

# Resistance Exercise Attenuates High-Fructose, High-Fat-Induced Postprandial Lipemia

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## ABSTRACT

**INTRODUCTION:** Meals rich in both fructose and fat are commonly consumed by many Americans, especially young men, which can produce a significant postprandial lipemic response. Increasing evidence suggests that aerobic exercise can attenuate the postprandial increase in plasma triacylglycerols (TAGs) in response to a high-fat or a high-fructose meal. However, it is unknown if resistance exercise can dampen the postprandial lipemic response to a meal rich in both fructose and fat.

**METHODS:** Eight apparently healthy men (Mean  $\pm$  SEM; age =  $27 \pm 2$  years) participated in a crossover study to examine the effects of acute resistance exercise on next-day postprandial lipemia resulting from a high-fructose, high-fat meal. Participants completed three separate two-day conditions in a random order: (1) EX-COMP: a full-body weightlifting workout with the provision of additional kilocalories to compensate for the estimated net energy cost of exercise on day 1, followed by the consumption of a high-fructose, high-fat liquid test meal the next morning (day 2) (~600 kcal) and the determination of the plasma glucose, lactate, insulin, and TAG responses during a six-hour postprandial period; (2) EX-DEF: same condition as EX-COMP but without exercise energy compensation on day 1; and (3) CON: no exercise control.

**RESULTS:** The six-hour postprandial plasma insulin and lactate responses did not differ between conditions. However, the postprandial plasma TAG concentrations were 16.5% and 24.4% lower for EX-COMP ( $551.0 \pm 80.5$  mg/dL  $\times$  360 minutes) and EX-DEF ( $499.4 \pm 73.5$  mg/dL  $\times$  360 minutes), respectively, compared to CON ( $660.2 \pm 95.0$  mg/dL  $\times$  360 minutes) ( $P < 0.05$ ).

**CONCLUSIONS:** A single resistance exercise bout, performed ~15 hours prior to a high-fructose, high-fat meal, attenuated the postprandial TAG response, as compared to a no-exercise control condition, in healthy, resistance-trained men.

**KEYWORDS:** fructose, triglycerides, triacylglycerols, energy balance, weightlifting, postprandial lipemia

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## Introduction

The consumption of a diet high in fructose has been shown to raise plasma triacylglycerols (TAGs) significantly more than a diet low in fructose.<sup>1–3</sup> The ingestion of liberal quantities of fructose and fat together, even in a single meal, can cause a significant rise in circulating postprandial TAGs.<sup>4</sup> Fructose is readily cleared by the liver and bypasses a key control step in the glycolytic pathway,<sup>5</sup> a phenomenon that contributes to high fructolytic flux with increased hepatic lactate and malonyl-CoA production.<sup>6–8</sup> The latter inhibits fatty acid entry into mitochondria and thus reduces the hepatic oxidation of fatty acids, potentiating an increase in very low-density lipoprotein (VLDL)-TAG secretions.<sup>6</sup> The higher fructolytic flux also appears to enhance de novo lipogenesis, while the lower insulin response to fructose compared to glucose may dampen lipoprotein lipase (LPL) activity, contributing to reduced clearance of circulating TAG-rich lipoproteins.<sup>4</sup> The elevation of VLDL-TAG resulting from fructose ingestion and the elevated chylomicron-TAG from dietary fat may provide a significant challenge for the clearance

of these TAG-rich lipoproteins during the postprandial period, following the ingestion of a meal high in both fat and fructose.<sup>4,9,10</sup> Men following a high-fructose meal appear to have a greater increase in VLDL-TAG than women.<sup>11</sup> Postprandial lipemia has been identified as a risk factor for cardiovascular disease (CVD),<sup>3</sup> which may contribute to the epidemiological evidence linking diets with high intakes of sugar-sweetened beverages with increased risk of coronary heart disease.<sup>12,13</sup>

