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Research article

Substrate utilization is influenced by acute dietary carbohydrate intake in active, healthy females

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Abstract
The present study compared the metabolic responses between a single low-carbohydrate (LC) and low-fat (LF) meal followed by an aerobic exercise bout in females. Subjects included 8 active, premenopausal females. Subjects completed a LC and LF testing session. Respiratory gas exchange (RER) measurements were taken for 20 min fasted, for 55 min postprandial (PP), and during 30 min of exercise. Blood was collected for assessment of glucose (G), insulin (IN), triglycerides (TG), and free fatty acids (FFA) during the final 10 min of each time period. The LF meal provided 396 kcal (78% carbohydrate, 7% fat, and 15% protein). The LC meal provided 392 kcal (15% carbohydrate, 68% fat, and 18% protein). No significant differences existed between test meals for fasting blood measurements. PP IN ($\mu U \cdot mL^{-1}$) levels were significantly lower following LC compared to LF [10.7 (6.1) vs. 26.0 (21.0)]. Postexercise (PE) FFA ($mEq \cdot L^{-1}$) levels were significantly greater following LC [1.1 (0.3) vs. 0.5 (0.3)]. PE TG ($mg \cdot dL^{-1}$) levels were significantly greater following LC [152.0 (53.1) vs. 114.4 (40.9)]. RER was significantly lower at all time points following LC compared to LF. In moderately active adult females, ingestion of a single LC meal resulted in greater lipid oxidation at rest and during exercise as compared to a single LF meal. Although macronutrient distribution appears to have dictated substrate utilization in the present study, more research is needed regarding the long-term effects of macronutrient redistribution with and without exercise on substrate utilization.

Key words: Macronutrient distribution, exercise, low-carbohydrate.

Introduction

It is well known that the growing prevalence of cardiovascular and metabolic diseases is an increasing concern for developed nations. It has been established that the metabolic effects of a single meal, including postprandial triglyceride, glucose, and insulin levels, contribute independently to the risk for cardiovascular and metabolic disease (Petitt et al., 2003; Pfeiffer et al., 2005). Additionally, the metabolic milieu resulting from individual meals may over time determine a metabolic pattern that contributes to the development of obesity and hyperinsulinemia, which may in turn indirectly contribute to the development of cardiovascular and metabolic diseases (Zhang et al., 2004). Several studies have shown that exercise performed before high-fat and high-carbohydrate meals with varying macronutrient distributions may beneficially alter the postprandial response by attenuating postprandial hypertriglyceridemia and improving postprandial insulin sensitivity (Kolifa et al., 2004; Petit et al., 2003; Zhang et al., 2004). In addition, several investigations have demonstrated that restricting dietary carbohydrate intake may improve the atherogenic risk profile by altering circulating levels of glucose, insulin, and lipoproteins (Feinman and Volek, 2008; Wood and Fernandez, 2009).

The effect of altering the carbohydrate and fat content of a single meal on metabolic responses has been extensively studied in obese, sedentary individuals and in athletes. Kern et al. (2007) determined that aerobic exercise performed for 30 min at 70% VO_{2max} lowered blood glucose and increased circulating free fatty acids (FFAs) similarly after a high-carbohydrate and a high-fat meal in minimally active women (less than 2 hr/week of exercise). Similarly, Marion-Latard et al. (2003) reported that compared to a control resting session, aerobic exercise performed at 50% VO_{2max} increased plasma FFAs concentrations, increased fat oxidation, and lowered plasma insulin levels in both lean and obese sedentary individuals. Exercise and rest were preceded by a high-carbohydrate breakfast composed of 63% carbohydrate, 11% protein, and 22% fat.

