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Effects of a High Carbohydrate and High Protein Formula Diet On Body Composition and Metabolic Risk Parameters in Obese Subjects

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Abstract

Background: In obese subject's weight loss is known to improve blood lipid profiles, glycemic control and other conditions that may contribute to the development of metabolic syndrome or cardiovascular diseases. However, the optimal dietary carbohydrate and protein composition to facilitate weight loss and improving potential adverse effects is still in debate. Therefore, the aim of this study was to compare the effect of two low-fat formula diets either high in carbohydrate or high in protein, on body composition and metabolic risk factors.

Methods: 154 obese (BMI 32.5 ± 0.14 kg/m^2) men and women were included in this randomized clinical trial and classified in two groups (high carbohydrate formula diet (HC) and high protein formula diet (HP)) of 80 matched subjects. They underwent an intervention for eight weeks, which consisted of two phases: (1) week 1 and 2: total replacement of three meals by a formula diet and (2) six week partial formula diet (replacement of 1-2 meals). Measurements were taken prior and post intervention for analysis of body composition and parameters of lipid and glucose metabolism.

Results: After eight weeks both groups lost significantly body fat mass (HC: -5.11 ± 0.51 kg, p<0.001; HP: -5.81 ± 0.54 kg, p<0.001), while only for subjects of HP group no change of lean body mass and body cell mass was observed. Metabolic risk parameters were reduced in both the HC and HP group; however, subjects in the HC group showed a higher reduction in triacylglycerol concentration (-29.1 mg/dl vs. -14.0 mg/dl, p<0.04). Further, the prevalence of the metabolic syndrome was reduced in both groups without difference (HC: -17.9%, p=0.004; HP: -18.4%, p=0.003).

Conclusion: Our data demonstrate, that even in a short period of time, a low-fat meal replacement diet high in carbohydrate or high in protein is effective in improving body composition and reducing metabolic risk parameters.

Keywords: Carbohydrate; Protein; Formula diet; Obesity; Body composition; Metabolic risk parameters

Abbreviations: BFM: Body Fat Mass; BCM: Body Cell Mass; BMI: Body Mass Index; DBP: Diastolic Blood Pressure; ECM: Extracellular Mass; HC: High Carbohydrate Formula Diet; HDL-C: High-Density Lipoprotein; HipC: Hip Circumference; HOMA-IR: Homeostasis Model Assessment for Insulin Resistance; HP: High Protein Formula Diet; hsCRP: High-Sensitivity C-Reactive Protein; LDL-C: Low-Density Lipoprotein Cholesterol; SBP: Systolic Blood Pressure; SD: Standard Deviation; TAG: Triacylglycerol; TC: Total Cholesterol; TW: Total Body Water; WC: Waist Circumference.

Introduction

High body weight is associated with an increased risk in hyperglycaemia, atherogenic dyslipidaemia and hypertension [1]. These risk factors potentiate the development of the metabolic syndrome (MetS), which is one of the most prevalent conditions that predispose to cardiovascular complications and diabetes mellitus type 2 [2]. Recommendations agree that people who are overweight and obese need to be advised and given perspective and practical strategies for weight reduction [3] due to prevent developing risk [4].

The rising levels of overweight and obesity have resulted in an increase of weight loss diets. Modest weight loss results from a reduction in energy intake, which can be achieved by a reduction in dietary fat [5]. However, the optimal dietary carbohydrate and protein composition to facilitate weight loss and improving potential adverse effects is still in debate [6-8]. Low fat/ high carbohydrate diets, which mainly of vegetable and fruit origin were still recommended cause of its effects on weight control [9,10] and cardio-protective potential [11,12]. Higher protein diets with replacing carbohydrate by protein have positive effects on glycemic control [13,14] and prevent lean body mass loss [15-18]. However, concerns have also been expressed that diets with protein from animal sources are often high in saturated fat, which have a tendency to increase risk of cardiovascular diseases [19,20]. Therefore, selecting low-calorie food with provided macronutrient composition to realize beneficial high carbohydrate or high protein diets may be difficult to maintain by conventional dietary approaches [21,22].

In addition, the use of meal replacements coupled with low-calorie diets represent strategies to facilitate an energy deficit for weight reduction [23]. Studies suggest that formula diets considerably increase the number of responder [24,25] and improved weight-related risk factors such as waist circumferences (WC), glucose, insulin, lipid profile, and blood pressure [21,25-30].