There is some evidence that exercise can attenuate postprandial lipemia,<sup>14–17</sup> however, the results from prior research have been somewhat discordant.<sup>14,15,18–20</sup> This variability is likely attributable to differences among studies in exercise modality, duration, and intensity; the nature of the test meal; overall dietary control and energy balance; and the training status of participants.<sup>16,20–23</sup> The timing of exercise in relation to the test meal may also influence the observed effects on postprandial TAG. It appears that when resistance exercise, which has increased in popularity in recent years, is performed just prior to a high-fat test meal, the postprandial circulating



TAG may actually be increased as compared to a control condition.<sup>20</sup> However, several studies have shown that when similar resistance exercise is performed the day prior to a high-fat test meal, a reduction in the lipemic response is observed over the duration of the postprandial period as compared to a non-exercise control condition.<sup>14,16,23</sup>

It has been argued that the effect of exercise on various metabolic variables is too often confounded by exercise-induced changes in energy balance.<sup>24</sup> In order to determine the effects of exercise independent of an acute energy deficit, it would follow that the energy cost of exercise must be coupled with the provision of additional kilocalories to compensate for the net exercise energy expenditure to maintain energy balance.<sup>24</sup> Several studies have attempted to control for energy balance by introducing a condition where participants remained in an exercise-induced calorie deficit in addition to a condition in which participants were calorically compensated for energy expenditure.<sup>21,25</sup> When participants did not receive caloric compensation for the energy cost of the exercise, the postprandial lipemic response was attenuated compared to both a no exercise control condition and an exercise with caloric compensation condition.<sup>21,25</sup>

The aforementioned studies have examined postprandial lipemia only in response to high-fat meals<sup>14–16,18,20</sup> as opposed to high-fructose, high-fat meals. However, the effect of a single bout of resistance exercise on postprandial plasma TAG excursions in response to a mixed liquid meal with significant quantities of both fructose and fat has not been examined. Therefore, the main purpose of this study was to determine whether or not a single bout of resistance exercise performed the day prior to a meal challenge could attenuate the postprandial increase in plasma TAG in response to a high-fructose, high-fat meal. Secondarily, the effect of energy balance was examined in conjunction with resistance exercise by studying the exercise conditions with and without dietary energy compensation for the estimated net energy cost of the single exercise bout. We hypothesized that there would be a significant attenuation of the postprandial lipemic response, following resistance exercise with no dietary energy compensation compared to a no-exercise control condition, but considered the possibility that providing additional food calories to compensate for the net cost of exercise would result in little to no attenuation of the postprandial lipemic response.

## Methods

**Study participants.** Nine men were recruited who met the eligibility requirements as follows: apparently healthy, normotensive males with a body mass index (BMI) between 23 and 29.9 kg/m<sup>2</sup> and participated in recreational weightlifting on an average of two to three times per week in the month prior to enrollment. Exclusionary criteria included cigarette smoking, history of CVD, bone and joint dysfunction that would preclude resistance exercise, self-reported dyslipidemia, metabolic disorders, actively training for either resistance or aerobic exercise competition, and use of any nutritional supplements

and/or medications that could alter metabolic function. Body weight (BW), BMI, and body fat percentage were assessed at an initial screening visit using a body composition analyzer (Tanita® Corporation). Weight was measured to the nearest 0.1 kg and body fat percentage to the nearest 0.1%. Height was measured using a stadiometer to the nearest 0.1 cm. One of the nine eligible participants had discontinued after enrollment due to difficulties with blood sampling. All subjects gave written informed consent. This study was approved by the Colorado State University Institutional Review Board. Participant characteristics are described in Table 1. This study was approved by the Colorado State University Institutional Review Board: The research reported here complied with the principles of the Declaration of Helsinki.

**Experimental design.** Study participants were randomized to each of the three study conditions in a counterbalanced, crossover design. Each of the three conditions lasted two days, with a minimum of a five-day washout between conditions. The conditions were as follows: (1) resistance exercise with calorie replacement (EX-COMP), (2) resistance exercise without calorie replacement (EX-DEF), and (3) no exercise control (CON). In the EX-COMP condition, participants completed a 95-minute resistance exercise protocol on the first day of the condition, 15 hours prior to the test meal the following morning. On the exercise day, they received additional kilocalories to compensate for the calories expended during the resistance exercise. Similar to the EX-COMP condition, participants also completed 95 minutes of resistance exercise on the first day of the EX-DEF condition. However, in the EX-DEF condition, participants were fed a similar amount of kilocalories as the control condition (therefore were likely in an energy deficit state for that day). The CON condition did not include any exercise, but participants reported to the laboratory for 95 minutes of quiet rest during the same time period in which they exercised in the EX-COMP and EX-DEF conditions.

