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Nutritional and Epidemiologic Factors Related to Heart Disease[1]

J. BROWN†, G.J. BOURKE, G.F. GEARTY, A. FINNEGAN, M. HILL, F.C. HEFFERNAN-FOX, D.E. FITZGERALD, J. KENNEDY, R.W. CHILDERS, W.J.E. JESSOP, M.F. TRULSON†, M.C. LATHAM, S. CRONIN, M.B. MCCANN, R.E. CLANCY, I. GORE, H.W. STOUDT, D.M. HEGSTED and F.J. STARE

Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts and Department of Social Medicine, Trinity College School of Medicine, Dublin, Ireland

Synopsis

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† Deceased

The Ireland-Boston Heart Study has been conducted jointly by the Department of Nutrition of Harvard University in Boston and the Department of Social Medicine of Trinity College, Dublin, Ireland. A preliminary progress report has been published [1]. The study seeks to examine various epidemiological factors which have been shown to be related to atherosclerotic heart disease and to make comparisons of these in persons of Irish stock living in different environmental situations.

At the time this study was designed the intake of dietary fat was the main factor implicated in atherosclerotic heart disease. In the intervening years our understanding of the role of this factor has been somewhat modified and several other factors, such as lack of physical activity, cholesterol content of foods, cigarette smoking and obesity, have been implicated. Also during these years new nutritional associations have been suggested including those of high sugar [2] and low fluoride intake [3]. Most authorities agree that there are multiple risk factors and that although the etiology of coronary disease is not established, these several factors contribute either to protecting the individual from or increasing his susceptibility to heart disease.

The factors believed to be involved are nutritional (including the intake of total calories, cholesterol, certain fats and carbohydrates, fluoride, magnesium and possibly others), cigarette smoking, activity, and social class. As well as these variables which to some extent are capable of manipulation, there are certain factors in the individual himself which appear to determine his liability to the disease. These include sex, age, serum cholesterol, serum lipids, blood pressure, obesity (as shown by skinfold thickness, relative weight, ponderal index, etc.), body build, behavior and personality factors, ECG abnormalities, the presence of diabetes and other hormonal or endocrine disturbances.

It is clear that some 'risk' factors are indeed clinical signs and that these 'signs' may be dependent on other risk factors. Thus, serum cholesterol levels can be altered to some degree by diet; abnormal ECG findings may be due to hypertension or may be an actual manifestation of coronary disease; and obesity is related to dietary intake and caloric expenditure. There is therefore, a complicated web of environmental factors acting on, and of inherent factors existing in the individual, all of which in some way appear to affect his chances of suffering coronary heart disease.

At the present time, because we do not know the precise etiology of the disease we tend to believe that many of these factors are causal. As in the case of other complex diseases whose cause was previously unproven, these related factors might fall logically into place once the exact etiology has been determined. At present it is helpful to consider these several factors,

to relate one to another and, using epidemiological methods, hopefully to get nearer to the answer. This approach may also be fruitful in suggesting logical preventive measures. When malaria was still thought to be due to bad air from swamps, deaths from malaria were prevented by re-locating people in the hills, and a century before the discovery of vitamins, scurvy was eliminated from the British navy by the use of lime juice. In the same way preventive measures may successfully be implemented against coronary disease before its precise etiology is proven.

In the Ireland-Boston study, many of these 'risk' factors, environmental, dietary, and physical have been investigated. Because of the detail in which data have been collected it has been possible to consider theories of etiology which have arisen subsequent to the design of the study. The use of the computer has allowed the consideration of many correlations which it would have been impractical to consider without this tool. Only some of these appear in the results in this paper.

From many geographic studies relating to atherosclerotic heart disease it has been shown that very different rates, both of mortality and morbidity, occur in different parts of the world. A partially successful attempt has been made to fit these into the pattern of risk factors found in different countries. Thus, a high consumption of saturated fats has been found mainly in those countries where coronary heart disease is common and in these same places high mean serum cholesterol levels are found in middle aged men. This type of evidence has been to some extent contradicted by later findings in which persons (such as the Masai in Tanzania) with a high intake of saturated fat were found to have low serum cholesterol levels and presumably little coronary heart disease [4]. This type of evidence had led some workers to believe that certain peoples, like the Japanese and the Masai, are innately less liable to develop atherosclerotic heart disease than are, for example, most Caucasians. This would imply that there are very significant hereditary or racial factors involved and that environmental and dietary factors are less important. However, the Japanese who have migrated to the United States have higher serum cholesterol levels and more atherosclerotic heart disease than do their compatriots in Japan [5–7].

The Ireland-Boston study was designed to get around this particular difficulty by eliminating racial and to some extent broad hereditary differences while at the same time ensuring considerable environmental variation by taking for the core study brothers who live several thousand miles apart. No study of atherosclerosis has to our knowledge used this technique, presumably because of the difficulties inherent in undertaking such a study.

