Intensive Lifestyle Changes for Reversal of Coronary Heart Disease

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Context.—The Lifestyle Heart Trial demonstrated that intensive lifestyle changes may lead to regression of coronary atherosclerosis after 1 year.

Objectives.—To determine the feasibility of patients to sustain intensive lifestyle changes for a total of 5 years and the effects of these lifestyle changes (without lipid-lowering drugs) on coronary heart disease.

Design.—Randomized controlled trial conducted from 1986 to 1992 using a randomized invitational design.

Patients.—Forty-eight patients with moderate to severe coronary heart disease were randomized to an intensive lifestyle change group or to a usual-care control group, and 35 completed the 5-year follow-up quantitative coronary arteriography.

Setting.—Two tertiary care university medical centers.

Intervention.—Intensive lifestyle changes (10% fat whole foods vegetarian diet, aerobic exercise, stress management training, smoking cessation, group psychosocial support) for 5 years.

Main Outcome Measures.—Adherence to intensive lifestyle changes, changes in coronary artery percent diameter stenosis, and cardiac events.

Results.—Experimental group patients (20 [71%] of 28 patients completed 5-year follow-up) made and maintained comprehensive lifestyle changes for 5 years, whereas control group patients (15 [75%] of 20 patients completed 5-year follow-up) made more moderate changes. In the experimental group, the average percent diameter stenosis at baseline decreased 1.75 absolute percentage points after 1 year (a 4.5% relative improvement) and by 3.1 absolute percentage points after 5 years (a 7.9% relative improvement). In contrast, the average percent diameter stenosis in the control group increased by 2.3 percentage points after 1 year (a 5.4% relative worsening) and by 11.8 percentage points after 5 years (a 27.7% relative worsening) ($P = .001$ between groups. Twenty-five cardiac events occurred in 28 experimental group patients vs 45 events in 20 control group patients during the 5-year follow-up (risk ratio for any event for the control group, 2.47 [95% confidence interval, 1.48-4.20]).

Conclusions.—More regression of coronary atherosclerosis occurred after 5 years than after 1 year in the experimental group. In contrast, in the control group, coronary atherosclerosis continued to progress and more than twice as many cardiac events occurred.

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THE LIFESTYLE Heart Trial was the first randomized clinical trial to investigate whether ambulatory patients could be motivated to make and sustain comprehensive lifestyle changes and, if so, whether the progression of coronary atherosclerosis could be stopped or reversed without using lipid-lowering drugs as measured by computer-assisted quantitative coronary arteriography. This study derived from earlier studies that used noninvasive measures.[1,2]

After 1 year, we found that experimental group participants were able to make and maintain intensive lifestyle changes and had a 37.2% reduction in low-density lipoprotein (LDL) cholesterol levels and a 91% reduction in the frequency of anginal episodes.[3] Average percent diameter stenosis regressed from 40.0% at baseline to 37.8% 1 year later, a change that was correlated with the degree of lifestyle change. In contrast, patients in the usual-care control group made more moderate changes in lifestyle, reduced LDL cholesterol levels by 6%, and had a 165% increase in the frequency of reported anginal episodes. Average percent diameter stenosis progressed from 42.7% to 46.1%.

Given these encouraging findings, we extended the study for an additional 4 years to determine (1) the feasibility of patients sustaining intensive changes in diet and lifestyle for a much longer time, and (2) the effects of these changes on risk factors, coronary atherosclerosis, myocardial perfusion, and cardiac events after 4 additional years.

METHODS

The design, recruitment, and study population were previously described.[3-5] In brief, we recruited men and women

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Table 1—Baseline Characteristics of Experimental and Control Groups*

Characteristic	Experimental (n = 20)	Control (n = 15)	*P* Value
Men, No.	20	12	.07
Women, No.	0	3	
Age, mean (SD), y	57.4 (6.4)	61.8 (7.5)	.08
Education, mean (SD), y	15.5 (2.7)	14.5 (3.4)	.29
Employed, No.	14	6	.10
Body mass index, mean (SD), kg/m^2	28.4 (4.1)	25.4 (3.5)	.03
No. with history of myocardial infarction	12	5	.17
Average No. of lesions studied, mean (SD)	5.3 (2.7)	5.3 (3.2)	.93
No. with history of percutaneous transluminal coronary angioplasty	5	4	>.99
No. with history of coronary artery bypass graft	1	0	>.99
Reported angina, No. (%)	11 (55)	6 (40)	.49

*Values are statistics unless otherwise indicated. *P* values are 2-tailed.

with coronary atherosclerosis documented by quantitative coronary arteriography.

