ARTICLE

Cite This: J. Of Food Sci. and Nutri. Disord.2021, 1, 8-15

SciForce

Journal of Food Science and Nutritional Disorders

Journal homepage: www.sciforce.org

Traditional weight loss and dukan diets as to nutritional and laboratory results

Patricia Naomi Sakae,[1,2] Anita L. R Saldanha,[3] Francisco Antonio Helfenstein Fonseca,[2] Henrique Trial Bianco,[2] Luciano Monteiro Camargo,[2] Maria Cristina de Oliveira Izar,[2] Ana Paula Pantoja Margeotto,[3] Andre L. Valera Gasparoto,[4] Bruno Abdala,[3] Tania Leme da Rocha Martinez,[3,*] Silvia Saiuli Miki Ihara[1]

[1] *Department of Pathology, Universidade Federal de São Paulo, São Paulo, Brazil*

[2] *Department of Medicine. Lipids, Atherosclerosis and Vascular Biology Division. Universidade Federal de São Paulo, São Paulo, Brazil*

[3] *Nephrology Department, BP - A Beneficência Portuguesa de São Paulo, São Paulo, Brazil*

[4] *Intensive Care Unit, BP - A Beneficência Portuguesa de São Paulo, São Paulo, Brazil*

ARTICLE INFO

Article history:
Received: 20210501
Received in revised form: 20210515
Accepted: 20210515
Available online: 20210617

Keywords:
Obesity;
Weight loss;
Anthropometry
Laboratory parameter

ABSTRACT

Background and Aims: Dukan diet, a popular diet with high content of protein and carbohydrate and fat restriction has been widely used for weight loss. We aimed to compare the effects of the Dukan diet with traditional low-calorie diet in nutritional, laboratory and vascular parameters in obese subjects. Methods and Results: Obese subjects classes I or II of both genders, aging 19 to 65 years were allocated into two groups: Traditional low-calorie diet (n=17) and Dukan Diet (n=17). Anthropometric, laboratory and vascular evaluations were performed at baseline, 3, 6 and 12 months. Body composition was evaluated by bioelectric impedance and endothelial function by flow-mediated dilation of the brachial artery, at same times. After 12 months, it was verified that Dukan diet was more effective ($p<0.05$) than traditional diet for: weight loss (-10.6 vs -2.9 kg), body mass index (-3.7 vs -1.1 kg/m^2), waist circumference (-11.2 vs -2.1 cm), fat (-5.7 vs -2.0 kg) and lean mass (-4.8 vs 0.8 kg) and basal metabolic rate (-152 vs -28 cal). In Dukan diet group, improvement ($p<0.05$ vs baseline) was observed in triglyceride levels (172.40 to 111.90 mg/dL) and insulin resistance, based on HOMA-IR index (4.98 to 3.26). The glomerular filtration rate decreased in this group after 3 months (132.50 to 113.80 mL/min) and no changes in flow-mediated dilation were observed throughout the study with both diets. Conclusion: Dukan diet was more effective than traditional diet for weight loss and laboratory parameters and without changes in endothelial function, in the 12-months follow-up of obese subjects.

*Corresponding author. Tel.: 55 11 98323-9863; fax: 55 11 3842-3789; e-mail: tamar@uol.com.br

Introduction

Low-carbohydrate diets have been one of the most recently used dietary therapies in patients with diabetes and obesity in clinical studies.[1] Among them, in addition to carbohydrate restriction, fat restriction and high protein concentration, as in the Diet Dukan, has been widely used by the general population, aiming at weight loss. The Dukan diet is designed to reduce carbohydrate and fat intake in the first phase of the diet, with exclusive intake of protein, followed by another three phases, with progressive and slow reintroduction of other nutrients such as fiber, carbohydrates and fats.

In recent years, there has been increasing interest in the effectiveness of very low carbohydrate diets, called ketogenic diets, in the effectiveness of weight loss in order to combat obesity and cardiovascular disease risk.[2] In this diet, ketone bodies are formed and they are used as an alternative energy source in the absence of glucose. Ketogenic diet promotes weight loss reducing appetite, increasing satiety and thermogenesis, due to the high protein consumption[3] affect hormones that control appetite, such as ghrelin and leptin[4] reduces lipogenesis and increases lipolysis[5-6] and gluconeogenesis.[7]

Replacing carbohydrates by proteins in the diet have been the aim of several studies but with inconsistent results. High protein intake has positive effects on weight loss, acting on satiety, body composition, lipid profile and glucose homeostasis. Furthermore, it increases thermogenesis, energy expenditure[8] and the elevation in the amino acid level in the plasma acts on the satiety center, decreasing appetite, since amino acids also stimulate insulin secretion resulting in decreased or maintained blood glucose levels.[9]

Few studies have been published with Dukan diet. Freeman et al. were the first to publish an article with the Dukan Diet in 2014, describing adverse effects in one patient undergoing this diet.[10] Nouvenne et al. reviewed studies about the influence of popular diets on kidney stone formation risk. In this article, the authors suggest that in the Dukan diet, due to the high consumption of animal protein, urinary calcium can increase and the citrate urinary excretion can decrease, increasing the risk of kidney stone formation.[11] In 2015, Wyka et al. evaluated dietary consumption in women adopting the Dukan-diet, based on the menu consumed in each of 4 phases of diet. They observed weight loss of around 15 kg after 8 to 10 weeks of diet and higher intake of proteins, mainly of animal origin, high consumption of potassium, iron and vitamins A, D and B2 and reduced consumption of carbohydrates, vitamin C and folates. They suggest that this diet may be harmful to health if adopted for a long time, developing of kidney and liver disease, osteoporosis and cardiovascular disease.[12]

Considering that the Dukan Diet is widely disseminated and it is used by the population in general for weight loss and few scientific studies are found in the literature, we propose to evaluate the nutritional, laboratory parameters related to cardiovascular disease, comparing this diet with traditional hypocaloric diet in obese individuals.