**Day 1 protocol.** In order to estimate energy requirements for the study participants, resting metabolic rate (RMR) was measured by indirect calorimetry using a Parvo Medics TrueOne® 2400 metabolic measurement system (Parvo Medics). All RMR tests began between 6 am and 9 am, with a consistent start time across the three conditions for each study participant. Following the RMR test, participants were provided with breakfast, lunch, and snacks for the day by the

**Table 1.** Baseline study participant characteristics (*n* = 8).

VARIABLE	MEAN ± SEM
Age (yrs)	27 ± 2
Height (cm)	180.0 ± 2.5
Weight (kg)	79.2 ± 1.5
BMI (kg/m <sup>2</sup> )	24.2 ± 0.3
Body Fat (%)	14.2 ± 1.8



researchers. Following either the resistance exercise bout or quiet rest, participants were provided with their dinner for the evening. All participants were instructed to consume only the food provided by the researchers and to return any uneaten food the following morning. Study participants were also instructed to refrain from alcohol, caffeine, and exercise on the day prior to beginning and during each condition (with the exception of the investigator-monitored resistance exercise bout in the two exercise conditions).<sup>4,14</sup> Adherence was verbally confirmed by the participants the morning of day 2 of each condition. Ten hours after the RMR test on day 1 of each condition, study participants either performed 95 minutes of resistance exercise (EX-COMP and EX-DEF) or reported to the lab for a 95-minute period of quiet rest (CON).

**Metabolic rate measurement.** The RMR measurements were obtained by indirect calorimetry (Parvo Medics<sup>®</sup> metabolic measurement system). The system was calibrated according to the manufacturer's specifications. Study participants were placed on a comfortable bed in a supine position in a semi-darkened, temperature-controlled room. The first 15 minutes of each RMR test was considered a habituation period, and the values were discarded. The final 30 minutes were averaged to determine each participant's RMR. The RMR values were then used to estimate the participants' daily energy requirements as described in the following sections.

**Day 1 diet.** All meals for the first day of each of the conditions were provided to study participants and designed to consist of a standard macronutrient composition of 50% carbohydrates (CHOs), 18% protein, and 32% fat. The EX-DEF and CON conditions included a total caloric intake determined by the measured RMR values multiplied by an activity factor of 1.4.<sup>26,27</sup> The caloric intake for the EX-COMP condition was calculated similarly by multiplying the measured RMR by an activity factor of 1.4 and then adding in extra kilocalories to compensate for the estimated net energy expenditure of the resistance exercise bout.<sup>14</sup> This additional caloric compensation was based on the net energy expenditure for resistance exercise, with the number of multiples of resting metabolic rate (METs) for resistance exercise derived from the Compendium of Physical Activities.<sup>28</sup> Net exercise energy expenditure was calculated using the following formula:

$$\text{Kilocalories} = [(\text{RMR}/1,440 \text{ minutes/day}) \times 6\text{METs} \times 90 \text{ minutes}] - [(\text{RMR}/1,440 \text{ minutes/day}) \times 90 \text{ minutes}]$$

**Resistance exercise protocol.** As indicated above, the resistance exercise protocol occurred on the first day of the EX-COMP and EX-DEF conditions, 15 hours prior to the fructose-fat test meal. The protocol consisted of 95 minutes of supervised resistance exercise. Four sets of 10 repetitions each of 14 different exercises were completed in supersets, with the exception of lunges for which only three sets were performed. The 90-second rest intervals occurred between the start of

one set and the start of the next set, with a two-minute rest interval following the completion of each superset. The fourth set of each exercise was performed to failure. The exercises included the following in order of performance: bench press, seated row, leg press, calf raise, shoulder press, lateral pull-down, leg extension, leg curl, bicep curl, triceps extension, lunges, lateral raise, sit-ups, and back extensions. The weight lifted for each exercise (~12 repetition maximums) was determined during an initial familiarization visit, where study participants performed an abbreviated version of the resistance exercise protocol. The weight utilized during lunges was standardized at approximately one-third of BW.