In the current study, we aimed to clarify if formula diets high in carbohydrate or high in protein have different effects on body composition and decreasing metabolic risk. We conducted an 8-week randomized trial to compare two relatively low fat meal replacement diets – one high in carbohydrate and the other high in protein- on

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weight loss, body composition and metabolic risk parameters in overweight and obese subjects.

Materials and Methods

Study design and population

The study protocol, subject selection and randomization procedure as well as anthropometric measurements methodology was described in detail in ref. [31]. In brief, 154 subjects between 30 and 65 years were randomized to two different treatment groups: (1) carbohydrate-rich formula diet (HC) and (2) protein-rich formula diet (HP). The formula diet was administered daily as a drink meal replacement. Shakes were prepared by combining 30 g of powdered HC meal replacement mix and 34 g of powdered HP meal replacement mix with 300 ml milk (low fat) and 5 g vegetable oil. The meal energy macronutrient composition per recommended preparation of the HC meal replacement was approximately 24% protein, 49% carbohydrate, 25% fat and 2% fiber. The macronutrient composition of the HP meal replacement was approximately 38% protein, 34% carbohydrate and 28% fat. Nutritional composition of both formula diets are shown in Table 1. All subjects were advised to replace three meals a day in the first two weeks of intervention. In week 3 and 4, the subjects consumed two meal replacements for both lunch and dinner. During the last intervention period (week 5 to 8), the subjects were encouraged to replace either lunch or dinner (depending on the daily routine) with the formula diet.

Body composition and blood sampling

The body composition was determined by means of bioelectrical impedance analysis (BIA) using a calibrated device, the Nutriguard-M (Data Input GmbH, Darmstadt, Germany) at baseline week 2 and 8 weeks (t_0, t_2, t_8).

Fasting blood samples (approximately 50 ml at each time point) were collected using sealed Blood Collection Tubes and System S-Monovettes® (Sarstedt, Germany). The samples were directly sent to an external laboratory (LADR laboratory, Hanover, Germany) for analysis of serum lipids, insulin and high-sensitivity C-reactive protein (hsCRP) as well as plasma glucose according to standardized procedures. The serum triacylglycerol (TAG) concentration, total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) levels were measured enzymatically (Beckman Coulter, Inc.). Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation [32]. Fasting plasma glucose measurements were performed by using the hexokinase method, an ultraviolet (UV) enzymatic (in vitro) assay (Beckman Coulter, Inc.). Serum insulin concentrations were determined by immunoassays (cobas®, Roche Diagnostics, Mannheim, Germany). An immunoturbidimetric method was used for determination of serum hsCRP.

Metabolic risk profile/parameters

The NCEP ATP-III criteria was used for defining the MetS, subjects were required to fulfill at least three of the following five criteria: WC >102 (men) or >88 cm (women), blood pressure 130/85 mmHg or treatment of hypertension, fasting blood glucose ≥100 mg/dl, TAG ≥ 150 mg/dl, HDL-C <40 mg/dl (men) and < 50 mg/dl (women) [33]. To enable us to estimate insulin resistance of subjects, Homeostasis model assessment of insulin resistance (HOMA-IR) were used. HOMA-IR derived from fasting glucose and insulin concentrations as follows (fasting plasma glucose x fasting serum insulin)/405) [34]. In addition, hsCRP levels ≥3 mg/L was used for classification to assess an inflammation state [35,36].

Nutritional values	High carbohydrate formula diet		High protein formula diet	
	per 100 g	per serving size*	per 100 g	per serving size**
Energy (kcal)	371.4	313	364	311
Carbohydrate (g)	65.6	34.1	34.0	26.0
from Sugar (g)	64.0	33.6	33.0	25.6
Protein (g)	22.5	16.9	56.4	29.2
Fat (g)	0.03	7.8	0.2	9.8
Total fiber (g)	7.4	2.2	0	0

*Serving size as recommended preparation: 300 ml milk (1.5% fat)+30 g carbohydrate-rich 5 powder+5 g vegetable oil; **Serving size as recommended preparation: 300 ml milk (1.5% fat)+34 g protein-rich 7 powder+5 g vegetable oil.

Table 1: Nutritional composition of the formula diets with recommended preparation.