Abbreviations

BIA, Bioelectric Impedance; **BMI**, Body Mass Index; **FMD**, Flow-Mediated Dilation; **GFR**, Glomerular Filtration Rate; **LDL-c**, Low-Density Lipoprotein Cholesterol; **TD**, Traditional Low-Calorie Diet

Methods

Study design

This study was a clinical trial with nutritional intervention, for one year. Patients were recruited from the Lipids, Atherosclerosis and Vascular Biology Division of the Universidade Federal de São Paulo (UNIFESP). The study conforms to the ethical guidelines and approval was obtained from the ethics committee and it was registered in the Brazilian Registry of Clinical Trials. All participants provided written informed consent and received no monetary incentive. A total of 40 subjects were initially recruited and the participants were followed up clinically by a cardiologist and nutritionist during the 12-month period with monthly visits. Of the 40 participants who started the study, 34 completed the 12-month follow-up, whose data are presented in this study. The inclusion criteria were: both genders, aging 19-65 years old, obesity grade I or II (body mass index between 30 kg/m² and 39.9 kg/m²), stable body weight in the previous 3 months and desire to lose weight. The main exclusion criteria were: patients in primary or secondary prevention of coronary heart disease with low-density lipoprotein cholesterol (LDL-C) levels greater than 190 mg/dL and triglycerides greater than 400 mg/dL; diabetes mellitus; untreated hypothyroidism; psychiatric and hepatic disease; chronic renal failure; cardiac and respiratory insufficiency; systemic infections; use of antidepressants, corticoids, diuretics and diabetes medications; bariatric surgery, cancer and failure to accept the conditions necessary to conduct the research. Two groups were constituted: Traditional low-calorie diet (TD): n=17, 14 females and 3 males, 45±11 years old, 90±11 Kg body weight and body mass index (BMI) 34±2Kg/m²; High protein/Low carbohydrate diet-Dukan Diet (DD): n=17, 10 females and 7 males, 38±11 years old, 95±9 Kg of body weight and BMI 34±2 Kg/m². The TD group received orientations according to the Food Guideline for the Brazilian Population, with 1 500–1 800 calories/day. They were stimulated to improve healthy eating habits increasing the consumption of natural foods without preservatives, such as vegetables and fruits rich in fiber and antioxidants. Daily consumption of fruits and vegetables at meals was recommended; carry out the fractionation of the meals throughout the day, avoiding prolonged fasting. Hydration and regular physical activity were recommended, according to healthier life habits.[13] The DD group followed the high-protein/low-carbohydrate diet as proposed by Dukan Diet, available at https://www.dietadukan.com.br and received an illustrated book about this diet.[14]

This diet is structured in four phases: two for weight loss (1st and 2nd phases) and two for weight maintenance (3rd and 4th phases):

1st stage - Attack: For 5 consecutive days, it is allowed to consume only proteins with lean meats, eggs, light cheese and milk, 1.5 tablespoons of oat bran per day and light physical activity for 20 minutes.

2nd stage - Cruise: This phase is maintained until the desired weight loss. The vegetables are introduced alternating with the pure protein day (first stage). It is recommended 2 tablespoons of oat bran per day and light physical activity for 30 minutes.

3rd phase - Consolidation: The time of this phase is equivalent to 10 days per kg of lost weight. In this stage carbohydrates and lipids are introduced by a controlled and moderate way, being divided in two parts: in the first part, corresponding to half of the period to be followed, is allowed: 1 fruit, 2 slices of bread (50 g) or 1 spoon of farinaceous per day and 1 gala dinner per week. In the second part, it is allowed 2 fruits, 4 slices of bread (100 g) or 2 spoons of farinaceous per day and 2 gala dinners per week. This phase has one rule: make one day of the week with pure protein (first stage) and it is recommended 2.5 tablespoons of oat bran per day and light physical activity for 35 minutes.

4th phase - Stabilization: In this phase, three rules must to be followed: one day a week it should follow up the pure protein diet, the daily consumption of 3 tablespoons of oat bran and at least 40 minutes of daily walking. From this phase, the participants followed up the low calorie diet.

The adherence of the participants was monitored by the interview with the nutritionist and qualitative evaluation of ketone bodies in the urine, using Lab test Uri Action 10 reagent strips. At baseline, 3, 6 and 12 months, the following evaluations were performed: nutritional assessment determining anthropometry, blood samples were collected for laboratory tests. Endothelial function was evaluated in fasting and 2-hours post prandial situations. In the periods between the predetermined visits, the participants were followed up by the nutritionist monthly and by telephone contact whenever requested and with medical attention whenever necessary.

