METABOLISM CLINICAL AND EXPERIMENTAL 60 (2011) 976–981

available at www.sciencedirect.com

ScienceDirect

www.metabolismjournal.com

Increased adipose tissue lipolysis after a 2-week high-fat diet in sedentary overweight/obese men

Harold R. Howe III[a], *Kimberly Heidal*[b], *Myung Dong Choi*[c], *Ray M. Kraus*[c], *Kristen Boyle*[c], *Robert C. Hickner*[c,d,e,*]

[a] *Department of Biology, East Carolina University, Greenville, NC 27858, USA*
[b] *Department of Nutrition Sciences, East Carolina University, Greenville, NC 27858, USA*
[c] *Human Performance Laboratory, Department of Exercise and Sport Science, East Carolina University, Greenville, NC 27858, USA*
[d] *Department of Physiology, East Carolina University, Greenville, NC 27858, USA*
[e] *Diabetes and Obesity Institute, East Carolina University, Greenville, NC 27858, USA*

ARTICLE INFO

Article history:
Received 21 January 2010
Accepted 18 September 2010

ABSTRACT

The purpose of this study was to determine if a high-fat diet would result in a higher lipolytic rate in subcutaneous adipose tissue than a lower-fat diet in sedentary nonlean men. Six participants (healthy males; 18-40 years old; body mass index, 25-37 kg/m^2) underwent 2 weeks on a high-fat or well-balanced diet of similar energy content (approximately 6695 kJ) in randomized order with a 10-day washout period between diets. Subcutaneous abdominal adipose tissue lipolysis was determined over the course of a day using microdialysis after both 2-week diet sessions. Average interstitial glycerol concentrations (index of lipolysis) as determined using microdialysis were higher after the high-fat diet (210.8 ± 27.9 μmol/L) than after a well-balanced diet (175.6 ± 23.3 μmol/L; $P = .026$). There was no difference in adipose tissue microvascular blood flow as determined using the microdialysis ethanol technique. These results demonstrate that healthy nonlean men who diet on the high-fat plan have a higher lipolytic rate in subcutaneous abdominal adipose tissue than when they diet on a well-balanced diet plan. This higher rate of lipolysis may result in a higher rate of fat mass loss on the high-fat diet; however, it remains to be determined if this higher lipolytic rate in men on the high-fat diet results in a more rapid net loss of triglyceride from the abdominal adipose depots, or if the higher lipolytic rate is counteracted by an increased rate of lipid storage.

1. Introduction

Obesity is a severe growing problem in the United States. From 1976 to 2000, the incidence of obesity in adults has skyrocketed from 15% to 31%. These individuals are at high risk for heart disease, diabetes, and other health-related issues. Seshadri and Iqbal [1] suggested that both environment and genetics play a role in this growing epidemic. Abundant resources and "office" jobs have exacerbated the problem. The United States is not alone in this dilemma. In

Author contributions: HRH—design and conduct of the study, data collection and analysis, data interpretation, and manuscript writing; KH—design and conduct of the study, data collection and analysis, data interpretation, and manuscript writing; MDC—data collection and analysis, data interpretation; RMK—conduct of the study, data collection and analysis; KB—data collection and analysis, data interpretation; RCH—design and conduct of the study, data collection and analysis, data interpretation, and manuscript writing.

* *Corresponding author*. Human Performance Laboratory, NC 27858, USA. Tel.: +1 252 737 4677; fax: +1 252 737 4689.
E-mail address: Hicknerr@ecu.edu (R.C. Hickner).

0026-0495/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.metabol.2010.09.007

Asia, developing nations are beginning to see the rise of obesity [1]. Many attempts have been made to address this rise in obesity, with diet and exercise being the commonly recommended solutions [2].

In today's hectic society, time is too often not allotted for exercise. Dieting is therefore often chosen by many individuals as the only practical means of addressing obesity. There are a variety of diets that are readily available to the general public. Popular diets for reducing energy intake include low-fat diets, very-low fat diets, moderate-fat/low-energy diets, and low-carbohydrate/high-protein diets [3].

