestion of carbohydrates at amounts of 1.0-1.5g/kg/h in smaller dosages every 15-20min is recommended. Exercise-induced hyponatraemia is a life-threatening condition in events >4h, thus athletes should temper their fluid consumption not allowing for weight gain during exercise and prefer sodium beverages. Energy availability (i.e. energy intake – energy spent for exercise) should not fall below 30-45kcal/kg FFM/d to avoid health consequences such as symptoms of the female athlete triad. Health professionals including nutritionists of the German Olympic sports centres may help endurance athletes to follow a healthy diet with prudent food choices.

Conflict of Interest

The author has no conflict of interest.

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