Nutritional evaluation

Nutritional assessment was performed by anthropometric determinations of weight, height, BMI, abdominal circumference and bioelectric impedance (BIA). BIA was carried out using the Biodynamics Model 450 TBW® apparatus, with portable plethysmograph and patients were instructed according to the manufacturer's instruction.[15]

Laboratory parameters

Peripheral blood samples were collected for dosages of total cholesterol and fractions, triglycerides, glucoses, insulin, iron, ferritin, ALT, AST, urea, creatinine, hemoglobin and hematocrit. Biochemical parameters were determined through the automated colorimetric enzymatic method in Cobas Mira® (Roche, Switzerland) and LDL-c was estimated by the Friedewald equation. Serum insulin concentration was determined by immunofluorometry and the insulin resistance calculated by the HOMA-IR – Homeostasis Model Assessment Insulin Resistance, and values ≥ 2.5 values were considered as presence of insulin resistance.[16] Glomerular Filtration Rate (GFR) was estimated by the Cockroft-Gault equation adapted to obese patients.[17]

Endothelial function

Endothelial function was assessed by Endothelial-dependent flow-mediated dilation (FMD) of the brachial artery[18], using an ultrasound system (Sonos5500; Hewlett-Packard-Phillips, Palo Alto, CA), equipped with vascular software for two-dimensional imaging, color and spectral Doppler ultrasound modes, internal electrocardiogram monitor and linear-array transducer with a frequency range from 7.5 to 12.0 MHz.

FMD evaluation was performed in two stages: fasted at least 6 hours and 2 hours after the consumption of a small meal, according to each diet. These meals were consisted of 374.04 calories, 36g proteins, 16g carbohydrates and 18g lipids in the DD and in TD, it was composed by 361.20 calories, 24g of protein, 41g of carbohydrates and 11g of lipids.

Statistical Analysis

The variables were expressed as mean and standard deviation. The distribution of the date normality was analyzed by the Kolmogorov-Smirmov (KS) test. When they did not present normal distribution, a logarithm [log(Y)] transformation was performed prior to analysis. The comparison between the variables of two groups was performed using Student's t-test for independent numerical variables and Fisher's exact test for categorical variables. Comparisons between more than two groups were performed by analysis of variance (ANOVA) for repeated measures, followed by the Tukey test, if differences were found. For the sample power calculation, the Statistical Software, Statistica Ultimate Academic, version 12.7, Concurrent Network was used. Values of $p \leq 0.05$ were considered for statistical significance and analysis was performed using the software [GraphPadPrism 4.0 (GraphPad Software, San Diego, CA, USA)].

Results

Participants' characteristics

At the beginning of the study, the groups were matched for age, gender, weight and BMI. At 3 months, all participants of DD group (100%) were in phase 2; at 6 months, 13 participants (76.4%) were in phase 3 and 4 (23.5%) in phase 2; and at 12 months, all (100%) were already in phase 4. The TD group followed the same recommendation during the 12 months. The qualitative evaluation of the presence of ketone bodies in the urine of the DD group participants, which were still in phase 2, was positive in 94% at 3rd month and 80% at the 6th month. The following adverse effects have been reported during the course of the study: weakness, fatigue, dizziness, lack of concentration, irritability, constipation, ketone breath and social life impairment. These symptoms were of low intensity and transient, especially in the early stages of the DD diet. These adverse effects were not causes for withdrawal from the study.

Anthropometry

The changes in body weight, BMI, waist abdominal circumference and BMR were more effective in DD than TD group during all follow-up evaluations. The changes after 12 months in relation to baseline of the anthropometric parameters in the DD and DT groups respectively were: Weight loss (-10.6 Kg, $p<0.0001$ and – 2.9 Kg, $p<0.0001$), BMI (-3.7 Kg/m^2, $p<0.0001$ and -1.1 Kg/m^2, $p<0.0001$), waist abdominal circumference (-11.2 cm, $p<0.0001$ and -2.1 cm, $p=0.0008$) and BMR (-152 cal, $p<0.0001$ and -28 cal, $p=0.0198$). After 12 months, the participants of DD group reached the overweight level but the TD group was still within the obesity range (Figure 1). Reductions were observed in both groups, in fat mass (-5.7 Kg, $p<0.0001$ and -2.0 Kg, $p<0.0001$), and in lean mass (-4.8 Kg, $p<0.0001$ and -0.8 Kg, $p=0.0196$, in DD and DT group, respectively) (Figure 2).

