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Acute Effects of High-Fat Meals Enriched With Walnuts or Olive Oil on Postprandial Endothelial Function

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OBJECTIVES We sought to investigate whether the addition of walnuts or olive oil to a fatty meal have differential effects on postprandial vasoactivity, lipoproteins, markers of oxidation and endothelial activation, and plasma asymmetric dimethylarginine (ADMA).

BACKGROUND Compared with a Mediterranean diet, a walnut diet has been shown to improve endothelial function in hypercholesterolemic patients. We hypothesized that walnuts would reverse postprandial endothelial dysfunction associated with consumption of a fatty meal.

METHODS We randomized in a crossover design 12 healthy subjects and 12 patients with hypercholesterolemia to 2 high-fat meal sequences to which 25 g olive oil or 40 g walnuts had been added. Both test meals contained 80 g fat and 35% saturated fatty acids, and consumption of each meal was separated by 1 week. Venipunctures and ultrasound measurements of brachial artery endothelial function were performed after fasting and 4 h after test meals.

RESULTS In both study groups, flow-mediated dilation (FMD) was worse after the olive oil meal than after the walnut meal ($p = 0.006$, time-period interaction). Fasting, but not postprandial, triglyceride concentrations correlated inversely with FMD ($r = -0.324$; $p = 0.024$). Flow-independent dilation and plasma ADMA concentrations were unchanged, and the concentration of oxidized low-density lipoproteins decreased ($p = 0.051$) after either meal. The plasma concentrations of soluble inflammatory cytokines and adhesion molecules decreased ($p < 0.01$) independently of meal type, except for E-selectin, which decreased more ($p = 0.033$) after the walnut meal.

CONCLUSIONS Adding walnuts to a high-fat meal acutely improves FMD independently of changes in oxidation, inflammation, or ADMA. Both walnuts and olive oil preserve the protective phenotype of endothelial cells. (J Am Coll Cardiol 2006;48:1666–71) © 2006 by the American College of Cardiology Foundation

Endothelial dysfunction is a critical event in atherogenesis that is implicated both in early disease and in advanced atherosclerosis (1). It is characterized by a decreased bioavailability of nitric oxide (NO) and increased expression of proinflammatory cytokines and cellular adhesion molecules (2). The predominant mechanism of NO inactivation is a perturbation of the L-arginine–NO pathway by oxidative stress leading to elevations of plasma asymmetric dimethylarginine (ADMA), which in turn exacerbates oxidative stress (3). Both a pro-oxidant status and increased ADMA are common features of disease states associated with atherosclerosis, including hypercholesterolemia (3,4).

Food intake is an important factor that affects vascular reactivity. Short-term feeding trials have shown the potential of food for improving endothelial function, either as isolated nutrients, such as n-3 polyunsaturated fatty acids (PUFA), L-arginine, and antioxidant vitamins, or as healthy food patterns (5). A high-fat meal is usually followed by transient endothelial dysfunction in association with raised triglyceride-rich lipoproteins (6). Abnormal vasoactivity after a fatty meal is attenuated by pretreatment with antioxidant phytochemicals (7) or addition of antioxidants to the meal (8,9), suggesting that postprandial oxidative stress plays an important role. Elevated concentrations of the endogenous NO inhibitor ADMA may also contribute to fatty meal-induced endothelial dysfunction (3).

Walnuts are a rich source of antioxidants, L-arginine, and α-linolenic acid (ALA), a plant n-3 PUFA. Recently we showed that, compared with a Mediterranean diet, a walnut diet improves endothelial function in hypercholesterolemic patients (10). To test the hypothesis that walnuts also would have acute favorable effects on vasoactivity, we examined the effects of adding walnuts or olive oil to a single high-fat meal on postprandial endothelial function of the brachial

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Abbreviations and Acronyms

ADMA = asymmetric dimethylarginine
ALA = α-linolenic acid
FID = flow-independent dilation
FMD = flow-mediated dilation
MUFA = monounsaturated fatty acids
NO = nitric oxide
PUFA = polyunsaturated fatty acids
sICAM-1 = soluble intercellular adhesion molecule 1
SFA = saturated fatty acids
sTNF-R = soluble tumor necrosis factor receptors
sVCAM-1 = soluble vascular cell adhesion molecule 1

artery and markers of oxidation and endothelial activation in controls and hypercholesterolemic subjects.

