Dietary cholesterol and the plasma lipids and lipoproteins in the Tarahumara Indians: a people habituated to a low cholesterol diet after weaning[1-3]

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ABSTRACT Eight Tarahumara Indian men participated in a metabolic study to measure the responsiveness of their plasma cholesterol levels to dietary cholesterol. They were fed isocaloric cholesterol-free and high cholesterol diets containing 20% fat, 15% protein, and 65% carbohydrate calories. On admission to the study, the Tarahumaras had a low mean plasma cholesterol concentration (120 mg/dl), reflecting their habitual low cholesterol diet. After 3 wk of a cholesterol-free diet their cholesterol levels were 113 mg/dl. The men were then fed a high cholesterol diet (1000 mg/day) which increased the mean total plasma cholesterol to 147 mg/dl ($p < 0.01$) and also increased the low-density lipoprotein cholesterol concentration. Tarahumaras, habituated to a low cholesterol diet after weaning, had the typical hypercholesterolemic response to a high cholesterol diet that has been previously observed in subjects whose lifelong diet was high in cholesterol content. *Am J Clin Nutr* 1982;35:741-744.

KEY WORDS Cholesterol, dietary cholesterol, Tarahumara Indians, egg yolk

Introduction

While many cholesterol-fat feeding studies have been carried out under metabolic ward conditions in subjects whose lifetime diets have been rich in cholesterol, saturated fat, and calories, few such studies have occurred in subjects of more primitive populations whose habitual diets are in great contrast. The Tarahumara Indians of Mexico, a tribe noted for their long distance running, have a traditional diet after weaning which is remarkably low in foods containing cholesterol and fat (1). Their exceptional physical fitness is accompanied by a lack of cardiovascular disease risk factors, including obesity, hypertension, and elevated plasma cholesterol levels (2).

The plasma cholesterol concentrations in the Tarahumara Indians are unusually low with a mean value of 125 mg/dl for all ages combined (2). The explanation for their low plasma cholesterol levels has been largely attributed to dietary factors, in particular, their low intake of cholesterol and saturated fat (2). Dietary cholesterol has been shown to

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have a significant influence on the plasma cholesterol concentrations in Americans under controlled metabolic experiments (3–5).

The present study was carried out in a metabolic unit set up in Sisigouchic, state of Chihuahua, Mexico. It was designed to answer the following questions: would Tarahumara Indians have a similar hypercholesterolemic response when given a large load of dietary cholesterol in the face of their habitual low cholesterol intake, i.e., an average of 71 mg/day? Or, conversely, would the low plasma cholesterol concentrations of the Tarahumaras result from metabolic adaptation making them insensitive to a high cholesterol diet?

Methods

Subjects

Eight healthy adult Tarahumara men, between 20 and 45 yr of age, volunteered to participate in the study in response to a general invitation to the community. The study was explained to them in detail in the Tarahumara language, and each man signed a consent form previously approved by the Human Research Committee. The study was approved by the Mexican government and the Sisigouchic Mission.

On admission, base-line measurements and a medical examination were carried out. The men were found to be healthy and were short and lean (mean ± SD 161.0 ± 6.0 cm height, 53.8 ± 7.1 kg weight, and 6 ± 1 mm triceps skinfold). Their mean blood pressure was 95 ± 13/60 ± 13 and the resting pulse rate, 56 ± 11 bpm.

Experimental design

A metabolic ward was set up in an unused school facility near the small community hospital. The food was weighed and prepared in the kitchen and the men were served in the adjacent dining room. The ward routine included morning weights, supervised regular meal times, and twice weekly fasting blood drawings. The subjects participated in the study for 6 wk: they first consumed the base-line cholesterol-free diet for 3 wk, followed by 3 wk of the experimental high cholesterol diet.

Design of diets

The typical Tarahumara food pattern consisting mainly of beans, tortillas, and pinole was used as the basic diet for the entire study. Local products, including dried beans and corn, vegetables, cereals, and fruits were used. Three meals and one snack were served daily.

