

Nutritional Recommendations for the Prevention of Type 2 Diabetes Mellitus

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NOTICE OF UPDATE

The DDG clinical practice guidelines are updated regularly during the second half of the calendar year. Please ensure that you read and cite the respective current version.

Preamble

These clinical practice guidelines are intended as a guide for all those who pay special attention to the prevention of metabolic disorders such as type 2 diabetes mellitus (T2DM). These can be patients with a such illness, people who have an increased familial relative risk or therapists who care for patients with an increased risk and, ultimately, all those who want to obtain the most evidence-

based information possible for a healthier ageing. Not least of all, to keep our health system functioning and financially viable, we must work together towards effective prevention. Especially in the context of prevention, we need to develop an awareness that leads us beyond an early risk assessment to adequate testing of a risk [1], without losing sight of risky living conditions in the event of a negative test result.

The present clinical practice guideline deals almost exclusively with nutrition. It is a particular challenge—in view of the complexity of possible diets, which reflect different biographies, preferences and aversions—to provide the most individual advice possible, as recommended by the Committee for Nutrition of the DDG in the clinical practice guideline for nutritional therapy of the T2DM [2]. The difficulty of finding the highest possible evidence-based recommendations in references is exacerbated by the breadth of symptoms that these recommendations are intended to target. It is precisely this diversity that highlights the fact that nutrition is a cross-sectional issue which unites many disciplines and makes in-

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terdisciplinary cooperation necessary. The recommendations for the prevention of gestational diabetes highlight the intersectoral cooperation with the Diabetes and Pregnancy Working Group.

The main goal of this work is primary prevention.

We must keep in mind that we are targeting healthy people, most of whom do not yet feel any symptoms. At first glance, targeted restriction of eating habits will hardly seem justified and must therefore be directed at the awareness of being responsible for one's own future well-being. The information that excess weight and obesity lead to the main causes of a glycaemic metabolic disorder seems abstract at first and only a continuous communication of the scientific facts can lead to success. Thus, the knowledge of the well-documented connection between an inappropriate diet and diabetes justifies a possible therapeutic approach [3].

These clinical practice guidelines summarize the extensive, sometimes heterogeneous data on the most diverse aspects of nutrition that can be found in international literature in the context of diabetes prevention and are nonetheless incomplete. The annual update makes it possible to keep an eye on the published literature and to continuously include new topics.

Lifestyle Intervention

Nutrition in general

Recommendation

- Recommendations for lifestyle changes are indicated when a dietary pattern suggests an increased risk of T2DM.
- Recommendations for dietary changes are indicated when there is a familial relative risk for T2DM.
- Dietary changes alone have a positive effect on the risk of diabetes even without a structured exercise program.

Comment

There is a general consensus that lifestyle changes can have a positive effect on the burden of disease [4]. In particular, the risk of T2DM is amenable to such a lifestyle change and delays the onset of T2DM [5]. Active intervention leads to a sustained delay in the onset of diabetes even after discontinuation of the measures. A number needed to treat (NNT) of 25 was calculated to prevent diabetes. How to classify exercise therapy, which only seems to have a significant effect on risk reduction in isolated studies without accompanying nutritional therapy, remains controversial [6]. While a nutritional intervention can reduce diabetes by as much as 32 %, the combination of both strategies is significantly more effective at 41 % [6]. Nevertheless, calories are given a special place in the discussion about the prevention of obesity, as various studies do not look beyond the calorie content to individual macronutrients and their effects on illnesses [7]. Thus, the question generally arises as to whether special diets that favour certain macronutrients are necessary and whether aspects of sustainability, for example, can be taken into account without sacrificing health.

In January 2019, the EAT-Lancet Commission published the "Planetary Health Diet (PHD)", a health-promoting reference diet for the entire world population with the aim of realigning global food systems, improving environmental sustainability and promoting human health [8]. The background to the initiative, on the one

hand, is the change from traditional eating habits, which mostly have a higher proportion of high-quality plant-based foods, towards a Western dietary pattern characterized by high-calorie, highly-processed foods (LM) and large amounts of animal products. In addition, this dietary pattern is unsustainable, as current food production causes climate change, biodiversity loss, pollution, and drastic changes in land and water use [9]. On the other hand, the dietary pattern recommended by the EAT-Lancet Commission is characterized by a variety of high-quality plant foods and low amounts of animal products, refined grains, added sugars and unhealthy fats. The consistent implementation of these requirements would not only provide high-quality nutrition, but also save costs [10, 11]. In addition, the PHD is designed in such a way that it can be flexibly adapted to local and individual circumstances, traditions and dietary preferences [8]. In this way, the PHD is similar to the guidelines of the German Society for Nutrition/Deutsche Gesellschaft für Ernährung (DGE). However, there are differences in the global versus Germany-specific orientation, as well as in the recommended amounts of milk and dairy products, and the calorie intake. The PHD indicates a calorie intake of 2500 kcal/day. By contrast, the DGE recommends a range of 1600 to 2400 kcal/day according to age and gender. While the PHD provides for a maximum of 500 g dairy equivalent per day, the DGE guideline values indicate a range of 596–728 g/day, as a result of using different bases for adequate calcium intake [12]. In fact, this could result in a calcium, vitamin B12, iron, and zinc deficiency, which can be countered by modifying the originally proposed PHD [13]. The PHD presents a radical change in current dietary habits and its implementation in most countries requires a reduction in the consumption of red meat and sugar by about 50 % and an increase in the consumption of fruits, vegetables, legumes and nuts by more than 100 % [14–17].

In a cross-sectional study of more than 14,000 participants, associations were found between adherence to PHD and low levels of blood pressure and total, low-density lipoprotein (LDL) and non-high-density lipoprotein (non-HDL) cholesterol, but there was no association with HOMA-IR (Homeostatic Model Assessment for Insulin Resistance) as a marker of insulin resistance [18]. In addition, participants who adhered to the PHD guidelines were less likely to be overweight or obese and had a smaller hip circumference [18]. Following the PHD recommendations also leads to a change in the gut microbiome with an increase in probiotic bacteria [19]. The multi-centre, prospective European Prospective Investigation into Cancer and Nutrition (EPIC) study with nearly 500,000 participants found associations between greenhouse gas emissions and land use affecting both all-cause mortality and cancer incidence rates. Depending on the degree of adherence to PHD, 19 to 63 % of deaths and 10 to 39 % of cancers could be prevented over a 20-year period [20]. In addition, the Spanish EPIC cohort of more than 40,000 participants found associations between greenhouse gas emissions and the risk of coronary heart disease (CHD) and T2DM [21].

Thus, a reduction in greenhouse gas emissions could have a positive effect not only on climate change, but also on human health. However, in a prospective cohort study from France with more than 60,000 participants, associations between adherence to PHD and cancer incidence were found only in some subgroups, and no associations were found with cardiovascular disease [22]. In a pro-

spective study of nearly 75,000 Mexican women, higher PHD adherence was associated with a lower incidence of T2DM [23]. This was also confirmed in a meta-analysis of seven studies [17].

