**Name of Journal:** *World Journal of Clinical Cases*

**Manuscript NO:** 80491

**Manuscript Type:** CASE REPORT

**Very low calorie ketogenic diet and common rheumatic disorders: A case report**

Rondanelli M *et al*. VLCKD and rheumatic disorders

Mariangela Rondanelli, Zaira Patelli, Clara Gasparri, Francesca Mansueto, Cinzia Ferraris, Mara Nichetti, Tariq A Alalwan, Ignacio Sajoux, Roberto Maugeri, Simone Perna

**Mariangela Rondanelli,** Department of Public Health, Experimental and Forensic Medicine, Unit of Human and Clinical Nutrition, IRCCS Mondino Foundation, Pavia 27100, Italy

**Zaira Patelli, Clara Gasparri, Francesca Mansueto, Mara Nichetti,** Endocrinology and Nutrition Unit, Azienda di Servizi alla Persona ‘‘Istituto Santa Margherita’’, University of Pavia, Pavia 27100, Italy

**Cinzia Ferraris,** Food Education and Sport Nutrition Laboratory, Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Pavia 27100, Italy

**Tariq A Alalwan, Simone Perna,** Department of Biology, College of Science, University of Bahrain, Sakhir 32038, Bahrain

**Ignacio Sajoux,** Chief Scientific Office, Medical Department Pronokal Group, Barcelona 08001, Spain

**Roberto Maugeri,** Medical Direction, PronoKal Group, Savigliano 12038, Italy

**Author contributions:** Rondanelli M, Sajoux I, and Maugeri R are responsible for conceptualization; Patelli Z, Gasparri C, and Mansueto F are responsible for the investigation; Alalwan TA, and Perna S contributed to the data curation; Patelli Z, and Gasparri C wrote the original draft preparation; Ferraris C, and Nichetti M wrote the review and editing; Rondanelli M is responsible for visualization and project administration; Rondanelli M, Sajoux I, and Maugeri R contributed to the supervision; All authors have read and agreed to the published version of the manuscript.

**Corresponding author: Clara Gasparri, MSc, Research Fellow,** Endocrinology and Nutrition Unit, Azienda di Servizi alla Persona ‘‘Istituto Santa Margherita’’, University of Pavia, Via Emila 12, Pavia 27100, Italy. clara.gasparri01@universitadipavia.it

**Received:** October 20, 2022

**Revised:** November 10, 2022

**Accepted:** January 9, 2023

**Published online:**

**Abstract**

BACKGROUND

The scientific literature provides evidence that nutritional ketosis can be an important support in the treatment of pathologies in which inflammation is present, as recent studies have shown that ketone bodies have anti-inflammatory activity in numerous diseases, including rheumatic diseases. We report the case of a 22-year-old woman with class I obesity and juvenile idiopathic arthritis who started treatment with a very low calorie ketogenic diet (VLCKD).

CASE SUMMARY

The patient was a 22-year-old woman diagnosed with juvenile idiopathic arthritis at age 4 years and with a body mass index (BMI) of 30.8 kg/m2, waist circumference (WC) 80 cm, fat mass (FM) 28.1 kg, free FM 45.7 kg, and visceral adipose tissue (VAT) 3.5 kg, assessed on bioimpedance analysis. She was treated using a commercial VLCKD weight-loss program (PNK® method); this program provides high-biological-value protein preparations and natural foods. Each protein preparation contains 15 g protein, 4 g carbohydrate, 3 g fat, and 50 mg omega-3 docosahexaenoic acid, with an energy content of 90–120 kcal. After four months on the program, the BMI was 28.6 kg/m2, WC 73 cm, FM 23.2 kg, free FM 41.9 kg, and VAT 2.9 kg.

CONCLUSION

VLCKD enabled the patient to reach her target weight and to reduce her joint pain and headaches. Laboratory inflammatory indices also normalized.