The most common traditional diet emphasizes limiting of fat consumption to 20% to 30% of daily energy intake. The majority of the daily amount of energy consumed is therefore from carbohydrates [3]. Most of these diets involve increased consumption of fruits, vegetables, and whole grains while limiting foods high in saturated fat and simple sugars [4]. The alternative diet plan is a low-carbohydrate diet (LCD) in which consumption of carbohydrates is restricted, typically to 20 to 60 g. The majority of energy intake is therefore from fats and lipids [5].

There is some indication that fatty acids, such as those derived from dietary fats, can directly alter lipolysis within adipose tissue. β-Adrenergic receptor (β-AR) stimulation by catecholamines, most notably epinephrine and norepinephrine, results in increased intracellular adenosine monophosphate levels, ultimately increasing lipolysis. Conversely, α_2-adrenergic receptors (α_2-ARs) act in opposition to β-ARs in the presence of catecholamines. Adipocytes predominantly express α_2-ARs over β-ARs, resulting in suppressed lipolysis under resting conditions. Gesta et al [6] have shown that free fatty acids act to inhibit α_2-AR activity, thereby increasing lipolysis, although the mechanism for this is not entirely known. Surprisingly, the effect of diet composition on in vivo lipolysis is poorly understood despite the importance of fatty acids released from subcutaneous adipose tissue on whole body substrate use [6].

The purpose of this study was to determine if a high-fat diet would result in a higher lipolytic rate in subcutaneous adipose tissue than a lower-fat diet in sedentary men. The diets compared were 2 weeks of either a well-balanced diet or a high-fat, high-protein diet of similar energy content. It was hypothesized that lipolysis, as indicated by interstitial glycerol concentrations, would be higher during a high-fat diet than a well-balanced diet. Local blood flow was also monitored to verify that any differences in interstitial glycerol were not due to differences in blood flow.

2. Methods

2.1. Participant characteristics

Participants were selected with the criteria of being sedentary (no purposeful exercise training or continuous exercise >1 time per week for >20 minutes per session as determined by questionnaire) healthy nonlean males ages 18 to 40 years with body mass indices of greater than 25 kg/m^2 and no prior history of diabetes, kidney, liver disease, or cardiovascular disease.

2.2. General protocol

Participants randomly underwent a 2-week regimen of either the high-fat or well-balanced diet. After a 1-week washout period, participants underwent a 2-week period on the second diet regimen. Abdominal subcutaneous adipose tissue lipolysis and microvascular blood flow were determined with a 20- to 24-hour microdialysis procedure under free-living conditions performed at the end of each 2-week diet.

Anthropometric and resting blood pressure measurements were conducted on each participant before and at the end of each 2-week diet period. Participants were asked to remove their shoes for a height measurement using a wall-mounted stadiometer (Perspective Enterprises, Portage, MI). Weight was recorded on a floor scale (Cardinal 708, Cardinal Scale Manufacturing Company, Webb City, MO). Participants' blood pressure was recorded to the nearest 2 mm Hg using a stethoscope and sphygmomanometer. Participants' skinfold thicknesses were then measured with Harpenden calipers at 7 different anatomical sites (chest, mid-axillary line, triceps, subscapular, abdominal, suprailiac, and thigh) [7]. Body composition was calculated (BodyComp32: version 2.235, copyright 1996-2003) using the Siri equation. The participants then began the first randomly assigned diet.

2.3. Dietary guidelines and records

Dietary information, designed and approved by a registered dietitian, was provided to each participant to serve as guidelines for recording nutrient intake during each of the diets. The high-fat diet was chosen as the LCD because of the popularity and relative simplicity of the diet. A well-balanced diet based on the USDA's Food Guide Pyramid was selected for the lower-fat diet. Diets were recorded by the participants 2 days before the microdialysis days as well as on microdialysis days. Dietary data were entered into Nutritionist Pro (version 3.040, 2007 Axxya Systems, Stafford, TX) to calculate macronutrient intake.