The role of losing weight

Recommendation

- Losing weight should be targeted in cases of excess weight/obesity and prediabetes.
- A 10 % weight loss in high-risk individuals with prediabetes prevents later diabetes.
- Appropriate dietary interventions for weight management include a reduction in calories, carbohydrates, and saturated fats, as well as an increase in fibre and plant-based proteins.

Comment

According to a 2021 assessment by the Organisation for Economic Co-operation and Development (OECD), about 60 % of adults in Germany are overweight and obese [24]. More than half of women and two-thirds of men in Germany are overweight, according to the basic publication of the Study on the Health of Adults in Germany (DEGS1) between 2008 and 2011. About a quarter of adult Germans are obese [25]. Obesity is a chronic disease associated with an increased risk of mortality, decreased quality of life, and numerous comorbidities and complications, including cardiovascular disease, arterial hypertension, non-alcoholic fatty liver disease, sleep apnoea syndrome, and T2DM [26]. With lifestyle changes, drug therapies and bariatric surgical interventions, various therapy options are available in the treatment of obesity. Independent of the therapeutic approach, a 10 % weight loss in high-risk individuals with prediabetes [27, 28] or metabolic syndrome [29] prevents later diabetes. The improvement in fasting glucose is directly associated with the extent of weight loss [30]. The improved insulin sensitivity stemming from weight loss results in an improvement in insulin-mediated suppression of fat oxidation [31] as well as in metabolic flexibility, i. e. the ability to increase fat oxidation with increased availability of fatty acids and to switch between fat and glucose as the primary fuel source after a meal. Three large randomized clinical trials, the Diabetes Prevention Program (DPP) [28], the Finnish Diabetes Study [27] and the Da Qing IGT and Diabetes Study [32] have impressively demonstrated the efficacy of lifestyle/behavioural therapy for the prevention of T2DM. In these studies, lifestyle changes generally included a reduction in calorie intake (by 500 to 1,000 kilocalories [kcal]/day), behavioural measures, and an increase in physical activity. The lifestyle intervention under the DPP, which was associated with a 7 % weight loss in the first year, reduced the 4-year incidence of T2DM by 58 % in men and women with impaired glucose tolerance [28]. In line with these results, the lifestyle intervention group [27] of the Finnish Diabetes Study also reduced their risk of diabetes by 58 % after 4 years. Thus, the lifestyle changes were almost twice as effective in T2DM prevention as metformin therapy, which resulted in a 31 % reduction in T2DM incidence [28]. The Da Qing IGT and Diabetes Study found that not only the combination of a diet and exercise intervention, but also the individual components could reduce the risk of diabetes by up to 46 % after six years [30]. In the DPP, each kilogram lost (up to 10 kg) reduced the risk of T2DM by 16 %, regardless of ethnicity, gender, age, or the initial severity of obesity [33]. In a meta-analysis of

63 studies that examined the effects of lifestyle modification on diabetes prevention, each kilogram participants lost was even associated with a 43 % lower risk of diabetes [34]. In the 10-year follow-up of the DPP, the cumulative T2DM incidence was still reduced by 34 % in the lifestyle treatment group, despite the fact that BMI values in the treatment groups had aligned [35]. Even after 15 years, the group treated with an intensive lifestyle intervention had a 27 % reduced incidence of T2DM [36]. In addition to the beneficial effects on T2DM manifestation, there was also evidence in the Da Qing IGT and Diabetes Study that cardiovascular events and mortality were reduced in the lifestyle intervention group compared to the control groups 23 years after the study ended [37]. In high-risk individuals with prediabetes, glycaemic and cardiometabolic outcomes can be further improved by intensifying the lifestyle intervention compared to a conventional lifestyle [38].

Based on these study results, a consensus report from the American Diabetes Association (ADA) recommends reducing and maintaining a loss of 7 to 10 % of the initial body weight to prevent the progression from prediabetes to T2DM [39]. Such weight loss can be achieved after six months by a calorie deficit of 500 to 1,000 kcal per day [40]. DDG Clinical Practice Guideline DDG Clinical Practice Guideline Very low-calorie diets (VLCDs) of less than 800 kcal per day are generally not recommended because, while they can lead to a weight loss of 15 to 20 % within 4 months, they do not lead to greater weight loss in the long term and, compared to low-calorie diets (LCD), they bring about a higher risk of complications such as gallstones [41]. Weight loss can be achieved through various diets, such as low-carb, low-fat or Mediterranean diets, although no approach seems to be superior to the others in the longer term [42]. Promising dietary approaches have the following in common: a reduced intake of calories, carbohydrates and saturated fats, and an increased consumption of fibre and, in particular, vegetable proteins [39]. Overall, the choice of dietary pattern and macronutrient composition should be individually tailored to the patient's preferences and living conditions, taking into account their lifestyle, (nutritional) habits, preferences and metabolic targets.

Importance of Nutrition in Telehealth for Prevention

Recommendation

- Telehealth can increase adherence to weight loss programs and accessibility.
- Telehealth applications can support the realization of behavioural modifications recommended in the prevention of T2DM.

Comment

The COVID-19 pandemic has led to an increased need for digital counselling methods in the therapy of diabetes mellitus prevention. Telehealth refers to the use of audiovisual communication technologies for the purpose of diagnosis, consultation and emergency medical services [43]. Telehealth care was already being used for diabetes patients before the COVID-19 pandemic and has established itself as a proven form of therapy. It has also proven to be positive in the DMP (Disease Management Program) for obesity patients.

As part of a telehealth program, therapy-relevant data (e. g. blood glucose level, body weight, blood pressure, lipid parameters) are sent to the specialist staff, after which the patient receives feedback. A distinction is made between telehealth therapy options via text messages/e-mail and by telephone/video conference.

In Germany, a randomized, controlled trial by Kempf et al. reported a 0.6 % lower HbA1c value and a 5 kg greater weight reduction at 1-year follow-up in the group cared for via telehealth therapy vs. standard therapy [44].

Telehealth applications can be prescribed by doctors and psychotherapists and reimbursed by the statutory health insurance companies if they are included in the BfArM (Bundesinstitut für Arzneimittel und Medizinprodukte/Federal Institute for Drugs and Medical Devices) directory and classified as digital health applications (Digitale Gesundheitsanwendungen = DiGA). This is regulated in the Digitaler Versorgungsgesetz/Digital Healthcare Act (DVG), which came into effect in December 2019. Digital health applications are usually used by the patient alone. However, it is also possible for patients and service providers to share the digital health applications, e. g. in the form of teleconsultations or chats. There are various digital health applications currently listed in the BfArM directory that are aimed at people who are overweight. Excess weight is a risk factor for diabetes and the digital health applications can also be used if prediabetes or diabetes has already been diagnosed. Other digital health applications, which are intended to target diabetes risk factors, can help to reduce stress, depression or smoking. The digital health application market is very dynamic and some applications are being taken off the platform while others are being added. A good overview can be found directly on the BfArM website (<https://diga.bfarm.de/de>).