Schrauwen et al. (1997) examined the response to exercise after either a reduced-fat or high-fat diet in untrained lean and obese individuals. The researchers determined that glycogen-lowering exercise increased fat oxidation after both the reduced-fat and high-fat diet. Fat oxidation was greatest, however, when exercise was combined with a high-fat diet. Results were similar in lean and obese individuals. Steigler et al. (2008) compared fat oxidation in inactive individuals following a high-protein and high-fat meal when aerobic exercise was performed at 65% $VO_{2reserve}$ before meal consumption. Preprandial exercise increased fat oxidation after each meal similarly in lean and obese individuals, however obese individuals demonstrated higher insulin levels for a greater period of time after meal intake. Matsuo and Suzuki (1999) compared preprandial and postprandial exercise in combination with either a high-carbohydrate (80% carbohydrate and 5% fat) meal or high-fat (37% carbohydrate and 48% fat) meal. Subjects were young (age 20 to 21 years), sedentary females. Postprandial exercise increased fat oxidation after either meal; however the greatest increase in fat oxidation was seen with the treatment combining postprandial exercise and a high-fat meal.

The majority of research regarding metabolic responses to meals of various macronutrient distributions has been performed in obese/overweight, sedentary individuals, in males, or in athletes. As such, there is a lack of

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literature pertaining to healthy, middle-aged females who are moderately active, meeting the recommendations for obtaining 30 min of aerobic activity on most days of the week (Pate et al., 1995). Individuals spend a large proportion of their waking hours in the postprandial state, and elevated postprandial TG, glucose, and insulin levels have been associated with increased risk for cardiovascular and metabolic disease (Petit et al., 2003; Pfeiffer et al., 2005). As such, examining the acute metabolic effects of a single meal in combination with aerobic exercise in various populations is essential for understanding how postprandial metabolism contributes to the development of chronic disease. The information gained by such investigations may be useful in informing interventions aimed at reducing disease risk by altering the macronutrient composition of the diet or increasing activity level. The present study was designed to test the hypothesis that mean postprandial insulin, glucose, TG, and FFAs levels would be different following a low-carbohydrate and low-fat meal in moderately active, adult females. Additionally, we tested the hypothesis that a single moderate-intensity 30-min exercise bout would alter the metabolic responses to macronutrient redistribution.

Methods

Subjects

The subjects for this investigation included 8 premenopausal females between the ages of 20 and 45 years who were recruited from local colleges and recreational facilities. Premenopausal was defined as less than or equal to 2 missed menstrual cycles in the previous year. Subjects had a body mass index (BMI) between 20 $kg \cdot m^{-2}$ and 30 $kg \cdot m^{-2}$. All of the subjects were moderately trained, which was defined as participation in aerobic activity for greater than or equal to 3 days per week for at least 6 months. Subjects were not taking any medications known to affect metabolism, were not smokers, had no known metabolic disease, and had not been actively trying to lose weight in the past 6 months. Subjects were tested during the follicular phase of the menstrual cycle (days 5-13), and had been taking hormonal contraceptives for at least 6 months. The subjects completed an informed consent, a medical history questionnaire, and a demographic information questionnaire prior to participation in the study. The subjects participated in the study voluntarily. All procedures were reviewed and approved by the Institutional Review Board of Springfield College prior to data collection.

Assessment of substrate utilization

Substrate utilization at rest and during exercise was determined using the respiratory exchange ratio (RER). Gas exchange measurements were taken using the Physiodyne Max-II Metabolic Cart (Fitness Instrument Technologies, Quogue, NY), which was calibrated according to manufacturer instructions prior to each testing session. The RER was determined by as the ratio of carbon dioxide produced to oxygen consumed as measured by the metabolic cart. A table was used to convert RER to energy from carbohydrates and fats (Wilmore et al., 2008).

Blood analyses

Blood collected via venipuncture for analysis of insulin, glucose, FFAs, and triglycerides following 30 min of fasting rest, 55 min after meal consumption, and immediately following 30 min of aerobic exercise. After clotting, blood was centrifuged 1,500 *g*, for 15 min at 4° C, with resultant serum divided into aliquots. Glucose and FFA were analyzed using an enzymatic assay kit (Wako Chemicals, Richmond, VA). TG was analyzed using an enzymatic assay kit (Roche Diagnostics, Indianapolis, IN) according to manufacturer's instructions. Insulin was analyzed using an enzyme-linked immunosorbent assay (ELISA) kit (Calbiotech, Spring Valley, CA). Absorbances for all ELISA and enzymatic assays were read using the Revelation MRX Microplate Absorbance Reader (Dynex Technologies, Chantilly, VA). The average C. V. was 4.26%, 9.49%, 6.28%, and 16.71% for TG, insulin, glucose, and FFA, respectively.