We identified 193 patients as potentially eligible for our study who agreed to undergo quantitative coronary angiography. Following angiography, 93 patients remained eligible and were randomly assigned to experimental or control groups using a randomized invitational design to minimize crossover, ethical concerns, nocebo effects, and dropout. Of these 93 patients who were eligible, 53 were randomly assigned to the experimental group and 40 to the usual-care control group. Patients were then contacted and invited to participate in the study; 28 (53%) and 20 (50%) agreed to participate in the experimental and control groups, respectively. The primary reason for refusal in the experimental group was not wanting to undergo intensive lifestyle changes and/or not wanting a second coronary angiogram; control patients refused primarily because they did not want to undergo a second angiogram. To detect possible selection biases, we collected data on age, marital status, reported angina, history of myocardial infarction, height, weight, number of diseased lesions, and stenosis severity for all patients who were randomized into the study but refused to participate. We did not exclude any experimental group patients who volunteered even if we doubted their ability to adhere to the lifestyle program. All patients who volunteered were followed up using the intention-to-treat principle.

After 1 year, 7 patients did not provide angiographic data, and the reasons for loss to follow-up have been reported.[3] Of the remaining 41 patients at baseline most had severe coronary atherosclerosis: 28 had 3-vessel disease, 12 had 2-vessel disease, and 1 had 1-vessel disease. Two of these patients whose angiographic data were not usable after 1 year agreed to undergo quantitative coronary arteriography after 5 years; these results are included in the baseline to 5-year comparisons.

Four experimental and 4 control patients who had an angiogram at 1 year did not have a third angiogram after 5 years. Three of these 4 patients in the experimental group refused a third angiogram (patients only volunteered for a 1-year study that was subsequently extended), and 1 died between years 1 and 4; of the 4 control group patients who did not undergo a third angiogram, 1 died, 2 underwent revascularization of the arterial lesions under study, and 1 developed Parkinson disease and became too ill to be safely tested. Cine arteriograms made in San Francisco, Calif, were sent to the University of Texas Medical School, Houston, for blinded quantitative analyses as previously described in detail.[4]

All results, except lesion changes at 1 year (18 experimental and 15 control subjects) and cardiac events after 5 years (all 28 experimental and 20 control subjects), are based on the total of 35 patients (20 experimental and 15 control subjects) who had both baseline and 5-year angiograms. From these 35 patients, there were 224 lesions studied at baseline, of which 24 were 100% occluded and were excluded a priori from the lesion-change analyses per the study protocol. Of the remaining 200 lesions, 14 were lost to the 4-year follow-up, as follows: in the experimental group, 2 lesions were excluded due to technical failure during the angiogram and 2 had views that did not match; in the control group, views did not match for 3 lesions, 3 lesions were excluded due to technical failure, 1 was excluded due to angioplasty, and 3 were excluded due to coronary artery bypass surgery. Of the 186 lesions available for analysis at 4 years, 109 were from the experimental group and 77 were from the control group.

The 1-year original study and the 4-year extension were approved by the committees on human research at California Pacific Medical Center and University of California, San Francisco, and each patient signed a written consent form after being fully informed of the study requirements.

Patients completed a 3-day diet diary at baseline and after 1 and 5 years to assess nutrient intake and dietary adherence.[6] Methods of lipid assays were the same as previously reported.[3] These 3-day diet diaries were analyzed with a software package (CBORD Diet Analyzer; CBORD Group Inc; Ithaca, NY) using the US Department of Agriculture database. Also, patients were asked to complete a questionnaire reporting the frequency and duration of exercise and of each stress management technique. Information from these sources was quantified into continuous scores using an a priori determined formula. The adherence measure was a continuous score reflecting daily intake of cholesterol (in milligrams), fat (in grams), frequency and duration of exercise, frequency and duration of stress management techniques, and smoking. A score of 1.0 equalled 100% adherence but scores could be greater than 1.0 if participants exceeded the recommended intensive lifestyle changes.

The technicians responsible for performing all medical tests were blinded to patient group assignment. Also, different personnel implemented the lifestyle intervention, conducted the tests, and computed statistical analyses, although the dietitian was made aware of the nutrient analysis to monitor patients' safety and adherence. Quantitative coronary arteriograms were blindly analyzed without knowledge of group assignment.

Program Intervention

Experimental group patients were prescribed an intensive lifestyle program that included a 10%-fat vegetarian diet, moderate aerobic exercise, stress management training, smoking cessation, and group psychosocial support previously described in detail.[3,7-10] Patients were encouraged to avoid simple sugars and to emphasize the intake of complex carbohydrates and other whole foods. Only 1 patient in the experimental group was actively smoking at baseline, and she quit at entry. Control group patients were asked to follow the advice of their personal physicians regarding lifestyle changes.