The Zanadio application to help treat obesity is already permanently included in the BfArM directory. Zanadio works on the basis of the guideline recommendations for treating obesity and supports conservative obesity therapy consisting of exercise, nutrition and behaviour change, and incorporates telehealth elements in which users are supervised by a nutritionist via the chat function. Another digital health application called Oviva Direkt also targets patients with obesity. Further applications in the field of nutritional medicine are currently in the process of approval.

One example of a telehealth application – although not approved as such – is the telehealth lifestyle intervention program TeLiPro. This app supports patients in helping observe and monitor lifestyle activities and includes the use bluetooth-compatible blood glucose meters, scales, and blood pressure monitors. Via a cloud, it is possible for the diabetes coach or consultant to view the data and interact directly with the patients via a chat function or over the phone. In the TeLiPro study, both groups received the app, scales, pedometers, blood glucose meters and blood pressure monitors. However, the groups differed in that a diabetes coach was only available to patients in the intervention group [45]. As a result, it was shown that the intervention group, in contrast to the control group, showed a significant reduction in the HbA1c value (mean \pm standard deviation -1.1 ± 1.2 % vs. -0.2 ± 0.8 %; $P < 0.0001$). In addition, a reduction in weight was recorded (TeLiPro -6.2 ± 4.6 kg vs. control -1.0 ± 3.4 kg, body mass index (BMI) $(-2.1 \pm 1.5$ kg/m² vs. -0.3 ± 1.1 kg/m²). Furthermore, the intervention group reported a generally better quality of life and a better nutritional status [44].

Food Group Insights

Fruits and vegetables

Recommendation

- Regular consumption of 200 to 300 g of fruit and vegetables per day significantly reduces the risk of type 2 diabetes.

Comment

In a systematic review of prospective studies on the dose-response relationship of fruit and vegetable consumption and the risk of T2DM, Halvorsen et al. [46] included 23 prospective cohort studies. Accordingly, the relative risk (RR) for high versus low consumption of fruits and vegetables and 200 g/day was 0.93 (95 % confidence interval (CI): 0.89 to 0.98, $I^2 = 0$ %, $n = 10$ studies) and 0.98 (95 % CI: 0.95 to 1.01, $I^2 = 37.8$ %, $n = 7$) for fruits and vegetables combined, 0.93 (95 % CI: 0.90 to 0.97, $I^2 = 9.3$ %, $n = 20$) and 0.96 (95 % CI: 0.92 to 1.00, $I^2 = 68.4$ %, $n = 19$) for fruit, and 0.95 (95 % CI: 0.88 to 1.02, $I^2 = 60.4$ %, $n = 17$) and 0.97 (95 % CI: 0.94 to 1.01, $I^2 = 39.2$ %, $n = 16$) for vegetables. A risk reduction of 14 % was observed at an intake of 300 g/day, with no further risk reduction at an intake above this level. Fruits such as apples, pears, blueberries, grapes and raisins are particularly suitable for reducing the risk.

One of the largest systematic reviews of fruit and vegetables to date summarizes international studies from the EPIC-InterAct (European Prospective Investigation into Cancer) dataset of 24,013 cases of T2DM. To enable comparison, a standard serving size of 106 g was defined. 9 studies found an association between fruit and vegetable consumption and the risk of T2DM. For fruit, an RR of 0.93 (95 % CI 0.88–0.99) and for vegetables of 0.90 (CI 0.80–1.01) was shown for one additional serving daily. Green leafy vegetables/lettuce indicated an RR of 0.87 (95 % CI 0.81–0.93) at an increase of 0.2 servings/day. Previous meta-analyses had already calculated special benefits for green leafy vegetables in terms of T2DM. For each serving of fruit/vegetables consumed per day, there was a risk reduction of 4 % [47].

Low consumption of fruits and vegetables contributes significantly to the global burden of disease [48]. Longitudinal data from 14,718 men and 20,589 women aged 25 to 84 years from the Stockholm Public Health Cohort in Sweden in 2010 and 2014 showed that men consumed significantly less fruit and vegetables compared to women (the consumption of fruits and vegetables, individually < 2 servings/day or together < 4 servings (100 g)/day, was set as a threshold for low intake). Nearly three-quarters of respondents consumed less than two servings of vegetables per day. The proportion of men and women who consumed less than two servings of vegetables per day was 79.0 % at baseline and 62.6 % at follow-up. Similar results were obtained for fruit consumption in the overall sample and for men and women separately. Only 20.3 % of the subjects consumed four or more servings per day, with the difference between men (10.3 %) and women (27.6 %) being about three times as large and the proportion slightly smaller at follow-up. The average total consumption of fruit was 1.2 (sd 0.8) servings/day, vegetables 1.2 (sd 0.9) servings/day, and fruits and vegetables combined 2.4 (sd 1.4) servings/day. A significantly lower consumption of fruits and vegetables was observed in men compared to women at the start of the study. Vegetable consumption

was lowest in the older age group, while fruit consumption was lowest in the youngest age group. Fruit and vegetable consumption was also lowest among people with obesity and with low levels of education. A 62% higher risk of developing T2DM over the 4-year period was observed in men with low vegetable consumption compared to men with high consumption after adjustment for age, education, body mass index (BMI), smoking, alcohol and physical activity (odds ratio [OR] 1.62; 95% CI 1.00, 2.63). In women, a significantly higher risk of T2DM was also observed with low vegetable consumption, but not after adjustment. The present study suggests that higher vegetable consumption appears to protect against the occurrence of T2DM in men. Therefore, increasing vegetable consumption in men should be a public health priority, according to the team of authors.

To investigate whether a plant-based diet can also be beneficial for T2DM, Satija et al. [49] evaluated data from the Nurses' Health Study (69,949 participants/f), Nurses' Health Study 2 (90,239 participants/f) and the Health Profession Follow-up Study (40,539 participants/m). In total, this resulted in data for 16,162 T2DM cases and 4,102,369 person-years. The observation period extended over 20 years. Over this study period, a vegetarian diet has been shown to reduce the risk of T2DM by up to 20%. If the vegetarian diet contains "healthy" plant-based foods (e. g. vegetables), the effect was 34% vs. an "unhealthy" plant-based diet with 16% relative risk (RR). Fruit juices, lemonades, white flour products, potatoes and sweets were classified as "unhealthy" vegetarian. After adjustment, a "healthy" plant-based diet showed an inverse relationship to T2DM, whereas a diet based on animal products was associated with an increased risk. In order to show whether a plant-based diet works in combination with "healthy" animal products such as yoghurt or fish, the foods were again subdivided. For fish, the positive effect was somewhat weakened. There were no relevant changes for yoghurt. This study shows that it is not necessary to follow a purely vegetarian diet, although there are many benefits to doing so. Combining "healthy" plant-based food with small amounts of "healthy" animal products such as yogurt also seems to be recommended.

