NUTRITION RESEARCH 36 (2016) 974–981

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Original Research

# Exercise raises high-density lipoprotein cholesterol in men after consumption of ground beef with a high but not low monounsaturated fatty acid–saturated fatty acid ratio

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ARTICLE INFO

*Article history:*
Received 8 April 2016
Revised 22 June 2016
Accepted 23 June 2016

*Keywords:*
Blood lipids
Fatty acids
Physical activity
Ground beef
Heart disease

ABSTRACT

Exercise and diets with higher monounsaturated fatty acid (MUFA):saturated fatty acid (SFA) ratios are independently linked to improved blood lipid profiles, yet interactive effects in men have not been studied. We hypothesized that dietary ground beef with a high MUFA:SFA ratio (HR = 1.1) would augment the beneficial changes in the lipid profile induced by exercise compared to dietary ground beef with a lower MUFA:SFA ratio (LR = 0.71). Untrained men (n = 13, age = 35 ± 12 y, weight = 91.4 ± 14.2 kg, body mass index = 27.8 ± 3.3 kg/m$^2$) consumed 5 HR or LR 114 g ground beef patties weekly for 5 weeks (random order) interspersed with a 4-week self-selected (SS) washout diet. One session of exercise (70% $VO_{2max}$, 1675 kJ) was completed at the end of HR and LR diets, and again after a 5-week SS diet. Diets and physical activity were otherwise not controlled. Fasting blood samples for lipid and lipoprotein analyses were obtained 30 min before and 24 h after exercise. Subjects reported no other changes in diets or physical activity patterns, and body weight and body mass index did not change over the study duration. Diet (3) × Exercise Time (2) repeated measures analysis of variance (α = .05) and follow-up analyses revealed that blood concentrations (mmol/L ± SD) of total cholesterol (5.07 ± 1.16 to 5.73 ± 1.36), high-density lipoprotein cholesterol (HDL-C) (1.19 ± 0.20 to 1.36 ± 0.29), $HDL_2$-C (0.24 ± 0.08 to 0.28 ± 0.11), $HDL_3$-C (0.94 ± 0.14 to 1.08 ± 0.20), and non-HDL-C (3.88 ± 1.24 to 4.37 ± 1.38) were significantly elevated with exercise after the HR beef diet, but not after LR and SS diets. Thus, in healthy, untrained men the dietary beef MUFA:SFA ratio affects the blood lipid response to a single session of aerobic exercise.



*Abbreviations:* CHD, coronary heart disease; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; Lp(a), lipoprotein a; MUFA, monounsaturated fatty acid(s); SFA, saturated fatty acid(s); TC, total cholesterol; TG, triglyceride(s).

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http://dx.doi.org/10.1016/j.nutres.2016.06.013
0271-5317/

## 1. Introduction

It is well established that blood high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), and triglyceride (TG) concentrations are risk markers for coronary heart disease (CHD). More recently, measures of lipoprotein subclass distributions have been applied toward assessment of CHD risk; e.g., small, dense LDL increase, and buoyant HDL reduce CHD risk [1]. Diets relatively high in saturated fatty acids (SFA) promote an increase in serum total cholesterol, modify the lipoproteins to a more atherogenic profile, and thereby raise CHD risk [2-4]. Replacing dietary SFA with unsaturated fatty acids may reduce CHD risk, provided the replacement unsaturated fatty acids are not trans-fatty acids [5]. For example, the Mediterranean diet, relatively high in the monounsaturated fatty acid (MUFA) oleic acid (18:1n-9), promotes a blood lipid profile associated with reduced CHD [6,7].

Physically active men exhibit lower blood TC, TG, and LDL-C, and higher HDL-C concentrations than sedentary men [8-10]. Even a single session of aerobic exercise performed by trained and untrained men produces up to a 48-h increase in blood HDL-C along with a reduction in TG and LDL-C [8,11,12]. Thus, both exercise training and acute physical activity are linked to a less atherogenic lipid profile.