Statistical Methods

We decided a priori to use percent diameter stenosis as the primary dependent variable. Statistical methods to compare the 2 groups were previously described.[3] Analysis of adherence variables and risk factor levels used time-structured repeated measures in which levels from all 3 measurement times (baseline, 1 year, and 5 years) were in-

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Table 2.—Adherence to Exercise, Stress Management, and Dietary Guidelines

	Mean (SEM) at Baseline		Mean (SEM) at 1 Year			Mean (SEM) at 5 Years		
	Experimental (n = 20)	Control (n = 15)	Experimental (n = 20)	Control (n = 15)	*P* Value* Baseline-1 Year	Experimental (n = 20)	Control (n = 15)	*P* Value* Baseline-5 Years
Exercise								
Times per week	2.66 (0.84)	2.38 (0.77)	4.97 (0.35)	2.87 (0.70)	.06	4.34 (0.49)	3.57 (0.56)	.64
Hours per week	2.26 (0.85)	2.42 (0.99)	5.02 (0.61)	2.52 (0.70)	.12	3.56 (0.56)	2.90 (0.65)	.50
Stress management								
Times per week	0.70 (0.41)	0.15 (0.10)	8.22 (0.73)	0.49 (0.25)	<.001	4.93 (1.02)	0.74 (0.39)	<.001
Minutes per day	6.01 (3.56)	1.71 (1.19)	87.25 (7.85)	4.47 (2.79)	<.001	48.53 (10.36)	8.44 (6.11)	.001
Fat intake								
Grams per day	63.67 (4.35)	57.42 (5.94)	12.71 (1.06)	52.38 (5.31)	<.001	17.34 (2.30)	44.09 (6.66)	<.001
% of Energy intake	29.71 (1.8)	30.52 (2.9)	6.22 (0.3)	28.76 (2.3)	<.001	8.51 (1.0)	25.03 (2.7)	<.001
Dietary cholesterol, mmol/L [mg/dL]	5.47 (0.672) [211.4 (26.0)]	5.49 (0.908) [212.5 (35.1)]	0.08 (0.002) [3.3 (0.8)]	4.69 (0.636) [181.3 (24.6)]	<.001	0.48 (0.140) [18.6 (5.4)]	3.59 (0.641) [138.7 (24.8)]	.002
Energy intake, J/d	8159 (473)	7159 (489)	7623 (473)	7004 (489)	.64	7724 (485)	6581 (489)	.86
Total adherence score†	0.62 (0.08)	0.60 (0.07)	1.29 (0.08)	0.64 (0.07)	<.001	1.06 (0.08)	0.72 (0.07)	<.001

*All *P* levels are 2-tailed and each is a result of a test of the null hypothesis that the change between 2 particular visits (eg, baseline and 1 year) does not differ between the experimental and control groups.
†Percentage of minimum recommended level of combined lifestyle change; includes all the above plus smoking cessation.

Table 3.—Baseline Levels, 1-Year, and 5-Year Change Scores in Coronary Artery Lesions*

	Mean at Baseline (95% CI)		Change Scores at 1 Year (95% CI)			Change Scores at 5 Years (95% CI)		
	Experimental (n = 20)	Control (n = 15)	Experimental (n = 18)	Control (n = 15)	*P* Value† Baseline-1 Year	Experimental (n = 20)	Control (n = 15)	*P* Value† Baseline-5 Years
Diameter stenosis, %	38.92 (35.29 to 42.54)	42.50 (38.18 to 46.81)	−1.75 (−4.08 to 0.58)	2.28 (−3.0 to 4.86)	.02	−3.07 (−5.91 to −0.24)	11.77 (3.40 to 20.14)	.001
Minimum diameter, mm	1.64 (1.44 to 1.84)	1.74 (1.50 to 1.97)	0.01 (−0.10 to 0.12)	−0.12 (−0.25 to −0.001)	.11	0.001 (−0.11 to 0.11)	−0.34 (−0.66 to −0.02)	.05
Normal diameter, mm	2.65 (2.39 to 2.92)	2.96 (2.64 to 3.27)	−0.06 (−0.16 to 0.03)	−0.10 (−0.27 to 0.06)	.68	−0.13 (−0.26 to 0.01)	0.045 (0.017 to 0.072)	.01

*CI indicates confidence interval.
†All *P* levels are 2-tailed and each is a result of a test of the null hypothesis that the change between 2 particular visits (eg, baseline and 1 year) does not differ between the experimental and control groups.

cluded in a single regression model. Statistical significances of group differences were obtained for baseline levels, 1-year changes, and 5-year changes using F tests. All repeated measures analyses were implemented using PROC MIXED under SAS version 6.08.[11] Analysis of lesion data used a repeated measures model in which the repeated measures were baseline or change values for multiple lesions within each subject. Change scores were used for the baseline to 1-year and baseline to 5-year follow-up periods, and analysis of baseline levels, 1-year changes, and 5-year changes were done separately. Again, F tests provided by SAS PROC MIXED were used to test significance of differences between groups with respect to baseline levels, 1-year changes, and 5-year changes. The SAS PROC MIXED linear regression, which allowed for dependence in data, was used to determine the relationship between adherence and percent diameter stenosis changes. Relative rates for cardiac events were analyzed and tested by Poisson regression using exact tests (Stata 5.0, College Station, Tex).

RESULTS

Baseline Comparisons of Volunteers With Refusals

Those who declined the invitation to be in the study were similar to those who volunteered in all available data except those who volunteered were more likely to have a history of angina (87% vs 65%; $P = .02$), a greater number of lesions (4.5 vs 3.5; $P = .04$), and slightly more severely stenosed lesions (2.3 vs 2.0 on a 3-point scale; $P = .05$).