**Day 2 protocol.** On the second day of each condition, study participants reported to the lab at the same time as on day 1. An intravenous catheter was placed in a forearm vein, and a 10-mL fasting baseline blood sample was collected by the syringe and handled as described in further detail in the following section. Following the baseline sample measurement, a slow 0.9% saline drip was initiated to keep the line patent for the duration of the condition. The study participants then consumed a high-fructose, high-fat beverage, as described in the following section. Additional blood samples of 5 mL were collected at each of 15, 30, 60, 90, 120, 240, 300, and 360 minutes following the beverage consumption. During the six-hour postprandial period, the study participants lay quietly in a recumbent position in a comfortable bed and were allowed access to reading material.

**High-fructose high-fat beverage.** The high-fructose, high-fat beverage was composed of 0.75 g/kg BW of fructose, 0.5 g/kg BW of safflower oil, 10 g protein (NutriBiotic<sup>®</sup> rice protein powder), and 357 g of unsweetened plain almond milk (Almond Breeze<sup>®</sup>), with the macronutrient content known to elicit a postprandial lipemic response in healthy men and women.<sup>4</sup> Participants were given the choice of either vanilla or chocolate rice protein powder, with the quantity of protein powder adjusted to maintain a constant 10 g of protein in the beverage. The high-fructose, high-fat beverage provided an average of 600 ± 8 kcal and 58.6 ± 0.8 g CHO, 39.0 ± 0.5 g fat, and 10.0 ± 0.0 g protein.

**Plasma assays.** Blood samples were collected at time 0 (fasted baseline) and 15, 30, 60, 90, 120, 180, 240, 300, and 360 minutes post beverage in ethylenediaminetetraacetic acid (EDTA)-containing tubes, gently inverted five times, and placed on ice until centrifugation. The blood was centrifuged at 3,200 rpm for 10 minutes at 4°C. The plasma from each EDTA-containing tube was pipetted into Eppendorf tubes and stored at -80°C for future analysis. Plasma samples were thawed from freeze at a later time, and plasma glucose and plasma lactate were measured in duplicate using the YSI 2300 Stat Plus<sup>™</sup> Glucose and Lactate Analyzer (Yellow Springs Instruments).

Plasma samples were assayed for TAG and insulin concentrations at the UCH-CTRC Laboratory at the Medical Campus of the University of Colorado Denver. Plasma TAG and plasma insulin concentrations were analyzed at all time points,



with the exception of 15 and 60 minutes following meal consumption. Insulin was measured utilizing a chemiluminescent immunoassay on a Beckman Access 2 analyzer (Beckman Coulter, Inc.), with a reportable range between 1 and 300  $\mu\text{UI}/\text{mL}$ . TAGs were measured using an enzymatic assay on a Beckman AU480 chemistry analyzer (Beckman Coulter, Inc.), with a reportable range between 15 and 950  $\text{mg}/\text{dL}$ .

**Statistics.** Paired  $t$ -tests were used to compare the differences between the amount of weight lifted during the resistance exercises between the EX-DEF and EX-COMP conditions. Repeated measures analyses of variance (ANOVAs) for a general linear model were used to analyze the changes in plasma analytes from baseline to six hours postprandial, with least squares difference post hoc tests used to compare the different conditions. The area under the curves (AUCs) for TAG and glucose were calculated using the trapezoidal rule. AUC is calculated using the following formula:

$$\int_0^8 0.5 * (t_{i+1} - t_i) * (d_i + d_{i+1})$$

where  $t_i$  is the time ( $i$ : 0, 0.5, 1, 1.5, 2, 3, 4, 5, 6) and  $d_i$  is the data at that time ( $i$ : 0, 0.5, 1, 1.5, 2, 3, 4, 5, 6). Baseline fasted samples represent time point zero, and the six-hour time point is represented by  $t_i = 6$ . Statistical analyses were run using the IBM SPSS Statistics software, Version 22. A  $P$ -value of 0.05 was considered statistically significant.