METHODS

Subjects. Twenty-four asymptomatic subjects were recruited into a protocol approved by the institutional review board and gave informed consent. Twelve subjects were healthy, normolipidemic controls, and 12 subjects had moderate hypercholesterolemia (low-density lipoprotein [LDL] cholesterol 150 to 220 mg/dl, triglycerides <200 mg/dl) (Table 1). All participants were nonsmokers, had normal body weight and blood pressure, consumed <30 g/day alcohol, and took no medications or antioxidant supplements. Lack of a history of allergy to nuts, normal fasting blood glucose and thyroid, renal, and hepatic function tests, and absence of carotid atherosclerosis at ultrasound examination were prerequisites for entry.

Table 1. Characteristics of Study Groups

Gender	Control Subjects (n = 12)	Hypercholesterolemic Subjects (n = 12)
Gender, men/women	9/3	11/1
Age, yrs	32 ± 8	45 ± 13
Body mass index, kg/m^2	24.7 ± 3.0	26.3 ± 3.5
Waist circumference, cm	93 ± 10	96 ± 7
Glycemic control		
Glucose, mg/dl	82 ± 4.5	85 ± 7.5
Insulin, mU/l	8.2 ± 2.4	9.1 ± 4.3
Free fatty acids, umol/l	673 ± 302	466 ± 202
Lipids		
Total cholesterol, mg/dl	185 ± 27	250 ± 25
HDL cholesterol, mg/dl	59 ± 13	58 ± 12
VLDL cholesterol, mg/dl	12 ± 9	19 ± 11
LDL cholesterol, mg/dl	115 ± 26	173 ± 22
Triglycerides, mg/dl	87 ± 47	128 ± 42
Apolipoprotein B, g/l	0.82 ± 0.17	1.18 ± 0.14
LDL cholesterol/LDL apoB	1.49 ± 0.10	1.57 ± 0.09
VLDL triglyceride/VLDL apoB	7.8 ± 3.1	8.2 ± 3.2
Inflammatory markers		
E-selectin, ng/ml	33 ± 8	37 ± 10
sICAM-1, ng/ml	265 ± 35	274 ± 44
sVCAM-1, ng/ml	917 ± 216	967 ± 319
sTNF receptors, ng/ml	2.12 ± 0.36	2.21 ± 0.44
ADMA, μmol/l	0.73 ± 0.1	0.74 ± 0.1

ADMA = asymmetric dimethylarginine; apoB = apolipoprotein B; HDL = high-density lipoprotein; LDL = low-density lipoprotein; sICAM-1 = soluble intercellular adhesion molecule 1; sTNF = soluble tumor necrosis factor; sVCAM = soluble vascular adhesion molecule 1; VLDL = very low-density lipoprotein.

Study protocol. Between 2 and 6 weeks before testing, candidates came to the clinic for clinical history, interview with the dietitian, anthropometric and blood pressure measurements, blood extraction, and carotid sonography to confirm eligibility. For 2 weeks before the first study and the ensuing period until the second study, participants were instructed to follow a cholesterol-lowering Mediterranean diet (10,11) and to abstain from physical exertion. Compliance with the background diet was assessed before testing using a 7-day food record. Participants were individually randomized in a crossover design between 2 meal sequences (high-fat meals with walnuts or olive oil) and were studied on 2 separate days 1 week apart. The experiments were performed in the afternoon to avoid confounding by the early morning blunting in endothelial function (12,13). On each study day, participants were asked to eat a low-fat breakfast with coffee ad libitum at 7:00 AM and to refrain from further food intake until 1:30 PM, when they reported to the clinic and had a blood extraction. At 2:00 PM a baseline ultrasound assessment of endothelial function in the brachial artery was performed. Thereafter, participants ate 1 of the 2 meals under the supervision of a clinical investigator. The protocol was repeated 4 h postprandially, with blood extraction at 5:30 PM and a second endothelial function test at 6:00 PM. In previous studies in subjects without overt hypertriglyceridemia, the largest changes in triglycerides and endothelial function have been observed at 3 to 4 h after the meal (4,12). During the 4-h interval, participants rested in a quiet room and were allowed to drink water. The primary end points were the between-meal differences in changes from baseline of flow-mediated dilation (FMD) assessed as the percentage change in brachial artery diameter during reactive hyperemia. Postprandial changes in flow-independent dilation (FID), glycemic control, lipoproteins, oxidation markers, and plasma concentrations of vitamins, ADMA, and inflammatory molecules were secondary end points.