Statistical analysis

The results are presented as the mean value ± standard error (SE). Statistical comparison between the groups was performed using the nonparametric Mann-Whitney U test for unpaired data. The changes in the parameters in comparison with baseline were analysed using the Wilcoxon test. The chi-square test was used to compare the difference between the frequencies of the groups. Differences were considered significant at $p \leq 0.05$. The statistical data analysis was carried out by using the Statistical Package for Social Sciences SPSS 22.0 (SPSS Inc., Chicago, Illinois, USA).

Results

Subjects and baseline characteristics

Included subjects (60 male; 94 female) had an average age of 50.4 years (range: 30-65 years). The anthropometric measurements, body composition and blood parameters were quantified of 154 participants (n=78 of them received HC formula diet and n=76 the HP formula diet) before and after eight weeks of weight reduction. No differences were observed at baseline between both groups regarding to the parameters (Tables 2 and 3). The selected risk parameters did not differ between the HC and the HP group. The prevalence of MetS at baseline was 46.2% in the HC group (n=36) and 52.6% in the HP group (n=40). The prevalence of insulin resistance (according to the definition of HOMA-IR ≥ 2 [34]) was 67.9% (n=53) in the HC group and 71.1% (n=54) in the HP group. Further, hsCRP level >3 mg/L was observed for 37.2% of subjects in HC group and 40.8% in HP group (Figure 1).

Change of body weight and body composition

The efficiency of both formula diets for reduction in body weight and WC has already been described in ref. [31]. In brief, the formula diet resulted in a significant weight loss of -6.52 ± 0.41 kg (6.61 ± 0.38%; $p<0.001$) in the HC group and -6.79 ± 0.42 (-6.96 ± 0.41%; $p<0.001$) in the HP group after eight weeks. Further, both groups showed significant reductions in WC ($p<0.001$) respectively.

Eight weeks of dietary intervention resulted in a significant reduction of body fat mass (BFM) in both HC group (-5.11 ± 0.51 kg; -14.3 ± 1.51%; $p<0.001$) and HP group (-5.81 ± 0.54 kg; -16.2 ± 1.51%; $p<0.001$) without significant difference between the groups. During the eight-week weight loss phase, body cell mass (BCM) and lean body

		HC group (n=78)	P (t_0 -->t_8)*	HP group (n=76)	P (t_0 -->t_8)*	P (HC vs. HP)**
		Mean ± SE		**mean ± SE**		
Weight (kg)	t_0	98.2 ± 1.46		97.6 ± 1.42		n.s
	t_8	91.7 ± 1.39	**<0.001**	90.8 ± 1.39	**<0.001**	n.s
BMI (kg/m²)	t_0	32.4 ± 0.21		32.5 ± 0.18		n.s
	t_8	30.3 ± 0.24	**<0.001**	30.3 ± 0.23	**<0.001**	n.s
WC (cm)	t_0	106 ± 1.11		106 ± 1.10		n.s
	t_8	97.4 ± 0.98	**<0.001**	97.5 ± 0.95	**<0.001**	n.s
HipC (cm)	t_0	115 ± 0.73		115 ± 0.73		n.s
	t_8	109 ± 0.71	**<0.001**	109 ± 0.66	**<0.001**	n.s
SBP (mm/Hg)	t_0	138 ± 1.73		142 ± 2.11		n.s
	t_8	129 ± 1.39	**<0.001**	129 ± 1.58	**<0.001**	n.s
DBP (mm/Hg)	t_0	84.5 ± 1.15		85.3 ± 1.27		n.s
	t_8	79.9 ± 0.91	**<0.001**	79.7 ± 0.99	**<0.001**	n.s
LBM (kg)	t_0	63.1 ± 1.49		61.6 ± 1.44		n.s
	t_8	61.5 ± 1.32	**0.007**	60.6 ± 1.40	n.s	n.s
BFM (kg)	t_0	35.3 ± 0.76		36.1 ± 0.72		n.s
	t_8	30.2 ± 0.79	**<0.001**	30.2 ± 0.81	**<0.001**	n.s
ECM (kg)	t_0	30.3 ± 0.66		30.2 ± 0.64		n.s
	t_8	29.9 ± 0.62	n.s	29.2 ± 0.61	**<0.001**	n.s
BCM (kg)	t_0	32.6 ± 0.90		31.4 ± 0.89		n.s
	t_8	31.7 ± 0.78	**0.009**	31.4 ± 0.87	n.s	n.s
ECM/BCM	t_0	0.95 ± 0.02		0.99 ± 0.02		n.s
	t_8	0.96 ± 0.01	n.s	0.95 ± 0.02	**<0.001**	n.s
TW (l)	t_0	46.1 ± 1.09		45.1 ± 1.05		n.s
	t_8	45.0 ± 0.97	**0.006**	44.4 ± 1.02	**0.049**	n.s