2.4. Preparation of microdialysis probes

The 2 microdialysis probes (CMA-20; PAES Membrane; 10 mm in length, CMA/Microdialysis AB, Stockholm, Sweden) were placed in 70% isopropyl alcohol (Cumberland SWAN, Smyrna, TN) for 20 minutes and rinsed 2 times, then stored overnight in sterile deionized water (B Braun Medical, Irvine, CA) to remove any glycerol present on the dialysis membranes.

2.5. Microdialysis procedure

Participants rested in a supine position on a bed for the microdialysis probe insertions. A split catheter over an 18G 1 1/2 angiocatheter (Becton Dickinson & Co, Franklin Lakes, NJ) was inserted into the subcutaneous abdominal adipose tissue immediately after the skin was temporarily anesthetized using ethyl chloride cold spray (Gebauer Company, Cleveland, OH). The catheter needle was removed and a microdialysis probe was then placed through the split catheter into the participant's subcutaneous adipose tissue approximately 0.5 to 1.0 cm below the skin surface. A second probe was placed in a similar manner in the adipose tissue on the contralateral

side of the abdomen approximately 3 to 5 cm from the umbilicus. Probes were fastened in place using an adhesive strip and were covered by a clear, sterile bandage (Steri-strip and Tegaderm: 3M Health Care, St Paul, MN).

Probes were perfused with 0.9% sodium chloride containing 10 mmol/L ethanol using CMA pumps (CMA 107, CMA/Microdialysis, Acton, MA) with a flow rate of either 2.0 μL/min (for blood flow monitoring) or 0.3 μL/min (for interstitial glycerol determination: the in vivo recovery of glycerol, and ethanol, is nearly 100% at 0.3 μL/min). After an hour of equilibration, baseline dialysate samples were collected for 1 hour. Participants were then allowed to eat breakfast and go about their normal daily activities. Participants were instructed to change the vials every hour and to write down their food and beverage intake as well as any physical activity during the microdialysis sampling over the ensuing 24-hour period. No samples were collected during the night when the participants were sleeping, but probe perfusion continued overnight and a nighttime dialysate sample was collected in the morning upon awakening. Dialysate and perfusate samples were stored at 0°C until analysis for ethanol [8] and for glycerol (CMA/600 automated analyzer: Stockholm, Sweden).

2.6. Blood collection and analysis

Blood was drawn from an antecubital vein into 6 vacutainers containing lithium heparin, potassium EDTA, or clot activator (Becton Dickinson & Co). Vacutainers were rotated 7 times for mixing. The heparin and potassium EDTA vials were placed on ice. The clot activator vacutainer was left at room temperature for 20 minutes during clotting. All of the vacutainers were then centrifuged at 2500*g* for 15 minutes. Serum or plasma was removed and placed into cryovials for storage at –80°C until analyzed.

β-Hydroxybutyrate concentrations were determined in plasma using a β-hydroxybutyrate assay kit (β-hydroxybutyrate Reagent Set, Pointe Scientific, Brussels, Belgium). Plasma insulin was determined with a paramagnetic particle, chemiluminescent immunoassay (Access Immunoassay System, Beckman Coulter, Fullerton, CA). Plasma lactate and glucose were determined using an oxidation reaction (YSI model 2300 Stat Plus, Yellow Springs Instruments, Yellow Springs, OH) [9]. Insulin sensitivity and resistance was calculated from plasma insulin and glucose data according to the homeostasis model assessment [10]. Serum samples for lipid profile (total cholesterol, triglycerides, and high-density lipoprotein cholesterol) determination were sent to a certified analytical laboratory (Labcorp, Greenville, NC) for analysis.

2.7. Statistics

Blood measures as well as 24-hour, prandial, and sedentary dialysate glycerol concentrations and ethanol outflow/inflow ratios were analyzed for significant differences between diet treatments using Student paired *t* tests. Weight, body mass index, and percent fat data were analyzed using a 2-way treatment (high-fat and well-balanced) by time (pre and post) repeated-measures analysis of variance. Significance was further evaluated using Student-Newman-Keuls post hoc analysis. Data are presented as mean and SEM.