Test meals. The meals were prepared at the hospital's kitchen and consisted of ~1,200 kcal with 63% fat (35% saturated fatty acids [SFA]), 15% protein, 22% carbohydrate, and 120 mg cholesterol, for a total fat content of 80 g. They included a sandwich with 100 g white bread, 75 g salami, and 50 g fatty cheese, 125 g fat-rich (10%) yogurt, and water ad libitum. Additionally, participants consumed 25 ml olive oil soaked into the bread (olive oil meal) or 40 g shelled walnuts (walnut meal). The unsaturated fatty acid content of the olive oil and walnut meals differed: 38% and 23% monounsaturated fatty acids (MUFA), and 7% and 23% PUFA, respectively. Only the walnut meal contained ALA (5.4 g). The nutrient composition of the walnuts used in the study has been published previously (10). The olive oil used contained 78% oleic acid and 30 mg/100 g α-tocopherol.

Endothelial function testing. The methods for ultrasound evaluation of endothelial function in the brachial artery and the within-subject variability of FMD in our laboratory have been described (10). The operator was unaware of meal sequences. Suitable measurements were obtained in all tests.

Laboratory determinations. Blood samples were centrifuged (1,500 *g*, 15 min, 4°C) immediately after collection, and serum and EDTA-plasma promptly stored at −80°C for later processing. Analytic techniques for serum glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, triglycerides, apolipoprotein B (apoB), lipoprotein separation by ultracentrifugation, and in vitro copper-induced LDL oxidation have been described (10). Analytes determined by subject in frozen samples of serum or EDTA-plasma were: insulin by radioimmunoassay (IRI-CIS, Gif-Sur-Yvette, France); free fatty acids by an enzymatic colorimetric method (Wako, Neuss, Germany); α- and γ-tocopherol, carotenoids, and vitamin C by standard HPLC methods; oxidized LDL by a monoclonal antibody-based immunoassay (Mercodia, Uppsala, Sweden); soluble E-selectin, soluble intercellular adhesion molecule 1 (sICAM-1), soluble vascular cell adhesion molecule 1 (sVCAM-1), and total soluble tumor necrosis factor receptors (sTNF-R) by standard ELISA (Bender, Wien, Austria).

Statistical analyses. Changes in clinical outcomes were assessed using repeated-measures analysis of variance (ANOVA) with 4 factors: group (control vs. hypercholesterolemia), period (olive oil vs. walnut meals), time (baseline vs. postprandial), and treatment sequence, and all their interactions. Period and time were factors with repeated measures. Because no carryover effects between treatment sequences were observed, final analyses were performed with repeated-measures ANOVA for the 3 factors (group, period, and time) and all their interactions. Only significant interactions are reported. Linear regression analysis was used to determine relationships between continuous variables. Statistical significance was set at $p < 0.05$. The SPSS software (version 11.0; SPSS, Chicago, Illinois) was used. All values are mean ± SD.

RESULTS

Except for the lipid profile, which differed by study design, the 2 groups of participants had similar clinical characteristics (Table 1). Age and adiposity measures were nonsignificantly higher in subjects with hypercholesterolemia compared with controls.

Table 2 and Figure 1 show that postprandial FMD was impaired after the olive oil meal in both control (−17%) and hypercholesterolemic (−36%) subjects, whereas it was unchanged in the control group and increased by 24% in the hypercholesterolemic group after the walnut meal (time–period interaction: $p = 0.006$). No postprandial changes of FID were observed. Blood pressure and heart rate were unchanged, and hyperemic flow increased to a similar extent after both meals.

