Polytechnic Journal

Polytechnic Journal

Volume 13 | Issue 2 Article 3

November 2023

The Ketogenic Diet Effect On Organ Chemistries

Rundk Hwaiz
Department of Nutrition and Dietetics, College of Health Sciences, Hawler Medical University, Kurdistan Region of Iraq

Mohammad Mostafa
Department of Nutrition and Dietetics, College of Health Sciences, Hawler Medical University, Kurdistan Region of Iraq

Sazan Talaat
Department of Nutrition and Dietetics, College of Health Sciences, Hawler Medical University, Kurdistan Region of Iraq, sazan_mazin@yahoo.com

Mohammed Merza
Department of Clinical analysis, College of Pharmacy, Hawler Medical University, Kurdistan Region of Iraq

How to Cite This Article

Hwaiz, Rundk; Mostafa, Mohammad; Talaat, Sazan; and Merza, Mohammed (2023) "The Ketogenic Diet Effect On Organ Chemistries," *Polytechnic Journal*: Vol. 13: Iss. 2, Article 3.
DOI: https://doi.org/10.59341/2707-7799.1718

The Ketogenic Diet Effect On Organ Chemistries

Abstract

Background: ketogenic diet refers to the diet plan that emphasizes foods that are high in fats, moderate proteins and very low carbohydrates to consume more calories from fat rather than carbohydrates and is commonly used as a weight-loss plan and in rare cases, as a treatment for some diseases. Objective: The aim of this study was to evaluate or assess organ functions in the individuals following ketogenic diet. Patients and methods: A total 31 samples were collected from individuals following ketogenic diet in male and femal aged from 20 to 55, and a control group which composed of 10 healthy individuals without ketogenic diet, and the diet duration was from 2 to 44 weeks. The sample were collected from Dec 2021 to Mar 2021 at Rozhalat emergency laboratory. We have measured serum urea, creatinine and hepatic enzymes in those individuals. We measured it statistically and regarded p-value for significance for less than 0.05. Result: Our result showed that ketogenic diet reduced the estimated glomerular filtration rate (eGFR) and induced Alanine transaminase(ALT) compared to control group (individual without ketogenic diet), moreover, there is no statistically difference in serum Aspartate transaminase(AST) and bilirubin compared to control group. The mean value of eGFR, ALT, AST, and bilirubin in ketogenic group are (79.3±5.7), (22.7± 3.6), (24.87±3.73), (0.72±0.05) respectively. Conclusion: We have observed that ketogenic diet affects the kidney function, the function of other organs like liver and induce hypercholesterolemia

Keywords

Ketogenic diet; kidney function; liver; lipid profile; cholesterol.

ORIGINAL ARTICLE

The Ketogenic Diet Effect on Organ Chemistries

Rundk Hwaiz [a,*], Mohammad Mostafa [a,c], Sazan Talaat [e], Mohammed Merza [b,d]

[a] Department of Nutrition and Dietetics, College of Health Sciences, Hawler Medical University, Kurdistan Region, Iraq
[b] Department of Clinical Analysis, College of Pharmacy, Hawler Medical University, Kurdistan Region, Iraq
[c] Layala Qasim Center for Diabetes, Ministry of Health, Kurdistan Region, Iraq
[d] Department of Medical Biochemical Analysis, College of Health Technology, Cihan University, Kurdistan Region, Iraq
[e] Department of Pharmacy, Noble Technical Institute, Kurdistan Region, Iraq

Abstract

Background: **ketogenic diet refers to the diet plan that emphasizes foods that are high in fats, moderate proteins and very low carbohydrates to consume more calories from fat rather than carbohydrates and is commonly used as a weight-loss plan and in rare cases, as a treatment for some diseases.**

Objective: **The aim of this study was to evaluate or assess organ functions in the individuals following ketogenic diet.**

Patients and methods: **A total 31 samples were collected from individuals following ketogenic diet in male and femal aged from 20 to 55, and a control group which composed of 10 healthy individuals without ketogenic diet, and the diet duration was from 2 to 44 weeks. The sample were collected from Dec 2021 to Mar 2021 at Rozhalat emergency laboratory. We have measured serum urea, creatinine and hepatic enzymes in those individuals. We measured it statistically and regarded p-value for significance for less than 0.05.**