3. Results

3.1. Participant characteristics

Participant weight, body mass index, and percent fat are presented in Table 1. There were no differences between the groups before the weight loss in any of these parameters. There was a significant decrease in body weight in the high-fat diet group and a trend ($P = .08$) for weight loss in the balanced diet group. There was also a trend ($P = .08$) for a decrease in body fat in the high-fat diet group in response to the diet period.

3.2. Diet analysis

Dietary data are presented in Table 2. Participants' overall daily energy consumption was not different on the high-fat and well-balanced diets. Daily carbohydrate intake was higher during the well-balanced than the high-fat diet ($P = .003$). Total fat and protein intake was higher in participants during the high-fat than the well-balanced diet condition ($P = .025$). Daily total fiber intake was lower during the high-fat than during the well-balanced diet condition; however, the daily soluble fiber intakes did not vary with the diet condition.

3.3. Dialysate glycerol data

The average dialysate glycerol concentration (reflective of actual interstitial glycerol concentration at 0.3 μL/min) over 24 hours from probes perfused at 0.3 μL/min was 210.8 ± 27.9 μmol/L at the end of the high-fat diet. The average dialysate glycerol concentration over 24 hours was 175.6 ± 23.3 μmol/L at the end of the well-balanced diet ($P = .026$ balanced vs high-fat). Participants' average dialysate glycerol concentration from probes perfused at 2.0 μL/min was 70.3 ± 9.5 μmol/L, whereas the average concentration for the well-balanced diet was 56.3 ± 9.1 μmol/L (P = NS; Table 3 and Fig. 1).

During consumption of food by participants on the high-fat diet, the average dialysate glycerol concentration from probes perfused at 0.3 μL/min was 159.8 ± 33.5 μmol/L. The corresponding value for participants on the well-balanced diet was 149.4 ± 24.4 μmol/L ($P = .54$ vs high-fat). During consumption of food by participants on the high-fat diet, the average dialysate glycerol concentration from probes perfused

Table 1 – Summary of weight, BMI, and percent fat of 6 nonlean adult males before and after the HF and BAL diets

	Diet	Before	After	*P*	Change	*P*
Weight (kg)	HF	93.2 ± 5.8	91.1 ± 5.4[a]	.02	2.1	.47
	BAL	94.1 ± 5.7	92.8 ± 5.8	.08	1.4	
BMI (kg/m^2)	HF	29.2 ± 1.6	30.2 ± 2.1	.64	0.94 ± 1.80	.60
	BAL	29.2 ± 1.5	29.1 ± 1.6	.32	0.18 ± 0.16	
Fat (%)	HF	22.4 ± 2.7	20.6 ± 2.7	.08	1.78 ± 0.82	.24
	BAL	21.1 ± 2.4	21.1 ± 2.7	.95	0.05 ± 0.66	

BMI indicates body mass index; HF, high fat; BAL, well balanced.
[a] Different from before.

Table 2 – Macronutrient intake and fiber intake in 6 overweight men consuming either a high-fat diet or a well-balanced diet over 14 days

	Total	Carbohydrate	Carbohydrate	Fat	Fat	Sat fat	Protein	Protein	Fiber	Fiber
	kJ	g	%	g	%	g	g	%	g	Soluble (g)
Balanced	7192	191	43.1	59.6	31.5	20.3	100.0	24.4	13.6	0.33
	(795)	(40)	(5.8)	(11.0)		(3.6)	(12.8)		(3.0)	(0.19)
High fat	6514	31[a]	9.2[a]	92.5[a]	53.8[a]	31.5[a]	129.9	32.9[a]	3.2[a]	0.043
	(795)	(6)	(3.0)	(11.9)		(7.1)	(21.6)		(1.0)	(0.04)

Data are presented as mean (SEM). Sat fat indicates saturated fat.
[a] Different from balanced.

at 2.0 μL/min was also not different (high fat, 58.8 ± 9.37 μmol/L; well balanced, 48.3 ± 8.8 μmol/L; P = .68; Table 3).