Glycemic control and triglyceride levels changed in the expected direction after the oral fat loads, and the changes were largely independent of meal composition (Fig. 2). Both glucose and insulin levels increased, and free fatty acid release was suppressed. The HDL cholesterol, LDL cholesterol, and apoB concentrations were reduced, and very

Table 2. Hemodynamic and Brachial Artery Vasoactivity Values Before and Four Hours After Fatty Meals

	High-Fat Meal With Olive Oil		High-Fat Meal With Walnuts		ANOVA p Value		
	Before	After	Before	After	Group	Time	Period
Systolic blood pressure, mm Hg					0.218	0.505	0.466
Control	115 ± 13	116 ± 12	114 ± 12	116 ± 12			
HC	119 ± 11	117 ± 10	117 ± 11	116 ± 15			
Diastolic blood pressure, mm Hg					0.317	0.435	0.704
Control	65 ± 12	65 ± 12	66 ± 8	66 ± 10			
HC	69 ± 9	68 ± 11	67 ± 11	68 ± 9			
Heart rate, beats/min					0.324	0.281	0.310
Control	59 ± 9	59 ± 10	60 ± 10	61 ± 8			
HC	61 ± 8	59 ± 9	63 ± 8	61 ± 10			
Radial artery diameter, mm					0.212	0.511	0.427
Control	4.5 ± 0.8	4.5 ± 0.8	4.5 ± 0.8	4.5 ± 0.8			
HC	4.9 ± 0.5	4.9 ± 0.5	4.8 ± 0.5	4.8 ± 0.5			
Flow-mediated dilation, %					0.395	0.471*	0.050*
Control	4.7 ± 1.4	3.9 ± 2.9	4.2 ± 1.4	4.2 ± 2.3			
HC	3.6 ± 1.3	2.3 ± 2.2	4.1 ± 1.9	5.1 ± 1.9			
Flow-independent dilation, %					0.075	0.207	0.423
Control	17.6 ± 7.5	17.3 ± 7.8	16.6 ± 6.4	18.1 ± 9.1			
HC	13.4 ± 5.9	13.8 ± 3.1	11.8 ± 3.8	13.4 ± 3.3			
Hyperemic flow, ml/min					0.549	<0.001	0.389
Control	250 ± 121	328 ± 137	247 ± 144	298 ± 115			
HC	276 ± 127	352 ± 132	267 ± 121	350 ± 95			

*Decrease after olive oil meal and no change/increase after walnut meal (time-period interaction: $p = 0.006$).
ANOVA = analysis of variance; HC = hypercholesterolemic subjects.

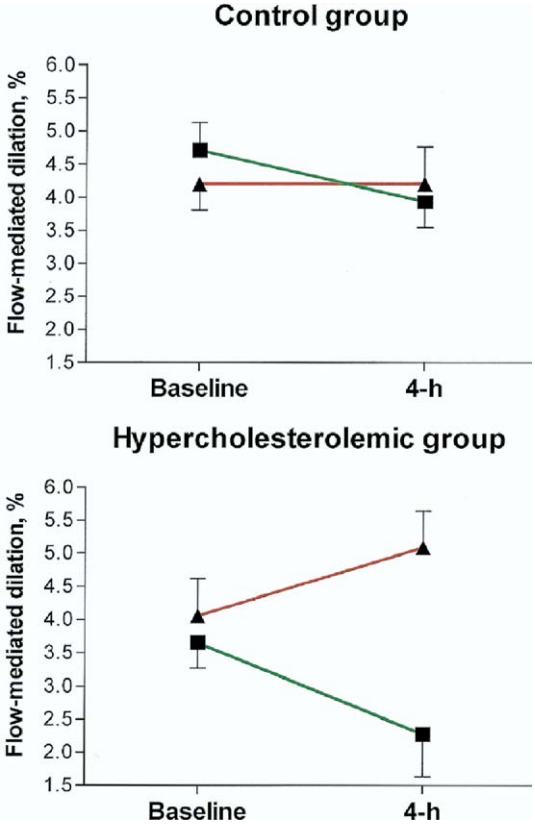

Figure 1. Mean flow-mediated dilation before and 4 h after fatty meals with added olive oil **(squares)** or walnuts **(triangles)**. Vertical bars indicate SE. Time–period interaction: p = 0.006 by repeated-measures analysis of variance.