Result: **Our result showed that ketogenic diet reduced the estimated glomerular filtration rate (eGFR) and induced Alanine transaminase(ALT) compared to control group (individual without ketogenic diet), moreover, there is no statistically difference in serum Aspartate transaminase(AST) and bilirubin compared to control group. The mean value of eGFR, ALT, AST, and bilirubin in ketogenic group are (79.3 ± 5.7), (22.7 ± 3.6), (24.87 ± 3.73), (0.72 ± 0.05) respectively.**

Conclusion: **We have observed that ketogenic diet affects the kidney function, the function of other organs like liver and induce hypercholesterolemia.**

Keywords: Ketogenic diet, Kidney function, Liver, Lipid profile, Cholesterol

1. Introduction

Ketogenic diet or keto diet is a very low-carbohydrate diet (less than 50 gm/day) with moderate amount of protein [1]. Originally, the KD consisted of a 4:1 ratio of fat-to-carbohydrate and protein and fat considered to provide more than 90% the caloric intake [2]. This method has been introduced for the first time in 1921 by Russel Wilder as an epilepsy treatment [3].

This method has become incredibly popular during the last ten years due to its high effectiveness in weight loss in a very short period of time [2]. Besides losing weight benefits, studies showed that KD correlated with decreasing the production of pro-inflammatory cytokine and increasing the production of adiponectin [4–6]. Reducing the pro-inflammatory cytokines in KD participants associated with the reduction of risk of metabolic syndrome and related diseases [7,8]. Moreover, increasing the adiponectin hormone associated with protecting the body from insulin resistance, diabetes type II, and atherosclerosis [9]. Another main advantage of KD is depriving cancer cells from glucose [10]. According to the Warburg effect theory, cancer cells use glycolysis to produce ATP rather than oxidative phosphorylation [11]. In addition, due to mitochondrial malfunction and down-regulation of ketone consumption enzymes, certain types of cancer cells are unable to metabolize ketone bodies [12].

Received 16 July 2023; accepted 20 September 2023.
Available online 6 November 2023

* Corresponding author.
E-mail addresses: rundk.hwaiz@hmu.edu.krd (R. Hwaiz), dr.mohammad.h84@gmail.com (M. Mostafa), sazan.mazin@noble.edu.krd (S. Talaat), mohammed.merza@hmu.edu.krd (M. Merza).

https://doi.org/10.59341/2707-7799.1718

Thus, as cancer cells starve for energy while normal cells can utilize ketone bodies, KD has been considered as one of the effects adjuvant therapy for cancer patients [11,13]. Additionally, researches showed the advantage of combining KD with the conventional cancer treatment such as chemotherapy and radiotherapy on neuroblastoma, renal tumour, colorectal, and breast cancer [11,14–16].

On the other hand, KD side effects can be classified into both sort-term and long-term side effects [2]. Short term side-effects emerging in the beginning of KD described as keto flu as well, which includes symptoms including dizziness, headaches, vomiting, exhaustion, constipation, nausea, and a reduced capacity for exercise [17]. Contrastingly, hepatic steatosis, renal stones, hypoproteinemia, and vitamin deficiencies are long-term adverse effects [2].

Additionally, application of this diet plan is contraindicated in some medical and metabolic conditions, including liver failure, pancreatitis, inborn disorders of fat metabolism, primary carnitine deficiency, carnitine palmitoyl transferase deficiency, carnitine translocase deficiency, porphyria, and pyruvate kinase deficiency [2].

As long as the genetics/race has a significant influence on the biomedical results such as LFT, kidney function tests, and lipid profile, we want to see the impact of the ketogenic diet on the Kurdish population [18–20]. Thus, the aim of this study is to shows the impact of ketogenic diet on the biochemical tests in the Kurdish population by monitoring the function of three most important organs, kidneys, liver and heart. For that reason, kidney function tests, lipid profile, and liver function tests, have been performed.

2. Methodology

2.1. Sample management

This study composed of 31 people who were following a ketogenic diet for at least 2 weeks in Erbil city center were examined to evaluate the effect of ketogenic diet on kidney, liver and heart chemistry. Samples were collected between Dec 2020 to Mar 2021, and it composes of 15 males and 16 females aged from 20 to 55 (see Table 1). Moreover, the individuals participating in this study followed a ketogenic diet for a period ranging from 2 to 24 weeks. For the purpose of comparison, serum samples have been collected and harvested in individual without ketogenic diet. The control group comprised 10 individual (5 males and 5 female). All these information regarding their personal information, weight, height and their health history has been recorded before the sample collection. Furthermore, volunteers participated in this study follow the general KD plan which compose of 70–80% fat from total daily calories, 5–10% carbohydrate, and 10–20% protein. For a 2000-calorie diet, this translates to about 165 g' fat, 40 g' carbohydrate, and 75 g’ protein [21].

