

# Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Fats, Fat Loading, and Sports Performance

*Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung (DGE): Fette, Fat Loading und sportliche Leistung*

## Summary

- ▶ **This position statement** represents the current state of scientific knowledge regarding the recommended fat intake in ambitious recreational and high level sports. It also addresses dietary strategies (fat-loading methods) and food supplements that are designed to influence fat metabolism during physical exercise.
- ▶ **No recommendation** has so far been established for sports-specific fat intake in absolute numbers (g/kg body weight [BW]/d), in line with international practices regarding carbohydrate and protein. However, there is consensus among scientific sports medicine associations that fat consumption should not exceed 30% of the energy intake (E%), nor fall below 20 E%, particularly in endurance sports.
- ▶ **Before competitions**, some athletes practice fat-loading strategies which include a ketogenic diet. This procedure is not advisable, as there is no scientific evidence of improvement in either endurance (>70%  $\dot{V}O_{2,max}$ ) or sprint/strength performance. Moreover, the extensive restriction of carbohydrate intake is not in accordance with the internationally-accepted nutritional guidelines for athletes, and the food choice is unbalanced according to the recommendations of the German Nutrition Society (DGE).
- ▶ **The current use of dietary supplements** which are supposed to improve the availability/oxidation of fatty acids, e.g. caffeine, carnitine, fish oil, middle chain triglycerides (MCT), is also generally discouraged.

## KEY WORDS:

Dietary Supplements, Ketogenic Diet, Carnitine, Fish Oil, Middle Chain Triglycerides (MCT)

## Zusammenfassung

- ▶ **Dieses Positionspapier** stellt den aktuellen wissenschaftlichen Kenntnisstand zur empfehlenswerten Fettzufuhr im ambitionierten Breiten- und Leistungssport dar. Darüber hinaus werden Ernährungsstrategien (fat-loading-Methoden) und Nahrungsergänzungsmittel thematisiert, die den Fettstoffwechsel während körperlicher Belastung beeinflussen sollen.
- ▶ **Eine Empfehlung** für eine sportgerechte Fettzufuhr in absoluten Zahlen (g/kg KG/d), wie international für Kohlenhydrate und Proteine üblich, wurde noch nicht etabliert. Seitens sportmedizinischer Fachgesellschaften besteht jedoch Konsens darüber, dass der Fettverzehr besonders im Ausdauersport 30 Energieprozent nicht über- und 20 Energieprozent nicht unterschreiten sollte.
- ▶ **Vor Wettkämpfen** praktizieren manche Sportler fat-loading-Strategien, wozu auch die ketogene Diät gehört. Hiervon wird abgeraten, weil es keine wissenschaftlichen Belege für eine Verbesserung der Ausdauerleistung (>70%  $\dot{V}O_{2,max}$ ) oder der Sprint-/Kraftleistung gibt. Außerdem ist die drastische Kohlenhydratrestriction nicht konform mit den international anerkannten Richtlinien für eine sportgerechte Ernährung und den lebensmittelbezogenen Empfehlungen der Deutschen Gesellschaft für Ernährung (DGE) für eine vollwertige Ernährung.
- ▶ **Auch die Verwendung von Nahrungsergänzungsmitteln**, die die Fettsäureverfügbarkeit/-oxidation verbessern (sollen), wie zum Beispiel Koffein, Carnitin, Fischöl oder mittelkettige Triglyceride (MCT), wird im Allgemeinen nicht befürwortet.

## SCHLÜSSELWÖRTER:

Nahrungsergänzungsmittel, ketogene Ernährung, Carnitin, Fischöl, mittelkettige Triglyceride (MCT)

## Reference Values for Fat Intake

Compared to the significance of carbohydrate in endurance sports and protein in resistance training, the quantity and quality of the fat consumed plays a rather subordinate role with regard to performance and health of ambitious recreational and high level athletes. This is why essentially the same recommendations as for the healthy general public apply.