Abbreviations: BFM: body fat mass; BCM: body cell mass; BMI: body mass index; DBP: diastolic blood pressure; ECM: extracellular mass; HC: high carbohydrate formula diet; Hip C: hip circumference; HP: high protein formula diet; SBP: systolic blood pressure; TW: total body water; WC: waist circumference.

Table 2: Anthropometric data and body composition in the HC and HP group at baseline (t_0) and after eight weeks (t_8).

		HC group (n=78)	P (t_0 -->t_8)*	HP group (n=76)	P (t_0 -->t_8)*	P (HC vs. HP)**
		mean ± SE		**mean ± SE**		
Glucose (mg/dl)	t_0	90.5 ± 1.14		90.4 ± 0.98		n.s
	t_8	88.8 ± 1.35	**0.006**	88.7 ± 0.99	**0.045**	n.s
Insulin (µU/ml)	t_0	12.5 ± 0.78		12.5 ± 0.71		n.s
	t_8	8.94 ± 0.56	**<0.001**	8.65 ± 0.56	**<0.001**	n.s
HOMA-IR	t_0	2.87 ± 0.21		2.83 ± 0.18		n.s
	t_8	2.01 ± 0.15	**<0.001**	1.93 ± 1.21	**<0.001**	n.s
TC-C (mg/dl)	t_0	234 ± 5.79		226 ± 4.75		n.s
	t_8	215 ± 5.00	**<0.001**	214 ± 4.60	**<0.001**	n.s
LDL-C (mg/dl)	t_0	151 ± 4.63		148 ± 4.26		n.s
	t_8	138 ± 4.10	**<0.001**	138 ± 3.79	**0.001**	n.s
HDL-C (mg/dl)	t_0	56.2 ± 1.47		53.9 ± 1.55		n.s
	t_8	47.2 ± 1.27	**<0.001**	51.1 ± 1.36	**0.001**	n.s
LDL/HDL	t_0	2.77 ± 0.09		2.86 ± 0.11		n.s
	t_8	2.69 ± 0.08	n.s	2.79 ± 0.08	n.s	n.s
TAG (mg/dl)	t_0	151 ± 7.99		136 ± 6.52		n.s
	t_8	124 ± 6.46	**<0.001**	122 ± 5.76	**0.040**	n.s
hsCRP (mg/l)	t_0	3.19 ± 0.47		3.29 ± 0.36		n.s
	t_8	2.64 ± 0.49	**0.007**	2.48 ± 0.28	**0.002**	n.s

Abbreviations: HC: high carbohydrate formula diet; HDL-C: high-density lipoprotein; HOMA-IR: homeostasis model assessment for insulin resistance; HP: high protein formula diet; hsCRP: high-sensitivity C-reactive protein; LDL-C: low-density lipoprotein cholesterol; TAG: triacylglycerol; TC: total cholesterol.

Table 3: Clinical parameters in the HC and HP group at baseline (t_0) and after eight weeks (t_8).