**Key Words:** Very low calorie ketogenic diet; Inflammation; PNK® method; Weight loss; Obesity; Rheumatic disorders; Case report

Rondanelli M, Patelli Z, Gasparri C, Mansueto F, Ferraris C, Nichetti M, Alalwan TA, Sajoux I, Maugeri R, Perna S. Very low calorie ketogenic diet and common rheumatic disorders: A case report. *World J Clin Cases* 2023; In press

**Core Tip:** A commercial weight-loss program (PNK® method) was used, based on a very low calorie ketogenic diet (VLCKD). VLCKD allowed the patient to achieve weight goal, better management of joint pain, headache episodes and normalization of inflammatory indices.

**INTRODUCTION**

Nutritional ketosis has been used since the 1920s as a treatment for refractory epilepsy[1] and the very low calorie ketogenic diet (KD) is currently gaining popularity as a potential therapy for obesity and metabolic disorders[2].

The Italian Association of Dietetics and Clinical Nutrition gives the following indications for very low calorie ketogenic diet (VLCKD): Morbid obesity or obesity with comorbidities (including type 2 diabetes, dyslipidemia, hypertension, metabolic syndrome, obstructive sleep apnea syndrome, bone disease or severe arthropathy); the preoperative period of severe obesity with an indication for bariatric surgery; patients with severe comorbidities and overweight, necessitating rapid weight loss; non-alcoholic fatty liver disease; and drug-resistant epilepsy[3,4].

In addition to these established indications, the scientific literature advocates the use of nutritional ketosis in the treatment of chronic inflammatory diseases, as recent studies have shown that ketone bodies have anti-inflammatory activity in numerous diseases[5,6].

The ketone body β-hydroxybutyrate (βOHB) is elevated during VLCKD treatment, and there is increasing evidence that βOHB acts not only as an energy substrate but also as a signaling molecule[6]. βOHB is a ligand for G protein-coupled receptors that bind short-chain fatty acids, including hydroxycarboxylic acid receptor 2 and free fatty acid receptor 3. It can attenuate oxidative stress in the spinal cord and kidney by suppressing class I histone deacetylases[6] and has been shown to suppress NOD-like receptor family pyrin domain containing 3 inflammasome-mediated inflammatory disease[6–10].

Inflammatory rheumatic disorders induce chronic inflammation in joints and other tissues[11] and are characterized by an increased expression of several proinflammatory cytokines, including interleukin (IL)-1, IL-6, tumour necrosis factor-α, IL-23, and IL-17[12].

A more recent review by Ciaffi *et al*[13] suggests that the KD could play a role in the treatment of patients with rheumatic musculoskeletal diseases as the KD can facilitate weight loss and modulate systemic inflammation, resulting in a rapid response to systemic therapy[13].

In obese patients, the VLCKD was significantly more effective than a standard low-calorie diet in terms of weight loss[14,15]. It has also been demonstrated that a VLCKD supplemented with omega-3 docosahexaenoic acid (DHA) has a significantly superior anti-inflammatory effect, despite non-significant differences in weight loss and metabolic improvement[16].

Given the potential benefits, a 22-year-old woman with a body mass index (BMI) of 30.8 kg/m2 and who had been diagnosed with juvenile idiopathic arthritis at the age of 4 years, was started on a VLCKD.

**CASE PRESENTATION**

***Chief complaints***

A 22-year-old woman attended outpatients at the Santa Margherita Nutritional Rehabilitation Institute, Pavia, Italy, for an endocrinology and dietary consultation. The patient reported gradual and persistent weight gain from the age of 10 years.

***History of present illness***

She had been diagnosed with juvenile idiopathic arthritis at age of 4 years, and occasionally presented headache and alternating episodes of constipation and diarrhea.

At the time of her first consultation at this outpatients, she was on estrogen-progestogen therapy and had been prescribed naproxen 550 mg or 7.5 mg meloxicam as required.

***Physical examination***

Weight (kg) was measured to an accuracy of ± 0.05 kg, and BMI was calculated as weight in kilograms divided by height in meters squared (kg/m2). Bioimpedance analysis (Zeus, Cosmed, Italy) provided whole-body and compartmentalized values for fat mass (FM) and fat-free mass, visceral adipose tissue (VAT), and intra- and extracellular water analysis for estimating hydration status.

Additionally, waist circumference (WC) was measured by a trained dietician at the level of the umbilicus at the end of normal expiration using a non-elastic measuring tape.

