Position Paper: Ketogenic Diets

INTRODUCTION

Based on a 2021 poll by the *International Food Information Council*, it is estimated that 39% of Americans have tried a diet in the past year, with low carbohydrate diets such as the ketogenic diet in the top five of the most commonly followed diets.[1] The two most common reasons for following a specific eating pattern included a desire to lose weight and to help maintain their health by preventing future illnesses.[1] Consumers have become increasingly interested in a ketogenic diet, as noted by the emergence of food and beverage products using the term "keto" in the product description, a new niche of cookbooks dedicated to ketogenic recipes, and the popularity of recipe blogs geared towards a ketogenic lifestyle. Restaurants have responded by offering diet-friendly options, such as a lettuce wrap around a burger instead of a bun. The popular Chipotle chain offers "lifestyle bowls" that can be customized for diets including ketogenic, paleo, vegetarian, and vegan.

Unlike most other diets that operate by banning specific food groups, a ketogenic diet does not prohibit any specific food or macronutrient. The only requirement is that sufficient carbohydrate restriction must be achieved in order to induce ketosis, which is typically no more than 20 to 50 grams a day, although individuals may vary in their response. This limit typically refers to digestible carbohydrates and therefore does not include fiber. Carbohydrate-dense foods can be included if the serving size is small enough such that the total daily carbohydrate content is below the aforementioned limit, which depends on other foods consumed that day. An underappreciated point is that there are many different ways for an individual to formulate a ketogenic diet; it can be low, moderate, or high protein, and it can align with a Mediterranean pattern or even a completely plant-based diet.

It is the position of this paper that appropriately designed ketogenic diets are nutritionally adequate, health-promoting, and can treat certain health conditions and diseases. The following sections will discuss each of these points in turn, followed by a general discussion of common concerns.

NUTRITIONAL ADEQUACY OF KETOGENIC DIETS

Well-Formulated Meal Plan

A well-formulated ketogenic diet can be nutritionally adequate by meeting daily requirements for protein, vitamins, and minerals. Table 1 displays a sample one-day meal plan with a full nutrient analysis, showing that a ketogenic diet can have a high micronutrient density that exceeds recommendations.

Table 1. *Example of a well-designed ketogenic diet meeting all nutritional requirements*

Breakfast	omelette with eggs, spinach, bell peppers, olive oil, and salt		
Lunch	salad with lettuce, salmon, avocado, cheese, flaxseeds, and balsamic vinaigrette		
Snack	almond milk yogurt with blackberries		
Dinner	tofu with mushrooms, broccoli, cauliflower, olive oil, and salt		
Nutrition Analysis:			
Calories	1762 kcal	Saturated Fat	18 g (91% DV)
Net Carbohydrates*	44 g	Omega-3 & -6 Fat	34 g
Fiber	40 g (100% DV)	Vitamin A	291140 IU (583% DV)
Protein	118 g (227% DV)	Vitamin C	423 mg (706% DV)
B1 (Thiamine)	1.6 mg (107% DV)	Vitamin D	1070 IU (267% DV)
B2 (Riboflavin)	2.6 mg (151% DV)	Vitamin E	26 mg (132% DV)
B3 (Niacin)	31 mg (155% DV)	Vitamin K	1043 µg (1304% DV)
B5 (Pantothenic Acid)	13 mg (133% DV)	Iron	22 mg (123% DV)
B6 (Pyridoxine)	4.3 mg (214% DV)	Magnesium	548 mg (137% DV)
B12 (Cobalamin)	9 µg (154% DV)	Manganese	6.4 mg (321% DV)
Choline	698 mg (127% DV)	Phosphorus	1857 mg (185% DV)
Folate	997 µg (249% DV)	Potassium	4393 mg (125% DV)
Calcium	1788 mg (178% DV)	Selenium	168 µg (240% DV)
Copper	2.4 mg (120% DV)	Sodium	2380 mg (99% DV)
Iodine	183 µg (122% DV)	Zinc	16 mg (111% DV)

* *This term refers to digestible carbohydrates only. Net Carb. = Total Carb. − Fiber*

Intake Concerns

Low or insufficient vegetable, fruit, and fiber intake are some of the common concerns regarding the nutritional adequacy of a ketogenic diet. While it is certainly possible to design a ketogenic diet (or any diet) with low intakes of these food groups, this does not need to be the case. According to the USDA MyPlate, an adult consuming 2000 kcal should have 2.5 cups of vegetables and 2 cups of fruit per day.[2] Adequate fiber intake is 14 g/day per 1000 kcal, according to the *Dietary Guidelines for Americans*.[3] Referring to the sample meal plan shared in Table 1, there are 2 cups of fruit (blackberries), more than 10 cups of vegetables, and 40 grams of fiber — such intake is equal to or more than adequate according to national recommendations.