Experimental protocol

The subjects participated in 3 testing sessions. The initial session included paperwork (informed consent, medical history, demographic information), a VO_{2peak} test, body fat analysis, and explanation of the 3-day food journal. Body composition was assessed using bioelectrical impedance analysis (BIA) (Tanita BC-418, Tokyo, Japan). Two days prior to the initial visit, the subject was contacted by telephone or email regarding the guidelines for BIA. Subjects were required to be fasted for 12 h, refrain from exercise within 12 h of the test, abstain from alcohol and diuretics for 48 h prior to the test, and to void completely 30 min before the test. The VO_{2peak} test was performed on the treadmill using the Modified McConnell running protocol (McConnell, 1988). The test was terminated when the subject voluntarily terminated the test or when one of the following criteria had been met: failure of heart rate (HR) to increase with increases in workload, an RER greater than 1.15, or a rating of perceived exertion (RPE) greater than 17 using the Borg scale. Subjects were given a 3-day food journal to determine the macronutrient composition and caloric content of the habitual diet preceding the testing sessions.

The treatments were given in random order. Prior to the second testing session, the subjects completed the 3-day food journal. Dietary analysis was performed using The Food Processor software (ESHA Research, Salem, OR). Subjects were tested in the morning after a 12 h fast. Upon arrival to the human performance laboratory, subjects sat quietly for 10 min after which the mouthpiece was inserted. Gas exchange measurements were taken using the metabolic cart for 20 min, and were averaged over the final 10 min of the fasting time period. The subjects then consumed either the LF or LC test meal, which are described in Table 1. Gas exchange measurements were taken for 55 min during the postprandial resting time period. Subjects were allowed to read or listen to music during this time period. Measurements were averaged for the first 25 min and final 30 min. Prior to exercise commencement, subjects were given a 5 min break. Subjects were allowed to drink water *ad libitum* during all sessions. Gas exchange measurements were taken continuously and averaged over the 30 min exercise period.

Exercise was performed on the treadmill at an

Table 1. Test Meal Compositions.

FOOD	gCHO	kcalCHO	gFAT	kcalFAT	gPRO	kcalPRO	kcal
Low-fat Meal							
Skim Milk (198.4 g)	11.38	45.5	0	0	7	28	73.5
Whole Grain Bread (2 slices)	40	160	3	27	8	32	219
Grape Jam (2 Tbsp)	26	104	0	0	0	0	104
TOTAL	77.38	309.5	3	27	15	60	396.5
Percentages		**78%**		**7%**		**15%**	
Low-Carbohydrate Meal							
Protein Powder (20g)	1.33	5.33	0	0	15.33	61.33	66.67
Chocolate Sugar Free Pudding (106g)	13	52	1.5	13.5	2	8	73.5
Canola Oil (2 Tbsp)	0	0	28	252	0	0	252
TOTAL	14.33	57.33	29.5	265.5	17.33	69.33	392.2
Percentages		**15%**		**68%**		**18%**	

intensity corresponding to 60% to 65% of the subject's VO_{2peak} obtained from treadmill testing during the initial visit. Exercise intensity was determined by the treadmill speed and grade on a previously calibrated treadmill. Identical exercise protocols, in regards to treadmill speed and grade, were performed at the LF and LC testing sessions for each subject. Venous blood collection occurred during the final 10 min of the fasting and postprandial time period, and again immediately following exercise. Serum was analyzed for insulin, glucose, TG, and FFAs. The third testing session followed the same protocol as the second testing session. The subject was provided with their 3-day diet record and instructed to follow as closely as possible.