The patient’s baseline basal metabolic rate (BMR) was assessed by indirect calorimetry (Cosmed Q-NRG) at the first anthropometric and nutritional evaluation.

The patient never had significant limitations in physical activity.

**FINAL DIAGNOSIS**

The patient had juvenile idiopathic arthritis and I grade obesity.

**TREATMENT**

The initial dietary approach was a balanced, low-calorie diet based on World Health Organization (WHO) criteria (WHO, Washington, DC, United States)[17] adapted to the BMR calculated by indirect calorimetry.

Then, the patient was started on a commercial weight-loss program based on a VLCKD (PNK® method, Barcelona, Spain). This program consists of high-biological-value protein products and whole natural foods. Each protein food provides 90-120 kcal and it’s composed by 15 g protein, 4 g carbohydrate, 3 g fat, and 50 mg omega-3 DHA. The program consists of three phases: Intervention, dietary re-education, and maintenance (Table 1).

The intervention phase consists of a very low calorie diet (600–800 kcal/day), with a low content of carbohydrate (20–50 g/day), and fat (10 g/day of olive oil). The intake of high-biological-value protein is fixed around 0.8 and 1.2 g *per* kg ideal body weight *per* day, in order to ensure the coverage of protein requirements. The intervention phase is composed by 3 steps. In step 1, patients consume 5 protein servings at high-biological-value and 2 portions of vegetables. The permitted vegetables are divided into two groups. Vegetables in group A have a very low glycemic index and include chard, celery, watercress, borage, broccoli, soybean sprouts, zucchini, lamb’s lettuce, cauliflower, chicory, spinach, turnip greens, fennel, lettuce, cucumber, pickled gherkins, green peppers, mushrooms, radishes, and rocket; consumption of these vegetables is not limited. Vegetables in group B have a low glycemic index and include artichoke, eggplant, cabbage, asparagus, green beans, turnip, yellow and red peppers, leeks, and tomatoes; consumption is limited to 100 g *per* day.

During step 2, a natural protein serving (100-150 g of meat, poultry, fish, or seafood, canned tuna in brine or two eggs) is consumed in place of one of the protein preparation, at lunch or dinner. Patients will therefore be consuming four high-biological-value protein preparations *per* day.

In step 3, a fresh source of protein is introduced at both lunch and dinner, choosing between 100-150 g of meat, poultry, fish, seafood, canned tuna in brine, or two eggs. In step 3, patients are therefore eating three high-biological-value protein preparations *per* day.

During the intervention phase, vitamin and mineral supplementation is provided in accordance with international requirements[18]. The composition is shown in Table 2.

During the dietary treatment, the patient followed a specially recommended physical activity program. During step 1, 2, and 3 the recommended physical activity is anaerobic, with toning exercises to be performed preferably in the morning, at least 2 or 3 times a week; each exercise should be performed for 3 sets, with one minute of rest between sets, for a total of 30 min of physical activity. In steps 4 and 5, in addition to toning exercises to be performed at least 2-3 times a week, cardiovascular activity, such as walking or exercise bike of gentle or moderate intensity, is planned for about 50-60 min, twice a week.

During the VLCKD the patient didn’t need to take the recommended medications.

**OUTCOME AND FOLLOW-UP**

After the VLCKD period, the patient has been administered with a low-calorie diet; she reduced her BMI from I class obesity to overweight. Telephone contacts with the patient continue and new check-ups will be scheduled in order to monitor body weight.

**DISCUSSION**

After two months, at the first follow-up visit, body weight remained unchanged (Table 3) and the patient reported increasing joint pain, for which the rheumatological team introduced hydroxychloroquine 200 mg/day. The patient was not satisfied with either the treatment or the dietary plan.

Given the failure of the low-calorie balanced diet, the nutrition team decided to switch to a VLCKD (the PNK® method). The patient received multidisciplinary support from doctors, physical activity instructors, and nutritionist-coaches throughout follow-up.