Table 1. The distribution of individuals with ketogenic diet and control groups according to their gender.

	Individual with KD (n)		Control group (n)	
Gender	Male	Female	Male	Female
Number	15	16	5	5
Percentage%	48.4	51.6	50	50

2.2. Sample handling

Samples were collected in serum-separated tubes and subsequently centrifuged after coagulation occurred. After that, all these sample has been transferred to the Rozhhalat Emergency Hospital to measure the biochemical tests for both groups.

2.3. Chemical tests

Biochemical tests have been taken for all the samples for comparing the impact of KD on the function of kidneys, liver and heart. For that reason, creatinine, urea, uric acid, triglycerides, cholesterol, albumin, ALT, and AST, were measured by (MIRA ONE-fully automated clinical chemistry analyzer based in Rome, Italy).

3. Results and discussion

The study comprised of 31 individuals that follow ketogenic diet for at least 2 weeks, 15 males and 16 females from different age ranged from 20 to 55 years (mean = 33.16 years old). On the other hand, 10 individuals,5 males and 5 females, participated as a volunteer in the control group, their age ranged between 20 and 55 (Table 2).

3.1. Effect of ketogenic diet on kidney function

In order to assess the influence of KD on kidney function, we conducted Kidney Function Tests (KFT), measuring urea and creatinine levels in both groups. We determined the level of serum creatinine in KD individuals and control group. Moreover, the result shows that there was a significant difference in serum creatinine between the KD individuals and control group (1.14 ± 0.07) and

Table 2. The distribution of individuals with ketogenic diet and control groups according to their age.

Age (year)	Number of individual with KD (n)	Percentage%	Number of individual without KD (n)	Percentage%
20–29	15	48.4	2	20
30–39	7	22.6	3	30
40–49	7	22.6	4	40
50–59	2	6.4	1	10
Total	31	100	10	100

(0.68 ± 0.04) respectively. Furthermore, comparing both control and KD group, there was not a significant difference in serum urea, P-value >0.05 (Figure 1).

In order to evaluate the estimated glomerular filtration rate, the creatinine value was used according to an equation:

Estimated glomerular filtration rate (eGFR) is calculated by the abbreviated MDRD equation: 186 x (Creatinine/88.4)-1.154 x (Age)-0.203 x (0.742 if female) x (1.210 if black).

The kidney function according to the eGFR (mL/min/1.73 m^2). There are five stages:

Stage 1 (eGFR of 90% or higher) indicates mild kidney damage, but your kidneys are working well.

Stage 2 (eGFR between 60% and 89%) indicates an increase in kidney damage from stage 1, but the kidneys continue to function well.

Stage 3 (eGFR between 30% and 59%) means you have decreased kidney function and may experience symptoms.

Stage 4 (eGFR between 15% and 29%) is poor kidney function, with moderate to severe kidney damage.

Stage 5 (eGFR below 15%) is a sign of kidney failure. It means less than 15% kidney function. This stage is the most serious and can be life-threatening. The patient will need or a kidney transplant.

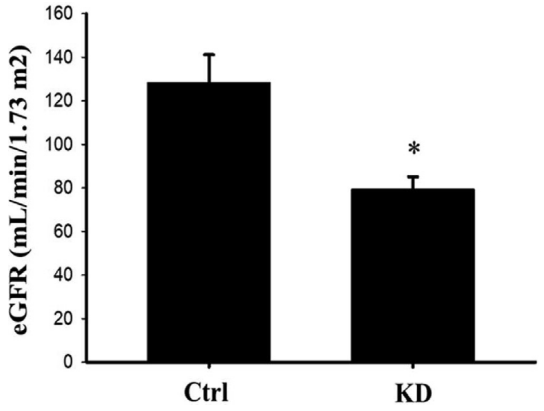

Figure 2. The level of eGFR (mL/min/1.73 m2) in control group and ketogenic diet subjects, (P-value <0.05), (Ctrl) n = 10 (KD) n = 31.*

The mean value of eGFR in KD group (79.3 ± 5.7) was significantly lower than that of control group (128.5 ± 12.6), P-value <0.001 (Figure 2).

We determined the level of serum uric acid in KD group and control group. Moreover, there was a significant difference in serum uric acid between these two groups (6.4 ± 0.4) and (4.7 ± 0.3) respectively, P-value = 0.014 (Figure 3).