The results of the EPIC-InterAct study [50, 51] showed that there is a lower association with T2DM when fibre content from grains and vegetables is increased (HR Q4 vs. Q1 0.82; 95% CI 0.69, 0.97). This effect could not be demonstrated for dietary fibre from fruit. The RR (CI 95%) per 10 g/day-increase in fibre was 0.75 for fibre from grains; 0.93 for fibre from vegetables and 0.95 for fibre from fruits. The EPIC-InterAct data showed an 18% risk reduction for T2DM with a high fibre consumption, compared to lower fibre consumption. This result was mainly due to fibre from grains and vegetables, but not from fruit. Regardless of BMI, the total fibre reduced the T2DM risk by 9% and grain fibre by 25%.

Legumes

Recommendation

- Regular consumption of legumes such as beans, lentils, and peas can significantly reduce the risk of T2DM
- The high-fibre diet including legumes can improve blood glucose control, and reduce the risk of insulin resistance

Comment

Despite the well-known health benefits of legumes, their consumption is often low. The aim of the review by Hughes et al. [52] was to assess the inclusion of legumes in global dietary guidelines and to review the consumption data for legumes. In the survey including 94 countries, the most important messages on legumes were identified as follows. The mean consumption of beans and legumes in countries ranged from 1.2 g/day (Norway) to 122.7 g/day (Afghanistan). In Europe (33 countries), legume consumption was by far the lowest, with more than a third of countries (36%) reporting a consumption of less than 10 g/day. The authors report that in order to promote the consumption of legumes for health, environmental and economic reasons, they need to be given greater prominence and possibly be repositioned in dietary guidelines.

The review by Bielefeld et al. [53] aimed to investigate whether medium- to long-term consumption of legumes had an impact on markers of glycaemic control. A total of 18 randomized controlled trials (RCTs) were included, of which 5 focused on people with diabetes mellitus, 12 on people without diabetes mellitus, and one on people with prediabetes. All interventions including legumes corresponded to acceptable macronutrient distribution ranges and included a variety of legume species. Only studies of individuals with T2DM reported significant effects of legume interventions, three lowering fasting glucose, two lowering HbA1c, one lowering fasting insulin, and one lowering 2-h plasma glucose ($P < 0.05$); however, the overall quality of the evidence was low. One possible mechanism by which legumes may help treat T2DM is their high content of fibre and resistant starch.

The analysis for legumes/soybeans and T2DM was carried out by Pearce et al. [54] using 27 prospective cohorts from different regions (807,785 individuals). Most participants came from the Western Pacific region (62%), followed by the Americas (22%), Europe (14%) and the Eastern Mediterranean (1%). The mean total consumption of legumes ranged from 0 to 140 g/day, tending to be higher in the Americas and Asia than in Europe. The mean soy consumption was zero, except in China (34 g/day) and Korea (22 and 39 g/day). During the follow-up period of 3.8 to 25.0 years, a total of 36,750 clinically-occurring T2DM cases (primary outcome) and 42,473 occurring T2DM cases (secondary outcome) were recorded. The mean total consumption of legumes ranged from 0 to 140 g/day across all cohorts, and a weak positive association between the total legume consumption and T2DM was observed. The positive association in Europe was mainly found in studies from Germany, the United Kingdom and Sweden. It can be argued that legume consumption is important in the overall context of a healthy dietary pattern. For example, no associations were observed in places where legumes are staple foods (e. g., Brazil, Mexico, and Puerto Rico), while in contrast, the strongest positive associations were observed in cohorts with low consumption (e. g., Germany, the United Kingdom, and Sweden).

The results of the study on the postprandial hypoglycaemic effect of lentils by Papakonstantinou et al. [55] conclude that lentil consumption consistently reduces acute blood glucose and insulin responses compared to starchy control foods, the exact mechanism is still unclear. It has been discussed that the smallest effective serving of lentils is about 110 g (cooked) to reduce postprandial blood glucose concentration by 20%. Lowering postprandial

blood glucose levels has been associated with the following factors: The protein (45 to 57 g) and fibre content (22 to 30 g) of lentils are low with the available carbohydrate content. Both large (> 100 g) and small (< 100 g) serving sizes of lentils had a favourable postprandial blood glucose and insulin-lowering effect, making it difficult to determine the optimal serving size of lentils for favourable dose-response effects. In a randomized cross-over study, the glycaemic index (GI) and glycaemic response to three traditional Greek mixed meals, lentils, tarhana and halva were investigated. Twelve healthy, fasting individuals were given test meals (25 g each of available carbohydrates) and 25 g of glucose for reference in random order. All three meals tested had low GI scores. The GI of lentils was 27 ± 5 , that of tarhana was 42 ± 6 and that of halva was 52 ± 7 . Blood glucose peaks were lowest with lentils. Further studies have reported that the beneficial glycaemic effect of lentils may be due to the resistant starch content.

The effect of legumes and nuts on T2DM risk was investigated in a systematic analysis [56] of 27 studies with a total of 501,791 participants (including 14,449 T2DM cases) with an average age of 53 years and a study duration of 13 years. Nuts consumed regularly reduced the risk by 13 %, whereas legumes (lower study number) were more neutral. The data were clearly protective for coronary artery disease in both food groups. The serving size for nuts was defined as 28 g and that for legumes as 100 g. The consumption of nuts varied from 0 to 213 g/week, for legumes from 0 to 938 g/week. 100,179 participants – including 2,746 T2DM cases – were investigated on the legumes and T2DM risk. This showed a RR of 0.78 (95 % CI 0.50–1.24).

Another study [57] investigated 2 isoenergetic diets (legume-rich vs. legume-free) in 31 participants with T2DM over 8 weeks. 3 days a week, 2 servings of red meat were replaced with dishes with legumes. After a washout period of 4 weeks, the groups were switched. Since soy differs significantly from other legumes in terms of ingredients, it was excluded. The legume diet consisted of 50 to 60 % carbohydrates, 25 to 30 g dietary fibre, 15 % protein and 25 to 35 % fat, of which < 7 % saturated fatty acids. Inflammatory biomarkers were determined as outcomes. In both groups, inflammatory markers (C-reactive protein [CRP], interleukin-6 and tumour necrosis factor [TNF]) decreased – and the effect was stronger for legumes. Weight remained comparable in both groups. Legumes contain indigestible, fermentable components, abundant fibre, phytic acid, magnesium, phenolic acid, flavonoids and anthocyanins – all substances that are said to have anti-inflammatory potential. In addition, the low GI has a beneficial effect.