The VLCKD intervention was started in early 2022, with a body weight of 79.9 kg. In step 1, the patient lost 8 kg, from 79.9 kg to 72 kg, the WC decreased from 82 cm to 75 cm, and the body composition improved, with a reduction in FM, from 29.4 kg (36.9%) to 25.3 kg (35.1%), and VAT, from 3.8 kg to 3.0 kg. At the follow-up visit at the end of step 1, the patient reported a subjective feeling of well-being and the headaches had ceased.

Step 2 started in February 2022 and led to a further loss of about 4 kg (Table 3). At the follow-up visit at the end of step 2, the patient reported tolerance of the dietary plan and that she performed the physical activity as defined in the PNK program. Her sleep pattern and quality had improved, as had her joint pain, and there had been no recurrence of the headaches. Body weight was 69 kg and the WC 72 cm; FM and the VAT decreased to 23.2 kg and 2.7 kg, respectively (Table 3).

The patient next moved to step 3 in April 2022. Body weight remained unchanged (69 kg) (Table 3). Contact with the patient took place by telephone, hence body composition measurements were not possible.

The patient did not lose weight during two weeks of step 3, and the nutrition team therefore decided to progress to step 4 (dietary re-education phase), moving the patient to a low-calorie diet to favor dietary compliance. During this stage the patient regained some of the weight she had lost, reaching a weight of 72.8 kg (Table 3).

Step 5 was initiated in June 2022 after the patient had completed step 4 and during this final step of the weight-loss phase, the weight remained practically unchanged (Table 3). Contact was by telephone, so again it was not possible to perform body composition analysis. The patient reported a feeling of well-being and good sleep quality, and there was no sensation of hunger.

Despite slight weight regain, the patient reported feeling better than before undertaking the VLCKD. We consider that this effect may be due as much to the beneficial effects of the nutritional ketosis or even the anti-inflammatory effect of the omega-3 DHA supplementation as to the weight loss. The serum inflammatory markers before and during the VLCKD are shown in Table 4.

A blood test was taken during the VLCKD and showed the following: Lupus anticoagulant, negative; silica clotting time ratio, 0.96; Russel’s viper venom time ratio, 1.05; ferritin, 10 ng/mL; erythrocyte sedimentation rate (ESR), 31 mm/h; complement component C3, 1.15 g/L; complement component C4, 0.19 g/L; rheumatoid factor, < 20 IU/mL, and C-reactive protein (CRP), < 5 mg/L. Protein electrophoresis trace did not reveal the presence of abnormal monoclonal components and the interferon-gamma release assay was negative.

The administration of a VLCKD would appear to improve all the parameters evaluated in order to assess inflammatory profile. In particular it’s noteworthy the reduction of CRP values from 17 mg/L up to the normal range. Similar results were obtained by previous studies conducted in obese[14] and overweight subjects[18].

Anthropometric parameters at baseline and their changes during the dietary treatment are shown in Table 3.

Considering the entire weight loss diet therapy program, from the beginning to the end of the ketogenic phase, the patient lost 5.3 kg (from 78.3 to 73), with a greater weight loss at the end of steps 2 and 3 (-9.3 kg), always going to improve her wellbeing. In steps 4 and 5 the patient gained 4 kg but it is very interesting to note how the improvement in body composition obtained during weight loss phase (with reduction of FM and preservation of fat free mass) has been maintained over time (step 4 and 5).

Finally, also the VAT, which is a well-known cardiovascular risk factor producing chronic low-grade inflammation[19], has significantly reduced (-600 g) from the beginning to the end of dietary program.

The goal of healthy weight loss was therefore achieved, since weight reduction has mainly affected FM, while lean mass was mostly preserved.

**CONCLUSION**

The VLCKD allowed the patient to achieve her target body weight (reducing from class I obesity to overweight), with an improvement in her joint pain and the episodes of headache, and an improvement in serum inflammatory markers (reduction in CRP from 17 mg/L to 5 mg/L and ESR from 95 mm/h to 31 mm/h).