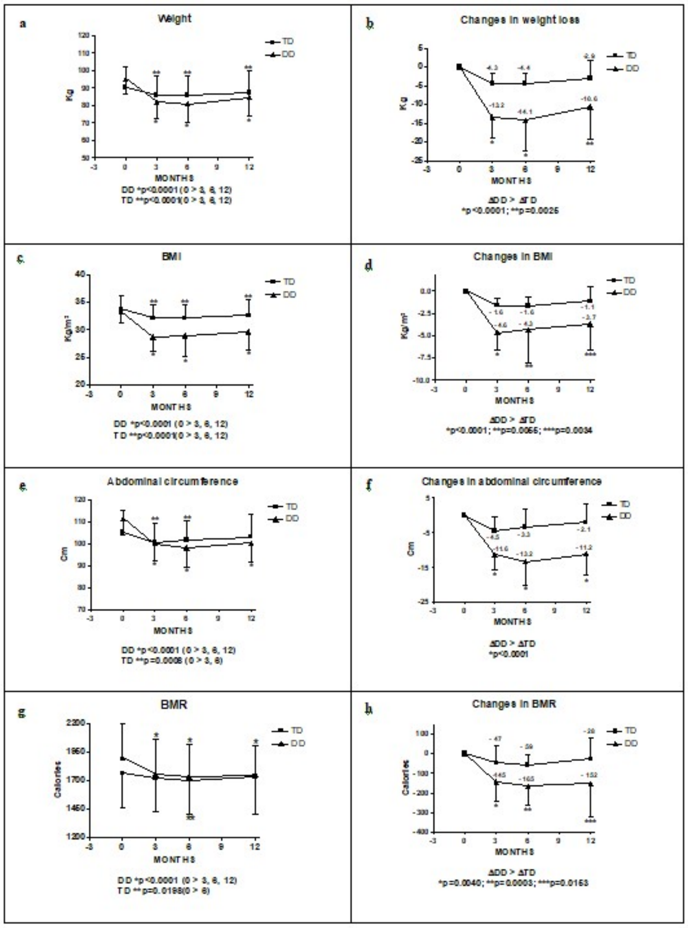


Figure 1. Evaluation of weight loss of traditional diet and Dukan diet groups

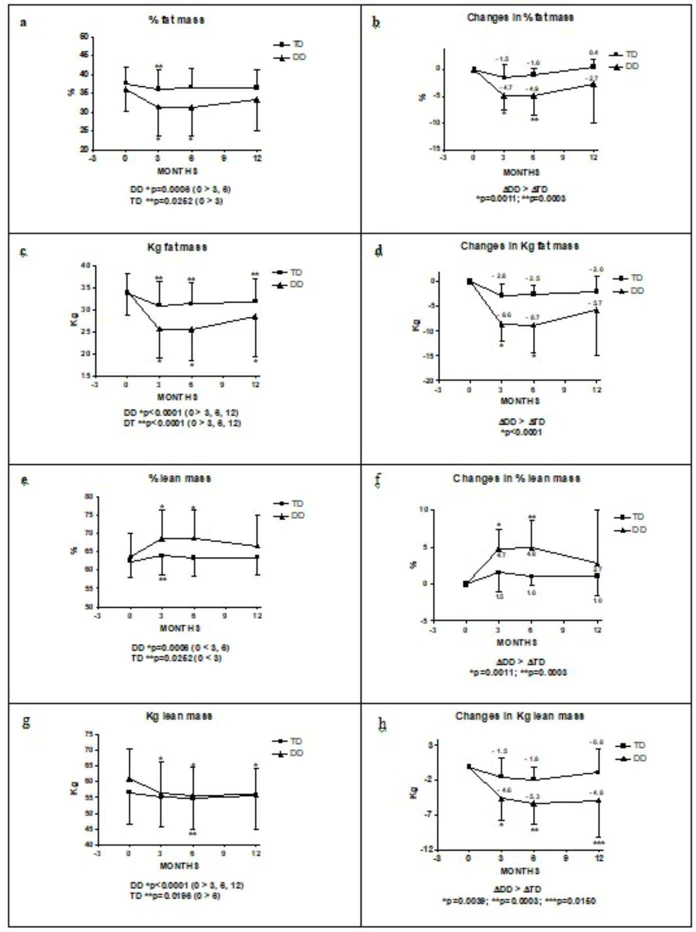
Variations of weight (a), body mass index (c), abdominal circunference (e) and basal metabolic rate (g) in 0, 3, 6 and 12 months of follow-up. Changes (Δ) in relation to the initial value of weight (b), body mass index (d), abdominal circunference (f) and basal metabolic rate (h). Dukan diet was more effective than traditional diet in all parameters analyzed.

*; ** and *** p <0.05. Statistical analysis by ANOVA of repeated measures followed by Tukey's test to compare variations throughout the follow-up in each group and Student's t-test to compare the changes between two diets

Figure 2. Evaluation of fat and lean mass (% e Kg) by impedance in traditional diet and Dukan diet groups

Variations of fat mass in % (a) and in Kg (c) and lean mass in % (e) and in Kg (g) in 0, 3, 6 and 12 months of follow-up. Changes (Δ) in relation to the initial value of fat mass % (b), fat mass Kg (d), leans mass % (f) and lean mass Kg (h). Differences between two groups were observed mainly until 6 months.

*; ** and *** p <0.05. Statistical analysis by ANOVA of repeated measures followed by Tukey's test to compare variations throughout the follow-up in each group and Student's t-test to compare the changes between two diets.



Laboratory parameters and endothelial function

In TD group, there was only hematocrit reduction after 6 months (p=0.0103) and glucose level after 3 months (p=0.0021) compared to baseline (Table 1). In DD group, laboratory alterations occurred in relation to hemoglobin, hematocrit, triglycerides, insulin, HOMA-IR and GFR. It was observed an improvement in the triglycerides levels (172.40 ± 62.36 mg/dL and 111.90 ± 43.22 mg/dL, p=0.0001) and insulin resistance determined by HOMA-IR at all times of study (4.98 ± 3.03 and 3.26 ± 2.03, p=0.0008) at baseline and 12 months, respectively. GFR was reduced only after 3 months (132.50 ± 31.13 and 113.80 ± 24.25 mL/min, p=0.0063) in the DD group (Table 2). No differences were observed in endothelial function in the two study groups, in both fasting and postprandial (Figure 3).

Table 1. Laboratory parameters of the TD group at 0, 3, 6 and 12 months.