## Results

**Day 1 food intake.** Table 2 provides information on the energy and macronutrient intakes on day 1 for the three conditions. The actual macronutrient composition intakes of the study participants ( $50.5 \pm 0.2\%$  CHO,  $31.8 \pm 0.2\%$  fat, and  $17.7 \pm 0.2\%$  protein) on day 1 varied minimally from the macronutrient intake goals, and the percentage of kilocalories consumed from each of the three macronutrients were not different across the three experimental conditions. Owing to small variations in measured RMR values across the three conditions, there were small insignificant differences in the calories ingested between the CON and EX-DEF conditions ( $2,499 \pm 88$  kcal vs.  $2,544 \pm 90$  kcal;  $P = 0.75$ ). In keeping with the study design, participants were provided significantly more calories for day 1 in the EX-COMP condition

**Table 2.** Day 1 meals.

	CON	EX-COMP	EX-DEF
Measured RMR	1718 $\pm$ 89	1753 $\pm$ 89	1759 $\pm$ 96
Compensatory kcals	–	581 $\pm$ 25	–
Total kcals	2499 $\pm$ 88	2988 $\pm$ 117	2544 $\pm$ 90
CHO (g)	315.9 $\pm$ 9.9	379.7 $\pm$ 13.4	323.7 $\pm$ 10.1
Fat (g)	89.0 $\pm$ 3.3	106.1 $\pm$ 5.0	90.3 $\pm$ 3.9
Protein (g)	111.8 $\pm$ 6.2	118.8 $\pm$ 8.8	112.2 $\pm$ 5.2

( $2,988 \pm 117$  kcal) than in either the EX-DEF or CON condition ( $P < 0.05$ ).

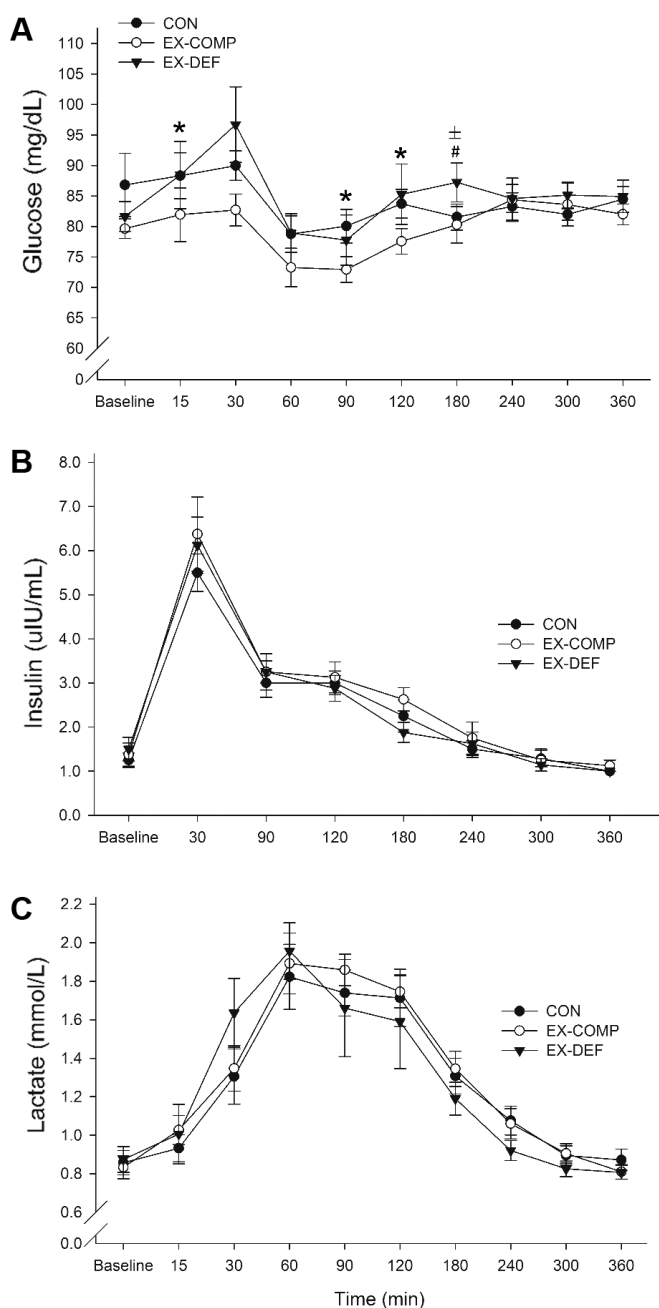
**Exercise.** During the 95-minute bout of resistance exercise, the subjects lifted a large mass of weight. The total mass lifted was not significantly different between the two exercise conditions (EX-COMP:  $37,325 \pm 1,237$  kg; EX-DEF:  $38,740 \pm 1,614$  kg;  $P = 0.28$ ).