**REFERENCES**

1 **Cooder HR**. Epilepsy in Children: With Particular Reference to the Ketogenic Diet. *Cal West Med* 1933; **39**: 169-173 [PMID: 18742621]

2 **Caprio M**, Infante M, Moriconi E, Armani A, Fabbri A, Mantovani G, Mariani S, Lubrano C, Poggiogalle E, Migliaccio S, Donini LM, Basciani S, Cignarelli A, Conte E, Ceccarini G, Bogazzi F, Cimino L, Condorelli RA, La Vignera S, Calogero AE, Gambineri A, Vignozzi L, Prodam F, Aimaretti G, Linsalata G, Buralli S, Monzani F, Aversa A, Vettor R, Santini F, Vitti P, Gnessi L, Pagotto U, Giorgino F, Colao A, Lenzi A; Cardiovascular Endocrinology Club of the Italian Society of Endocrinology. Very-low-calorie ketogenic diet (VLCKD) in the management of metabolic diseases: systematic review and consensus statement from the Italian Society of Endocrinology (SIE). *J Endocrinol Invest* 2019; **42**: 1365-1386 [PMID: 31111407 DOI: 10.1007/s40618-019-01061-2]

3 **Muscogiuri G**, Barrea L, Laudisio D, Pugliese G, Salzano C, Savastano S, Colao A. The management of very low-calorie ketogenic diet in obesity outpatient clinic: a practical guide. *J Transl Med* 2019; **17**: 356 [PMID: 31665015 DOI: 10.1186/s12967-019-2104-z]

4 **Muscogiuri G**, El Ghoch M, Colao A, Hassapidou M, Yumuk V, Busetto L; Obesity Management Task Force (OMTF) of the European Association for the Study of Obesity (EASO). European Guidelines for Obesity Management in Adults with a Very Low-Calorie Ketogenic Diet: A Systematic Review and Meta-Analysis. *Obes Facts* 2021; **14**: 222-245 [PMID: 33882506 DOI: 10.1159/000515381]

5 **Puchalska P**, Crawford PA. Multi-dimensional Roles of Ketone Bodies in Fuel Metabolism, Signaling, and Therapeutics. *Cell Metab* 2017; **25**: 262-284 [PMID: 28178565 DOI: 10.1016/j.cmet.2016.12.022]

6 **Newman JC**, Verdin E. Ketone bodies as signaling metabolites. *Trends Endocrinol Metab* 2014; **25**: 42-52 [PMID: 24140022 DOI: 10.1016/j.tem.2013.09.002]

7 **Shimazu T**, Hirschey MD, Newman J, He W, Shirakawa K, Le Moan N, Grueter CA, Lim H, Saunders LR, Stevens RD, Newgard CB, Farese RV Jr, de Cabo R, Ulrich S, Akassoglou K, Verdin E. Suppression of oxidative stress by β-hydroxybutyrate, an endogenous histone deacetylase inhibitor. *Science* 2013; **339**: 211-214 [PMID: 23223453 DOI: 10.1126/science.1227166]

8 **Cheng CW**, Biton M, Haber AL, Gunduz N, Eng G, Gaynor LT, Tripathi S, Calibasi-Kocal G, Rickelt S, Butty VL, Moreno-Serrano M, Iqbal AM, Bauer-Rowe KE, Imada S, Ulutas MS, Mylonas C, Whary MT, Levine SS, Basbinar Y, Hynes RO, Mino-Kenudson M, Deshpande V, Boyer LA, Fox JG, Terranova C, Rai K, Piwnica-Worms H, Mihaylova MM, Regev A, Yilmaz ÖH. Ketone Body Signaling Mediates Intestinal Stem Cell Homeostasis and Adaptation to Diet. *Cell* 2019; **178**: 1115-1131.e15 [PMID: 31442404 DOI: 10.1016/j.cell.2019.07.048]

9 **Kong G**, Liu J, Li R, Lin J, Huang Z, Yang Z, Wu X, Huang Z, Zhu Q, Wu X. Ketone Metabolite β-Hydroxybutyrate Ameliorates Inflammation After Spinal Cord Injury by Inhibiting the NLRP3 Inflammasome. *Neurochem Res* 2021; **46**: 213-229 [PMID: 33108630 DOI: 10.1007/s11064-020-03156-2]