While there are recommended intakes in absolute values (g/kg body weight [BW]/d) for carbohydrate and protein in endurance and

strength sports on an international level, there is only a guideline for fat intake: not to exceed 30% of the energy intake (E%), nor fall below a rate of 20 E% (66). The lower limit is meant to ensure that:

1. An adequate amount of essential fatty acids and fat-soluble vitamins is supplied/absorbed,
2. The person feels satiated between meals,
3. The intramuscular triglycerides are replenished after long-lasting physical exercise. ▶

## POSITION STAND

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1. REDAKTION LEISTUNGSSPORT (DOSB), Germany
2. DEUTSCHE SPORHOCHSCHULE KÖLN, Institut für Biochemie; Deutsches Forschungszentrum für Leistungssport, Köln, Germany
3. HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN HAMBURG, Fakultät Life Sciences/Department Ökotrophologie, Hamburg, Germany
4. OLYMPIASTÜTZPUNKT RHEINLAND-PFALZ/ SAARLAND, Germany
5. ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG, Institut für Sport und Sportwissenschaft, Arbeitsbereich Ernährung, Freiburg, Germany
6. BUNDESINSTITUT FÜR RISIKOBEWERTUNG (BfR), Berlin, Germany
7. OLYMPIASTÜTZPUNKT STUTTGART, Germany
8. UNIVERSITÄTSKLINIKUM TÜBINGEN, Abteilung Sportmedizin, Tübingen, Germany
9. DEUTSCHE GESELLSCHAFT FÜR ERNÄHRUNG E. V. (DGE), Germany
10. RHEINISCHE FRIEDRICH-WILHELMS-UNIVERSITÄT BONN, Institut für Ernährungs- und Lebensmittelwissenschaften, Ernährungsphysiologie, Bonn, Germany
11. UNIVERSITÄT PADERBORN, Institut für Ernährung, Konsum und Gesundheit, Paderborn, Germany



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## CORRESPONDING ADDRESS:

Dr. oec. troph. Alexandra Schek  
Redaktion "Leistungssport" (DOSB)  
Mühlstr. 11, 35390 Gießen, Germany  
✉: [schek@leistungssport.net](mailto:schek@leistungssport.net)

Table 1

Foods with high proportions of individual fatty acids or different types of fatty acids (calculated with DGExpert version 1.9.3.1), EN%=percent of energy.

FATTY ACIDS	FOODS (FAT CONTENT IN EN%)
<b>Polyunsaturated Fatty Acids</b>	
<b>Linoleic acid (n-6, essential)</b>	Wheat germ oil (57), soybean oil (54), sunflower seeds (31), pumpkin seeds (30)
<b><math>\alpha</math>-linolenic acid (n-3, essential)</b>	Linseed oil (54), walnuts (13), walnut oil (12), canola oil (9)
<b>Eicosapentaenoic acid (EPA; n-3)</b>	Herring (8), sprat (6), tuna (6), salmon (4)
<b>Docosahexaenoic acid (DHA; n-3)</b>	Tuna (9), sprat (8), salmon (7), mackerel (5)
<b>Monounsaturated Fatty Acids</b>	
	Olive oil (72), hazelnuts (71), peanut oil (57), avocado (56), canola oil (50), cashews (44), pumpkin seeds (27)
<b>Saturated Fatty Acids</b>	
	Coconut oil (88), butter (65), whipping cream (56), Gouda, 45 % fat in dry matter (49), palm oil (47), lard (40), bacon (39), milk chocolate (34), liverwurst (33), nut nougat cream (32), Hollandaise sauce (32), salami (31), egg yolk (23)
<b>Trans Fatty Acids</b>	
	Are often contained in variable proportions in e.g.: deep-frying oil, pastries, rusk, crackers, potato chips, instant soups, margarine made from one type of oil

The reference value of 30 E% for healthy adolescents and adults is considered the upper limit of fat intake in ambitious recreational and high level sports to prevent food-related illnesses (15,18). Persons with increased energy expenditure (physical activity level [PAL] >1.7) may require more than 30 E% (18). However, especially in regards to endurance sports, reputable international associations encourage limiting fat intake to 30 E%, which takes into account the fact that deriving energy from carbohydrate takes precedence (66).