I. Study design and methods

It is known from vital statistics reports that mortality from arteriosclerotic heart disease (classification 420–422) is higher for males aged 45–64 in the United States than in Ireland. Because there are a large number of Irish immigrants in Boston a study was designed in which men born in Ireland but living in Boston were compared with brothers who had remained in Ireland. Comparisons were made of dietary, physical and certain other factors which might be related to atherosclerosis. Accordingly, through publicity Irish born men in the Boston area who were between 30 and 65 years of age, and who had a brother still living in Ireland were contacted and, if willing to cooperate, were enrolled. Each was given a form letter to post to his brother in Ireland and the latter was contacted by staff from the Department of Social Medicine of Trinity College in Dublin. In this manner a total of 1154 brothers, all matched, each within ten years of the other's age, were enrolled and examined.

As the study progressed, it became evident that the majority of the brothers in Ireland were rural farm workers, whereas the Boston brothers lived and worked in a large urban area. Because even within countries there are differences in the incidence of arteriosclerotic heart disease between urban and rural men, it was decided to enroll a group of urban subjects in Ireland for comparison with the rural brothers and the urban subjects in Boston. Accordingly, we secured the cooperation of C.I.E. (the Irish transport company) and of Guinness's Brewery. As a result 151 transport and 161 brewery workers living in Dublin were enrolled.

Evidence such as that in which U.S. servicemen killed in Korea at an average age of 22 years were found to have arterial atherosclerotic lesions [8], indicates that the physical findings related to this condition in middle age are a reflection not only of factors at play during earlier adult life, but also those during childhood. Because our Boston brothers had mainly come to the United States when they were over 20 years of age, all would have been affected by dietary and environmental factors both while in Ireland and while in the United States. For this reason, a sample of comparable men, both of whose parents were born in Ireland, but who had themselves been born in the United States, was sought. This group we called 'First Generation' and in all 376 of these men were enrolled.

Table I. Total number of subjects

	In Boston		In Ireland			
Age in Years	I First Generation	II Boston Brothers	III Irish Brothers	IV Guinness	V Transport	VI Rural
20–39	117	115	97	85	64	50
40–49	121	112	161	59	47	69
50–59	104	243	174	17	29	25
60+	34	109	143	0	11	8
Total	376	579	575	161	151	152
Mean age	45.4	50.3	50.7	40.2	42.3	43.9
Mean ± S.D.	± 9.6	±10.0	±11.6	± 6.4	±10.9	± 8.5

A sixth group in the study was a group of rural Irish who were not brothers of the Boston subjects. These 152 men were enrolled in order to provide a better basis for urban-rural comparisons in Ireland.

The six groups of men in the study (and they have been labeled thus) are: 1. First Generation, 2. Boston Brothers, 3. Irish Brothers, 4. Guinness Workers, 5. Transport Workers, 6. Rural (non-brothers). A total of 1994 men are included in the study (see table I).

This paper describes the methods used and the results obtained from dietary interviews, physical examination, anthropometric measurements, electrocardiograph readings, serum cholesterol estimations and questioning on alcohol consumption and cigarette smoking in 1994 men in the six study groups. Besides the examination and interview of these groups of subjects, two other studies were conducted to help broaden the picture. In the first a comparison has been made of mortality data in Ireland with that of persons dying in Massachusetts who are Irish born or born in the United States of Irish born parents. In the second study, coronary arteries and aortas were collected in Ireland and from Irish subjects coming to autopsy in Boston. These have been compared for their extent of atherosclerotic involvement.

II. Results

A. Food availability in Ireland and the United States

It is known that the incidence of arteriosclerotic heart disease has increased significantly over the past several decades in many countries of the world, including the United States and Ireland. Furthermore, the results of animal and human experimentation have suggested that diet may alter not only lipid levels but also cardiovascular morbidity and mortality. Many dietary components, particularly fat and carbohydrate, have been implicated. Other dietary factors have been considered including total calories, the amount of cholesterol, type and amount of protein and carbohydrate, fiber content, minerals and trace elements.

The ever increasing body of evidence that dietary factors may be associated with the development of cardiovascular disease has stimulated interest in changes in diet composition over the years. A comparison of food available for human consumption in Ireland [9–11] and the United States [12] during the past three decades is given in table II. Four time periods have been selected to show trends in food consumption in these two countries.

Ireland as indicated by FAO food balance sheets, has one of the most plentiful food supplies in the world. The most recent data available for Ireland, 1960–62, indicate a total of 3486 calories available *per capita* per day with fat providing 34% of total available calories. In the United States

Table II. Calories available for consumption *per capita* per day and percentage of total calories contributed by major food groups in selected periods in Ireland and the United States