During the sedentary, non-eating periods (non-active/no energy consumption) of the day, dialysate glycerol concentration from probes perfused at 0.3 μL/min was 198.8 ± 30.6 μmol/L for the high-fat diet and 147.4 ± 28.2 μmol/L for the well-balanced diet (P = .012). During the sedentary periods of the day, dialysate glycerol concentration from probes perfused at 2.0 μL/min was 105.54 ± 34.1 μmol/L for the high-fat diet participants and 53.41 ± 9.1 μmol/L for the participants on the well-balanced diet (P = .23; Table 3).

3.4. *Adipose tissue blood flow*

The ethanol outflow/inflow ratio is inversely related to blood flow [8,11]. Average ethanol outflow/inflow ratio over 24 hours from probes perfused at 2.0 μL/min in participants on the high-fat diet was 0.60 ± 0.05 compared with 0.70 ± 0.04 in participants on the well-balanced diet (P = .20). Ethanol data are only presented from dialysate collected from the probe perfused at 2.0 μL/min. The nearly total net movement of ethanol out of the probe over the dialysis membrane into the participant when probes were perfused at 0.3 μL/min prohibited measurement of an accurate outflow/inflow ratio at 0.3 μL/min.

Table 3 – Comparison between participants' dialysate (nearly equal to interstitial) glycerol concentrations (μmol/L) when on the high-fat or well-balanced diet

Flow rate (μL/min)	Diet	Overall	Time period eating	Sedentary
0.3	High fat	211* (35.4)	159.8	198.8*
0.3	Well balanced	177.2 (33.2)	149.4 (24.4)	147.4 (28.2)
2.0	High fat	90.4 (21.6)	58.8 (9.4)	105.5 (34.1)
2.0	Well balanced	53.6 (13.9)	48.3 (8.8)	53.4 (9.1)

Data are presented as a 24-hour average (overall average), during consumption of energy-containing foods/beverages (eating average), and during non-eating sedentary periods (sedentary average). Microdialysis probes were placed in the abdominal subcutaneous adipose tissue and perfused at 0.3 or 2.0 μL/min. N = 6. Data are presented as mean (SEM).
* P < .05; different from well-balanced diet at 0.3 μL/min.

3.5. *Blood metabolites*

Blood metabolite data are presented in Table 4. There were no differences in glucose, insulin, β-hydroxybutyrate, or blood lipids at the end of a 2-week period on the high-fat diet as compared to the well-balanced diet. There were trends (P = .07) for a higher β-hydroxybutyrate and a lower insulin resistance after the high-fat diet.