Legumes as a component of the classic Mediterranean diet are too rarely eaten in Western nations, although their benefit on the risk of coronary heart disease, obesity and T2DM has been widely demonstrated. Soluble fibre as well as resistant starch have a beneficial effect on blood glucose and insulin levels. They also improve satiety. The World Health Organization (WHO) recommends legumes to reduce the risk of lifestyle diseases. The US Dietary Guidelines advise eating about 3×275 g of legumes per week.

Nuts

Recommendation

- Regular consumption of nuts has been shown to be associated with health benefits.

Comment

Potential mechanisms that could explain the protective effect of nuts are the lowering of cholesterol levels and blood pressure, the improvement of vascular function and oxidative stress in the body, as well as the anti-inflammatory effect. This is likely because of the content of unsaturated fats, antioxidants and polyphenols in nuts. In addition, the consumption of nuts can regulate body weight by curbing appetite and food consumption, increasing postprandial energy expenditure and fat oxidation, and absorbing less fat than expected. In addition, a nut-rich diet shows a reduction in postprandial glycaemic response to meals containing carbohydrates as well as a reduction in fasting insulin and insulin resistance, although no effects on fasting blood glucose or glycated haemoglobin A1c (HbA1c) have been observed [58].

The results of 56 intervention studies, 9 narrative and 3 systematic reviews, and 12 meta-analyses evaluating the beneficial effects of different types of nuts on selected metabolic markers, showed that, depending on the type, dose and time, the consumption of nuts improved metabolic markers including glycaemic factors, lipid profile, and inflammatory and oxidative stress parameters, in both healthy individuals and those with metabolic disorders [59].

The effect of nut consumption on metabolic syndrome parameters was investigated by Blanco et al. [49] RCTs with 2,226 participants met the set criteria. The sources of nuts were: almonds, cashews, hazelnuts, pecans, pistachios, walnuts or nut mixes. Nuts showed a significant decrease in fasting glucose. Replacing higher GI carbohydrates with nuts appears to contribute not only to blood glucose improvement, but also to triglyceride reduction. The earlier assumption that nuts would increase body weight because of their high fat content was refuted by the authors, instead a weight-reducing effect was determined. In addition, abdominal circumference was reduced when the nuts were consumed as a substitute for high-GI carbohydrates [60]. Consumed 3 times per week, nuts also showed a lower risk of obesity and T2DM [61].

The research group led by Wu et al. [62] searched six databases for a review and a meta-analysis to investigate associations between nut consumption and T2DM. 36 papers with 30,708 participants were found. The observation period ranged from 4.6 to 30 years. When comparing the lowest and highest nut consumption, there was no significant association with T2DM. In 3 large cohorts with around 150,000 participants, 2 showed a reduced risk of T2DM with higher nut consumption. The smallest of the 3 cohorts – the Iowa Women's Health Study (1800 participants) – could not prove this. In its meta-analysis, there was no risk reduction (RR 0.98, 95 % CI 0.84–1.14), although previous studies (e. g., PREDIMED) had indicated this. The PREDIMED data were not included in their work because it dealt with a Mediterranean diet and not primarily nut consumption. Almonds showed a decreased increase in blood glucose. Pistachios also reduced the blood glucose response. In addition, nuts led to a decrease in inflammatory cytokines and adiponectin [62].

The American Heart Association (AHA) recommends 5 servings of nuts of 25 g/week. The DASH diet (Dietary Approaches to Stop Hypertension) also makes a clear recommendation for nuts.

Meat

Red meat

Recommendation

- There is insufficient evidence from intervention studies on the superiority of vegetarian or vegan diets for diabetes prevention. From a health perspective, a low-meat diet is probably the most preventatively effective against T2DM. For ethical and ecological reasons, meat consumption should be reduced
- In terms of glycaemia, high-protein diets and low-carb diets range from beneficial to possibly superior. Animal sources, including meat, can also be used as protein sources
- Currently, there is no clear benefit of replacing red meat with white meat, although red meat is associated with an increased risk of diabetes in epidemiological studies

Comment

In addition to an increased risk of T2DM, a higher consumption of meat is epidemiologically associated with certain cancers and coronary heart disease. This increased risk is particularly pronounced for red meat, especially highly-processed red meat.

Intervention studies show an improvement in numerous metabolic parameters when the daily meat consumption is reduced to a very low level. However, this study either used isocaloric compensation with other potentially beneficial foods (e. g., whole grains, vegetables, legumes, nuts) or tested meat avoidance in a hypocaloric setting. Thus, even in RCTs, the causality for the benefit of the low-meat diet is unclear.

Many RCTs on the exchange of meats (red for white meat) carry similar confounding to observational studies, as only rarely has an isolated substitution of red meat by white meat occurred. It then becomes questionable as to whether avoiding red meat has a preventive effect. To date, approximately 10 RCTs have compared red and white meat in a methodologically good comparison; metabolic differences were not found here.

In 2019, the NutriRECS consortium complained about a lack of evidence to recommend meat reduction in five meta-analyses. At the same time, the evaluation of many dietary components is methodologically difficult to implement, even on the basis of RCTs. The medical uncertainty regarding the health benefits of avoiding (red) meat is offset by clear ecological and ethical benefits [63].

Processed meat

Recommendation

- Highly-processed meat products should not be consumed if possible

Comment

The high consumption of processed meat products in particular is epidemiologically associated with T2DM, coronary heart disease (CHD) and cancer. Residual confounders could explain these effects even after extensive adjustment.

However, mechanistic studies (in-vitro, in-vivo in animal models and in humans) indicate that several components of processed meat products (nitrosamines, polycyclic aromatic hydrocarbons (PAHs), trimethylamine N-oxide (TMAO), iron and ferritin, added

or primary saturated fat and salt) have the potential to promote metabolic and neoplastic diseases.

In a healthy dietary pattern, processed meat products can be given up without having to forgo animal products and meat in general. The likely health benefit is not offset by any relevant restriction of food choice and quality of life.

Beverages

Sugar-sweetened beverages

Recommendation

- The consumption of sugar-sweetened beverages, including fruit juices, should be minimized as much as possible to prevent T2DM
- Sugar-sweetened beverages should be replaced with water
- Calorie-free sweetened beverages can be consumed as an alternative

Comment

The potential for preventing T2DM via behavioural changes such as dietary habits is enormously high [64] and various studies show that dietary changes and weight loss can significantly reduce the risk of diabetes [28, 32, 65, 125]. The central outcome parameter is the lowering of blood glucose, usually postprandial and possibly also at fasting [64], which is why it is clearly necessary to take a closer look at foods and beverages with high amounts of added sugars and their influence.

The UK Guideline on Diabetes Prevention and Management makes a clear recommendation to reduce the consumption of sugar-sweetened beverages in all population groups due to an increased risk. The reason for this is that reducing the total calorie consumption for weight loss is the most dominant factor in prevention [66]. In addition, the high glycaemic index associated with sugar-sweetened beverages increases the risk of developing T2DM [67].