Statistical analyses

A 2 X 4 Repeated Measures Factorial Analysis of Variance (ANOVA) was used to analyze the data for the fasting, postprandial, and exercise time periods for RER. A 2 X 3 Repeated Measures Factorial ANOVA was used to analyze the data for the fasting, postprandial, and exercise time periods for all other variables. The independent variables were time and test meal. The dependent variables included the RER, insulin, glucose, FFA, and TG. The time periods for RER were fasting, postprandial 0 to 25 min, postprandial 25 to 55 min, and post-exercise. The time periods for glucose, insulin, TG, and FFA were fasting, postprandial, and post-exercise. If a significant main effect was found for time then pairwise comparisons were computed. If a significant interaction was found a simple effects test was computed. All data are reported as mean $\pm$ SD (n = 8). Data for fasting, postprandial, and post-exercise RER, glucose, insulin, FFA, and TG were obtained for all subjects and time-points with the exception of exercise FFA, which was unavailable for subject 2 due to technical errors. Post hoc power analysis for RER revealed with a medium effect that 8 subjects (power estimate = 0.83) would be needed to find differences (Cohen, 1988).

Results

All data are presented as mean (SD). A total of 8 subjects participated in the research. The mean age for the subjects was 33.0 (6.3) years. Descriptive statistics for age, weight, body mass index (BMI), body fat, peak oxygen consumption, and activity level are reported in Table 2.

Table 2. Demographic information for subjects.

Variable	Group Mean
Age (years)	33.0 (6.3)
Weight (kg)	74.7 (11.3)
Body Mass Index ($kg \cdot m^{-2}$)	26.8 (3.5)
Body fat %	30.9 (6.1)
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	41.8 (5.7)
Activity level (days/week)	4.3 (1.3)

Values are presented as mean (SD), n = 8.

Habitual diet

In order to control for habitual diet between the second and third testing sessions subjects were instructed to eat similarly and to complete a 3-day dietary record prior to each testing session. The absolute amount of fat, protein, and carbohydrate in the habitual diets were not significantly different ($p > 0.05$) before the two sessions. The mean macronutrient composition of the habitual diet prior to the LC session was 36% fat, 45% carbohydrate, and 17% protein. The mean macronutrient composition of the habitual diet prior to the LF session was 33% fat, 48% carbohydrate, and 15% protein.

Exercise data

The mean percentage of VO_{2peak} achieved during the LC testing session was 68.4 (6.5) %. The mean percentage of VO_{2peak} achieved during the LF testing session was 62.4 (5.6) %. Although subjects performed the same exercise protocol during both testing sessions, the relative oxygen consumption during exercise was significantly greater during the LC testing session ($p < 0.05$) than during the LF testing session. Oxygen consumption during exercise was significantly greater ($p < 0.05$) during the LC session compared to the LF session when expressed in absolute terms as well [2.1 (0.4) $L \cdot min^{-1}$ for LC vs. 1.9 (0.3) $L \cdot min^{-1}$ for LF].

Energy expenditure during exercise was significantly greater ($p < 0.05$) during the LC testing session compared to the LF session [305 (54) kcal and 281 (50) kcal, respectively]. The percentage of total energy expended that was derived from carbohydrate during exercise was significantly greater ($p < 0.05$) in the LF session compared to the LC session [53 (14) % in LF and 36 (15) % in LC]. Conversely, the percentage of energy derived from fat was significantly greater ($p < 0.05$) during exercise in the LC session compared to LF [63 (15) % in LC vs. 47 (14) % in LF]. Energy derived from fat was significantly greater ($p < 0.05$) during LC exercise compared to LF exercise [193 (57) kcal vs. 131 (44) kcal, respec-

tively], while energy derived from carbohydrate was significantly lower ($p < 0.05$) in LC vs. LF [112 (56) kcal vs. 150 (58) kcal]. Significantly more grams of fat were oxidized during exercise in the LC session when compared to exercise during the LF session [21.4 (6.3) g in LC vs. 14.6 (4.8) g in LF, $p = 0.01$].

Metabolic data

There was no significant interaction ($p > 0.05$) between test meals for fasting values of RER, glucose, insulin, TG, or FFA. A significant main effect ($p < 0.05$) of time existed for glucose. Glucose values were not significantly different ($p > 0.05$) between the fasting and postprandial time periods [LC: 91.8 (5.9) mg·dL^{-1} fasting and 82.2 (11.5) mg·dL^{-1} postprandial; LF: 88.7 (9.6) mg·dL^{-1} fasting and 90.3 (16.3) mg·dL^{-1} postprandial]. Glucose levels following exercise were significantly greater ($p < 0.05$) than postprandial values for both test meals [96.3 (16.1) mg·dL^{-1} for LC and 96.11 (16.1) mg·dL^{-1} for LF].