**Glucose, insulin, and lactate.** The plasma glucose, plasma insulin, and plasma lactate concentration data are presented in Figure 1. There were no differences in fasting glucose concentrations across the three conditions, and plasma glucose rose only modestly during the postprandial period across all the three conditions. Statistical analyses revealed a significant time effect as well as a time by condition interaction, with subsequent contrasts between conditions showing a significant difference between CON and EX-COMP and between EX-COMP and EX-DEF ( $P < 0.05$ ). However, the six-hour AUC values for glucose were not different among conditions. There were no differences in fasting insulin concentrations (CON =  $1.3 \pm 0.2$   $\mu\text{IU}/\text{mL}$  EX-COMP =  $1.4 \pm 0.3$   $\mu\text{IU}/\text{mL}$ ; EX-DEF =  $1.5 \pm 0.3$   $\mu\text{IU}/\text{mL}$ ) or in fasting lactate (CON =  $0.86 \pm 0.06$   $\text{mmol}/\text{L}$ ; EX-COMP =  $0.83 \pm 0.06$   $\text{mmol}/\text{L}$ ; EX-DEF =  $0.87 \pm 0.07$   $\text{mmol}/\text{L}$ ) across the three conditions, although as expected there was a significant time effect for insulin and lactate as they increased and then decreased during the six-hour postprandial period across the three conditions. There were no time by condition interactions for insulin or lactate, indicating that the changes in these metabolites over time were not different among the conditions.

**Triacylglycerol.** The TAG data are presented in Figure 2. There was not a significant difference in fasting plasma TAG across the three conditions. As expected, there was a significant time effect across the three conditions owing to the rise and subsequent fall of TAG during the postprandial period. The repeated measures ANOVA revealed a significant time by condition interaction with contrasts, showing both EX-COMP and EX-DEF to be significantly lower than CON ( $P < 0.05$ ), but no differences between EX-COMP and EX-DEF. Post hoc tests revealed differences at several time points that were statistically significant ( $P < 0.05$ ) between CON and EX-COMP and CON and EX-DEF, as shown in Figure 2. Additionally, the total six-hour AUC for TAG was significantly lower for both the EX-COMP and the EX-DEF conditions as compared to the CON condition ( $P < 0.05$ ).

## Discussion

The main finding of our study is that compared to a no-exercise control condition, resistance exercise performed 15 hours prior to a high-fructose, high-fat liquid meal attenuates the postprandial lipemic response to the meal. This study appears to be the first to show this ostensibly beneficial effect of a single resistance exercise bout on postprandial lipemia induced by an acute high-fructose, high-fat meal. We examined the