TRADITIONAL DIET (n = 17)					
	0	**3**	**6**	**12**	**p**
Hb (g/dL)	13.84±1.43	13.65±1.09	13.40±1.18	13.61±0.97	0.0652
Ht (%)	41.56±3.39	41.12±2.88	39.85±3.24	40.95±2.60	**0.0103* (0>6)**
Iron (mcg/dL)	103.20±29.18	90.89±25.59	93.44±30.58	82.33±20.29	0.3551
Ferritin (mcg/dL)	182.90±165.70	146.10±140.00	156.00±139.50	155.00±129.00	0.1167
AST (IU/L)	18.08±5.07	19.68±10.32	17.50±4.16	18.75±5.31	0.7935
ALT (IU/L)	22.83±15.77	22.08±17.08	18.67±7.31	23.67±10.40	0.6613
TC (mg/dL)	212.40±30.52	195.60±43.90	204.0±34.75	212.2±32.17	0.1381
HDL-c (mg/dL)	52.14±12.46	49.29±12.22	52.71±10.78	54.36±12.08	0.0738
LDL-c (mg/dL)	127.60±28.60	122.50±32.88	127.50±29.18	135.10±28.96	0.3478
Not-HDL-c (mg/dL)	153.40±31.07	134.80±48.43	147.80±30.75	152.80±30.26	0.3227
TG (mg/dL)	112.50±33.06	102.70±41.65	102.80±38.34	101.00±29.41	0.4373
Glucose (mg/dL)	94.24±9.39	89.12±6.80	91.29±9.08	94.94±9.64	**0.0021* (0>3 and 3<12)**
Insulin (mg/dL)	17.23±6.01	12.31±5.89	12.04±4.11	14.35±6.80	0.1045
HOMA-IR	3.95±1.55	2.77±1.34	2.76±1.05	3.48±1.68	0.1350
Urea (mg/dL)	33.27±8.71	29.73±8.71	33.18±8.69	33.00±9.79	0.1381
Creatinin (mg/dL)	0.81±0.17	0.77±0.13	0.81±0.16	0.82±0.14	0.1421
GFR (mL/min)	117.10±24.17	120.50±29.21	114.50±27.59	114.30±27.34	0.3301

Numerical values are expressed as mean ± standard deviation.
Glucose level was reduced only after 3 months, whithout modifications in others biochemical parameters.
n: number of participants; Hb: hemoglobin; Ht: hematocrit; Vit: vitamin; AST: aspartate aminotransferase; ALT: alaninaminotransferase; TC: total cholesterol; HDL-c: high density lipoprotein cholesterol; LDL-c: low density lipoprotein cholesterol; TG: triglycerides; HOMA-IR: homeostasis model assessment insulin resistance; GFR: glomerular filtration rate
*p <0.05 - ANOVA of repeated measures and Tukey test.

Table 2. Laboratory parameters of Dukan diet group at 0, 3, 6 and 12 months.

DUKAN DIET (n = 17)					
	0	**3**	**6**	**12**	**P**
Hb (g/dL)	14.81±1.35	14.50±1.12	14.28±1.28	14.44±1.42	**0.0127* (0>6)**
Ht (%)	44.35±4.31	43.68±3.64	42.58±3.57	43.31±4.19	**0.0035* (0>6)**
Iron (mcg/dL)	101.70±28.53	91.10±35.14	121.80±47.07	91.50±44.60	0.0862
Ferritin (mcg/dL)	231.90±180.60	232.60±168.80	228.00±188.40	214.20±174.90	0.8513
AST (IU/L)	17.50±6.82	16.43±4.65	15.50±3.77	18.07±6.56	0.3550
ALT (IU/L)	23.55±21.81	22.18±14.51	19.45±8.53	24.45±14.98	0.7746
CT (mg/dL)	192.50±26.57	188.10±34.53	196.00±45.25	190.90±41.25	0.7678
HDL-c (mg/dL)	42.43±8.88	45.57±8.05	46.00±11.02	46.29±11.76	0.5095

LDL-c (mg/dL)	108.20±32.71	119.30±33.15	129.20±39.22	111.30±41.77	0.3182
Non-HDL-c (mg/dL)	156.70±26.81	149.50±39.42	167.30±39.14	151.20±47.76	0.4685
TG (mg/dL)	172.40±62.369	100.60±31.04	113.10±36.64	111.90±43.22	**< 0.0001* (0>3, 6 and 12)**
Glucose (mg/dL)	87.47±10.49	87.53±8.61	85.94±8.73	88.24±7.75	0.6012
Insulin (mg/dL)	22.29±12.62	11.81±4.94	11.33±5.03	14.51±8.30	**0.0003* (0>3, 6 and 12)**
HOMA-IR	4.98±3.03	2.67±1.28	2.45±1.12	3.26±2.03	**0.0008* (0>3, 6 and 12)**
Urea (mg/dL)	34.43±9.85	40.79±11.98	39.29±12.00	37.86±15.38	0.1873
Creatinin (mg/dL)	0.82±0.14	0.90±0.19	0.82±0.23	0.88±0.23	0.0834
GFR (mL/min)	132.50±31.13	113.80±24.25	127.80±36.93	120.70±32.24	**0.0063* (0>3)**

Numerical values are expressed as mean ± standard deviation.
In Dukan diet group, improvement in TG levels and Insulin resistance evaluated by HOMA-IR index were observed during the 12 months follow up. GFR was reduced after 3 months. Hematological changes have no clinical relevance.
n: number of participants; Hb: hemoglobin; Ht: hematocrit; Vit: vitamin; AST: aspartate aminotransferase; ALT: alaninaminotransferase; TC: total cholesterol; HDL-c: high density lipoprotein cholesterol; LDL-c: low density lipoprotein cholesterol; TG: triglycerides; HOMA-IR: homeostasis model assessment insulin resistance; GFR: glomerular filtration rate
*p <0.05 - ANOVA of repeated measures and Tukey test.