Baseline Comparisons of Experimental Group With Control Group

Analyses across the 35 volunteers at baseline for whom 4-year lesion data were available showed no significant differences between the experimental group and the control group in demographic characteristics, history of myocardial infarction, angioplasty, bypass surgery, lesion number, lesion stenosis, dietary fat or cholesterol intake, exercise and stress management practice, blood pressure, exercise capacity, and psychosocial measures (Tables 1-3).

Among the many comparisons, only a few differed significantly ($P<.05$). More women were randomly assigned to the control group (4) than to the experimental group (1); this fact accounted for half the weight difference (10 kg) between the 2 groups and most of the height difference (6 cm).

Experimental group patients had a slightly larger body mass index (measured as the weight in kilograms divided by the square of the height in meters) (28.4 vs 25.4 kg/m^2; $P = .03$) and had lower high-density lipoprotein (HDL) cholesterol levels (1.04 mmol/L [40.1 mg/dL] vs 1.36 mmol/L [52.4 mg/dL]; $P = .04$), which was also reflected in lower apolipoprotein A-I levels (3.45 mmol/L [133.1 mg/dL] vs 4.08 mmol/L [157.5 mg/dL]; $P = .03$). The lower body mass index in the control group may be due to the larger number of women in the control group. Other lipid values, including ratios of total cholesterol to HDL and LDL to HDL, did not differ significantly at baseline (Table 4).

Program Adherence

In the experimental group, adherence to all aspects of the program was excellent during the first year and good after 5 years, whereas control group patients maintained more moderate changes during the 5 years consistent with conventional guidelines (Table 2). The percentage of daily energy (calories) provided by fruits, vegetables, whole grains, soy, other legumes, nonfat dairy, and alcohol was comparable at 1 year and at 5 years. In the experimental group, fat intake decreased from approximately 30% to 8.5%, cholesterol from 211 to 18.6 mg/d, energy from 8159 to 7724 J (1950-1846 cal), protein from 17% to 15%, and carbohydrates increased from 53% to 76.5%. In

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Table 4.—Changes in Risk Factors

Risk Factor	Mean (SEM) at Baseline		Mean (SEM) at 1 Year	
	Experimental (n = 20)	Control (n = 15)	Experimental (n = 20)	Control (n = 15)
Serum lipids, mmol/L [mg/dL]				
Total cholesterol	5.83 (0.31) [225.1 (11.9)]	6.42 (0.24) [247.9 (9.4)]	4.22 (0.22) [162.9 (8.4)]	6.33 (0.38) [244.3 (14.7)]
Low-density lipoprotein	3.72 (0.29) [143.80 (11.21)]	4.30 (0.19) [166.40 (7.46)]	2.24 (0.24) [86.56 (9.41)]	4.25 (0.38) [164.13 (14.85)]
High-density lipoprotein	1.04 (0.07) [40.05 (2.78)]	1.36 (0.14) [52.36 (5.54)]	0.94 (0.10) [36.28 (3.81)]	1.34 (0.10) [51.87 (3.81)]
Triglyceride	5.90 (0.69) [227.8 (26.5)]	5.78 (1.63) [223.3 (63.0)]	6.69 (0.75) [258.2 (29.1)]	4.30 (0.40) [166.1 (15.5)]
Apolipoproteins, g/L				
A-I	1.331 (0.046)	1.575 (0.092)	1.308 (0.057)	1.761 (0.121)
B	1.000 (0.054)	1.024 (0.062)	0.7685 (0.046)	1.085 (0.053)
Blood pressure, mm Hg				
Systolic	135.3 (4.0)	137.2 (4.5)	126.4 (3.9)	128.8 (4.5)
Diastolic	81.70 (2.05)	80.27 (3.15)	77.03 (2.01)	75.07 (8.15)
Weight, kg	91.40 (3.42)	75.74 (4.37)	80.64 (2.48)	77.18 (4.73)

*All *P* levels are 2-tailed and each is a result of a test of the null hypothesis that the change between 2 particular visits (eg, baseline and 1 year) does not differ between the experimental and control groups.