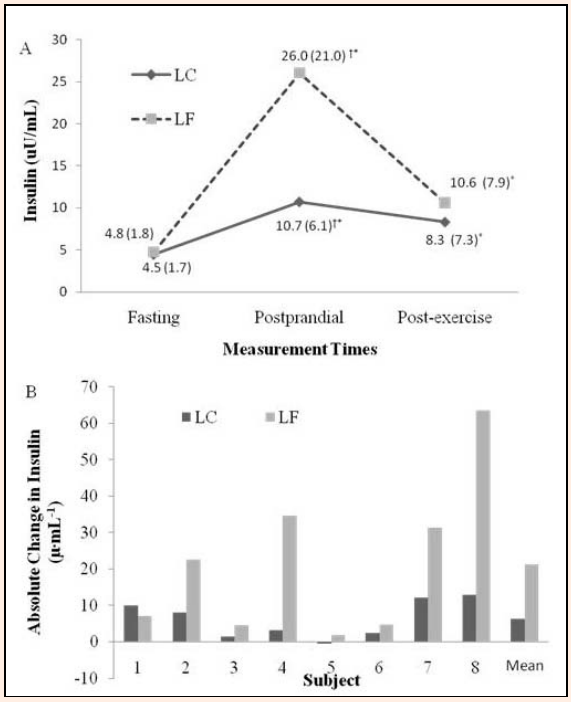

Figure 1. Mean and individual insulin responses to test meals.

For all other variables, a significant interaction ($p < 0.05$) was found between test meal and time. Although insulin levels increased after both meals, postprandial insulin levels were significantly lower ($p < 0.05$) following the LC meal compared to LF meal. There were no significant differences ($p > 0.05$) in insulin values between the test meals for the post-exercise time period. Mean serum insulin levels at baseline, 55 min postprandial, and post-exercise, and individual subject data for the absolute change in insulin concentrations following the LC and LF meal are presented in Figure 1a and b, respectively.

There were no significant differences ($p > 0.05$) in postprandial FFA concentrations between the LF and LC meals. Post-exercise FFA levels were significantly greater ($p < 0.05$) following the LC meal. Similarly, there were no significant differences ($p > 0.05$) for postprandial TG between the LF and LC meals, however following exercise TG levels were significantly lower ($p < 0.05$) after ingestion of the LF meal compared to the LC meal (Figure 2 and Figure 3).

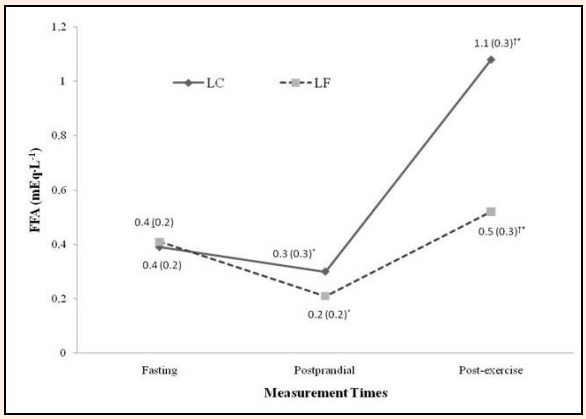

Figure 2. Free fatty acid levels following test meals over time.

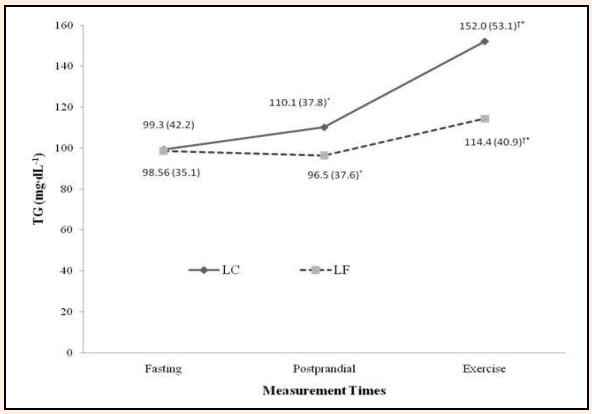

Figure 3. Triglyceride levels following test meals over time.