10 **Kong G**, Huang Z, Ji W, Wang X, Liu J, Wu X, Huang Z, Li R, Zhu Q. The Ketone Metabolite β-Hydroxybutyrate Attenuates Oxidative Stress in Spinal Cord Injury by Suppression of Class I Histone Deacetylases. *J Neurotrauma* 2017; **34**: 2645-2655 [PMID: 28683591 DOI: 10.1089/neu.2017.5192]

11 **Korte SM**, Straub RH. Fatigue in inflammatory rheumatic disorders: pathophysiological mechanisms. *Rheumatology (Oxford)* 2019; **58**: v35-v50 [PMID: 31682277 DOI: 10.1093/rheumatology/kez413]

12 **Gabay C**, McInnes IB. The biological and clinical importance of the 'new generation' cytokines in rheumatic diseases. *Arthritis Res Ther* 2009; **11**: 230 [PMID: 19519923 DOI: 10.1186/ar2680]

13 **Ciaffi J**, Mitselman D, Mancarella L, Brusi V, Lisi L, Ruscitti P, Cipriani P, Meliconi R, Giacomelli R, Borghi C, Ursini F. The Effect of Ketogenic Diet on Inflammatory Arthritis and Cardiovascular Health in Rheumatic Conditions: A Mini Review. *Front Med (Lausanne)* 2021; **8**: 792846 [PMID: 34970568 DOI: 10.3389/fmed.2021.792846]

14 **Rondanelli M**, Perna S, Ilyas Z, Peroni G, Bazire P, Sajuox I, Maugeri R, Nichetti M, Gasparri C. Effect of very low-calorie ketogenic diet in combination with omega-3 on inflammation, satiety hormones, body composition, and metabolic markers. A pilot study in class I obese subjects. *Endocrine* 2022; **75**: 129-136 [PMID: 34532829 DOI: 10.1007/s12020-021-02860-5]

15 **Moreno B**, Bellido D, Sajoux I, Goday A, Saavedra D, Crujeiras AB, Casanueva FF. Comparison of a very low-calorie-ketogenic diet with a standard low-calorie diet in the treatment of obesity. *Endocrine* 2014; **47**: 793-805 [PMID: 24584583 DOI: 10.1007/s12020-014-0192-3]

16 **de Luis D**, Domingo JC, Izaola O, Casanueva FF, Bellido D, Sajoux I. Effect of DHA supplementation in a very low-calorie ketogenic diet in the treatment of obesity: a randomized clinical trial. *Endocrine* 2016; **54**: 111-122 [PMID: 27117144 DOI: 10.1007/s12020-016-0964-z]

17 **World Health Organization (WHO) Technical Report Series 894**. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. [cited 10 October 2022]. Available from: https://www.who.int/

18 **Merra G**, Gratteri S, De Lorenzo A, Barrucco S, Perrone MA, Avolio E, Bernardini S, Marchetti M, Di Renzo L. Effects of very-low-calorie diet on body composition, metabolic state, and genes expression: a randomized double-blind placebo-controlled trial. *Eur Rev Med Pharmacol Sci* 2017; **21**: 329-345 [PMID: 28165552]

19 **Magnuson AM**, Fouts JK, Regan DP, Booth AD, Dow SW, Foster MT. Adipose tissue extrinsic factor: Obesity-induced inflammation and the role of the visceral lymph node. *Physiol Behav* 2018; **190**: 71-81 [PMID: 29501838 DOI: 10.1016/j.physbeh.2018.02.044]

**Footnotes**

**Informed consent statement:** Informed consent was obtained from the participant in the study.

**Conflict-of-interest statement:** I.S. and R.M. are employed by PronoKal Group. The remaining authors declare no conflict of interest.

**CARE Checklist (2016) statement:** The authors have read the CARE Checklist (2016), and the manuscript was prepared and revised according to the CARE Checklist (2016).