For a fat intake up to 30 E%, the proportions of fatty acid fractions should ideally be as follows (18):

- 7-10 E% saturated fatty acids (max. one third of energy supplied as fat),
- 7 E% polyunsaturated fatty acids (sum of n-3 and n-6 fatty acids) or up to 10 E% if the energy supply from saturated fatty acids exceeds 10% of the total energy intake,
- Monounsaturated fatty acids make up the difference to the total fat content,
- The proportion of trans fatty acids should be less than 1 E%.

For adolescents and adults, the recommended intake of essential fatty acids that cannot be formed in the human body is 2.5 E% for linoleic acid (n-6) and 0.5 E% for  $\alpha$ -linolenic acid (n-3) (18). The latter can be converted in the body into the long-chain n-3 fatty acids eicosapentaenoic (EPA) and docosahexaenoic acid (DHA), however only to a limited extend (approx. 10-20%) (18).

### Food-Related Recommendations for Fat Intake

A wholesome diet according to the nutritional recommendations of the DGE (16, 17) includes a high proportion of plant-based food and – bearing in mind a healthy energy

balance – a supply of oils with a high amount of  $\alpha$ -linolenic acid (linseed, walnut, canola oil) and fish with a high amount of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (herring, salmon, mackerel). If possible, fish from a sustainable source should be consumed once to twice per week (16, 17). Additionally, the consumption of foods with a high proportion of saturated (coconut oil, palm oil, animal-derived products) and trans fatty acids (convenience foods) should be reduced and replaced with food containing high levels of monounsaturated fatty acids (olive oil, canola oil, nuts and seeds). Table 1 shows foods containing high levels of the above-mentioned fatty acids.

### Fat Consumption

Data about fat consumption in ambitious recreational sports are sparse, as illustrated by the compilation in table 2. Most (cross-sectional) studies were performed with high level athletes. The latter mostly adhere to the reference value of 30 E% fat, as documented in detail by Schek (2018, p. 15-22) (61), in endurance as well as (high-speed) strength and team sports, while the intake of carbohydrate is often in the lower range of the recommended intake. This also seems to apply for the endurance disciplines in ambitious recreational sports (Table 2). However, the available data do not allow for any estimates beyond this. Given the popularity of city marathons and high-intensity fitness classes, there is a need for further research.

### Disputable Strategies before Competition (Fat Loading)

Studies have been conducted for about 35 years on whether the availability or oxidation rate of fatty acids in the active muscles can be increased by varying the fat content in food or using dietary supplements. The aim is to protect the glycogen reserves (63), which hypothetically leads to an improvement in endurance performance.

Fat loading is a pre-competition strategy that is practiced either three to four hours before the start (acute) or five and more days before the competition (chronic). Chronic fat loading can be further distinguished into ketogenic and non-ketogenic low-carb, high-fat (LCHF) diets.

The interest in fat loading resurged during the past five years (4, 33, 52, 71), although not many new studies have been conducted. Since fat loading is getting increasing exposure on internet platforms and blogs (for the search terms ketogenic diet performance 7,300,000 results on google.com on August 31, 2020), the different strategies are briefly introduced and critically examined below.

In the scientific databases PubMed and LIVIO as well as via Google Scholar RCT studies and systematic reviews were searched in August 2018 and checked for updates in May 2020 using the keywords “fat loading performance”, “low carbohydrate diet performance” and “ketogenic diet performance”. Included in the position statement presented here are all identified contributions in which the subjects were athletes with moderate to very high performance levels. For space reasons the focus of this paper is on endurance sports.