Beef is a protein staple of the diet in the United States. Consumption of beef products high in SFA may elevate serum TC in humans, whereas diets high in polyunsaturated fatty acids may lower TC and modify its distribution among the major lipoproteins [3,13]. Thus, the fatty acid composition of beef products is of considerable interest in terms of human health [14,15]. Animal nutrition studies have shown that the fatty acid composition of beef can be modified by the composition of the feed consumed by the cattle [16,17]. Moreover, the fatty acid composition of the various anatomical locations of adipose tissue on a beef carcass varies considerably [18,19] supporting the role of processing on the fatty acid content of beef sold for human consumption.

We have published three independent investigations of the effects of ground beef naturally enriched with MUFA on lipoprotein cholesterol metabolism [20-22]. Adams et al [20] demonstrated that ground beef high in SFA and trans-fatty acids decreased the concentrations of HDL-C and TG, whereas ground beef high in MUFA returned HDL-C and TG concentrations to baseline values. Gilmore et al [21] reported that blood HDL-C was increased in men after diets which included beef with a relatively high ratio (HR) of oleic acid (MUFA:SFA ratio = 1.10), but not after consuming beef from grass-fed cattle with a relatively low (LR) MUFA:SFA ratio (0.71). In postmenopausal women, HR ground beef increased HDL-C and $HDL_{2b}$-C concentrations [22]. A single bout of exercise attenuated the increase in HDL-C but not $HDL_{2b}$-C [22], suggesting that exercise and diet increase HDL-C concentrations by separate mechanisms.

We now report on a subset of the subjects from Gilmore et al. [21] who volunteered to participate in a separate investigation to test the possible interaction between exercise and dietary beef fat composition. We hypothesized that daily consumption by adult men of ground beef with a relatively high MUFA:SFA ratio would: (1) augment the benefits of exercise on blood lipids and lipoproteins, and (2) favorably alter their blood lipid profiles.

## 2. Methods and materials

### 2.1. Approval

The study was conducted according to the Declaration of Helsinki guidelines. All procedures involving human participants were approved by the Texas A&M University Institutional Review Board for use of human participants in research (Protocol number 2005–0435). Written consent was obtained from all participants.

### 2.2. Participants and study design

Fourteen 24- to 50-year-old healthy non-smoking volunteers were a subset of the 27 men from our previous study who gave their informed consent to participate in exercise [21]. The men were not consuming diets intended to induce weight loss or medications that might affect exercise or lipid metabolism. All men were free-living and instructed to maintain their habitual physical activity (compliance assessed by questionnaire) and body weight to within ±2.2 kg of entry weight for the duration of the study; none were physically trained. Other than the experimental beef diets, their nutrient intakes were not controlled.

At least 1 week prior to the initiation of the diet protocols the men reported to the laboratory for baseline eligibility screening which included demographic measures, fasting blood sampling, physical examination by a physician, and treadmill exercise test to volitional exhaustion for $VO_{2max}$ (CPX/D Exercise Stress Testing System, Medical Graphics Corp, Minneapolis, MN, USA) and maximal heart rate. Blood was drawn before exercise from an antecubital vein without stasis into serum separator vacutainer tubes with the subject seated quietly at rest. The samples were allowed to clot at room temperature, low-speed centrifuged to obtain serum, refrigerated, and subsequently analyzed for lipids and lipoprotein-lipids within 6 hours by a certified commercial laboratory (St Joseph Hospital, Bryan, Texas) using standard analytical procedures. Blood chemistries and lipid/lipoproteins were within normal ranges as defined by the testing laboratory with the exception of one subject, who was excluded from the study on the basis of elevated TG values (>5 mmol/L) leaving 13 men to complete the study (Table 1). A 3 (Diet Period) × 2 (Exercise Time) experimental design with randomization on the diet factor was employed (Figure).

### 2.3. Preparation of ground beef

The source of the ground beef and the ground beef preparation methods have been previously described in detail [21]. Briefly, Angus steers were fed pasture (n = 6) or grain-based diets (n = 6) specifically to produce ground beef with MUFA:SFA of 0.70 or 1.10, representing pasture-fed and intensively grain-fed ground beef, respectively. Grain-fed steers then were fed a