low-density lipoprotein (VLDL) lipids increased substantially after either meal in both groups ($p < 0.001$ for all) (data not shown). Postprandial lipemia was enhanced in hypercholesterolemic compared with control subjects. Table 1 shows baseline lipoprotein lipid to apoB ratios. The VLDL triglyceride/apoB ratio, a measure of VLDL size, increased after both meals ($p < 0.001$). In control subjects, it increased by 85% and 57% after the olive oil and walnuts meals, respectively (group–period interaction: p = 0.034). The rises in hypercholesterolemic subjects were similar after either meal. The meals had little effect on LDL cholesterol/apoB ratios, indicating unchanged LDL size (data not shown).

The plasma levels of vitamin C, α-tocopherol, and γ-tocopherol decreased significantly ($p < 0.05$) and to a similar extent in the 2 groups. The changes ranged from −2% to −14% and were unrelated to meal type. The α-carotene and β-carotene levels were similar before and after either meal (data not shown). As shown in Table 3, baseline oxidized LDL was higher in hypercholesterolemic compared with control subjects and decreased postprandially in the 2 groups. In the copper-induced oxidizability experiments, opposite effects were observed in lag times of LDL-conjugated diene production depending on study group and meal type.

The values of inflammatory cytokines and adhesion molecules differed little at baseline between groups (Table 1), and their responses to meals were similar by group, a reason the data are assembled in Figure 3 to show that all values decreased to a small extent after either meal. The decrease in soluble E-selectin was more pronounced after the walnut meal than the olive oil meal (time-period interaction: p = 0.033). There were no changes in ADMA.

In the overall participants, baseline FMD correlated inversely and significantly with fasting triglycerides ($r = -0.324$; $p = 0.024$) and nonsignificantly with the VLDL triglyceride/apoB ratio ($r = -0.262$; $p = 0.072$). Postprandial FMD was unrelated to triglycerides after either meal. The relationship between FMD and VLDL triglyceride/apoB ratios approached statistical significance after the olive oil meal ($r = -0.355$; $p = 0.088$) but not after the walnut meal ($r = -0.246$; $p = 0.247$). The FMD changes from baseline after either meal were unrelated to changes in any variable.

DISCUSSION

Our main finding was that, in comparison with olive oil, walnuts reverse the impairment of endothelial function associated with eating a fatty meal. The fact that a single walnut meal positively effects postprandial vasoactivity further supports the beneficial effects of walnuts on cardiovascular risk (10,11).

The results confirm and extend those of an earlier feeding trial in hypercholesterolemic subjects showing that a walnut meal in a background walnut diet was associated with improved brachial artery vasoactivity in comparison with an olive oil meal during a Mediterranean diet (10). In that study, the benefit on endothelial function was mediated in part through an improved lipid profile. This mechanism cannot be implicated in our acute studies, where both meals induced postprandial hypertriglyceridemia to a similar extent. However, VLDL triglyceride/apoB ratios increased after the olive oil meal in comparison with the walnut

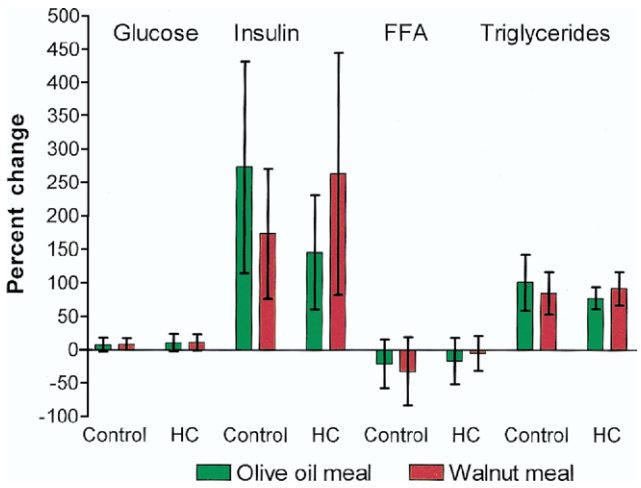

Figure 2. Changes from baseline of variables related to glycemic control and triglycerides after the test meals in study groups. Vertical bars are 95% confidence interval. No group, time, or period interactions were observed for any of the variables by repeated-measures analysis of variance. FFA = free fatty acids; HC = hypercholesterolemia group.