### Acute Fat Loading

Acute fat loading involves eating a high-fat meal (60-90 E% fat) three to four hours before a strenuous endurance exercise bout. Studies involving competitive athletes show that a high-fat loading meal does not positively influence the time to exhaustion, but instead may even shorten it:

Table 2

Energy and macronutrient intake determined to date in ambitious recreational athletes to illustrate the nutrient distribution in practice. ACSM=American College of Sports Medicine; BW=body weight; CHO=carbohydrate; D=day; f=females, m=males; N=number.

	N	AGE (YEARS)	TRAINING (MIN/D)	ENERGY (KCAL/D)	CHO (G/KG BW/D)	PROTEIN (G/KG BW/D)	FAT (E%)
Values set of the ACSM (66)				Sufficient to meet requirements	5-12	1,2-2,0	20-30
<b>Endurance Sports</b>							
Modern pentathlon (46)	12 m+f	39,8	64	2739	5,5	1,6	32
Triathlon (46)	22 m+f	37,4	111	2925	5,5	1,7	31
Ironman (46)	39 m+f	41,4	143	3703	7,3	2,1	28
„Ultradistance“ (73)	55 m	46,4	87	2681	4,5	1,3	30,4
	12 f	44,3	86	2205	4,8	1,3	31,1
<b>Fitness Sports</b>							
Cross fit (73)	5 m	25,6	41	3308	3,4	1,8	39,6
	6 f	31,5	90	2609	3,8	2,1	38,5

- Okano et al. (1996; 1998) and Whitley et al. (1998) were able to show a slightly higher proportion of fatty acids in the energy supply, but only at an early stage of the exercise and without any effect on endurance capacity (55, 56, 75).
- Wee et al. (1999) determined a negative influence of a high fat intake compared to a high carbohydrate intake on the time to exhaustion (-14%), which the authors attributed to delayed gastric emptying (74).
- In the context of high-intensity (Hawley et al., 2000) or intermittent exercise (Hulton et al., 2013), only a slightly higher availability and oxidation of fatty acids could be determined after a high-fat meal. The performance was not improved (30, 36).

Concerns about gut comfort after ingesting a high-fat loading meal were not addressed in any of the mentioned studies. However, a correlation between high fat intake and gastrointestinal distress can be observed particularly in endurance sports (35).

### Ketogenic LCHF Diet (Short: Ketogenic Diet)

The ketogenic diet, which is carried out particularly with the goal of weight reduction, sometimes for weeks, although there is no proof that it is superior to energy restricted types of diets, is characterized by a fat content of 75-85 E%, a protein content of 15-25 E% and a carbohydrate content of <50 g/day. The studies which were mostly performed in the realm of endurance sports reveal no positive effects on performance capacity, but may even show negative effects:

- Phinney et al. (1983) were not able to prove any influence on the time to exhaustion with bicyclists, which led them to conclude: "The price paid for the conservation of CHO during exercise appears to be a limitation of the intensity of exercise that can be performed" (57).
- Zajac et al. (2014) did see a minor increase in the relative oxygen intake, but this was attributed to the weight loss by 1.8 kg (in four weeks). The maximum work load on the bicycle ergometer was lower (76).
- Zinn et al. (2017) showed a weight loss of 4 kg (in ten weeks) on the one hand, and a decrease in time to exhaustion in a bicycle ergometer step test on the other hand (78).
- Heatherly et al. (2018), despite demonstrably lower glucose oxidation rates, found no influence on various performance parameters during five 10-minute running bouts at multiple

individual race paces and a 5 km time trial. They assume that possible performance reductions were offset by the observed weight loss of 2.5 kg (in three weeks) (31).