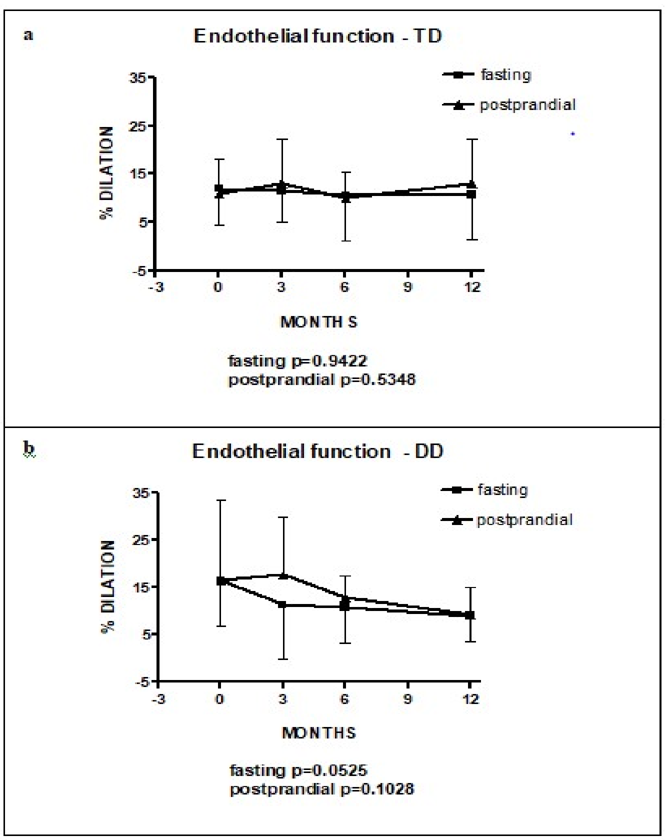


Figure 3. Endothelial function assessed by dilation of the flow-mediated brachial artery in fasting and 2 hours postprandial at 0,3, 6 and 12 months of follow up. a) Traditional diet group, b) Dukan diet group. No changes were observed in dilation of the flow-mediated brachial artery in the follow-up of both groups.

Statistical analysis by ANOVA of repeated measures followed by the Tukey test.

Discussion

This study demonstrated higher weight loss in the Dukan diet group, compared to the traditional low calorie diet. The effect of weight loss in the DD group was persistent and remained until 6th month, but in 12 months it was observed a gain around 3.41 ± 0.21 Kg. The DD is performed in phases, with severe restriction until the 3rd phase and at about the 6th month; carbohydrates and a gala meal are reintroduced, promoting a weight gain. Sacks et al. observed that regardless of the nutritional composition of the diet, obese participants that had a weight loss, after 12 months of treatment, they can gain weight, but with a reduction of approximately 11.4% of the initial weight.[19] We observed that participants of TD group also presented significant weight reduction, suggesting the effectiveness of the close follow up with nutritionist and physician.

Abdominal circumference is an indirect parameter of fat mass corresponding to visceral fat that is associated with a higher risk for cardiovascular diseases. In our data, we observed a reduction in waist circumference in both groups after 12 months. Moreno et al. comparing ketogenic diet with standard diet in a group of obese patients found an important reduction in abdominal circumference with partial recovery after 24 months.[20]

Although DEXA Scan is considered the gold standard for body composition determination, BIA is a non-invasive and relatively inexpensive method and widely used.[21] A significant reduction in the relative values of body fat was observed at 3 and 6 months in the DD group and only after 3 months in the TD. Increase in percent of lean mass was observed in the DD group at 3 and 6 months, but this increase does not represent a gain of lean mass, since the relative increase is a result of the reduction of body weight, promoting a relative increase in the values of lean mass. The loss of lean mass in the DD group may be due to the low caloric intake of the diet, as Chaston et al. (2007) pointed out that diet with low-calorie diet promote marked weight loss, but there is a decline in lean mass resulting from this process.[22] In our study, in spite of consuming a large amount of protein, this nutrient alone is not enough to promote the maintenance of lean mass and exercise stimulation is still necessary, which did not happen in this study, since the participants were all sedentary.

In obese individuals, weight gain after marked loss is common, with reduction in basal metabolic rate.[23] several studies have observed this phenomenon during rapid weight loss[24] and diets with low carbohydrate intake are among the factors that influence metabolic adaptation. Some studies suggest that low amounts of carbohydrate (<45%) decrease the basal metabolic rate during and after weight loss. This type of diet can promote fat mass loss and preservation of lean mass during weight loss, reducing the basal metabolic rate. Reduction in BMR was observed in both groups, but in the DD group, the reduction occurred at all times in relation to baseline whereas in TD group the reduction was greater only after 6 months of intervention.

Improvement in insulin resistance and triglycerides were observed only in the DD group. Individuals with insulin resistance have greater difficulty to metabolize carbohydrates, diverting a greater amount of dietary carbohydrates to the liver, where much of it is converted to fat (lipogenesis), rather than being oxidized in energy in the skeletal muscle. For this reason, very low carbohydrate diets applied in obese individuals, in addition to leading to weight loss also improves glycemic and lipid control. The effects of the very prolonged ketogenic diet are still poorly investigated and for this reason this diet should only be used for a limited period (from 3 weeks to a few months) to stimulate fat loss, improve metabolism, and then adjusting a transition to a normal diet.[25]