Postprandial RER from min 0 to min 25 was significantly higher ($p < 0.05$) following the LF meal compared to the LC meal. Postprandial RER from min 25 to 55 was also significantly higher ($p < 0.05$) following the LF meal. RER during the 30 min exercise period was significantly higher ($p < 0.05$) following the LF meal compared to the LC meal (Table 3).

Table 3. Data for Respiratory Exchange Ratio.

Time	Low-Carbohydrate	Low-Fat
Fasting 20 min	.78 (.04) *	.77 (.05) *
Postprandial 25 min	.72 (.04) *,†	.80 (.04) *,†
Postprandial 55 min	.75 (.03) *,ŧ	.86 (.04) *,ŧ
Exercise 30 min	.81 (.04) *,§	.86 (.04) *,§

Values are presented as means (SD), $n = 8$. Respiratory Exchange Ratio measurements represent averages over fasting (20 min), postprandial (0 to 25 min and 25 to 55 min), and exercise (30 min) time periods. † Significant interaction of time and test meal between fasting and postprandial 25 min measurements. ŧ Significant interaction of time and test meal between postprandial 25 min and postprandial 55 min measurements. § Significant interaction of time and test meal between postprandial 55 min and exercise measurements.

Discussion

Discerning the metabolic consequences of dietary manipulation and acute activity prior to the development of obesity and disease may inform disease prevention programs.

The primary finding in the present study was that RER was lower at rest 25 min and 55 min after ingestion of a LC meal in moderately active, healthy females eating a mixed habitual diet. Additionally, RER was lower during 30 min of aerobic treadmill exercise following the LC meal. RER is an indicator of substrate utilization, such that a lower RER indicates more lipid oxidation and a higher RER is indicative of greater carbohydrate oxidation (Ferrannini, 1988). Thus, the RER values seen in the present study indicate that there was greater lipid oxidation and less carbohydrate oxidation following the LC meal at rest and during exercise in healthy, active females between the ages of 20 and 45 years. These findings were supported by blood measurements of FFA and insulin. Insulin levels were reduced, while FFA levels were greater following the LC meal, supporting the conclusion that there was increased lipid mobilization following the LC meal in this population.

The results are similar to those reported by Bowden and McMurray (2000) when they compared RER following a high-carbohydrate (HC) and high-fat (HF) meal in highly trained ($VO_{2max} \geq 50$ ml·kg^{-1}·min^{-1}) women between the ages of 21 and 45 years. In agreement with the present study, RER was lower indicating fat oxidation was higher following the HF meal compared to the HC meal at both 30 and 60 min postprandial time periods. In the present study the LF meal was composed of 78% CHO, 7% fat, and 15% protein, and the LC meal was composed of 15% CHO, 68% fat, and 18% protein. The LF and LC meal contained 396 kcal and 392 kcal, respectively. The HC and HF meals used in the research performed by Bowden and McMurray (2000) were 76% CHO, 23% fat, 5% protein and 21% CHO, 72% fat, and 8% protein, respectively. The HC meal provided 494 kcal and the HF meal 500 kcal. The higher calorie content, lower protein content, and differing macronutrient compositions may have explained the higher RER values reported by Bowden and McMurray. Similar to the responses seen in highly trained females, Ezell et al. (1999) reported that RER increased during exercise after a high-carbohydrate meal in sedentary females. Sedentary females completed 1 h of cycling at 60 to 65% VO_{2max} following ingestion of a test meal. The test meal consisted of 384 kcal with a macronutrient composition of 29% fat, 14% protein, and 57% CHO.

Postprandial insulin levels were lower 60 min after the LC meal compared to after the LF meal. These results are in agreement with Knuth et al. (2008) who determined that insulin levels were lower 60 min after a high-fat meal compared to 60 min after the same meal with 1 g CHO per kg body mass added in inactive males and females (inactive defined as less than 2 hr/week of activity). The researchers also reported that bioavailability of FFAs was reduced and glucose levels increased concomitantly with increased insulin levels when CHO was added to the HF meal. These results are in disagreement with the present study, in which FFAs and glucose levels were not significantly different following different test meals at rest. Differences may be attributed to the differing macronutrient distributions of the test meals used. In the present study, insulin levels were reduced from postprandial values following exercise regardless of which meal was consumed. There were no longer differences in insulin values between test meals following 30 min of aerobic exercise. Similar findings have been reported following 30 min of exercise in sedentary females (Ezell et al., 1999).