Table 5.—Reported Angina Symptoms

	Mean (SD) at Baseline		Mean (SD) at 1 Year			Mean (SD) at 5 Years		
	Experimental (n = 18)	Control (n = 14)	Experimental (n = 18)	Control (n = 14)	*P* Value* Baseline-1 Year	Experimental (n = 18)	Control (n = 14)	*P* Value* Baseline-5 Years
Chest pain frequency, times per week	5.8 (14.7)	1.4 (1.8)	0.5 (0.8)	4.0 (9.3)	.08	1.6 (2.7)	0.9 (1.9)	.32
Chest pain duration, min	3.1 (4.8)	3.2 (8.4)	1.8 (4.7)	7.6 (15.9)	.11	0.9 (1.3)	1.0 (2.7)	.93
Chest pain severity (1-7 scale)	1.5 (1.5)	0.6 (0.8)	0.7 (1.2)	1.4 (1.2)	<.001	0.9 (1.4)	0.6 (1.1)	.29

*All *P* levels are 2-tailed and each is a result of a test of the null hypothesis that the change between 2 particular visits (eg, baseline and 1 year) does not differ between the experimental and control groups.

the control group, fat intake decreased from 30% to 25%, cholesterol from 212.5 to 138.7 mg/d, energy from 5.49 to 3.59 J (1711-1573 cal), protein from 19% to 18%, and carbohydrates increased from 51% to 52%. Since patients volunteered originally only for a 1-year study, there was a significant decrease in meeting attendance after 1 year for 4 of the patients. Walking was the recommended form of exercise, but some patients jogged or did more strenuous exercise.

Risk Factor Changes

Patients in the experimental group lost 10.9 kg (23.9 lbs) at 1 year and sustained a weight loss of 5.8 kg (12.8 lbs) at 5 years, whereas weight in the control group changed little from baseline. In the experimental group, LDL cholesterol levels decreased by 40% at 1 year and remained 20% below baseline at 5 years. In the control group, LDL cholesterol levels decreased by 1.2% at 1 year and by 19.3% at 5 years. There were no statistically significant differences in LDL levels between the 2 groups at 5 years, primarily because 9 (60%) of 15 control patients took lipid-lowering drugs between year 1 and year 5 of the study. None of the experimental group patients took lipid-lowering drugs during the 5 years of the study. Fourteen patients in the experimental group and 11 patients in the control group took aspirin during the study.

Triglycerides did not change significantly in either group. Apolipoprotein A-I did not change in the experimental group, but it increased in the control group ($P = .04$). High-density lipoprotein levels and blood pressure did not differ between the 2 groups.

Angina Pectoris

Experimental group patients had a 91% reduction in reported frequency of angina after 1 year and a 72% reduction after 5 years (Table 5). In contrast, control group patients had a 186% increase in reported frequency of angina after 1 year and a 36% decrease in frequency after 5 years. The decrease in angina in the control group after 5 years was in large part because 3 of the 5 patients who reported an increase in anginal episodes from baseline to 1 year underwent coronary angioplasty between years 1 and 5. Because of this reduction in angina in control group patients who underwent revascularization, the between-group differences were no longer significant after 5 years (Table 5).

Angiographic Changes

All detectable lesions that matched at baseline and 5-year follow-up and were not 100% occluded at baseline were included in the analyses (n = 186). At baseline, there were no significant differences between the experimental and control groups in any measure of lesion severity (Table 3). In the experimental group, the average percent diameter stenosis at baseline decreased 1.75 absolute percentage points after 1 year (a 4.5% relative improvement) and by 3.1 absolute percentage points after 5 years (a 7.9% relative improvement). In contrast, the average percent diameter stenosis in the control group increased by 2.3 percentage points after 1 year (a 5.4% relative worsening) and by 11.8 percentage points after 5 years (a 27.7% relative worsening). These between-group differences were statistically significant after both 1 year and 5 years ($P = .02$ and $P = .001$, respectively, Figure 1).

Figure 2 shows the experimental group changes in percent diameter stenosis from baseline to 5 years according to tertiles of adherence to the lifestyle intervention. As seen at 1 year,[3] there was also a strong correlation between adherence and percent diameter stenosis after 5 years in a dose-response relationship; the tertile of patients that was most adherent to the program had the most regression, the tertile with intermediate adherence had less regression, and the tertile with the least adherence halted the progression of disease without regression ($P = .04$). Of interest is that this relationship was not related to age or disease severity. There was no significant relationship between adherence and lesion changes in the control group, perhaps because many of these patients began taking lipid-lowering drugs, which may have confounded the ability to detect a possible relationship. Indeed, we found significant correlations between changes in lipid levels (LDL and total cholesterol) and changes

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	Mean (SEM) at 5 Years		
P Value* Baseline-1 Year	Experimental (n = 20)	Control (n = 15)	*P* Value* Baseline-5 Years
.004	4.87 (0.20) [188.0 (7.8)]	5.62 (0.20) [217.0 (7.9)]	.60
.003	2.99 (0.20) [115.35 (7.59)]	3.47 (0.21) [133.80 (8.25)]	.76
.35	0.90 (0.05) [34.75 (2.03)]	1.28 (0.12) [49.27 (4.47)]	.54
.17	6.11 (0.59) [236.1 (22.9)]	5.48 (0.78) [211.5 (30.2)]	.78
.11	1.302 (0.092)	1.839 (0.139)	.04
.004	1.014 (0.072)	0.991 (0.083)	.63
.96	130.0 (3.9)	123.3 (4.7)	.19
.91	76.63 (2.01)	73.61 (3.25)	.74
.001	85.64 (2.88)	77.09 (4.5)	.001