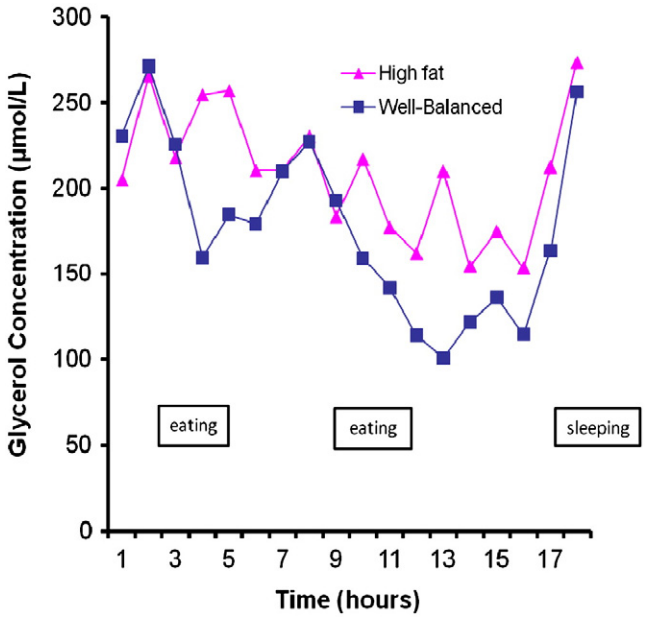

Fig. 1 – Comparison between participants' overall interstitial glycerol concentrations over time when on the high-fat and well-balanced diets. Dialysate samples were collected every hour from microdialysis probes perfused at 0.3 μL/min and placed in subcutaneous abdominal adipose tissue in nonlean adult males. The first sample was collected the first morning at approximately 9:00 AM in a fasted state. The second-to-last sample was collected during the overnight period. The final sample was collected the following morning in a fasted state. The first meal was consumed in the late morning during the well-balanced diet microdialysis day, and not until a typical lunch time during the high-fat microdialysis day. The late first meal was due to the need for microdialysis probe insertion, equilibration, and a first microdialysis sample in the fasting state. P = .026; N = 6,6.

Table 4 – Summary of plasma data insulin, glucose, ß-hydroxybutrate, and blood lipids from 6 nonlean adult males at the end of a 2-week period on either a HF diet or a BAL diet

Plasma	Diet	Measurement	P
Insulin (uU/mL)	HF	6.72 ± 2.1	.11
	BAL	15.46 ± 5.6	
Glucose (mg/dL)	HF	93.0 ± 4.3	.31
	BAL	104.7 ± 14.7	
HOMA-%B (%)	HF	156.03 ± 38	.12
	BAL	129.13 ± 43	
HOMA insulin resistance	HF	0.93 ± 0.25	.07
	BAL	1.72 ± 0.58	
β-Hydroxybutrate (mmol/L)	HF	0.901 ± 0.45	.07
	BAL	0.247 ± 0.05	
Triglyceride (mg/dL)	HF	95.67 ± 13.9	.35
	BAL	105.00 ± 18.5	
HDL (mg/dL)	HF	42.83 ± 4.6	.46
	BAL	41.83 ± 3.7	
Total cholesterol (mg/dL)	HF	169.00 ± 11	.56
	BAL	172.83 ± 14.9	

HF indicates high fat; BAL, balanced; HOMA, homeostasis model assessment.

4. Discussion

We investigated if lipolytic rate is higher in subcutaneous adipose tissue of sedentary males when they consume a high-fat diet as compared to a well-balanced diet. The present data suggest that interstitial glycerol concentrations are indeed higher in the absence of any difference in adipose tissue blood flow in sedentary overweight males on the high-fat diet as compared to the well-balanced diet. This is the first report of a higher in vivo lipolytic rate in subcutaneous adipose tissue in response to a higher-fat, LCD as compared to a balanced diet over the course of a day.

The primary measure in the present study was lipolysis as determined using microdialysis measures of interstitial glycerol and local adipose tissue nutritive blood flow. The average interstitial glycerol concentration over the course of the day from probes perfused at 0.3 μL/min was higher when participants were on the high-fat diet as compared to when they were on the well-balanced diet. Furthermore, during the portions of the day when participants were sedentary, instead of ambulatory, interstitial glycerol concentrations from probes perfused at 0.3 μL/min were also higher during the high-fat diet than during the balanced diet. Although dialysate glycerol concentration from probes perfused at 2.0 μL/min (Table 3) was not significantly different, the 0.3 μL/min flow rate provides nearly 100% recovery (Table 3 and Fig. 1) and is therefore a better indicator of actual interstitial glycerol concentration than dialysate from 2.0 μL/min perfusate flow that we have found to yield approximately 40% recovery. Local adipose tissue blood flow, as monitored by the ethanol clearance from the probe, was not different between the diets. Differences in average interstitial glycerol between the 2 diet plans were therefore not the result of differences in blood flow that may influence interstitial metabolite concentrations, microdialysis probe recovery, or adipose tissue metabolism. The higher interstitial glycerol concentration with an absence of detectable difference in blood flow indicates that lipolytic rate was higher when the participants were on the high-fat diet plan than when they were on the balanced diet plan. These data do not agree with a previous study [1], in which it was reported that there was no difference in interstitial glycerol concentration in the fasted or fed resting state in participants ingesting a low-carbohydrate as compared to a high-carbohydrate diet. The discrepancies in results may be attributable to the durations of the studies. The previous study by Suljkovicova et al [12] allowed for only 5 days on each diet, whereas in the present study participants consumed each diet for 14 days.