- McSwiney et al. (2018) did not find any influence on the result in a 100 km time trial. The increase in relative power in a simulated final sprint can be attributed to an improved power-to-mass ratio resulting from a weight reduction by 5 kg (in three months) (48).
- Burke et al. (2017) showed that under competitive conditions, the time for a 10 km race walk could not be improved after a three-week ketogenic diet – in contrast to the results after diets providing chronic or periodised high carbohydrate availability. The authors propose that the low-carbohydrate diet prevented a positive training effect, which could partially be attributed to a reduced exercise economy (8). Additionally, there seems to be a plausible link between a ketogenic diet, shifts in the bacterial colonization in the gut, and impairments in exercise capacity (50). Concerning the long-term health impact of this dietary intervention, it must be noted that a 3.5-week ketogenic diet in elite endurance athletes has negative effects on the markers of bone modeling/remodeling at rest and during a prolonged high intensity exercise session (32).
- Mujika (2018), in the scope of an individual case study, states that during an eight-month reduction in carbohydrate intake to <52 g/day, a world-class triathlete dropped from the top ranks to the 18th and 14th position and had to cancel a competition. Five weeks after switching to a diet rich in carbohydrate, he finished second and fourth in two Ironman events separated by only three weeks. Moreover, there was a positive impact on the athlete's subjective psychological well-being (49).
- According to the systematic review of McSwiney et al. (2019), including eight studies involving strength endurance training (50-84% 1RM), resistance training (>85% 1RM), high-intensity interval training (64-90%  $\dot{V}O_2$ max), and sprint training (>91%  $\dot{V}O_2$ max), no decrease in performance occurs following adaptation to a ketogenic diet. Reported beneficial effects during short duration vigorous, and sprint bouts of exercises are most likely confounded by greater weight loss in the ketogenic diet group. In trained endurance athletes the decrease in exercise economy coming along with higher intensities (>70%  $\dot{V}O_2$ max) may negate performance within field settings (47). >



A striking observation, when considering the extensive carbohydrate restriction in a ketogenic diet, is that it is at odds with the widely accepted nutritional guidelines for athletes (66) and the food-related recommendations by the DGE for a balanced diet (16, 17). Micronutrient-dense foods, such as fruit, potatoes or cereal products, can only be consumed in very limited amounts in a ketogenic diet. It is therefore possible that long-term use can lead to negative effects on health, nutrient supply and performance.

### Non-Ketogenic LCHF Diet

This diet, which also limits the food selection so severely that it is no longer wholesome, involves the consumption of 60-70 E% fat and 15-20 E% of each protein and carbohydrate for one to several weeks before a competition. Based on endurance-oriented studies, it can be inferred that the non-ketogenic LCHF diet does not have a significant influence on performance or may even have a negative influence:

- In the study by O'Keeffe et al. (1989), to date the only study performed on women, a decline in endurance capacity was evident (54).
- Lambert et al. (1994) did find an increase in endurance time to exhaustion, but this was after a prior supramaximal exercise test, which heavily strained the muscle glycogen reserves and has little in common with real-life conditions (44).
- Two additional studies (Rowlands & Hopkins, 2002; Vogt, 2003) were unable to show any influence on the maximum oxygen intake, distance, duration or power output in a time trial or on the half-marathon time (59, 70).

What has been shown so far about fat-loading strategies leads to the conclusion that a fatty acid oxidation rate that has been moderately increased by a higher fat intake (58) has no benefit with respect to (endurance) performance. A possible cause of this could be that the low carbohydrate intake is accompanied by a reduced availability of glycogen/glucose (5). It can be assumed that the disadvantage of reduced muscular glycogen reserves outweighs the benefit of a glycogen-sparing effect during physical exercise.