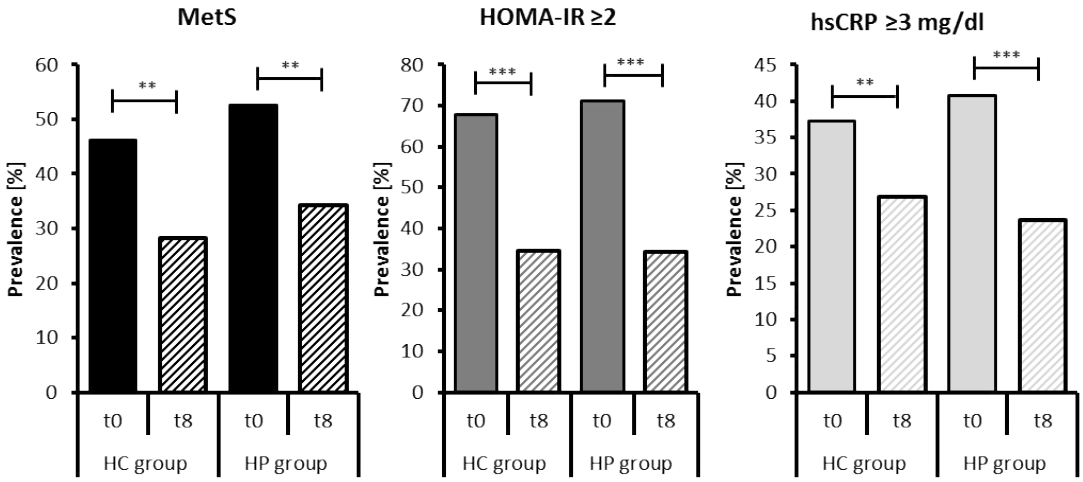

Figure 1: Change of prevalence [%] in metabolic risk parameters in overweight and obese subjects of HC (n=78) and HP (n=76) group after eight weeks (t_8). Abbr.: HC: High Carbohydrate Formula Diet; HDL-C: High-Density Lipoprotein; HOMA-IR: Homeostasis Model Assessment for Insulin Resistance; HP: High Protein Formula Diet; hsCRP: High-Sensitivity C-Reactive Protein; MetS: Metabolic Syndrome; TAG: triacylglycerol; Significant Differences between the Two Time Points were Determined by Wilcoxon test for Skewed Distributed Variables. *p≤0.05, **p<0.005, ***p<0.001.

mass (LBM) among the HC group reduced by a mean of 0.99 ± 0.33 kg and 1.42 ± 0.46 kg, representing a 2.12 ± 0.94% and 1.73 ± 0.70%; decreased from baseline (p=0.009; p=0.007), whereas the HP group has been shown no significant changes from baseline (p=0.928; p=0.051) (Table 2).

Change of clinical and metabolic risk parameters

At week eight, both groups significantly lowered fasting blood glucose and insulin levels by a mean of -1.72 ± 0.82 mg/dl glucose (-1.78 ± 0.83%; p=0.006) and -3.60 ± 0.53 µU/ml insulin (-22.3 ± 3.93%; p<0.001) in HC group as well as -1,70 ± 0.87 mg/dl glucose (-1.56 ± 0.95%; p=0.045) and -3.86 ± 0.52 µU/ml insulin (-27.57 ± 3.57%; p<0.001) in HP group. Similar, both groups experienced significant changes in low TC, LDL-C but also HDL-C at eight weeks (each p<0.005, respectively), without significant differences between the groups. During the eight week intervention, serum concentrations of TAG decreased in the HC (-12.10 ± 3.26%) and HP (-4.29 ± 3.68%) group (p<0.001 and p<0.040). This difference reflected a significant higher reduction in TAG concentration after the HC formula diet (p<0.040). Regarding the metabolic risk profile, after eight week dietary intervention the prevalence of subjects with HOMA-Index ≥2 and hsCRP levels ≥3 mg/dl decreased in both groups significantly (p<0.001, respectively) (Figure 1). In addition, after eight week of dietary intervention, the prevalence of MetS decreased in the HC group by 17.9% (n=14; p=0.004) and in the HP group by 18.4% (n=14; p=0.003). Further, subjects with MetS showed significant reduction of TC concentration by a mean of (-26.3 ± 6.75 mg/dl; p) in HC and (-10.6 ± 5.29 mg/dl) in HP group. Only the subjects in HC group with Mets reduced significantly LDL-C (-15.4 ± 5.51 mg/dl).The decreased TAG concentration was significantly higher (p=0.001) in subjects with MetS of HC group (-65.1 ± 11.06 mg/dl) compared to HP group (-23.3 ± 10.56 mg/dl) (Figure 2).

Dietary Intake

At baseline, the reported energy intake was similar in both groups (HC: 2454 ± 88.2 kcal/d; HP: 2371 ± 95.6 kcal/d). In addition, the percent energy intake from protein (HC: 16.1 ± 0.41 %; HP 16.9 ± 0.42%), carbohydrate (HC: 42.4 ± 1.04%; HP: 42.1 ± 0.94%) and fat (HC: 36.7 ± 0.68%; HP: 38.3 ± 0.78%) did not differ between both groups at baseline. After the eight week intervention energy intake was significantly reduced within each group but not between both groups (HC: 1530 ± 61.8 kcal/d; HP: 1559 ± 56.8 kcal/d). Percent energy intake from carbohydrates and proteins in HC group (44.8 ± 0.96% and 20.7 ± 0.52%) was significantly different compared to HP group (42.1 ± 0.91%; p=0.034 and 23.7 ± 0.50%; p<0.001).