Table 3. Values of LDL Oxidation Analytes Before and Four Hours After Fatty Meals

	High-Fat Meal With Olive Oil		High-Fat Meal With Walnuts		ANOVA p Value		
	Before	After	Before	After	Group	Time	Period
Oxidized LDL, U/l					0.031	0.051	0.722
Control	37.7 ± 10.1	36.9 ± 10.0	36.9 ± 8.5	36.6 ± 11.1			
HC	45.7 ± 8.7	44.5 ± 7.7	45.8 ± 8.0	43.5 ± 6.7			
Conjugated diene formation							
Lag time, min					0.253*	0.617*	0.773*
Control	54.7 ± 21.9	62.6 ± 36.0	56.1 ± 24.9	43.3 ± 31.8			
HC	41.3 ± 23.7	36.5 ± 19.0	43.7 ± 25.0	52.1 ± 25.2			
Vmax, nmol/min/mg protein					0.539	0.296	0.778
Control	16.1 ± 3.6	16.6 ± 4.6	17.7 ± 5.4	13.8 ± 6.9			
HC	16.0 ± 5.2	13.9 ± 4.7	14.9 ± 4.0	15.3 ± 4.8			
Cmax, nmol/mg protein					0.819	0.067	0.274
Control	552 ± 194	538 ± 247	482 ± 94	425 ± 225			
HC	508 ± 115	449 ± 123	550 ± 192	435 ± 136			

*Increase in control subjects and decrease in HC after olive oil meal with opposite changes after walnut meal (group-time-period interaction: p = 0.034).
ANOVA = analysis of variance; Cmax = maximum concentration; HC = hypercholesterolemic subjects; LDL = low-density lipoprotein; Vmax = maximum velocity.

meal and were related to impaired FMD. Because this ratio is an indirect measure of the presence of large triglyceride-rich VLDL particles that are highly atherogenic (14), our findings may explain in part the differential effects of the test meals on endothelial function. Abnormal vasoactivity after a lipid challenge has been related to accumulation of postprandial triglyceride-rich lipoproteins in other studies (6,9,15).

That a fatty meal induces endothelial dysfunction has been shown by most (5–9,13,15,16) but not all (5,16) studies. Because earlier studies were designed so that baseline testing was performed in the early morning and postprandial testing was done 3 to 4 h later, a reason for this discrepancy is that the physiologic improvement of FMD during the morning counteracted any changes due to the fat challenge (12,13). For the same reason, the deterioration of FMD after a fatty meal may be more pronounced than usually reported. This objection may also apply to studies of the acute vasomotor effects of unsaturated fats and could explain the inconsistent effects on FMD reported after meals rich in MUFA from olive oil or other sources (5,8,16,17) or the lack of effect of an n-3 PUFA-rich salmon meal (8). Recently, West et al. (17) reported increased FMD in diabetic patients after meals enriched with either marine n-3 PUFA or ALA, thus supporting the beneficial role of ALA-rich walnuts on endothelial function. Besides ALA, other cardioprotective constituents of walnuts, such as L-arginine and antioxidants (10), could favorably influence vasoactivity.

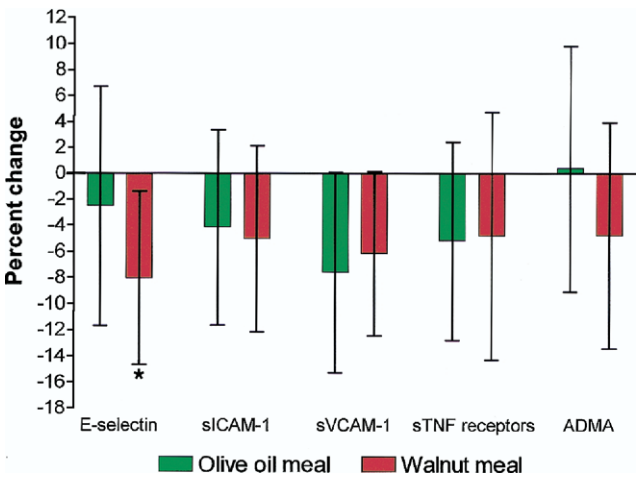

Figure 3. Changes from baseline of inflammation and endothelial activation markers and asymmetric dimethylarginine (ADMA) after the test meals in study groups. Vertical bars are 95% confidence interval. *Greater reduction after the walnut meal compared with the olive oil meal (time–period interaction: p = 0.033 by repeated-measures analysis of variance). sICAM-1 = soluble intercellular adhesion molecule 1; sTNF = soluble tumor necrosis factor; sVCAM-1 = soluble vascular cell adhesion molecule 1.