### LCHF Diet in Combination with Carbohydrate Loading

In an attempt to avoid the possible disadvantage of suboptimal glycogen storage due to an LCHF diet, several studies were conducted in which a five- to 11-day non-ketogenic LCHF diet was followed by one to three days of carbohydrate loading with 7-11 g of carbohydrate/kg BW/d. However, the study results suggest that the combination of an LCHF diet with carbohydrate loading does not have a positive effect on endurance performance:

- In five studies, no effect on cycling performance could be determined in a time trial following an endurance exercise bout at moderate intensity (6, 7, 9, 44, 51); one study showed a 4% improvement (43).
- The realistic study of competitive cyclists by Havemann et al. (2006) showed decreased performance in the final sprint. The authors conclude: "Adaptation to the LCHF diet followed by CHO restoration increased fat oxidation during exercise (...), but it reduced high-intensity sprint power performance, which was associated with increased muscle recruitment, effort perception and heart rate" (29).

In summary, it can be assumed that during intermediate and final sprints, glycolysis is limited owing to a downregulation of the pyruvate dehydrogenase activity caused by an LCHF diet (58). This means that the upregulation of fatty acid

oxidation is ultimately more likely to result in a limitation of glycogen use than to have a glycogen sparing effect (5). In addition, it is possible that during an exercise bout after fat loading, the higher concentrations of free fatty acids and ammonium ions in blood plasma promote general fatigue (10). This is why high-fat dietary practices are discouraged.

### Dietary Supplements for the Alleged Increase of Fatty Acid Oxidation

The influence of various dietary supplements on the availability or oxidation rate of fatty acids has been studied repeatedly. The hypothesis underlying these studies is that an increase in energy supply from fatty acids could spare glycogen and thus enhance endurance performance. Does it make sense to use food supplements is discussed below.

#### Caffeine

Caffeine was on the list of banned drugs until 2004. Heretofore, it was assumed that the alkaloid stimulates the release of adrenaline, thereby increasing the mobilization of fatty acids from adipocytes and myocytes, which can be used as energy sources (11). Graham et al. (2000), however, showed that caffeine does neither enhance the uptake of fatty acids by the working muscles, nor does it influence fat or carbohydrate metabolism (27). Nor could Greer et al. (2000) determine any influence on the breakdown of muscle glycogen, although an increased time to exhaustion was shown (28). This is why the metabolic theory was discarded. As a matter of fact, caffeine has a positive psychotropic effect which is discussed in detail elsewhere (61).

The European Food Safety Authority (EFSA) certifies that caffeine, as an adenosine receptor antagonist, has a positive effect on alertness and concentration with a single serving of 75 mg (about one cup of coffee) (21) or a favorable influence on endurance performance and capacity with a consumption of 3 mg/kg BW (20). The safety aspects of caffeine consumption are clarified by the "Position of the working group sports nutrition of the German Nutrition Society (DGE): Safety aspects of dietary supplements in sports" (77).

#### Carnitine

During exercise of moderate intensity, carnitine functions as a carrier of long-chain fatty acids through the inner mitochondrial membrane. In the case of high work loads, carnitine buffers excess acetyl residues, thereby preserving the pool of free coenzyme A, an essential factor in oxidation reactions (pyruvate dehydrogenase, citrate cycle enzymes) (58, 60, 64). All studies that investigated the effect of carnitine supplementation of 2-6 g/day over a period of one to 16 weeks showed that carnitine per se does not influence the proportion of fat and carbohydrate in the energy supply, nor does it improve endurance performance or reduce body fat (3, 60). This is because orally ingested carnitine does not increase the carnitine concentration in the myocytes (60, 64). This is only possible if carnitine is administered with large amounts (2 x 80 g/day) of readily available carbohydrate (64, 65, 72), which is not desirable from a nutritional and physiological perspective.

According to the EFSA, carnitine does not favorably influence endurance capacity or recovery (22). In the scope of testing carnitine tartrate for use in particular foods, the EFSA has rated an intended daily supply corresponding to 2 g of carnitine as well tolerated, and assured that gastrointestinal distress was only reported for consumptions of 4-6 g of carnitine or more per day in tolerance studies (19).