The American Diabetes Association recommends a breakdown of macronutrients according to individual therapy goals and dietary patterns for the prevention of T2DM [68]. For this purpose, the suggestion is made to minimise processed foods and replace sweetened beverages with water (level B of the guideline) [39].

The basic recommendation to replace sugar-sweetened beverages with water or other low-calorific or non-nutritive-sweetened beverages is aimed at people with T2DM as well as people who are at risk of developing the disease and should therefore also be included in prevention recommendations. This makes it possible to keep blood glucose in check and reduces the risk of cardiovascular disease. The use of calorie-free beverages serves to reduce total calorie and carbohydrate consumption and is supported if the calorie deficit is not compensated by the consumption of other foods (level of evidence B). Therefore, calorie-free sweetened beverages can be chosen if an alternative to water is desired and makes it easier to avoid sugar-sweetened beverages [68]. Replacing a sugar-sweetened beverage with coffee or tea also lowers the risk of T2DM [59]. An ideal percentage of carbohydrate reduction for diabetes prevention cannot be specified [68].

In meta-analyses with prospective cohort studies, consuming one serving of sugar-sweetened beverages per day increased the risk of developing T2DM by 18 % [67] and 26 % respectively [70]. Several recent publications over the past five years, such as the Mexican Teacher's Cohort [71], the Northern Manhattan Study [72], and the Women's Health Initiative [73], confirm a dose-response relationship between sugar-sweetened beverage consumption and T2DM risk [69].

Furthermore, there are indications that the increased consumption of sugar-sweetened beverages, regardless of the type of saccharides, increases the concentration of fibroblast growth factor 21 (FGF21), which may be associated with possible FGF21 resistance and thus the impairment of metabolic health. FGF21, which presumably co-controls glucose absorption, plays a role in carbohydrate metabolism and could therefore also be associated with the formation of T2DM [74]. One limitation of these findings, however, is the small study population.

In conclusion, a general recommendation to reduce sugar-sweetened beverages should be made to the general population, to people with prediabetes and those with an increased risk of developing T2DM.

Alcohol

Recommendation

- Moderate alcohol consumption has a diabetes-preventing effect in observational studies
- Alcohol should only be consumed in moderation, as moderate alcohol consumption can also be associated with negative health effects

Comment

In observational studies, moderate alcohol consumption is associated with a decreased incidence of some T2DM and cardiovascular disease, but it is increasingly associated with other health complications (e. g., cancer, chronic liver disease). Larger amounts of alcohol can increase the risk of individual cardiovascular complications (atrial fibrillation) and no individual consumption levels for prevention or therapy can be derived from data from observational studies.

The maximum tolerable alcohol consumption for healthy individuals is given as 10 g/day for women and 20 g/day for men. The consumption of alcohol is associated with various health consequences [75]:

1. J-shaped association:

- 1) Ischaemic heart disease
- 2) Ischaemic stroke
- 3) Diabetes mellitus

2. Positive association:

- 1) Atrial fibrillation
- 2) Pancreatitis, cirrhosis/chronic liver disease
- 3) Various cancers

The following remarks were taken from the DDG clinical practice guideline Psychosocial Factors and Diabetes by Kulzer et al. [76]: Moderate alcohol consumption, compared to low consumption or

abstinence, also seems to have a protective effect on the development of T2DM (all Class of evidence [CoE] IIb), an effect that is also confirmed for older patients (CoE IIb). The data on the risk of metabolic syndrome are heterogeneous. Several studies report a protective effect of moderate alcohol consumption (all CoE IIb), while this association is not confirmed in other studies (CoE III), (both CoE IIb).

In some studies, the effect can be observed in women, but not in men (both CoE IIb). The protective effect of moderate alcohol consumption can be explained by higher insulin sensitivity (both CoE Ib). The level of insulin resistance is lowest in people with regular moderate alcohol consumption but increases in both heavy drinkers and people who abstain from alcohol. However, this effect is moderated by other factors in terms of insulin sensitivity: It does not show up in people with an elevated BMI or with existing insulin resistance (CoE III) or in smokers (CoE III). The effect of alcohol on blood pressure is also moderated by body weight (CoE III). In the case of existing chronic or alcohol-related chronic pancreatitis, continued alcohol consumption increases the risk of manifestation of diabetes mellitus (both CoE III) [76].

Dairy products

Recommendation

- Low-fat dairy products should be part of a diabetes prevention diet
- Statement: The influence of milk substitutes on the risk of diabetes requires further investigation, even if a reduction in milk consumption makes sense from a sustainability point of view

Comment

Due to their high saturated fat content, milk and dairy products have been viewed critically in the past with regard to the development of obesity and cardiovascular diseases. However, epidemiological studies have been able to refute a negative influence of dairy products on the development of these diseases [77, 78]. By contrast, low-fat dairy products in particular have even been shown to reduce the risk of metabolic syndrome and cardiovascular disease [79–82]. A risk reduction was also shown for T2DM [82–84].

The beneficial effect of dairy products on T2DM risk may be mediated in part by the effect on factors influencing the disease, such as body weight [85] and glucose homeostasis [86]. Certain components in dairy products, such as calcium, magnesium, lactose, and milk protein, can promote weight loss and lower blood pressure [86].

Insights into individual (isolated) nutrients

Sweeteners

Recommendation

- Substituting nutritive sweeteners with artificial sweeteners within the acceptable daily allowance may be beneficial for weight management and diabetes prevention, especially in overweight and obese individuals
- Artificial sweeteners could be used safely within an acceptable daily amount

- Consumption of artificial sweeteners can have adverse health effects with cardiometabolic consequences

Comment

The health benefits of using artificial sweeteners are controversial in the scientific community. DDG Clinical Practice Guideline DDG Clinical Practice Guideline Systematic reviews and meta-analyses show that the use of low-energy artificial sweeteners can replace sugar-sweetened products, which appears to have a beneficial effect on weight control and cardiometabolic risk factors and thus on the prevention of T2DM, especially in overweight/obese individuals [87–89]. On the one hand, artificial sweeteners do not appear to have any effect on glucose or insulin levels [90–92]. On the other hand, further available data show that artificial sweeteners can have undesirable effects on body weight, glycaemia, adipogenesis and the gut microbiota via various indirect mechanisms [93]. Thus, the consumption of artificial sweeteners can promote metabolic changes, especially in glucose metabolism [94], a worsened glycaemic response and an increase in insulin secretion [95]. A recent meta-analysis showed that a one-serving/day increase in the consumption of beverages containing artificial sweeteners was associated with a 13 % increase in T2DM risk [96]. In addition, recent data show that beverages with artificial sweeteners are recommended as a substitute strategy, although their benefits are still controversial and it is feared that they could induce glucose intolerance through changes in the gut microbiome [97]. Artificial sweeteners are metabolized differently because of their different chemical properties, with various effects on glucose homeostasis and underlying mechanisms, which may be the cause of the differences in the metabolic behaviour of artificial sweeteners as well as the conflicting results [98].