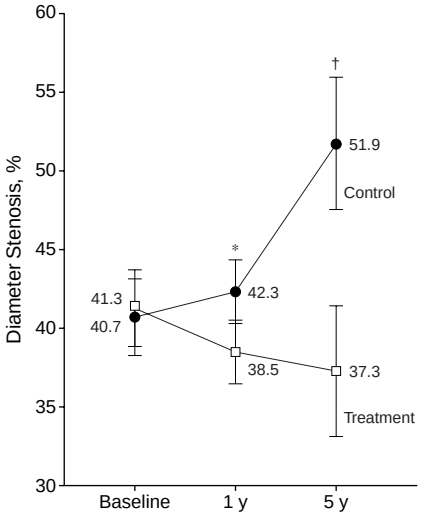

Figure 1.—Mean percentage diameter stenosis in treatment and control groups at baseline, 1 year, and 5 years. Error bars represent SEM; asterisk, $P = .02$ by between-group 2-tailed test; dagger, $P = .001$ by between-group 2-tailed test.

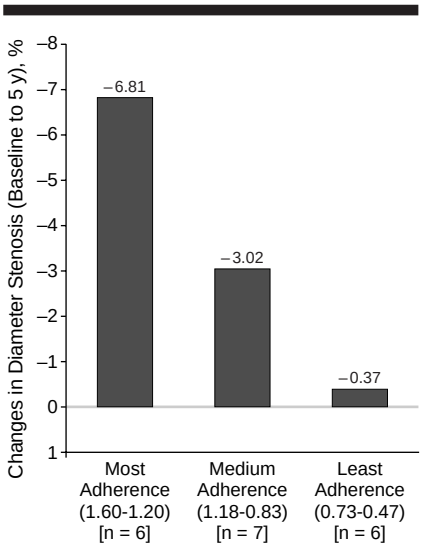

Figure 2.—Changes in percentage diameter stenosis by 5-year adherence tertiles for the experimental group.

in lesions in both groups. These correlations remained significant when examining either the lipid values at 5 years or the change in lipid values from baseline to 5 years.

As a secondary analysis, we examined the results in control group patients who began taking lipid-lowering drugs during the study. Percent diameter stenosis progressed from 45.7% to 51.7%, a change of 6.0 absolute percentage points. In the control patients who did not take lipid-lowering drugs the disease progressed from 40.7% to 59.7%, a much greater change of 19.0 absolute percentage points. (No experimental group patients took lipid-lowering drugs during the study.)

The change in body mass index from baseline to 1 year ($r = -0.85$; $P < .001$) and from baseline to 5 years ($r = -0.72$; $P = .001$) was significantly correlated with the change in percent diameter stenosis in the control group only. In other words, those who gained weight were more likely to show progression of atherosclerosis.

Cardiac Events

Data on cardiac events were obtained from all 48 patients. Cardiac events included myocardial infarction, coronary angioplasty, coronary artery bypass surgery, cardiac-related hospitalizations, and cardiac-related deaths. At 5 years, there were more cardiac events in the control group (45 events for 20 patients, or 2.25 events per patient) than the experimental group (25 events for 28 patients, or 0.89 events per patient) (Table 6). Control group patients were more likely to have undergone coronary angioplasty and bypass surgery and/or to have been hospitalized for cardiac-related problems than were experimental group patients.

COMMENT

The primary end point of this study, chosen a priori, was percent diameter stenosis. On average, there was more reduction (continued improvement) after 5 years than after 1 year in experimental group patients who were asked to make intensive lifestyle changes. In contrast, control group patients showed much more progression (continued worsening) in average percent diameter stenosis after 5 years than after 1 year, even though more than half of the control group patients were prescribed lipid-lowering medications during the course of the study. Although the sample size was relative small,[12] these differences were statistically significant at both 1 year and 5 years. These findings support the feasibility of intensive lifestyle changes in delaying, stopping, or reversing the progression of coronary artery disease in ambulatory patients over prolonged periods.

We found more than twice as many cardiac events per patient in the control group than in the experimental group. These findings are consistent with other clinical trials showing that even small changes in percent diameter stenosis are often accompanied by marked reductions in cardiac events.[13-16] Other studies have demonstrated how quickly the coronary artery endothelium stabilizes in response to lipid-lowering drugs.[17,18]

Although there was some reduction in adherence to the intensive lifestyle intervention between years 1 and 5 in the experimental group, long-term adherence remained remarkably high in this sample of self-selected patients. The level of lifestyle change, even at 5 years, is greater than in any other published study of ambulatory populations. These results are especially encouraging because these patients initially volunteered to participate for only 1 year when they entered the study.