The serum albumin in KD individual was significantly higher than in control group, (5.6 ± 0.05) (4.1 ± 0.1) respectively, P-value <0.001 (Figure 3).

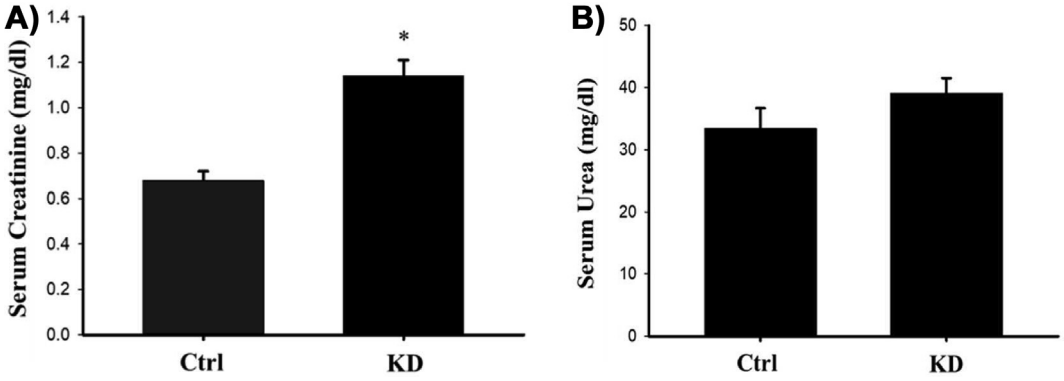

Figure 1. A) Serum level of creatinine (mg/dl) in control group and ketogenic diet subjects, (P-value <0.05), B) Serum level of Urea (mg/dl) in control group and ketogenic diet subjects, (P-value >0.05), (Ctrl) n = 10 (KD) n = 31.*

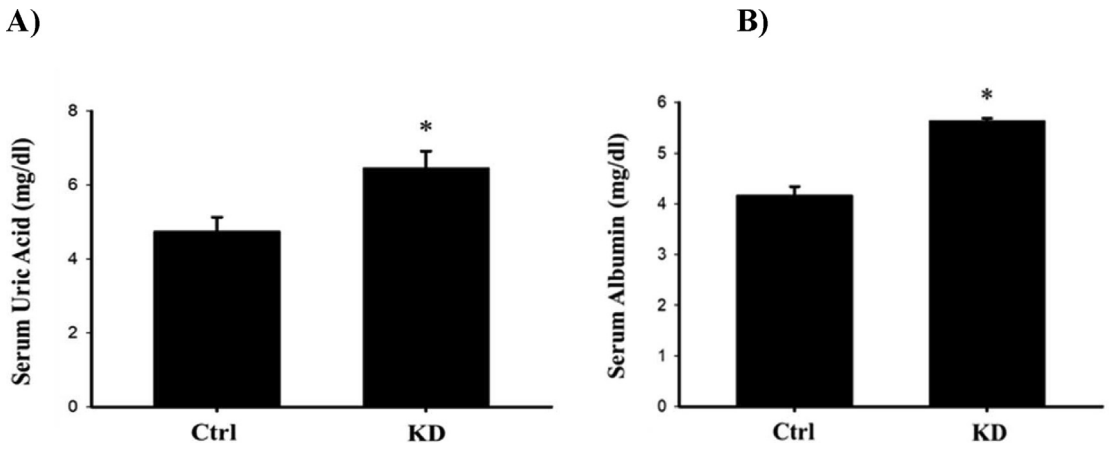

Figure 3. The level of (A) serum uric acid and (B) albumin (mg/dl) in control group and ketogenic diet subjects, (P-value <0.05), (Ctrl) n = 10 (KD) n = 31.*