Adjusting For Dietary Preferences

Many diets cannot be combined with other diets because they contain contradicting allowed and disallowed foods. Since the ketogenic diet is only defined as sufficient carbohydrate restriction to achieve ketosis, one advantage is that it is flexible enough to be paired with other eating patterns to suit an individual's dietary preferences. For instance, a ketogenic diet can be adjusted to accommodate common diets such as vegetarian, vegan, dairy-free, and Mediterranean. A vegetarian ketogenic diet can utilize protein sources such as soy, eggs, and dairy. A vegan ketogenic diet will likely heavily rely on soy in all forms, including tofu, soy milk, protein powder, and protein shakes. Both vegan and dairy-free ketogenic diets may require a daily calcium supplement, with the former possibly also needing a B12 supplement. A Mediterranean ketogenic diet is easily achieved by prioritizing fish and other seafood, a variety of vegetables, olive oil, nuts, and fruits (both sweet and savory).

KETOGENIC DIETS ARE HEALTH-PROMOTING

Cardiovascular Risk Factors

Ketogenic diets have been consistently shown in randomized controlled trials to improve cardiovascular risk factors. Such effects include a decrease in abdominal circumference, a decrease in blood pressure, an increase in HDL cholesterol, and a decrease in triglycerides.[4] These improvements are especially applicable for individuals with insulin resistance and type 2

diabetes. In particular, a ketogenic diet is more effective at increasing HDL cholesterol than other dietary interventions such as low fat, low glycemic, Ornish, Zone, and sometimes Mediterranean.[4] The ketogenic diet also lowers blood triglyceride concentrations significantly more than low fat diets.[4] Both HDL cholesterol and triglycerides are important markers of cardiovascular health, given that a high triglyceride-to-HDL ratio is predictive of extensive coronary artery disease.[5]

Glycemic Control

Higher glucose variability and peaks are associated with an accelerated onset of disease and death, even for healthy nondiabetic individuals. Studies show that higher glucose levels are linked to an increased risk of cancer[6,7], cardiovascular disease[8,9], and mortality[10]. There is also evidence that high glucose peaks can cause endothelial dysfunction and may play a key role in the development of atherosclerosis.[11–13] One study found severe glucose variability in 25% of nondiabetic individuals according to continuous glucose monitoring data, indicating that glucose dysregulation is more prevalent than previously thought.[14]

A ketogenic diet can be highly beneficial for glycemic control because it avoids high glucose variability and peaks by restricting carbohydrates. Since carbohydrates increase blood glucose more than other macronutrients[15,16], a ketogenic diet results in lower postprandial glucose variability and lower peaks. Clinical trials show that low carbohydrate diets are more effective than high carbohydrate diets for glycemic control, with a stronger glucose lowering effect for greater degrees of carbohydrate restriction.[17,18] Consequently, ketogenic diets can be health-promoting through its stabilization of blood glucose.

KETOGENIC DIETS CAN TREAT HEALTH CONDITIONS AND DISEASES

Obesity And Weight Loss

A ketogenic diet can perform as well or better than a high carbohydrate (low fat) diet for weight loss in obese individuals, based on meta-analyses and clinical trials up to one year in duration.[4,19–21] The ketogenic diet can even perform equally well when it is consumed in unrestricted amounts; a two-year trial showed that weight loss was equal at all time points between a low carbohydrate diet and a low fat diet, with the low carbohydrate group

consuming an ad libitum ketogenic diet and the low fat group restricting themselves to a maximum of 1800 kcal/day.[22] Additionally, a ketogenic diet can be effective at losing weight from specific adipose tissue depots. In an eight-week randomized controlled trial studying older adults with obesity, participants on a ketogenic diet lost three times more visceral adipose tissue than those on a low fat diet.[23]

The success of a ketogenic diet for weight loss is hypothesized to be at least partially due to the lower perceived hunger and higher satiety of a high fat diet.[24,25] The mechanisms behind this well-known phenomenon are elusive, given that ketosis can exert both appetite-stimulating and fullness responses.[26] Interestingly, a study showed that young men requested meals during dynamic declines in their blood glucose, and these meal requests took twice as long to occur when the participants were preloaded with fat versus carbohydrates.[27] This result suggests that a high carbohydrate meal may be less satiating than a high fat meal because carbohydrates cause a rise in glucose followed by a decline that signals hunger and meal initiation.

Diabetes

Current recommendations from the *American Diabetes Association* state that reduction of overall carbohydrates for individuals with diabetes is the most evidence-based strategy for improving glycemia.[28] While fasting glucose and HbA1c are important parameters, it is also crucial to monitor postprandial glucose so that it does not exceed 135 mg/dl to reduce cardiovascular risk, according to the *European Diabetes Policy Group*.[9] Given that a ketogenic diet restricts carbohydrates, it is an ideal strategy for glycemic control and reducing variability and peaks, as described in a previous section in this paper. A recent meta-analysis of randomized controlled trials showed that a ketogenic diet resulted in improved metabolic parameters and glycemic control for type 2 diabetics compared to a low fat diet.[29] Carbohydrate restriction can also improve beta cell function, as seen in a six-week crossover trial where participants were randomized to a carbohydrate restricted diet or a conventional diabetes diet.[30] In addition, a two-year intervention with continuous care demonstrated that a ketogenic diet can result in reduced medication use and diabetes resolution (53.5% reversal and 17.6% remission).[31]