The experimental group reduced LDL cholesterol levels by 40% at 1 year and by 20% after 5 years; these reductions are comparable with those achieved with lipid-lowering drugs in an ambulatory population.[19] In contrast, the Step II diet reduces LDL cholesterol by only 5% or less.[20,21]

High-density lipoprotein levels decreased and triglycerides increased in experimental group patients overall, although the ratio of LDL to HDL was improved. Recent reports assert that this phenomenon, which is often seen in very low-fat diets, may be harmful.[22,23] However, patients in the Lifestyle Heart Trial showed even more regression of coronary atherosclerosis after 5 years than after 1 year as well as significantly decreased cardiac events. Low

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Table 6.—Cardiac Events During 5-Year Follow-up

	No. of Events				
	Experimental* (n = 28)	Control† (n = 20)	Risk Ratio	95% Confidence Interval	*P* Value
Myocardial infarction	2	4	2.74	0.393-30.3	.26
Percutaneous transluminal coronary angioplasty	8	14	2.40	0.939-6.60	<.05
Coronary artery bypass graft	2	5	3.43	0.561-36.0	.14
Cardiac hospitalizations‡	23	44	2.62	1.55-4.55	<.001
Deaths	2	1	0.685	0.012-13.2	.81
Any event	25	45	2.47	1.48-4.20	<.001

*Person-years of observation was 108.04.
†Person-years of observation was 78.81.
‡Includes myocardial infarction, percutaneous transluminal coronary angioplasty, and coronary artery bypass graft.

HDL cholesterol levels due to reduced fat intake are the result of a decreased transport rate rather than the increased catabolism that is responsible for most cases of low HDL cholesterol levels in persons consuming a typical Western diet.[24] Populations consuming low-fat, plant-based diets have low HDL cholesterol levels and low rates of coronary heart disease. Our data provide evidence using quantitative coronary arteriography in this population that diet-induced lowering of HDL cholesterol does not confer the same risk of atherosclerosis as do low HDL cholesterol levels in Americans consuming a high-fat diet.[25] Experimental group patients whose triglycerides increased during the first year were asked to minimize their intake of simple carbohydrates, and triglyceride levels decreased between year 1 and year 5.

The experimental group's marked reduction in frequency, severity, and duration of angina after 1 year was sustained at similar levels after 5 years. This long-term reduction in angina is comparable with that achieved following coronary artery bypass surgery or angioplasty and helps to maintain long-term adherence.[26] Between-group differences in most measures of chest pain were not statistically significant after 5 years because there was a large variability in angina and control group patients who were the most symptomatic underwent revascularization.

When we began this study, we believed that the younger patients with milder disease would be more likely to show regression, but we did not find this to be true. Instead, we found that the primary determinant of change in percent diameter stenosis in the experimental group was neither age nor disease severity but adherence to the recommended changes in diet and lifestyle. This relationship of adherence to percent diameter stenosis in the experimental group was found after 1 year[3] and also after 5 years in a dose-response relationship. Coronary artery minimum diameter remained stable in the experimental group but markedly narrowed in the control group during the 5 years of the study. At 5 years, the differences between the experimental and control groups were statistically significant for both percent diameter stenosis and minimum diameter, even though control group patients reported risk reduction behavior consistent with a Step II diet of the National Cholesterol Education Program and the American Heart Association: they consumed an average of 25% of energy (calories) from fat and exercised an average of 3.5 times per week. These data are consistent with other studies indicating that moderate changes in diet and lifestyle may not be sufficient to stop the progression of coronary atherosclerosis unless combined with lipid-lowering drugs.[27]

After 5 years, the normal diameter (the segment of least narrowing proximal to the minimum diameter) decreased slightly in the experimental group but widened slightly in the control group. A slight decrease in normal diameter, at least up to a point, may improve myocardial perfusion by streamlining flow—decreasing the forward flow losses that occur when going from a larger to a sharply reduced lumen diameter.[4] Conversely, the slight increase in the normal diameter and reduction in the minimum diameter seen in control group patients increased the entry angle, further reducing blood flow. These theoretical considerations are consistent with the substantially increased myocardial perfusion in the experimental group and decreased myocardial perfusion in the control group that we measured using cardiac positron emission tomography scans.[5]

A much earlier study by Morrison[28] found that moderate reductions in fat and cholesterol intake improved cardiac survival: after 12 years, all of the control group patients had died compared with only 62% of experimental group patients in a nonrandomized trial. More recently, an important study by Esselstyn et al[29] reported that a similar diet plus lipid-lowering drugs in 11 patients caused regression of 11 lesions and stabilization in the remaining 14 lesions after 5.5 years. Although there was no control group, those who were adherent to the diet reported substantially fewer cardiac events than those who were not adherent.[29]

Like all clinical trials, our study has limitations. Although the study participants were a diverse group, they may not be representative of the general population of patients with coronary heart disease. Half of the patients who underwent quantitative coronary arteriography in the participatory hospitals did not meet all of the inclusion and exclusion criteria and were not invited to participate in the study. Also, half of the patients who were invited declined to enroll in the study. Nevertheless, it is encouraging that 50% of the patients who were contacted agreed to volunteer despite the requirement for repeated arteriography and that experimental group patients were able to make and maintain comprehensive lifestyle changes. The angiographic measures lost to follow-up may have affected the treatment and control groups differently, although there are no data to suggest that this occurred. In addition, there is a possibility of differential loss of lesions in patients, although no evidence indicates that this occurred; in both groups, there were 14 lesions that were lost to follow-up. Also, 4 lesions were lost in the control group to bypass surgery or angioplasty; since these lesions were worsening sufficiently to require revascularization, the exclusion of these lesions from analysis would make between-group differences more difficult to detect. We recently completed a multicenter demonstration project to assess the practicality and cost-effectiveness of this intervention in a larger sample of economically and geographically diverse patients with coronary heart disease.[30]