Discussion

We previously described that both formula diets are effective strategies for weight loss and WC reduction in overweight and obese subjects [31]. In this context the influence of energy restriction and macronutrients composition of both formula diets on body composition and metabolic risk parameters will be discuss.

A rapid weight loss induced by energy restricted diets has often been associated with loss of BFM in addition to the reduction of LBM [15,37]. LBM may lead to retention of resting energy expenditure, which is essential for weight maintaining after weigh loss [38]. We observed that both low-fat formula diets induce comparable reductions of BFM, but only subjects of HP group showed retention of LBM and BCM. This is in accordance to studies, which suggest that high protein diets have been associated with no change of LBM compared with high carbohydrate diets [14,17,18] even when there has been no differences in change of body weight. The required daily protein intake is 0.83 g/kg of body weight. However, this reference protein intake per day may not be directly applied to overweight and obese subjects, because they are closely associated to LBM and this LBM is lower than in normal weight persons [39]. Therefore, the European Food Safety Authority (EFSA) suggested a daily protein intake during energy restriction diets of 75 g/day to preserve LBM in obese subjects [39]. Further, a meta-analysis of 87 weight loss diets comparing different macronutrient compositions, suggested that protein intake >1.05 g/kg body weight per day is associated with greater retention of LBM compared with lower protein intake [17]. During the partial meal replacement plan the daily protein intake in HC group was about 0.82 g/kg (75.2 g protein/day)

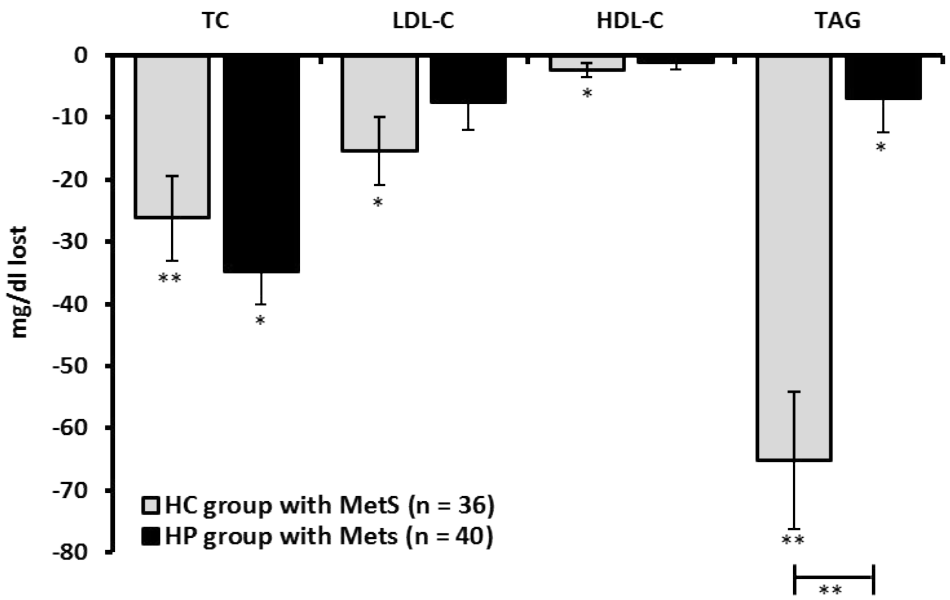

Figure 2: Loss of Lipid Parameters in Subjects with Metabolic Syndrome after Eight Weeks of Intervention (t_8). Mean ± SE, Abbr.: BF: HC: High Carbohydrate Formula Diet; HDL-C: High-Density Lipoprotein; HP: High Protein Formula Diet; LDL-C: Low-Density Lipoprotein; TAG: Triacylglycerol; TC: Total Cholesterol. Significant Differences between the No Inflammation and Low-grade Inflammation Group were Determined by Independent Sample t-test for Normal Distributed Variables and the Mann-Whitney U Test for Skewed Distributed Variables. Significant Differences between the Two Time Points were Determined by Wilcoxon Test for Skewed Distributed Variables. *p ≤ 0.05, **p<0.005, ***p<0.001.