The dialysate glycerol data presented in Fig. 1 demonstrate the time course of differences in mean changes over the day. It should be noted that interstitial glycerol may not only reflect the overall rate of lipolysis but may also instead be the net result of triglyceride and glycerol metabolism and thus reflect net glycerol turnover. However, there are interesting trends in glycerol (Fig. 1) that warrant discussion. It can be seen that there are reductions in lipolysis with the well-balanced diet during and after first meal and the evening meal. This suppression of lipolysis, likely due to the insulin response to the ingested (high-carbohydrate) meal, was not apparent in the high-fat diet condition. The higher total daily lipolysis with the high-fat diet is therefore not due to an increased lipolysis but due to a reduced suppression of lipolysis following meals. There is therefore likely an insulin resistance with respect to suppression of lipolysis after 14 days of a high-fat diet. We have previously reported a reduced suppression of lipolysis in obese as compared to lean women [13]. However, there does not appear to be insulin resistance with respect to glucoregulation in the high-fat diet condition in the current study: the homeostasis model assessment (HOMA) calculated insulin resistance tends to be lower in the high-fat than in the well-balanced diet condition.

4.1. *Energy content of the diets*

There was no significant difference in energy intake when comparing the high-fat and well-balanced diets; however, the participants consumed less energy during the diet period than was needed to maintain weight stability. This factor likely contributed to the weight loss seen in both groups. Differences in weight loss between the 2 diets were not due to differences in energy intake, as energy intake during both diets was similar. It is likely that the larger weight loss on the high-fat than the well-balanced diet was due to a greater water loss on the high-fat diet, as has been previously demonstrated [1].

4.2. *Macronutrient diet composition*

Participants on the high-fat diet consumed a higher quantity of total fat than participants on the well-balanced diet, although saturated fat intake was not significantly different between the 2 diets. Protein consumption was higher on the high-fat diet. It has been proposed that higher levels of protein and fats in an LCD contribute to a greater “satiety” effect than a traditional balanced diet, resulting in a lower energy intake in dieters consuming an LCD as compared to a balanced diet [1]. In the present study, however, total energy intakes on the 2 diets were not different from one another (Table 2).

The limitation of the present study in this respect is that the nutrient intakes were self-reported, although the data indicate that percentage of fat and protein in the diet did not have a large effect on energy intake in the present study. The timing of the morning meal did appear to be diet dependent, as the first meal of the day was consumed on the high-fat diet 30 to 120 minutes later than when participants were on the well-balanced diet. Dinner, however, was consistently consumed at a similar time of day regardless of the diet type.

4.3. *Blood metabolite data*

Our plasma data demonstrated that there were no differences in fasting plasma insulin, glucose, and lactate on the high-fat diet as compared to the well-balanced diets in our participants. This was contrary to previous research that showed individuals on an LCD exhibited lowered plasma insulin and glucose [14,15]. The previous studies were conducted over a much longer timeframe than our study and on a greater number of participants. The insulin resistance results from our study, although not statistically significant, demonstrate that an LCD may induce higher insulin sensitivity, as suggested in previous studies [16]. A limitation of the present study is that plasma catecholamines were not measured. Local catecholamine concentration in the adipose tissue could alter lipolytic rate, but if the higher lipolytic rate in the high-fat diet condition was due to a higher catecholamine concentration, the higher catecholamine concentration in the high-fat diet condition would be expected to reduce, not enhance, insulin sensitivity.

There was no difference between the 2 diets with respect to fasting serum triglycerides, high-density lipoprotein (HDL), and total cholesterol levels. We were not able to verify the lipid profile improvements shown in other studies with longer-term dietary intervention, likely because of the relatively short duration of our study [17]. It appears that there is a rapid alteration in lipid metabolism with respect to lipolysis, and fat oxidation, but a diet duration longer than 2 weeks is needed for alterations in fasting HDL and total cholesterol.