### Fish Oil

Fish oil, which contains high amounts of EPA and DHA, was first recommended specifically for athletic purposes by Simopoulos (2007) (62). In vitro, EPA results in an induction of the gene expression of acetyl-CoA carboxylase which regulates the fatty acid oxidation in the mitochondria (34). However, human studies have not verified any influence of long-chain n-3 fatty acids on the proportionate energy supply from fat and carbohydrate, either at rest (53) or during exercise (2). This explains why fish oil has no effect on endurance performance, as Da Boit et al. (2017) presented in their review (12).

For adults, the EFSA does not note any health concerns for a combined supplementation of EPA and DHA with amounts of up to 5 g per day or, if only EPA is supplemented, of up to 1.8 g/day. If only supplemented with DHA, this applies to doses of up to about 1 g/day for the general population (23).

### Medium-Chain Triglycerides (MCT)

Medium-chain triglycerides (MCT) contain fatty acids with a medium chain length (6-12 C atoms). They can contribute to energy production in the skeletal muscles, but only at an extent of 3-8% of all oxidized fatty acids (39, 40, 45). The maximum oxidation rate of 0.12 g/min is reached after strenuous exercise lasting approx. two to three hours (39, 40, 45). Most of the few studies that have examined the influence of a combined intake of MCT and carbohydrate before and during endurance exercise show no indication of a glycogen sparing or performance enhancing effect (1, 26, 38, 42, 69). Only van Zyl et al. (1996), who administered 86 g of MCT to their study subjects during an endurance exercise bout, found an improvement in their performance in the subsequent time trial (67). However, Goedecke et al. (2005) identified a performance impairment in the scope of a simulated ultra-endurance competition during which a total of 148 g of MCT had been supplied. The authors speculated that the gastrointestinal symptoms (especially intestinal cramps) reported by some participants contributed to the impaired performance (25). Ivy et al. first outlined in 1980 that gastrointestinal distress had occurred in 100% of their study subjects after a bolus of 50 or 60 g of MCT. When the dose was reduced to 30 g, gastrointestinal discomfort was reported by only 10% of the participants (37). Décombaz et al. (1983) used single dosages of 25 g of MCT, because preliminary studies had not shown any adverse effects for this amount (13). Jeukendrup et al. (1995; 1998) consider a single administration of approx. 30 g of MCT prior to physical exercise to be the upper limit (39, 41). This amount is too low to influence performance, however.

### Coconut Oil

MCT in the form of coconut oil are currently experiencing a revival as part of the ketogenic diet for weight reduction (24). Coconut oil contains about 54% medium chain fatty acids, of which only 12% with 8 and 10 carbon atoms are rapidly converted into ketones by the liver (68). The use of MCT to support weight loss is not to be recommended (14, 15). This is because only 80-120 kcal can be saved, owing to the average tolerable intake level of about 60 g per day, which is reached when an initial MCT supply of 20 g/day is slowly increased by 5-10 g/day (14). It can thus be assumed that coconut oil is not an effective means of reducing weight, for example as part of competition preparation.

### Conclusion

In contrast to carbohydrate and protein, for which recommended intakes were internationally derived in g per kg of body weight and day for various types of sports, the reference value for fat intake is specified in terms of a percentage of energy supply. The diet of ambitious recreational and high level athletes should provide a maximum of 30 and a minimum of 20 E% fat and prioritize a health-promoting fatty acid pattern.

Attempts to increase fatty acid availability by means of acute or chronic fat loading strategies (with or without subsequent replenishing of glycogen stores) failed to show improvements in endurance performance, although fatty acid oxidation was enhanced. In the worst case, fat loading may even result in performance impairment in intermediate or final sprints, which is why low-carb, high-fat (LCHF) diets are not recommended.

The use of dietary supplements which are supposed to increase the availability/oxidation of fatty acids does not result in performance enhancing effects and is thus not recommended. ■

### Conflict of Interest

*The authors have no conflict of interest.*

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