Although we did not use lipid-lowering drugs in the experimental group, their value has been demonstrated in studies that have been published since the Lifestyle Heart Trial began. We do not know if experimental group patients may have demonstrated even more improvement by including lipid-lowering drugs.[14-16] Patients in the control group who were not prescribed lipid-lowering drugs during the study showed more than 3 times as much progression in percent diameter stenosis as those who were. No experimental group patients took lipid-lowering drugs during the study, yet they showed better results than control group patients who were taking these drugs. Lipid-lowering drugs are expensive, compli-

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ance is difficult to achieve,[31] and long-term safety is unknown.[32] In practice, patients may be offered a range of therapeutic options, including comprehensive lifestyle changes, lipid-lowering drug therapy, and revascularization, either separately or in combination.

In summary, these ambulatory patients were able to make and maintain comprehensive changes in diet and lifestyle for 5 years and showed even more regression of coronary atherosclerosis after 5 years than after 1 year as measured by percent diameter stenosis. In contrast, patients following more conventional lifestyle recommendations showed even more progression of coronary atherosclerosis after 5 years than after 1 year, and had more than twice as many cardiac events as patients making comprehensive lifestyle changes.

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counseling and testing data system was begun, and 1 (Florida) began HIV reporting very recently and not enough time has elapsed to have adequate data for analysis. The year-to-year median percentage changes in total number of HIV tests during 1992 through 1996 for areas with and without HIV reporting were similar in magnitude and trend.[2]

Although we showed no large declines in testing among MSM and other risk groups after HIV reporting, we agree with Aragón and Myers and Dr Woods and colleagues that trends in some subgroups—for example, in a small number of MSM concerned with reporting issues—could be hidden within the larger community of MSM. Because there will always be individuals concerned about these issues, we emphasized the importance of making anonymous testing available to promote knowledge of HIV status among at-risk people. The approval by the US Food and Drug Administration of home sample collection tests for HIV expands the availability of anonymous testing in all areas.[3]

Woods et al also state that, except for New Jersey, we included only low-prevalence states. This is incorrect. Louisiana (acquired immunodeficiency syndrome [AIDS] rate of 33.7 per 100 000 in 1997) and Tennessee (25.1 per 100 000) have high AIDS incidence, comparable with their own state of California (29.8 per 100 000)[1] and are considered moderate-prevalence states.

Dr Solomon and colleagues are concerned that the study design was ecological and subject to the fallacy inherent in such studies, ie, that ecological correlations cannot be validly substituted for individual correlations. However, to demonstrate the impact of a policy change on a large population, ecological methods may be the most practical design. In an individual-level study, each individual's awareness of the change in policy would be determined. On a population basis, this would be a difficult study to conduct, especially if attitudes of high-risk persons were to be assessed. Although our study cannot distinguish between people who were aware ("exposed") and unaware ("not exposed") of the change in reporting policy, the important fact remains that no large changes in testing behavior were observed in the population. Our results are supported by a recent study of more than 2500 people in high-risk groups (MSM, IDUs, and attendees of sexually transmitted disease clinics) in 9 states.[4] In this study, more than 60% of participants were unaware of their state's HIV reporting policy and, of those avoiding testing, only 2% stated that reporting was a main factor for not being tested.[4] Furthermore, as Dr Paul and colleagues demonstrated in New Jersey, large numbers of people did not go to nearby states to be tested after HIV reporting was implemented.

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CORRECTIONS

Author Omitted: In the Original Contribution entitled "Intensive Lifestyle Changes for Reversal of Coronary Heart Disease" published in the December 16, 1998, issue of THE JOURNAL (1998;280:2001-2007), the name of Shirley E. Brown, MD, was omitted from the list of authors. The full list of authors should read "Dean Ornish, MD; Larry W. Scherwitz, PhD; James H. Billings, PhD, MPH; Shirley E. Brown, MD; K. Lance Gould, MD; Terri A. Merritt, MS; Stephen Sparler, MA; William T. Armstrong, MD; Thomas A. Ports, MD; Richard L. Kirkeeide, PhD; Charissa Hogeboom, PhD; Richard J. Brand, PhD."

Incorrect Location: In the MSJAMA Essay entitled "Physician-Legislators: Physicians Practicing Public Service" published in the March 3, 1999, issue of THE JOURNAL (1999;281:862), Congressman Vic Snyder was listed as representing Arizona when, in fact, he represents Arkansas.

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