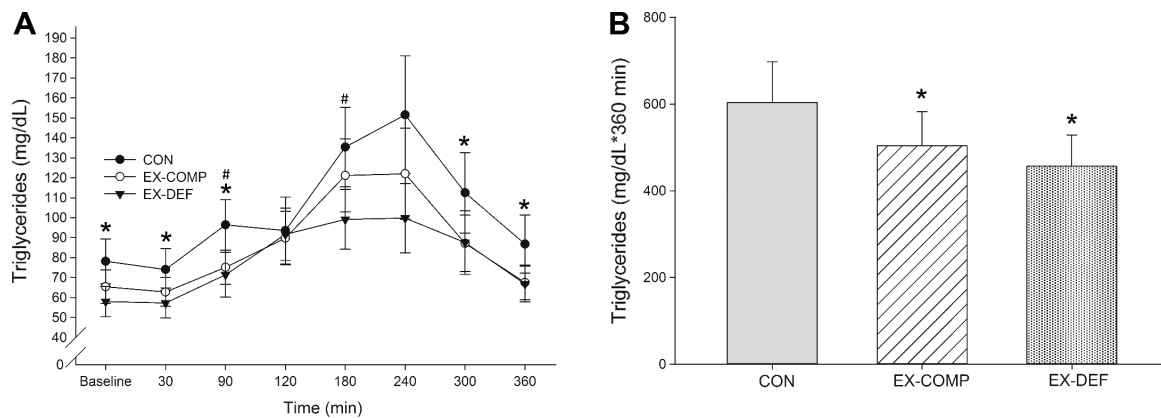
**Figure 1.** Mean ( $\pm$ SEM) plasma analyte concentrations. **(A)** Plasma glucose concentrations at baseline (fasted values) were not significantly different between the three conditions. During the six-hour postprandial period in response to a high-fructose, high-fat liquid meal, there was a significant condition by time interaction. Post hoc tests revealed that the mean concentrations over the six-hour period were significantly lower in EX-COMP than in EX-DEF and CON ( $P < 0.05$ ). ( $*P < 0.05$  for CON vs. EX-COMP;  $\#P < 0.05$  for CON vs. EX-DEF;  $\pm P < 0.05$  for EX-COMP vs. EX-DEF). **(B)** Plasma insulin concentrations at baseline (fasted values) were not significantly different between the three conditions. There was a significant time effect, but no significant time by condition interaction, during the six-hour postprandial period in response to a high-fructose, high-fat liquid meal between the three conditions. **(C)** Plasma lactate concentrations at baseline (fasted values) were not significantly different between the three conditions. There was a significant time effect, but no time by condition interaction, during the six-hour postprandial period in response to a high-fructose, high-fat liquid meal.

possibility that without an acute energy deficit created by the resistance exercise bout, the latter would not attenuate the postprandial TAG excursion. However, there was no statistical difference between the six-hour TAG AUC for EX-COMP and EX-DEF. Importantly, even in the face of energy compensation, resistance exercise significantly reduced the six-hour postprandial TAG AUC by 20% in comparison to the no-exercise control condition.

While we made no attempts in this study to determine the mechanisms behind the dampened postprandial lipemic response following the resistance exercise, it would follow that the decrease in postprandial TAG must be due to a decreased rate of appearance of TAG, an increased rate of disappearance of TAG, or both in combination. Previous research may allow some speculation as to the mechanistic effects. The kinetics of TAG appearance and disappearance have been examined in relation to endurance exercise performed the evening before testing. Studies utilizing stable-isotope tracers to determine the rates of both appearance and disappearance of TAG following a bout of endurance exercise indicate that the likely culprit for decreased VLDL-TAG following exercise is an increased rate of disappearance as compared to a non-exercise control condition.<sup>29,30</sup> Comparing arterial and venous blood samples from femoral veins and arteries the morning following an hour-long bout of treadmill running provides a similar insight that the decrease in plasma TAG may be attributable to an increased rate of disappearance of TAG from circulation.<sup>29–31</sup> Plasma LPL, but not muscle LPL, concentrations were found to be significantly increased following endurance exercise, suggesting that increased LPL expression may be at least partly responsible for the decrease in TAG.<sup>30,31</sup> The rates of postprandial TAG appearance and disappearance following resistance exercise are an area ripe for future investigation.

The reason for the slightly, but statistically significant, lower postprandial plasma glucose response for the EX-COMP condition is not readily apparent. The lack of any condition differences in the glucose AUC values suggests that the aforementioned difference may be relatively inconsequential.