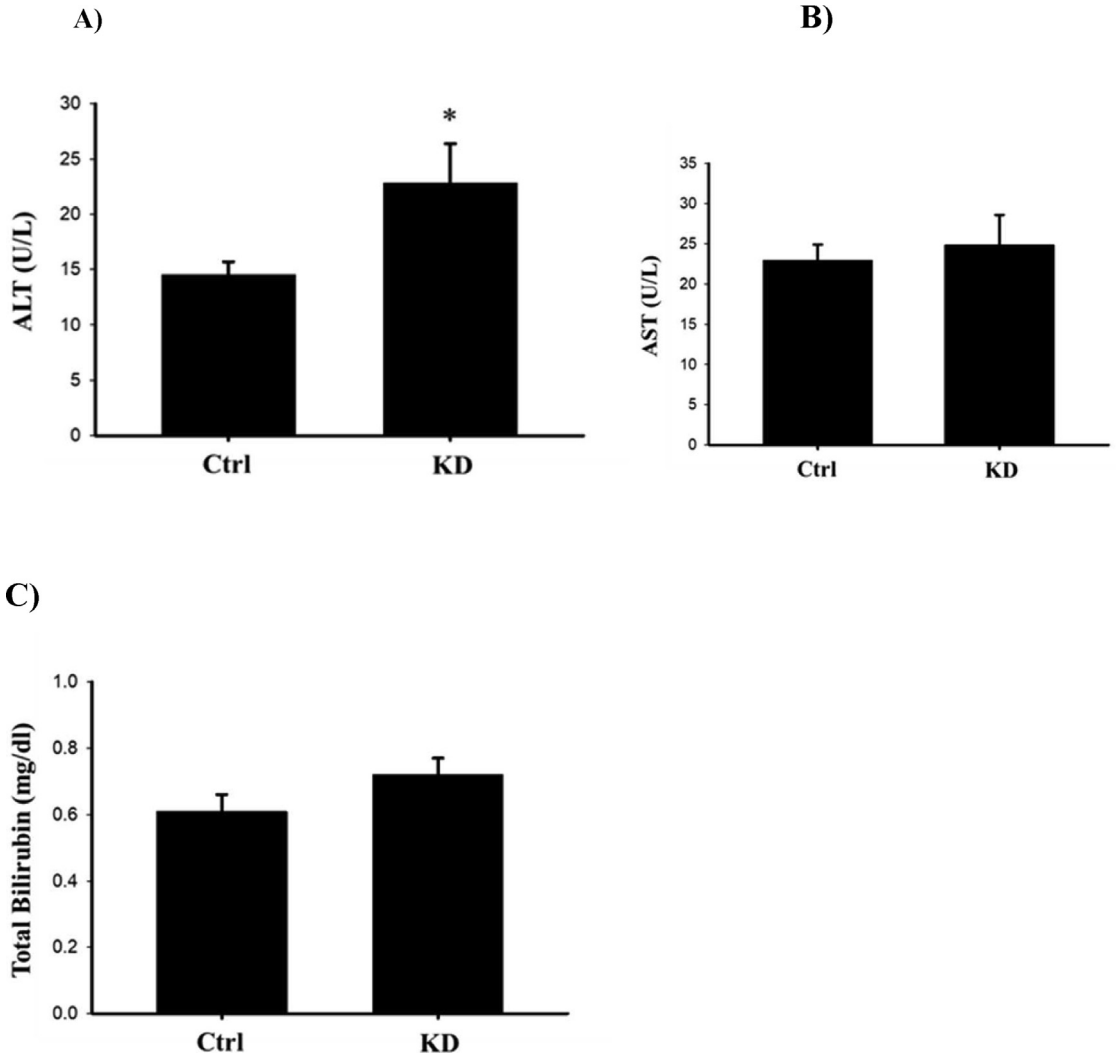

Figure 4. The level of serum (A) ALT, (B) AST and (C) TBili in control group and ketogenic diet subjects, (Ctrl) n = 10 (KD) n = 31.