An interesting observation in the present study was the individual variation in the postprandial insulin response between subjects. As illustrated in Figure 2, the insulin responses to the LF meal demonstrated greater individual variability than the response to the LC meal. Following the LC meal, the absolute change in insulin ranged from a reduction of 0.4 μ·L^{-1} to an increase of 12.9 μ·L^{-1}. In comparison, the absolute change in insulin following the LF meal ranged from an increase of 1.77 to 63.5 μ·L^{-1}. Individual responses to a high-carbohydrate meal suggest varying degrees of "carbohydrate tolerance" based on individual characteristics, possibly including habitual diet, activity level, and genetics. Further investigation into the underlying mechanisms explaining the individual variation in the insulin response to high-carbohydrate meals is warranted.

Following 30 min of exercise FFAs and TG levels were greater with the LC meal compared to the LF meal. Further reductions in insulin levels coupled with increased sympathetic nervous system activity and demand for fuel may have promoted lipid mobilization and explain why differences in FFA levels appeared following exercise and not at rest. Other researchers have also reported that free fatty acid levels increased significantly from baseline following 30 min of aerobic exercise in inactive individuals (Ezell et al., 1999; Knuth et al., 2008). Knuth et al. (2008) also found that increasing the carbohydrate content of a meal attenuated the TG response 60 min after meal consumption. Elevated TG levels following a LC meal and 30 min of exercise may be explained by lower insulin levels. Lower insulin levels coupled with the demands of exercise may have lead to a reduced inhibition of hormone sensitive lipase (HSL) and reduced activation of lipoprotein lipase (LPL) at the adipose tissue. Furthermore, exercise was performed one hour after meal consumption, which is not sufficient time for complete digestion and absorption of dietary fat. Therefore, elevated circulating TG may have been a reflection of the continued processing and transportation of chylomicrons. Triglyceride concentrations have been reported to peak between 2 and 4 h after a high-fat meal in men with metabolic syndrome (Plaisance et al., 2008).

The present investigation had several limitations. Measurement of serum glycerol levels would have provided a more accurate indicator of lipolysis. Additionally, analysis of blood parameters and substrate utilization further into exercise recovery may have been beneficial. It has been shown that lipid utilization prevails during recovery from endurance exercise without compensatory energy intake (Kolovou and Bilianou, 2008). Additional research is needed to determine the long-term effects of

dietary macronutrient redistribution on metabolism and fat storage in moderately active females prior to the development of metabolic or cardiovascular disease. Ultimately, such investigations may aid in the prevention of these conditions.

Conclusion

In summary, the major findings of the present study were that in moderately active adult females, ingestion of a single LC meal resulted in a reduced RER at rest and during exercise, and a reduced insulin response during the postprandial period compared to a LF meal. RER values suggested that consumption of a single LC meal increased fat oxidation, while a LF meal resulted in a diminished lipolytic response and increased insulin levels. A similar response has been demonstrated in sedentary and obese individuals and in athletes; however to the best of our knowledge, this is the first study to show the dramatic metabolic consequences of a single meal in moderately active females who habitually ate a mixed macronutrient diet. Thirty minutes of aerobic exercise resulted in equivalent insulin levels between the LC and LF meals, indicating that the effect of exercise on insulin levels was greater than the effect of a single meal. These results demonstrate a possible role for aerobic exercise in the prevention of chronic disease by altering and attenuating the effects of dietary consumption on metabolism.

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Key points

- The relative carbohydrate content of a single meal has a significant impact on postprandial metabolism and substrate utilization in healthy, active females.
- A single bout of aerobic exercise performed within an hour of meal ingestion has the potential to modify the postprandial response.
- Interventions aimed at improving body composition and preventing chronic disease should focus on dietary macronutrient redistribution and postprandial metabolism in concert with exercise training.

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