The cholesterol-free and the high cholesterol diets were identical in calories (estimated individually for each subject based on weight, height, and age), in protein (15% of cal), in fat [20% of cal with 10% monounsaturated, 4% polyunsaturated (P) and 6% saturated (S) fat calories, P/S ratio 0.7], in carbohydrate (65% of cal with 62% from complex and 3% from simple carbohydrate) and in fiber (78 g of dietary fiber).

The menus were identical during the cholesterol-free and high cholesterol diets with two exceptions: egg whites and vegetable shortening (Inca) in the cholesterol-free period were replaced by a combination of egg yolks and a lesser amount of the shortening during the high-cholesterol period. This substitution allowed the diets to be equivalent in protein, fat, and P/S ratio but widely different in dietary cholesterol—from cholesterol-free to approximately 1000 mg daily. The egg yolk during the high cholesterol diet was weighed for each subject, scrambled, and given in thirds, one portion at each meal.

Diet calculations were based on standard food composition tables and our analysis of the fatty acid composition of the Inca shortening (38.8 mg saturated, 53.7 mg monosaturated, and 7.4 mg polyunsaturated fatty acids per 100 g) (6). Actual analysis of the egg yolk used indicated that the high cholesterol diet contained 905 mg of cholesterol (1240 mg cholesterol/100 g egg yolk) (7).

Lipid measurements

Plasma samples, obtained by venipuncture twice a week, were frozen and transported to our laboratory for analysis. After thawing the plasma, the cholesterol, and triglyceride content was analyzed with the Autoanalyzer II (Technicon Instruments Corp, Tarrytown, NY) (8). Lipid and lipoprotein lipid analyses were carried out by established Lipid Research Clinics techniques (8). An analysis of variance with repeated measures followed by the Newman Keul's procedure for multiple comparison (9) was used to compare the plasma lipids at admission and during wk 3 of each diet.

Results

The eight subjects were cooperative and tolerated the diets well. The mean total plasma cholesterol concentration was typically low on admission, 120 ± 7 (SEM) mg/dl, remained low after 3 wk of the cholesterol-free diet, 113 ± 8 mg/dl, and increased 30% after the high cholesterol feeding to 147 ± 11 mg/dl ($p < 0.01$) (**Table 1**). This increase began during the 1st wk of the high cholesterol diet and continued to rise until it stabilized during wk 3 (**Fig. 1**). Such stabilization of the plasma cholesterol levels after 10 to 14 days of dietary cholesterol feeding in normocholesterolemic Caucasians has been demonstrated in previous studies (3, 11) and continues indefinitely (at least for 11 wk). All subjects had increased plasma cholesterol levels after the feeding of dietary cholesterol. The mean increase was +34 mg/dl and the entire range of values was +42, +28, +19, +57, +29, +46, +18, and +26 mg/dl.

Most of the increase in plasma cholesterol occurred in the low-density lipoprotein (LDL) cholesterol fraction which changed from 72 ± 6 (SE) mg/dl after the cholesterol-free diet to 94 ± 9 after the high cholesterol

TABLE 1
The effects of dietary cholesterol on the total plasma cholesterol, triglyceride, and lipoproteins

	Admission	Cholesterol free diet	High cholesterol diet
Cholesterol (mg/dl)			
Total	120 ± 7*	113 ± 8	147 ± 11†
HDL	31 ± 3	27 ± 1	31 ± 2
LDL	72 ± 4	72 ± 6	94 ± 9†
VLDL‡	15 ± 12	8 ± 6	19 ± 3
LDL/HDL	2.48	2.70	3.22
Triglyceride (mg/dl)			
Total	96 ± 12	100 ± 7	111 ± 12
HDL	17 ± 2	15 ± 1	15 ± 2
LDL	27 ± 2	24 ± 2	30 ± 4
VLDL	51 ± 10	59 ± 7	68 ± 11

* Mean values ± SEM.
† Significantly different than admission and cholesterol-free period, $p < 0.01$.
‡ Very low-density lipoprotein.

diet ($p < 0.01$), a 31% elevation. The very low-density and high-density (HDL) lipoprotein cholesterol concentrations were unchanged by the dietary manipulations (Table 1). Base-line mean total plasma triglyceride and the lipoprotein triglyceride fractions remained similar during the study. The ratio of cholesterol to triglyceride in LDL and VLDL did not increase statistically during the high cholesterol diet.