Fibre

Recommendation

- Fibre from natural sources should be consumed daily.
- Despite little evidence for recommending 30 g of fibre per day (15 g/1000 kcal), this is a valid target for nutrition counselling.
- Carbohydrates should preferably be obtained from fibre-rich foods and especially whole grains. Supplementation has not yet been proven to be effective.
- Fibre-rich foods from grains, but also vegetables, legumes and low-sugar fruits are recommended for T2DM prevention and are presumed to be beneficial. The long-term benefit of supplementation has not been proven, despite proven short-term effects on glycaemia, lipid status and sometimes blood pressure.

Comment

In cohort studies, a high consumption of insoluble fibre, especially grain origin, is associated with a reduced risk of T2DM, CHD, cancer and other diseases. In patients with T2DM, the risk of mortality decreases in relation to the amount consumed. Whole grains (bread, rice, pasta) are therefore a protective food group. High-fibre diets and fibre supplements have a beneficial effect on body weight, glycaemia and insulin resistance, lipid profile and inflammatory status, and sometimes also on blood pressure, even under isocaloric conditions.

The GI is not a suitable indicator for recommended high-fibre foods. The label “whole grain” and the actual fibre consumption are the most meaningful. Based on an average dietary pattern including 20 grams of fibre, an increase of 15 grams to 35 grams per day is targeted.

The study situation on fibre is methodologically heterogeneous in many respects. Whole grain rice, but not whole grain wheat and rye products, show a glycaemic benefit. Apart from a small weight reduction, no cardiometabolic benefits in meta-analyses can be clearly attributed to whole grain products. Targeted studies for the evaluation of insoluble fibre are rare. However, there are indications of a diabetes-preventing effect. For soluble fibre, there is little epidemiological evidence of long-term benefit in terms of morbidity and mortality.

Soluble fibre is extensively researched and marketed in supplements. For beta-glucans, inulin, and psyllium, benefits for blood glucose and insulin resistance in the short- to medium-term (weeks to months) have been described. There are, however, no long-term or prevention data. This is mechanistically a result of the fermentation of fibre to short chain fatty acids, not of the weight loss.

Psyllium, konjac glucomannan and beta-glucans also lower LDL cholesterol and triglyceride levels, while there is no evidence that other soluble fibres (guar, pectin) do the same.

Antihypertensive effects have been described for all viscous fibres, especially psyllium. However, the effect is hardly clinically-relevant.

Protein

Recommendation

- If there is an increased risk of diabetes, the recommended protein consumption is 10 to 25 % of the dietary energy consumption (%E) for patients under 60 years of age and 15 to 25 % for people over 60 years of age with intact renal function (glomerular filtration rate [GFR] > 60 ml/min) and a constant weight
- In the case of impaired renal function at any stage, protein reduction to less than 0.8 g/kg body weight (BW) is unlikely to be beneficial and should be avoided due to the risk of malnutrition, especially in the case of more severe renal insufficiency etc

Comment

There is a detailed AWMF-S3 guideline for recommending protein consumption in T2DM; there is no analogous study for prediabetes/diabetes risk patients.

The minimum protein requirement to prevent malnutrition and sarcopenia is about 0.8 g/kg BW or 10 E %. For older people, a higher protein consumption of at least 1 g/kg BW/day is recommended to compensate for age-related weaker protein utilization.

Epidemiologically, a high protein intake is associated with increased mortality and diabetes incidence but is overlaid by strong confounders.

Intervention studies show beneficial effects of a high-protein diet in overweight people without diabetes. The PREVIEW study observed no increase in diabetes incidence or other hard outcomes under three years of high-protein (> 20 %) vs. conventional diets.

Higher protein consumption improves satiety and energy expenditure through postprandial thermogenesis; both promote weight management. Older people have an increased risk of sarcopenia, which is why a higher protein consumption is recommended—unless contraindicated—for this group of people.

Nutritional strategies for prevention

Plant-based, vegetarian and vegan diets

Recommendation

- A plant-based diet, especially when it includes healthy plant-based foods such as fruits, vegetables, whole grains, legumes and nuts, has been shown to have a diabetes-preventive effect in observational studies.
- Vegan and vegetarian diets are also associated with a reduced risk of developing T2DM.
- Overall, the evidence is limited and shows no superiority of a plant-based (including vegetarian/vegan) diet in terms of its diabetes-preventive effect.

Comment

For foods and dietary components of plant origin such as whole grains, fibre, vegetable fats and plant-based protein, there is strong evidence that their consumption is associated with lower risk of T2DM [100–103], while a higher consumption of animal products such as meat (especially red and processed meat) and animal fats are associated with an increased risk of T2DM [100–103] (see chapters “Food Group Insights” and “Insights into individual (isolated) nutrients”). So far, however, there are only a few studies with limited evidentiary certainty of their findings that combine both aspects and investigate a plant-based dietary pattern in connection with the incidence of T2DM instead of isolated foods (groups) or nutrients of plant or animal origin [103]. A commentary in the paper by Schlesinger [103] clearly summarizes this evidence and, supplemented by the review by Ley et al. [104], results in the following study situation:

Plant-based dietary patterns

A systematic review and meta-analysis of nine prospective cohort studies shows a 23 % reduced risk of developing T2DM with higher vs. lower adherence to a plant-based dietary pattern. This inverse association became stronger when healthy plant-based foods such as fruits, vegetables, whole grains, legumes, and nuts were included in the dietary pattern [105].

Vegetarian dietary patterns

A systematic review and meta-analysis based on 14 prospective observational and cross-sectional studies specifically investigated the association between vegetarian dietary patterns and the incidence of T2DM. A vegetarian diet compared to an omnivorous diet was associated with a 27 % lower risk of T2DM [106]. However, the evidentiary value of the results was considered to be low [100]. A large prospective observational study from the U.S. and Canada grouped the total of 41,387 participants in the Adventist Health Study-2 as vegan, ovo-lacto-vegetarian, pesco-vegetarian, semi-vegetarian, or non-vegetarian (reference group). Compared to the

omnivores, ovo-lacto and semi-vegetarian diets were associated with a lower incidence of T2DM [107].

Vegan dietary patterns

In addition to the ovo-lacto and semi-vegetarian diets, a vegan diet was also associated with a lower risk of T2DM compared to the omnivores in the Adventist Health Study-2 and appeared to have the greatest protective effects. However, there was no significant difference between the three diets, and due to the very small number of people on a vegan diet who developed T2DM, these results should be interpreted with caution [107]. Furthermore, an umbrella review identified four cross-sectional studies that investigated the association between a vegan diet and the incidence of T2DM. Here, a vegan diet was associated with a 21 % lower risk of T2DM compared to an omnivorous diet [108].

Meal-timing/intermittent fasting

Recommendation

- Intermittent fasting supports weight management.
- Intermittent fasting exerts a positive influence on glycaemic parameters.
- Skipping meals cannot be recommended for weight control and diabetes prevention.