Polycystic Ovary Syndrome

Polycystic ovary syndrome (PCOS) is a common endocrine disorder in women of reproductive age, and is characterized by an imbalance of the female sex hormones. In a 12-week single-arm study of women with PCOS, a ketogenic diet resulted in a significant reduction of androgens, luteinizing hormone, and ratio of luteinizing hormone to follicle stimulating hormone.[32] This suggests that the hormonal anomalies associated with PCOS may have regressed, making the ketogenic diet a potentially useful treatment option. In another trial, women with PCOS were randomized to either a ketogenic diet or a conventional pharmacological treatment.[33] Women in both groups had improved menstrual cycles, but only women in the ketogenic group experienced improved liver function and reduced body weight.[33]

Epilepsy

The ketogenic diet has been used for managing intractable epilepsy in children for a century, with an efficacy equal or better than anticonvulsant medications.[34,35] Typically, children who try the ketogenic diet have already tried five or more drugs but failed to respond to them.[34] The underlying mechanism behind the ketogenic diet's effectiveness is not known, but it is thought to involve glucose stabilization, the effects of ketones on the function of neurons, and the anti-epileptic property of fatty acids.[34] The "classic" ketogenic diet is a 3:1 or 4:1 weight ratio of fat to combined protein and carbohydrates[34], which corresponds to 90% of calories from fat and 10% from protein and carbohydrates. In recent years, modified versions of this classic ketogenic diet have been used, making the diet more palatable and flexible for patients.[34]

Alzheimer's Disease

Brain glucose metabolism deteriorates in individuals with neurodegenerative disorders such as Alzheimer's disease. It is logical to consider methods to improve brain energetics, such as using ketones as a source of energy for neurons. In fact, brain ketone metabolism has been shown to be normal in Alzheimer's patients despite their impaired glucose utilization.[36] Mitochondrial oxidative phosphorylation is required for generating ATP from ketones, which suggests that mitochondrial function is still normal in these patients.[36] In a randomized crossover trial of 26 participants, researchers found that a ketogenic diet improved daily function and quality of life compared to a low fat diet.[37]

COMMON CONCERNS

Saturated Fat

The *Dietary Guidelines for Americans* recommends that saturated fat be limited to less than 10% of calories, starting at age two.[3] Given that only 23% of Americans follow this guideline[3], concerns about saturated fat should be extended to not only ketogenic diets but the standard American diet as well. Limiting saturated fat is important because its consumption raises LDL cholesterol[38], which is causal in the development of atherosclerotic cardiovascular disease.[39] Fortunately, it is straightforward to follow a ketogenic diet that emphasizes unsaturated fats. See Table 1, which provides an example of a well-formulated ketogenic diet where saturated fat is less than 10% of calories. The *Dietary Guidelines for Americans* provides useful recommendations on how this can be achieved, which also apply for a ketogenic diet: using monounsaturated or polyunsaturated oils instead of butter, coconut oil, or palm oil, choosing lean instead of high-fat meats, and using non-fat instead of full-fat dairy products.[3]

Diabetic Ketoacidosis

A common concern is that ketosis is a dangerous physiological state. This usually occurs because someone has confused diabetic ketoacidosis (blood ketone concentration > 25 mmol/L, pH < 7.3) with nutritional ketosis (blood ketone concentration 1 - 7 mmol/L without acidosis).[4] The former is a life-threatening situation, but the latter is a normal physiological response when carbohydrate intake is sufficiently reduced such that the body switches its primary fuel utilization to fat. This switch allows glucose to be spared for the brain, which has high energy needs and requires about 25 g/day of glucose in fat-adapted individuals.[4] Ketosis also occurs in the neonatal period and during fasting, and low amounts of blood ketones (0.1 - 0.3 mmol/L) can even be found in adults not on a ketogenic diet.[4]

Sustainability

Another frequent concern is that the ketogenic diet is not sustainable in the long term. However, clinical trials show that adherence to a ketogenic diet is similar to that of low fat diets.[4] Accordingly, it does not appear that a ketogenic diet is any more difficult to adhere to than any other diet. As is the case with all diets, a particular diet may not be suitable for everyone and its effectiveness is determined by the level of adherence, making it most suitable

for highly motivated individuals. As mentioned previously, the ketogenic diet has a unique and well-known capacity to increase satiety and lower hunger, which may make it more sustainable for some individuals.

CONCLUSION

Well-formulated ketogenic diets are micronutrient-dense and more than nutritionally adequate — they exceed the dietary recommendations for fiber, vitamins, and minerals. Such diets are also health-promoting through their beneficial effects on cardiovascular risk factors and their stabilization of blood glucose. Lastly, a ketogenic diet can successfully treat certain health conditions and diseases. Clinical trials have demonstrated its efficacy for metabolic disorders including obesity, diabetes, and PCOS. The ketogenic diet is also used for neurological disorders, with an extensive history of treating epilepsy in children and only just beginning to be explored for Alzheimer's disease. By addressing concerns and misconceptions commonly raised by nutrition professionals and other medical staff, clinicians can be reassured that the ketogenic diet is a safe and effective strategy for improving health outcomes for many individuals, especially those with metabolic syndrome and insulin resistance.

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