5. Conclusion

It can be concluded from this study that over a 2-week period, the high-fat diet induces a higher rate of lipolysis than a well-balanced diet in subcutaneous abdominal adipose tissue of sedentary overweight adult males. The higher rate of lipolysis over a 1-day cycle is most evident during the postprandial, fasting, and sedentary conditions. There is a greater suppression of lipolysis after mealtime in the well-balanced than in the high-fat diet condition. The effect of diet composition on lipolysis in women, and in depots other than subcutaneous abdominal adipose tissue depots, remains to be determined.

Acknowledgment

The authors wish to thank Drs Kalmus and McConnell, Patty Brophy, Emily Johnson, Lenna Westerkamp, and Jason Finkelstein for their assistance with this study. RCH is supported by NIH R01DK071081.

REFERENCES

[1] Seshadri P, Iqbal N. Low carbohydrate diets for weight loss: historical & environmental perspective. Indian J Med Res 2006;123:739-47.
[2] Melanson K, Dell'Olio J, Carpenter M, et al. Changes in multiple health outcomes at 12 and 24 weeks resulting from 12 weeks of exercise counseling with or without dietary counseling in obese adults. Nutrition 2004;20: 849-856.
[3] Baker B. Weight loss and diet plans. Am J Nurs 2006;106:52-9 [quiz 60].
[4] Burke V, Beilin L, Cutt H, et al. A lifestyle program for treated hypertensives improved health-related behaviors and cardiovascular risk factors, a randomized controlled trial. J Clin Epidemiol 2007;60:133-41.
[5] Last A, Wilson S. Low-carbohydrate diets. Am Fam Physician 2006;73:1942-8.
[6] Gesta S, Hejnova J, Berlan M, et al. In vitro and in vivo impairment of alpha2-adrenergic receptor-dependent antilipolysis by fatty acids in human adipose tissue. Horm Metab Res 2001;33:701-7.
[7] American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription, 7th Ed; 2005. p. 366. Philadelphia, PA Lippincott Williams & Wilkins.
[8] Hickner R, Rosdahl H, Borg I, et al. The ethanol technique of monitoring local blood flow changes in rat skeletal muscle: implications for microdialysis. Acta Physiol Scand 1992;146: 87-97.
[9] Hittel D, Kraus W, Tanner C, et al. Exercise training increases electron and substrate shuttling proteins in muscle of overweight men and women with the metabolic syndrome. J Appl Physiol 2005;98:168-79.
[10] Mathews DR, Hosker JP, Rudenski AS, et al. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412-9.
[11] Fellander G, Linde B, Bolinder J. Evaluation of the microdialysis ethanol technique for monitoring of subcutaneous adipose tissue blood flow in humans. Int J Obes Relat Metab Disord 1996;20:220-6.
[12] Suljkovicova H, Marion-Latard F, Hejnova J, et al. Effect of macronutrient composition of the diet on the regulation of lipolysis in adipose tissue at rest and during exercise: microdialysis study. Metabolism 2002;51:1291-7.
[13] Hickner RC, Racette SB, Binder EF, et al. Suppression of whole body and regional lipolysis by insulin: effects of obesity and exercise. J Clin Endocrinol Metab 1999;84: 3886-95.
[14] Noble C, Kushner R. An update on low-carbohydrate, high-protein diets. Curr Opin Gastroenterol 2006;22: 153-159.
[15] Yancy WJ, Olsen M, Guyton J, et al. A low-carbohydrate, ketogenic diet versus a low-fat diet to treat obesity and hyperlipidemia: a randomized, controlled trial. Ann Intern Med 2004;140:769-77.
[16] Mavropoulos J, Yancy W, Hepburn J, et al. The effects of a low-carbohydrate, ketogenic diet on the polycystic ovary syndrome: a pilot study. Nutr Metab (Lond) 2005;2:35.
[17] Rosenfeld PJ. Low-carbohydrate diet and coronary heart disease in women. The New England. J Med 2007; 356:3.