and in HP group 0.96 g/kg (87.3 g protein/day). Therefore, the daily protein intake in HP meal replacement plan achieved more than 75 g protein/day and was nearly the cut off level >1.05 g/kg, thus it may be possible to attribute the observed difference of LBM retention by different protein intake. Nevertheless, to avoid LBM and BCM loss and increase energy expenditure, dieting should be combined with physical exercise [16]. However, our results demonstrate that the retention in BCM and LBM in HP group was probably not caused by an increase in physical activity, because these levels were similar in both groups [31]. Studies suggest that high GL diets and elevated insulin response might preserve the release of free fatty acids from adipose tissue due to the lipogenic actions of insulin, which maintain the BFM [40]. Considering the HC formula diets was classified as high GL food and the HP as low GL food [41] we found similar reduction of BFM after consumption of both formula diets.

In the present study, both formula diets were similar in their effect on blood lipid reduction. Although a beneficial effect of weight loss on blood lipids was found in both intervention groups, more favorable improvements were seen in the HC group. There was a significantly greater reduction in serum TAG levels after eight weeks in obese subjects with and without MetS. These changes in TAG levels were in disagreement with other studies, which found that higher carbohydrate diets are associated to increase production of TAG [15,26,42]. Diets containing lower amounts of carbohydrates would lead to a lower synthesis in very low density lipoproteins (VLDL) and potentially lower TAG storage in the liver [43]. The inconsistence between our results and others might be because the consumed meals during partial meal replacement led to a lower difference in macronutrient intake of both groups resulting in an underestimation effect of the HC and HP diet plan on TAG concentrations. The reduced HDL-C levels during the intervention of this low-fat diets is well known [30]. Improvements of HDL-C have commonly been observed in studies lasting, more than 12 weeks [37] or combined increased physical activity [44-46].

For metabolic risk estimation also the fat distribution is useful [47]. Subjects of this study exceed the cut of value for WC of 102 cm in men (112 ± 0.73 cm) and 88 cm (101 ± 0.98 cm) in women. The accumulation of visceral adipose tissue is closely associated with decrease of insulin sensitivity and low-grade inflammation state [48], which were considered primary factors in the development of insulin resistance, type 2 diabetes and MetS [49]. The value of HOMA-IR <2 was regarded normal ≥2 was pathologic and values >4 represented the prediabetic phase [50]. The prevalence of subjects with HOMA-IR ≥2 was 67.9% in HC and 71.1% in HP group implying a pathological to prediabetic stage. Visceral obesity is further viewed as a key factor responsible for the up regulation of inflammation in obese subjects [48,51]. Regarding the mean hsCRP levels, subjects of both groups demonstrate values of hsCRP ≥3 mg/L (37.2% in HC and 40.8% in HP group), which are thought to reflect an elevated inflammation state and considered as predictor for future cardiovascular and metabolic diseases [35,36]. In contrast to studies which shown that HP diets lowered CRP more effectively in women with high TAG concentrations [26] hsCRP levels in this study were not influenced by dietary composition. Nevertheless, in the present study the significant decrease of body weight and WC in both groups suggests a change in abnominal fat distribution, which would explain the reduction of HOMA-IR and hsCRP levels independent of dietary macronutrient composition [52].

Further, we demonstrated that consumption of the HC and HP formula diets led to a significant reduction in the prevalence of MetS,

which is one of the most prevalent conditions that predict diabetes and cardiovascular diseases [2,53]. Some studies found that an energy-restricted high protein diet or high carbohydrate diet resulted in a significant decrease of MetS prevalence [54], while others found no effect of different macronutrient distribution on MetS prevalence [55,56]. Therefore, the influence of macronutrients on MetS prevalence remains unclear. Given the importance of abdominal fat and lipid metabolism in the pathogenesis of MetS [57], it may be speculated that the observed reduction of WC and improvements of lipid profile in this study could be the reasons for reduced prevalence of MetS even in this short time period.

Conclusions

In addition to similar weight loss, these data demonstrate that both low-calorie meal replacement diets - high in carbohydrate or high in protein - were effective strategies for improvement of body composition and metabolic risk parameters. In this short term, the HC formula diet produced greater improvement in TAG concentration, while the HP formula diet led to a better maintenance of LBM. On this basis, subjects on energy restricted weight loss diets could have been able to choose meal replacements high in carbohydrate or high in protein to facilitate the required macronutrient ratio of the diet.

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