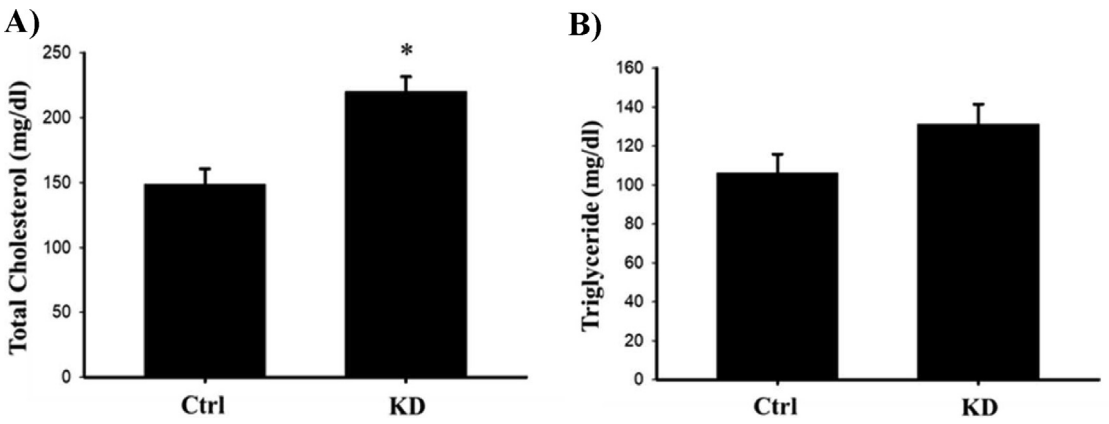

Figure 5. The level of serum (A) total cholesterol and (B) triglyceride (mg/dl) in control group and ketogenic diet subjects, (Ctrl) n = 10 (KD) n = 31.

3.2. Effect of ketogenic diet on liver function

In order to assess the liver performance, we have measured the serum hepatic enzyme ALT, AST and total bilirubin Figure 4. The mean value of serum ALT (22.7 ± 3.6) of individual with KD was higher than in control group ALT (14.5 ± 1.1), *P-value* <0.001. However, the serum levels of AST and total bilirubin of KD were higher than in control group but no significant difference were observed between these two groups *P-value* > 0.05.

3.3. Effect of ketogenic diet on heart function

We determined the lipid profile include cholesterol and triglyceride for expecting the effect of KD on the heart related disease such as atherosclerosis. The level of serum cholesterol in KD group was significantly higher than that of control group (220.1 ± 11.5) and (148.3 ± 12.4), P-value <0.001. However, there was no significant difference in serum Tg in between KD and control groups (131.1 ± 10.3) and (105.9 ± 9.9) respectively, P-value = 0.160, as shown in Figure 5.

The adoption of various weight-loss techniques by obese individuals without seeking medical guidance has seen a significant surge, and a common hurdle they face is sustaining these methods long enough to achieve their goals [22]. Among these approaches, the Ketogenic Diet (KD) has gained considerable popularity over the past decade, largely attributed to its short-term effectiveness [17]. While KD has shown promise in managing conditions like diabetes, cancer, and cardiovascular disease [23–25], it also comes with several drawbacks affecting various organs in the body [2,26].

Our study sought to shed light on the impact of KD on kidney, liver, and heart functions. The kidneys, vital for several critical functions, are particularly susceptible to the effects of KD since they are responsible for eliminating urea and creatinine from the body [27]. Our findings revealed that over 50% of KD participants exhibited an estimated glomerular filtration rate (eGFR) lower than 90 ml/min/1.73 m^2 (Figure 2). This aligns with previous research highlighting the adverse effects of a ketogenic diet on kidney health [25].

Following the kidneys, the liver is the second organ affected, given its role in detoxification and ammonia-to-urea conversion [28]. Increased protein consumption associated with KD can lead to liver strain and potentially contribute to various liver-related disorders [29]. In our study, liver-related biochemical tests indicated a detrimental impact of KD. While we observed normal levels of AST, T-Bilirubin, and one component of ALT, certain results showed significantly higher levels than those in the control group, raising concerns about future implications. Differences between our study and previous research can be attributed to the use of rodents in their experiments and a larger sample size [30].

Furthermore, a fat-based diet as the primary energy source increases the risk of conditions like atherosclerosis [31]. To examine the effect of KD on serum lipid concentrations, we measured triglyceride and total cholesterol levels, revealing a clear association between KD and hyperlipidemia (Figure 5).

Our findings suggest that high consumption of animal products, such as tallow and meat, is linked to elevated cholesterol levels and normal triglyceride levels. To mitigate the adverse effects of the diet on LDL cholesterol, one potential strategy is substituting saturated fats from animal sources with polyunsaturated fats found in foods like avocados, almonds, seeds, coconut oil, and olive oil [31].

4. Conclusions

The ketogenic diet is a high-fat, moderate-protein, very low-carbohydrate diet that can induce weight loss and improvement in glycemic control, but poses a risk of reducing glomerular filtration rate, inducing hyperlipidemia, and elevation of liver enzymes. Like any other restrictive dietary plan, the ketogenic diet is often difficult to maintain long-term. Cycling in and out of ketosis reduces its metabolic effects. Patients on a ketogenic diet should be monitored with frequent laboratory testing of blood ketones, lipids, and liver enzymes.

Author contributions

All authors contributed equally in design, data collection, analysis of interpretation, writing and manuscripts preparation.

Conflicts of Interest

None to declare.