Mean body weight increased only slightly throughout the study, a similar minor change in both periods: +0.8 kg during the cholesterol-free diet and +0.9 kg during the high cholesterol diet.

Discussion

In this metabolic ward study, a high cholesterol diet produced a significant increase in plasma cholesterol and LDL concentrations in Tarahumara Indians whose habitual diet had been low in cholesterol content. Their response was neither exaggerated as might have been expected from the virtual absence of cholesterol in their usual diet nor attenuated as would have been predicted from the hypothesis that the dietary cholesterol in breast milk might protect against cholesterol overload later in life (10). Tarahumara infants are routinely breast-fed. Indeed, the mean plasma cholesterol increase of 34 mg/dl and the LDL cholesterol increase of 22 mg/dl were similar to increases ob-

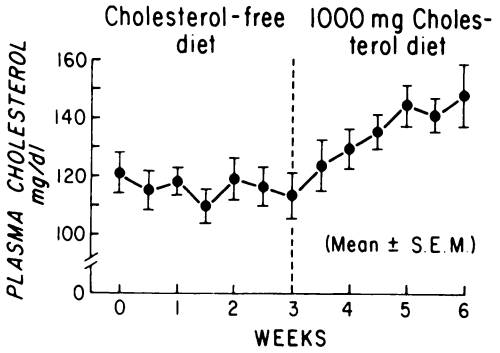

FIG. 1. The plasma cholesterol concentrations in eight Tarahumara men receiving cholesterol-free and 1000-mg cholesterol diets for 3 wk each.

tained in normal American volunteers consuming a similar amount of dietary cholesterol after a cholesterol-free dietary period (3–5, 11). The Americans would have had a dietary background after infancy high in cholesterol content. Thus, the results of this study emphasize the universality of the increased plasma total cholesterol and LDL cholesterol concentrations after the ingestion of a high cholesterol diet after a cholesterol-free period. This point has been previously reviewed in depth (12, 13).

With regard to other plasma lipids and lipoproteins, the plasma triglyceride levels did not change nor did the HDL concentrations. However, the LDL/HDL ratio, a measure of the atherogenicity of the plasma lipoproteins, increased considerably after the high cholesterol diet. Of particular interest was the relatively low HDL level of the Tarahumaras (31 mg/dl) and its lack of responsiveness to the high cholesterol diet. Low HDL levels were previously noted in an epidemiological study of the Tarahumaras (2) and have been found also in populations in Asia and Africa whose total plasma cholesterol levels were low like the Tarahumaras (14).

The results of our study are in contrast to two previous studies which showed primitive populations of Papua New Guineans and African Masai to be unresponsive to increasing the dietary cholesterol content. The dietary design of these studies was quite different than that of the present study. The Masai received crystalline cholesterol which is known to be poorly absorbed in contrast to egg yolk cholesterol (15). Papua New Guineans were fed egg yolks but their total di-

etary intake was not known and a control dietary period was not included (16).

The unusually low mean plasma cholesterol concentration at all ages in the Tarahumara Indians places them at a low risk for atherosclerotic cardiovascular disease (2, 17). Their low plasma cholesterol concentrations appear to be closely related to their habitually low dietary intakes of cholesterol and saturated fat. In the previous nutritional survey of this population, a significantly positive correlation was found between the plasma cholesterol levels and the intake of dietary cholesterol ($r = 0.898$) (2). The present study confirms the sensitivity of their plasma cholesterol concentrations to the dietary cholesterol content.

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