A role for oxidative stress in the causation of postprandial endothelial dysfunction is suggested by the protective effect of different antioxidants when added to fatty meals (5,7–9). Unexpectedly, oxidized LDL decreased postprandially, independently of group and meal type, and the susceptibility of LDL to oxidation was unaffected overall (Table 3). Although the supplemental foods provided vitamin E compounds (α-tocopherol in olive oil and γ-tocopherol in walnuts), their plasma levels were slightly reduced after meals. Presumably, partial consumption of circulating antioxidants helped preserve the resistance of LDL to oxidation. These results provide further evidence that, in spite of a high PUFA content, walnut intake does not promote lipid peroxidation (10,11). They also suggest that FMD changes after a fatty meal are independent of lipoprotein oxidation (18,19).

Besides denoting impaired FMD, endothelial dysfunction comprises a specific state of endothelial activation that is characterized by enhanced expression and release into the circulation of inflammatory cytokines and adhesion molecules (1,2). A fatty meal thus activates the endothelium, and this process is counteracted by antioxidant vitamins (20). Given the positive effects of the walnut meal on FMD, the fact that the circulating levels of sTNF-R, soluble

E-selectin, sICAM-1, and sVCAM-1 did not increase was not unexpected. However, a similar lack of endothelial activation was observed after the olive oil meal, in clear dissociation from its effects on FMD. Postprandially, inflammatory biomarkers decreased independently of meal type, except for soluble E-selectin, an adhesion molecule involved in the early steps of monocyte recruitment to the endothelium (21), which decreased more after the walnut meal than after the olive oil meal. We have previously shown that a walnut diet attenuates endothelial activation, as suggested by decreased sVCAM-1 levels (10). Our findings are consistent with the evidence of decreased expression of adhesion molecules by endothelial cells exposed to marine n-3 PUFA or oleic acid (21). A recent study (22) has shown that diets enriched in ALA from walnuts reduce the levels of inflammatory biomarkers. Taken together, these findings suggest that ALA shares the anti-inflammatory effects of marine n-3 PUFA.

The plasma ADMA level was unchanged after either meal (Fig. 3), suggesting that this factor was not involved in the changes of endothelial function.

Study limitations. Our study is limited by the small representation of women; therefore, the findings may only apply to men. Hypercholesterolemic subjects were slightly older than control subjects, but participants in both groups had no other nonlipid risk factors and showed similar hemodynamics and lack of carotid atherosclerosis. Besides, the study was crossover and focused on between-meal differences, not between-group ones. Another limitation is that we did not evaluate the effects of fat loads made up only of foods rich in SFA. Olive oil alone may impair endothelial function (8,16), thus it is not completely clear whether between-meal differences were due to a beneficial effect of walnuts or a detrimental effect of olive oil, or both.

Conclusions. The mechanisms underlying impaired endothelial function in the postprandial state are likely multifactorial (3,5,6,20). We showed that supplemental walnuts, but not olive oil, counteracted the detrimental changes in FMD associated with eating a fatty meal. Vasomotor changes, however, did not appear to occur through pro-oxidative, inflammation-sensitive, or ADMA-related mechanisms. Because of an increased delivery of ALA, improved FMD after the walnut meal could be mediated by increased membrane fluidity of endothelial cells promoting enhanced synthesis and/or release of NO, as has been postulated for marine n-3 PUFA (21). Nevertheless, unsaturated fatty acids and antioxidants in both olive oil and walnuts appear to preserve the protective phenotype of endothelial cells. Additional work is needed to prove these contentions and explore basic mechanisms for the vascular effects of different fats, such as vascular cell signaling and pro- or antiatherogenic gene expression.

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