References

[1] Kirkpatrick CF, Bolick JP, Kris-Etherton PM, Sikand G, Aspry KE, Soffer DE, et al. Review of current evidence and clinical recommendations on the effects of low-carbohydrate and very-low-carbohydrate (including ketogenic) diets for the management of body weight and other cardiometabolic risk factors: a scientific statement from the National Lipid Association Nutrition and Lifestyle Task Force. J Clin Lipidol 2019;13(5):689–711.e1. https://doi.org/10.1016/j.jacl.2019.08.003.

[2] Batch JT, Lamsal SP, Adkins M, Sultan S, Ramirez MN. Advantages and disadvantages of the ketogenic diet: a review article. Cureus 2020;12(8):e9639. https://doi.org/10.7759%2Fcureus.9639.

[3] Kim JM. Ketogenic diet: old treatment, new beginning. Clin Neurophysiol Pract 2017;2:161–2. https://doi.org/10.1016%2Fj.cnp.2017.07.001.

[4] Sharman MJ, Volek JS. Weight loss leads to reductions in inflammatory biomarkers after a very-low-carbohydrate diet and a low-fat diet in overweight men. Clin Sci (Lond) 2004;107(4):365–9. https://doi.org/10.1042/cs20040111.

[5] Monda V, Polito R, Lovino A, Finaldi A, Valenzano A, Nigro E, et al. Short-term physiological effects of a very low-calorie ketogenic diet: effects on adiponectin levels and inflammatory states. Int J Mol Sci 2020;21(9). https://doi.org/10.3390%2Fijms21093228.

[6] Yamauchi T, Kamon J, Waki H, Terauchi Y, Kubota N, Hara K, et al. The fat-derived hormone adiponectin reverses insulin resistance associated with both lipoatrophy and obesity. Nat Med 2001;7(8):941–6. https://doi.org/10.1038/90984.

[7] Dupuis N, Curatolo N, Benoist JF, Auvin S. Ketogenic diet exhibits anti-inflammatory properties. Epilepsia 2015;56(7):e95–8. https://doi.org/10.1111/epi.13038.

[8] Gershuni VM, Yan SL, Medici V. Nutritional ketosis for weight management and reversal of metabolic syndrome. Curr Nutr Rep 2018;7(3):97–106. https://doi.org/10.1007%2Fs13668-018-0235-0.

[9] Achari AE, Jain SK. Adiponectin, a therapeutic target for obesity, diabetes, and endothelial dysfunction. Int J Mol Sci 2017;18(6). https://doi.org/10.3390/ijms18061321.

[10] Mundi MS, Mohamed Elfadil O, Patel I, Patel J, Hurt RT. Ketogenic diet and cancer: fad or fabulous? JPEN J Parenter Enteral Nutr 2021;45(S2):26–32. https://doi.org/10.1002/jpen.2226.

[11] Weber DD, Aminazdeh-Gohari S, Kofler B. Ketogenic diet in cancer therapy. Aging (Albany NY) 2018;10(2):164–5. https://doi.org/10.18632%2Faging.101382.

[12] Morscher RJ, Aminzadeh-Gohari S, Feichtinger RG, Mayr JA, Lang R, Neureiter D, et al. Inhibition of neuroblastoma tumor growth by ketogenic diet and/or calorie restriction in a CD1-Nu mouse model. PLoS One 2015;10(6):e0129802. https://doi.org/10.1371/journal.pone.0129802.

[13] Klement RJ. Beneficial effects of ketogenic diets for cancer patients: a realist review with focus on evidence and confirmation. Med Oncol 2017;34(8):132. https://doi.org/10.1007/s12032-017-0991-5.

[14] Liskiewicz AD, Kasprowska D, Wojakowska A, Polanski K, Lewin-Kowalik J, Kotulska K, et al. Long-term high fat ketogenic diet promotes renal tumor growth in a rat model of tuberous sclerosis. Sci Rep 2016;6:21807. https://doi.org/10.1038/srep21807.

[15] Klement RJ, Schafer G, Sweeney RA. A ketogenic diet exerts beneficial effects on body composition of cancer patients during radiotherapy: an interim analysis of the KETOCOMP study. J Tradit Complement Med 2020;10(3):180–7. https://doi.org/10.1016/j.jtcme.2019.03.007.