**Strengths and limitations.** There are a number of strengths of the present study that add to the credibility of our findings. The within-subjects crossover design allowed tight control over participant characteristics and limited potential confounding factors between the conditions. Each of the exercise protocols was supervised by the same individuals for consistent treatment, with a matched supervised control period. All meals on the first day were prepared and provided by the same investigator (JW) and were controlled to meet specific targeted macronutrient compositions. Additionally, the timing of all meals provided was repeated across each condition for each study participant. The postprandial changes in the plasma concentrations of glucose, insulin, and lactate were within expected ranges in response to the high-fructose, high-fat meal, lending credibility to our TAG differences between the conditions.



**Figure 2.** Plasma TAG concentrations. **(A)** During the six-hour postprandial period in response to a high-fructose, high-fat liquid meal, there was a significant condition by time interaction for plasma TAG concentrations (mean  $\pm$  SEM), with baseline samples representing fasted values. Post hoc tests revealed that the mean concentrations over the six-hour period were significantly lower in EX-COMP and EX-DEF than in CON ( $P < 0.05$ ) ( $*P < 0.05$  for CON vs. EX-COMP;  $\#P < 0.05$  for CON vs. EX-DEF). **(B)** AUC (mean  $\pm$  SEM) for plasma TAG concentrations, calculated using the trapezoidal rule, over the six-hour postprandial period ( $*P < 0.05$ , compared to CON).

Several limitations are noteworthy. (1) Despite the tight control of energy intake among our participants, energy balance is difficult to measure and control in free-living individuals. We requested each participant to be sedentary (only movement required to complete the minimal activities of daily living) apart from the exercise bouts, and therefore, we assumed an activity factor of 1.4. We did not directly measure the energy expenditure of the exercise, as this is difficult to accurately determine given the significant anaerobic metabolism present with resistance exercise. Rather, we estimated the energy cost of the exercise bouts based on published values minus RMR. Thus, we recognize that our attempts at achieving zero energy balance for CON and EX-COMP and an energy deficit for EX-DEF are not without their limitations. A whole room calorimeter could be used in a future study to remove some of the estimations required of free-living study participants. Nevertheless, we believe our approach did create an approximate energy balance in the CON and EX-COMP conditions and some degree of negative energy balance in the EX-DEF condition. The additional energy provided for the EX-COMP condition clearly did not negate the effect of the resistance exercise in attenuating the postprandial lipemic response. (2) The reasons for the condition differences in the plasma glucose concentrations in response to the meal are not readily apparent, but these differences were quite small and may have little physiological relevance. (3) We chose to use a test meal with the same relative dose of energy, fructose, and fat used in a previously published study<sup>4</sup> that was shown to induce a significantly greater postprandial lipemic response to fructose than to glucose. We reasoned that it was necessary to have a large postprandial lipemic response incurred from fructose and fat together in order to determine if resistance exercise could attenuate the response. However, given that fructose ingestion is most often accompanied by glucose in a meal

(eg, fructose and glucose exist in a 1:1 ratio in the disaccharide sucrose, a major source of dietary fructose), we recognize that the meal used in our study limits the real-world application. (4) We only included apparently healthy young men, all of whom exhibited fasting TAG concentrations within normal limits. Future research will be required to determine whether a similar exercise-induced attenuation of the postprandial TAG response occurs in individuals who exhibit hypertriglyceridemia.

## Conclusions

Resistance exercise performed the evening prior to a high-fructose, high-fat meal significantly attenuated the six-hour postprandial TAG excursion in apparently healthy young men. Future research should seek to understand the mechanisms behind this exercise-induced lipemic attenuation and also determine the potential consequences of this phenomenon to vascular health.

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## Author Contributions

Conceived and designed the experiments: CLM, JRW, and JB. Analyzed the data: CLM and JRW. Wrote the first draft of the manuscript: JRW. Contributed to the writing of the manuscript: CLM and AW. Agree with manuscript results and conclusions: CLM, JRW, JB, and AW. Jointly developed the structure and arguments for the paper: CLM and JRW.



Made critical revisions and approved final version: CLM, JRW, and AW. All authors reviewed and approved the final manuscript.

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