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: https://creativecommons.org/Licenses/by-nc/4.0/

**Provenance and peer review:** Unsolicited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review started:** October 20, 2022

**First decision:** October 31, 2022

**Article in press:**

**Specialty type:** Medicine, research and experimental

**Country/Territory of origin:** Italy

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): 0

Grade C (Good): C, C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Kotlyarov S, Russia; Xie Y, China **S-Editor:** Fan JR **L-Editor:** A **P-Editor:** Fan JR

**Table 1 Structure of the PronoKal PnK method**

|  |  |  |
| --- | --- | --- |
| **Intervention (80% of the target weight loss)** | **Dietary re-education (20% of the target weight loss)** | **Maintenance** |
| Weight loss | New lifestyle |
| Step 1: 40% of the target weight loss | Step 2: 20% of the target weight loss | Step 3: 20% of the target weight loss | Step 4: 10% of the target weight loss | Step 5: 10% of the target weight loss |
| Very low calorie ketogenic diet (630-700 kcal/day) | Low-calorie diet (800-1500 kcal/day) | Balanced diet (1500-2000 kcal/day) |

**Table 2 Composition of the vitamin and mineral supplementation during the very low calorie ketogenic diet**

|  |  |
| --- | --- |
|  | **In 2 sachets** |
| Vitamin A (μg) | 800  |
| Vitamin D (μg) | 5  |
| Vitamin E (mg) | 12  |
| Vitamin K (μg) | 75  |
| Vitamin C (mg) | 80  |
| Thiamine (mg)  | 1.1 |
| Riboflavin (mg)  | 1.4 |
| Niacin (mg)  | 16 |
| Vitamin B6 (mg)  | 1.4 |
| Folic acid (μg)  | 200 |
| Vitamin B12 (μg)  | 2.5 |
| Biotin (μg)  | 50 |
| Pantothenic acid (mg) | 6 |
| Potassium (mg) | 2000 |
| Calcium (mg) | 800 |
| Magnesium (mg) | 375 |
| Iron (g) | 14 |
| Zinc (mg) | 10 |
| Copper (mg) | 1 |
| Manganese (mg) | 1 |
| Selenium (μg) | 55 |
| Chrome (μg) | 40 |
| Molybdenum (μg)  | 50 |
| Iodine (μg) | 150 |

**Table 3 Changes in the anthropometric parameters during dietary treatment**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Base-line** | **First follow-up visit during LCD** | **Second follow-up visit during LCD** | **VLCKD, end Step 1** | **VLCKD, end Step 2** | **End of step 3 of intervention phase** | **End of step 4 of intervention phase** | **End of step 5 of intervention phase** |
| Body weight (kg) | 78.3 | 78 | 79.9 | 72 | 69 | 69 | 72.8 | 73 |
| BMI (kg/m2) | 30.8 | 30.7 | 31.3 | 28.3 | 27.1 | 27.1 | 28.6 | 28.7 |
| Waist circumference (cm) | 80 | 80 | 82 | 75 | 72 | / | 73 | 73 |
| Fat mass (%) | 35.9 | 35.6 | 36.9 | 35.1 | 33.6 | / | 33.7 | / |
| Fat mass (kg) | 28.1 | 27.8 | 29.4 | 25.3 | 23.2 | / | 24.5 | / |
| Fat free mass (kg) | 45.7 | 45.8 | 45.7 | 42.6 | 41.9 | / | 44.2 | / |
| VAT (kg) | 3.5 | 3.4 | 3.8 | 3.0 | 2.7 | / | 2.9 | / |

LCD: Low-calorie diet; VLCKD: Very low calorie ketogenic diet; VAT: Visceral adipose tissue.

**Table 4 Serum inflammatory markers during dietary treatment**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **During the LCD** | **During the VLCKD** | **Laboratory reference range** |
| Erythrocyte sedimentation rate (mm/h) | 95 | 31 | < 15 |
| C-reactive protein (mg/L) | 17 | < 5 | < 5 |
| Complement component C3 (g/L) | 1.34 | 1.15 | 0.90-1.80 |
| Complement component C4 (g/L) | 0.26 | 0.19 | 0.10-0.40 |
| Silica clotting time (ratio) | 1.08 | 0.96 | ≤ 1.16 |
| Russell’s viper venom time (ratio) | 1.24 | 1.05 | < 1.20 |

LCD: Low-calorie diet; VLCKD: Very low calorie ketogenic diet.