[16] Iyikesici MS, Slocum AK, Slocum A, Berkarda FB, Kalamian M, Seyfried TN. Efficacy of metabolically supported chemotherapy combined with ketogenic diet, hyperthermia, and hyperbaric oxygen therapy for stage IV triple-negative breast cancer. Cureus 2017;9(7):e1445. https://doi.org/10.7759/cureus.1445.

[17] Masood W, Annamaraju P, Uppaluri KR. Ketogenic Diet. StatPearls. Treasure Island (FL) ineligible companies. Disclosure: Pavan Annamaraju declares no relevant financial relationships with ineligible companies. Disclosure: Kalyan Uppaluri declares no relevant financial relationships with ineligible companies. 2023. Available from: http://www.ncbi.nlm.nih.gov/books/nbk499830/.

[18] Bathum L, Petersen HC, Rosholm JU, Hyltoft Petersen P, Vaupel J, Christensen K. Evidence for a substantial genetic influence on biochemical liver function tests: results from a population-based Danish twin study. Clin Chem 2001;47(1):81–7. https://doi.org/10.1093/clinchem/47.1.81.

[19] Hsu CY, Yang W, Parikh RV, Anderson AH, Chen TK, Cohen DL, et al. Race, genetic ancestry, and estimating kidney function in CKD. N Engl J Med 2021;385(19):1750–60. https://doi.org/10.1056/nejmoa2103753.

[20] Masood W, Annamaraju P, Khan Suheb MZ, et al. Ketogenic diet. [Updated 2023 Jun 16]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK499830/.

[21] Chang MH, Ned RM, Hong Y, Yesupriya A, Yang Q, Liu T, et al. Racial/ethnic variation in the association of lipid-related genetic variants with blood lipids in the US adult population. Circ Cardiovasc Genet 2011;4(5):523–33. https://doi.org/10.1161/circgenetics.111.959577.

[22] Alexander SC, Cox ME, Yancy WS, Boling Turer C, Lyna P, Ostbye T, et al. Weight-loss talks: what works (and what doesn't). J Fam Pract 2011;60(4):213–9. https://pubmed.ncbi.nlm.nih.gov/26048291.

[23] Chung JY, Kim OY, Song J. Role of ketone bodies in diabetes-induced dementia: sirtuins, insulin resistance, synaptic plasticity, mitochondrial dysfunction, and neurotransmitter. Nutr Rev 2022;80(4):774–85. https://doi.org/10.1093/nutrit/nuab118.

[24] Weber DD, Aminzadeh-Gohari S, Tulipan J, Catalano L, Feichtinger RG, Kofler B. Ketogenic diet in the treatment of cancer – Where do we stand? Mol Metab 2020;33:102–21. https://doi.org/10.1016/j.molmet.2019.06.026.

[25] Zhang W, Guo X, Chen L, Chen T, Yu J, Wu C, et al. Ketogenic diets and cardio-metabolic diseases. Front

Endocrinol (Lausanne) 2021;12:753039. https://doi.org/10.3389/fendo.2021.753039.
[26] Crosby L, Davis B, Joshi S, Jardine M, Paul J, Neola M, et al. Ketogenic diets and chronic disease: weighing the benefits against the risks. Front Nutr 2021;8:702802. https://doi.org/10.3389/fnut.2021.702802.
[27] Musso CG, Alvarez Gregori J, Jauregui JR, Macias Nunez JF. Creatinine, urea, uric acid, water and electrolytes renal handling in the healthy oldest old. World J Nephrol 2012;1(5):123–6. https://doi.org/10.5527%2Fwjn.v1.i5.123.
[28] Olde Damink SW, Jalan R, Dejong CH. Interorgan ammonia trafficking in liver disease. Metab Brain Dis 2009;24(1):169–81. https://doi.org/10.1007/s11011-008-9122-5.
[29] Griffin JWD, Bradshaw PC. Effects of a high protein diet and liver disease in an in silico model of human ammonia metabolism. Theor Biol Med Model 2019;16(1):11. https://doi.org/10.1186/s12976-019-0109-1.
[30] Anekwe CV, Chandrasekaran P, Stanford FC. Ketogenic diet-induced elevated cholesterol, elevated liver enzymes and potential non-alcoholic fatty liver disease. Cureus 2020;12(1):e6605. https://doi.org/10.7759/cureus.6605.
[31] Siri-Tarino PW, Sun Q, Hu FB, Krauss RM. Saturated fatty acids and risk of coronary heart disease: modulation by replacement nutrients. Curr Atheroscler Rep 2010;12(6):384–90. https://doi.org/10.1007/s11883-010-0131-6.