Comment

The term intermittent fasting refers to a number of methods, all of which aim to limit calorie intake. The time-based restrictions on food consumption help to stick to set times while largely maintaining individual eating habits. ► **Table 1** summarizes some of the most commonly used intermittent fasting methods.

Nutrition before and during pregnancy to prevent gestational diabetes

Recommendation

- Measures to reduce the risk of gestational diabetes (GDM) through diet, physical activity or lifestyle counselling should be carried out before pregnancy or in the first trimester.
- Appropriate measures to reduce the risk of GDM should be aimed at avoiding excessive weight gain during pregnancy. A combined diet and exercise intervention appears to have the greatest effect.
- Women with an increased risk of GDM (defined by the prepartum variables BMI, ethnicity, age, parity, GDM, and/or macrosomia in a previous pregnancy) appear to benefit most from lifestyle intervention.

Comment

Although studies on the influence of diet and physical activity on the risk of GDM are very heterogeneous, some observational studies, RCTs and Cochrane reviews indicate that the risk of GDM can be influenced by diet, physical activity and lifestyle advice [109–111], especially if the interventions take place before pregnancy [112, 113]. The Nurses' Health Study showed that a “healthy” plant-based diet before pregnancy (rich in fruits, vegetables, whole grains, nuts, legumes, vegetable oils, tea and coffee, and low con-

► **Table 1** Definitions of individual plant-based diets. Data according to [99].

Type of nutrition	Description
Plant-based	High consumption of plant-based products, low consumption of meat and/or products of animal origin
Pesco-vegetarian	Abstaining from meat and all products derived from it
Ovo-lacto-vegetarian	Abstaining from meat, fish and other seafood, as well as all products derived from them
Lacto-vegetarian	Avoidance of meat, fish and other seafood, eggs and all products derived from them
Ovo-vegetarian	Abstaining from meat, fish and other seafood, milk and dairy products, as well as all products derived from them
Semi-vegetarian	Severely limited consumption of meat, fish and other seafood, but not complete abstinence from these foods
Vegan	Abstaining from all animal products

sumption of red, processed meat) was associated with a lower risk of GDM, but this was not the case for an “unhealthy” plant-based diet (rich in fruit juices, white flour products, potatoes, sugary drinks, sweets and desserts) [114]. These results are consistent with the recommendations for the prevention of T2DM ► **Table. 2**.

A review of previously-published Cochrane reviews on “Interventions for the prevention of gestational diabetes” concluded that a combined diet and exercise intervention during pregnancy may reduce the risk of GDM compared to standard care (RR 0.85, 95 % CI 0.71 to 1.01) [111]. The quality of the evidence was assessed as moderate. The systematic review included 19 RCTs with a total sample size of 6633 women, and the interventions included all types of diet/exercise interventions. By contrast, an isolated diet or exercise intervention was not associated with the risk of gestational diabetes [111].

The reason for the sometimes contradictory statements of the already-published studies on the effectiveness of lifestyle measures could be the great heterogeneity of the study collectives examined. This indication was provided by a subgroup analysis carried out as part of a Cochrane review, which described a greater protective effect of dietary counselling during pregnancy vs. standard care in women with excess weight and obesity [115]. This was also reinforced by a meta-analysis that identified four key aspects that modify or improve the effect of lifestyle measures: 1. Inclusion of women with a significantly-increased risk of GDM, 2. Beginning the intervention before or in early pregnancy, 3. Intensity of the intervention measure (relating to a reduction in energy intake and intensity of physical activity) and 4. Avoidance of excessive weight gain during pregnancy [113]. This study also showed that the use of BMI alone is not an appropriate measure to classify GDM risk. The inclusion of additional non-invasive variables (ethnicity, age, parity, GDM and/or macrosomia in a previous pregnancy) and the use of previously-published predictive models [116] significantly improved risk prediction. Although there is no international consensus on optimal weight gain during pregnancy as a function of preconception BMI, weight gain during pregnancy appears to be

► **Table 2** Intermittent fasting methods.

Designation	Intervention
16/8	Food is only consumed in a time window of 8 hours while abstaining from food for the remaining 16 hours of the day
5:2	This involves eating normally five days a week and reducing your calorie intake to about 500–600 calories per day on the remaining two days
Alternate-day fasting	Here, fasting days alternate with normal days. On fasting days, either no food or only a very small number of calories is consumed
24-hour fasting/ eat-stop-eat	This method involves fasting once or twice a week for 24 hours

associated with the risk of GDM (OR 1.42, 95 % CI 1.20–1.68) [117]. In women with GDM, excessive weight gain during pregnancy (defined according to Institute of Medicine [IOM] criteria) [124] was associated with a higher incidence of insulin dependency, a higher dose of insulin and a higher risk of large-for-gestational age birth [118].

Some RCTs investigated the impact of vitamin or mineral supplementation during pregnancy for the risk GDM. The effect of these interventions was summarized in a Cochrane review [111]. While omega-3 fatty acid supplementation has been shown to have no effect on GDM risk, the data for other supplements such as vitamin D, myo-inositol and probiotics is less homogeneous and further studies are needed to before recommendations can be formulated. In general, dietary recommendations during pregnancy for the prevention of GDM should always be formulated taking into account the increased need for some minerals and vitamins (reference values of the DGE) [119].

“Precision nutrition” outlook and diabetes prevention

Recommendation

- The lack of data for a genotype diet means that no recommendation can be made at present

Comment

A diet for the prevention of T2DM must be personalised for better adherence. This can only be derived from the respective preferences and possibilities of the patients. Nutrigenomics deals with the effects of genotype on the metabolising of foods. So far, a number of single nucleotide polymorphisms (SNPs) have been identified that could explain the metabolic diversity of responses to specific dietary interventions [120–122]. However, these genetic modifications could also explain the success of weight-loss therapies and thus reduce the risk of T2DM. In particular, certain variants in SGLT-1, the most important monosaccharide transporter of the intestine, show an association with a reduced rate of diabetes and obesity, and the variants with reduced glucose/galactose resorption were also mathematically reduced by up to 50 % over a 25-year pe-

riod [123]. These results currently have no impact on dietary recommendations, as genetic information is currently not available outside of studies.

Conflicts of Interest

Thomas Skurk: Lecture fees: Novo Nordisk; Research funding: Savanna Ingredients GmbH and Tate & Lyle; Arthur Grünerbel: Fees from KV Bayern, research funding by BMG, fees from Lilly, Sandra Hummel: none; Stefan Kabisch: Fees and travel expenses by Sanofi, Berlin Chemie, Boehringer Ingelheim and Lilly; Travel expenses and research funding by J. Rettenmaier & Söhne, Holzmühle; further research funding by Beneo Südzucker and the California Walnut Commission; Winfried Keuthage: none; Karsten Müssig: none; Helmut Nussbaumer: none; Diana Rubin: Lecture fees: DGVS and Kaiserin-Friedrich Foundation.

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