No changes in levels of total cholesterol, HDL-c and LDL-c were observed in any group. However, only in the DD group there was a significant reduction in TG level. In general, diets with reduced carbohydrates and high levels of proteins and fats increase LDL-c and TG levels showing beneficial effects of the ketogenic diet on cardiovascular risk factors. Most studies show that reducing carbohydrates can bring significant benefits in reducing total cholesterol, increases in HDL-c and reduction of triglycerides in the blood. HMG-CoA reductase, a key enzyme in the synthesis of endogenous cholesterol is activated by insulin, so that a reduction in blood glucose and hence insulin levels, leads to lower cholesterol synthesis. Thus, a reduction in dietary carbohydrate associated with adequate cholesterol consumption leads to inhibition of cholesterol biosynthesis.[26] When insulin is elevated, lipolysis is reduced and lipogenesis is increased, resulting in overproduction of VLDL containing TG, formation of small and dense LDL particles and reduction of HDL. Low concentrations of glucose and insulin also reduce the expression of the carbohydrate-sensitive response element binding protein (ChREBP) transcription factor, and expression of the binding protein of the sterol regulatory element (SREBP-1c), responsible for the synthesis of fatty acids, as well as their incorporation into triglycerides and phospholipids, activating the main lipogenic enzymes, reducing hepatic lipogenesis and VLDL production.[27]

When we evaluated the GFR, a reduction only in DD group was observed at 3 months of intervention, but still in normal reference levels. Our results did not show significant changes in serum creatinine levels, but GFR decrease in DD group. Carbohydrate-restricted diets have higher amounts of protein may affect glomerular filtration leading to progressive loss of renal function.[28] In the study conducted by Brinkworfh et al. (2010), renal function was evaluated in 68 obese individuals without renal dysfunction who consumed two similar hypocaloric diets for one year, one with carbohydrate reduction and another with high carbohydrate content, and observed that creatinine serum levels and the GFR did not change in any of the dietary groups.[29]

In general, endothelial function improves after weight loss in obese individuals.[30] However, associations between changes in endothelial function with anthropometric and biochemical parameters are still controversial.[31]We observed that the endothelial function did not present a significant difference in the two study groups, both in fasting and in the 2 hours postprandial. Volek et al. (2009) observed that low-carbohydrate diet improves postprandial vascular function compared to a low-fat diet in overweight individuals with moderate hypertriglyceridemia[(32)]. Low-carbohydrate diets, may improve vascular function in individuals with metabolic adaptations[32] and carbohydrate-restricted diets may induce benefits in endothelial function in the presence of insulin resistance, since impaired insulin action may be related to endothelial dysfunction. In our study, the meal offered for postprandial evaluation was not high in fat, but correspond to the diet proposed in each group. According to Nicholls et al. (2006), a single carbohydrate-restricted meal does not alter endothelial function[33] and this may be the reason we did not observe a change in endothelial function in the DD group in this study.

Conclusion

Comparing the nutritional and laboratory effects of traditional and hyper-protein diets with carbohydrate reduction, we can conclude that Dukan diet was more effective than traditional diet for weight loss, as well as for laboratory parameters and without changes in endothelial function, in the 12-months follow-up of obese subjects.

Conflict of interest

No conflict of interest.

Acknowledgement

Patricia Naomi Sakae had a scholarship from CAPES – Brazil.

References:

1. Gogebakan O.; Kohl A.; Osterhoff MA.; van Baak MA.; Jebb SA.; Papadaki A.; et al. Effects of weight loss and long-term weight maintenance with diets varying in protein and glycemic index on cardiovascular risk factors: the diet, obesity, and genes (DiOGenes) study: a randomized, controlled trial. *Circulation*. **2011**, 124(25), 2829-2838.
2. Merino J.; Kones R.; Ferre R.; Plana N.; Girona J.; Aragones G.; et al. Low-carbohydrate, high-protein, high-fat diet alters small peripheral artery reactivity in metabolic syndrome patients. *Clin Investig Arterioscler*. **2014**, 26(2), 58-65.
3. Krieger JW.; Sitren HS.; Daniels MJ.; Langkamp-Henken B. Effects of variation in protein and carbohydrate intake on body mass and composition during energy restriction: a meta-regression 1. *Am J Clin Nutr.* **2006**, 83(2), 260-274.
4. Samaha FF.; Iqbal N.; Seshadri P.; Chicano KL.; Daily DA.; McGrory J.; et al. A low-carbohydrate as compared with a low-fat diet in severe obesity. *N Engl J Med*. **2003**, 348(21), 2074-2081.
5. Paoli A.; Rubini A.; Volek JS.; Grimaldi KA. Beyond weight loss: a review of the therapeutic uses of very-low-carbohydrate (ketogenic) diets. *Eur J Clin Nutr*. **2013**, 67(8), 789-796.
6. Nordmann AJ.; Nordmann A.; Briel M.; Keller U.; Yancy WS, Jr.; Brehm BJ.; et al. Effects of low-carbohydrate vs low-fat diets on weight loss and cardiovascular risk factors: a meta-analysis of randomized controlled trials. *Arch Intern Med*. **2006**, 166(3), 285-293.
7. Veech RL. The therapeutic implications of ketone bodies: the effects of ketone bodies in pathological conditions: ketosis, ketogenic diet, redox states, insulin resistance, and mitochondrial metabolism. *Prostaglandins Leukot Essent Fatty Acids*. **2004**, 70(3), 309-319.
8. Feinman RD.; Fine EJ. Nonequilibrium thermodynamics and energy efficiency in weight loss diets. *Theor Biol Med Model*. **2007**, 4, 27.
9. Veldhorst MA.; Westerterp-Plantenga MS.; Westerterp KR. Gluconeogenesis and energy expenditure after a high-protein, carbohydrate-free diet. *Am J Clin Nutr*. **2009**, 90(3), 519-526.
10. Freeman TF.; Willis B.; Krywko DM. Acute intractable vomiting and severe ketoacidosis secondary to the Dukan Diet(c). *J Emerg Med*. **2014**, 47(4), e109-112.
11. Nouvenne A.; Ticinesi A.; Morelli I.; Guida L.; Borghi L.; Meschi T. Fad diets and their effect on urinary stone formation. *Transl Androl Urol*. **2014**, 3(3), 303-12.
12. Wyka J.; Malczyk E.; Misiarz M.; Zolotenka-Synowiec M.; Calyniuk B.; Baczynska S. Assessment of food intakes for women adopting the high protein Dukan diet. *Rocz Panstw Zakl Hig*. **2015**, 66(2), 137-42.
13. Ministério da Saúde. Guia alimentar para a população brasileira: Promovendo a alimentação saudável. Brasília; **2006**.
14. Dukan P. O Método Dukan Ilustrado 1a edição ed. Rio de Janeiro; **2013**.
15. Heyward V Stolarczyk L. Métodos de dobras cutâneas. In: Heyward VV.; Stolarczyk LM. Avaliação da composição corporal aplicada. São Paulo; **2000**.
16. Sakae PN.; Ihara SS.; Ribeiro DA.; de Carvalho L.; Parise ER. Insulin resistance is associated with DNA damage in peripheral blood cells in non-diabetic patients with genotype 1 chronic hepatitis C. *Free Radic Res*. **2013**, 47(9), 750-756.
17. Salazar DE.; Corcoran GB. Predicting creatinine clearance and renal drug clearance in obese patients from estimated fat-free body mass. **Am J Med**. **1988**, 84(6), 1053-1060.
18. Fonseca HA.; Fonseca FA.; Monteiro AM.; Bianco HT.; Boschcov P.; Brandao SA.; et al. Obesity modulates the immune response to oxidized LDL in hypertensive patients. *Cell Biochem Biophys*. **2013**, 67(3), 1451-1460.
19. Sacks FM.; Bray GA.; Carey VJ.; Smith SR.; Ryan DH.; Anton SD.; et al. Comparison of weight-loss diets with different compositions of fat, protein, and carbohydrates. *N Engl J Med*. **2009**, 360(9), 859-873.
20. Moreno B.; Crujeiras AB.; Bellido D.; Sajoux I.; Casanueva FF. Obesity treatment by very low-calorie-ketogenic diet at two years: reduction in visceral fat and on the burden of disease. *Endocrine*. **2016**, 54(3), 681-690.
21. Matthie JR. Bioimpedance measurements of human body composition: critical analysis and outlook. *Expert Rev Med Devices*. **2008**, 5(2), 239-261.
22. Chaston TB.; Dixon JB.; O'Brien PE. Changes in fat-free mass during significant weight loss: a systematic review. *Int J Obes (Lond).* **2007**, 31(5), 743-50.
23. Muller MJ.; Bosy-Westphal A. Adaptive thermogenesis with weight loss in humans. Obesity *(Silver Spring).* **2013**, 21(2), 218-228.
24. Camps SG.; Verhoef SP.; Westerterp KR. Weight loss, weight maintenance, and adaptive thermogenesis. *Am J Clin Nutr*. **2013**, 97(5), 990-994.
25. Paoli A.; Bianco A.; Grimaldi KA.; Lodi A.; Bosco G. Long term successful weight loss with a combination biphasic ketogenic Mediterranean diet and Mediterranean diet maintenance protocol. *Nutrients*. **2013**, 5(12), 5205-5217.
26. Paoli A. Ketogenic diet for obesity: friend or foe? *Int J Environ Res Public Health*. **2014**, 11(2), 2092-2107.
27. Volek JS.; Fernandez ML.; Feinman RD.; Phinney SD. Dietary carbohydrate restriction induces a unique metabolic state positively affecting atherogenic dyslipidemia, fatty acid partitioning, and metabolic syndrome. *Prog Lipid Res*. **2008**, 47(5), 307-318.
28. Crowe TC. Safety of low-carbohydrate diets. *Obes Rev*. **2005**, 6(3), 235-245.
29. Brinkworth GD.; Buckley JD.; Noakes M.; Clifton PM. Renal function following long-term weight loss in individuals with abdominal obesity on a very-low-carbohydrate diet vs high-carbohydrate diet. *J Am Diet Assoc*. **2010**, 110(4), 633-638.
30. Mavri A.; Poredos P.; Suran D.; Gaborit B.; Juhan-Vague I. Effect of diet-induced weight loss on endothelial dysfunction: early improvement after the first week of dieting. *Heart Vessels*. **2011**, 26(1), 31-38.
31. Hamdy O.; Ledbury S.; Mullooly C.; Jarema C.; Porter S.; Ovalle K.; et al. Lifestyle modification improves endothelial function in obese subjects with the insulin resistance syndrome. *Diabetes Care*. **2003**, 26(7), 2119-2125.
32. Volek JS.; Ballard KD.; Silvestre R.; Judelson DA.; Quann EE.; Forsythe CE.; et al. Effects of dietary carbohydrate restriction versus low-fat diet on flow-mediated dilation. *Metabolism*. **2009**, 58(12), 1769-1777.
33. Nicholls SJ.; Lundman P.; Harmer JA.; Cutri B.; Griffiths KA.; Rye KA.; et al. Consumption of saturated fat impairs the anti-inflammatory properties of high-density lipoproteins and endothelial function. *J Am Coll Cardiol*. **2006**, 48(4), 715-720.