	U.S. 1935–39	Ireland 1934–38	U.S. 1947–49	Ireland 1948–50	U.S. 1957–59	Ireland 1957–59	U.S. 1960–62	Ireland 1960–62	Change U.S. 1935–39 to 1960–62	Change Ireland 1934–38 to 1960–62
Calories	3276	3401	3230	3431	3133	3514	3127	3486	—149	+85
% Calories protein	11.0	11.6	11.8	11.2	12.1	11.0	12.1	10.0	+1.1	—1.6
% Calories fat	36.5	28.2	39.3	30.5	41.2	33.8	41.0	33.9	+4.5	+5.7
% Calories carbohydrate	52.5	60.2	48.9	58.3	46.7	55.2	46.9	56.1	—5.6	—4.1
Food groups										
Meat, poultry, fish including fat pork cuts	14.5	13.8	17.4	11.9	18.2	13.0	18.8	14.2	+4.3	+0.4
Eggs	2.0	1.8	2.6	1.5	2.6	1.7	2.4	1.9	+0.4	+0.1
Dairy products excluding butter	11.2	10.7	13.2	11.4	13.5	14.1	12.8	12.9	+1.6	+2.2
Butter	4.6	7.7	2.9	10.3	2.3	7.8	2.1	7.8	—2.5	+0.1
Other fats and oils	10.8	1.9	11.6	2.7	13.7	4.0	14.0	4.5	+3.2	+2.6
Fruits	3.3	0.7	3.4	1.5	3.3	1.3	3.4	1.8	+0.1	+1.1
Vegetables, excluding potatoes	2.4	1.1	2.6	1.0	2.6	1.1	2.7	1.1	+0.3	0
Potatoes	3.7	11.0	3.0	10.6	2.8	7.8	2.9	7.8	—0.8	—3.2
Dry beans, peas, nuts, soya products	3.0	0.3	2.9	0.4	2.9	0.5	2.9	0.5	—0.1	+0.2
Flour and cereal products	28.2	38.7	23.9	37.4	21.4	32.7	24.1	31.3	—4.1	—7.4
Sugar and other sweeteners	15.7	11.9	15.7	10.9	15.8	13.2	16.2	14.5	+0.5	+2.6
Coffee and cocoa products	0.8	0.3	0.8	0.3	0.8	0.2	0.8	0.3	0	0

for the same three year period, 3127 calories were available *per capita* per day of which 41% (142 g) was from fat.

The principal differences in present food supply between these two countries are that more cereals, potatoes and butter are available in Ireland while more meat, edible oils (including margarine and marine oils), fruits and vegetables are available in the United States. Slightly more of the total calories in the United States are provided by sugar and other sweeteners (16.2%) than in Ireland (14.5%). More than twice as many calories are available from potatoes in Ireland than in the United States (7.8% vs. 2.9%), and Ireland obtains 31.3% of her calories from flour and cereal products compared with 24.1% in the United States. Dairy products excluding butter provide approximately 13% of total calories in both countries, but over three times as many of the total calories come from butter in Ireland than in the United States (7.8% vs. 2.1%). Meat, poultry and fish contribute more of the total calories in the United States (18.8%) than in Ireland (14.2%). While Ireland, as stated, eats more butter, the United States obtains more than three times as many of its calories from other fats and oils (14.0%) than does Ireland (4.5%).

There are without doubt regional and local differences in both countries. Thus, farmers in Connemara eat differently from brewers in Dublin. Similarly Boston businessmen do not eat the same foods as cotton pickers in Mississippi. Estimates of the actual quantities of various foods consumed by the subjects in the Ireland-Boston study were obtained and the differences in intakes of the important nutrients are given.

B. Food trends in Ireland and the United States

Changes in food availability in the United States and Ireland over the past three decades are shown in table II. The general trend, reflecting changes seen in reports of international dietary intakes where economic development is occurring, has been towards an increase in the percentage of calories provided by fat, a decline in overall calories from carbohydrate, and a replacement of some complex carbohydrate with simple sugar.

Protein

Protein contributed between 10 to 12.1% of the total calories in both countries over the three decades, contributing slightly more of the total calories (+1.1%) in the United States in 1960–62 as compared with 1935–39.

Conversely, a slight downward shift was seen (–1.6%) in the calories provided by protein in Ireland over this same period.

Fat

A number of investigators have considered the changing American diet with special reference to fat [13–16]. According to food availability data shown in table II, fat contributed 4.5% more of the total calories in 1960–62 than in 1935–39. A similar increase of 5.7% from fat is seen in Irish food availability data. An intriguing observation reported by several investigators is a shift upward in the P/S ratio (ratio of polyunsaturated to saturated fatty acid) in the United States [17, 18]. ANTAR *et al.* [17] in an analysis of fat from all food sources available in the United States retail market, reported a small increase in the P/S ratio from 1909 to 1961 (from 0.24 to 0.31%). A similar trend in fatty acid availability was noted by CALL and SANCHEZ [18]. The increased consumption of other fats and oils reflected in table II is chiefly responsible for the change in fatty acid composition of the American diet. Although much less of these fats and oils is used in Ireland there has been a trend upward over the years. Slightly fewer calories (0.9%) were supplied by dairy products and butter in the United States, and slightly more (2.2%) in Ireland in 1960–62 as compared with the later 1930's.

Cholesterol

ANTAR *et al.* [17] reported little change in supplies of total cholesterol in the American diet. In 1909, 683 mg of cholesterol were available *per capita* per day compared with 734 mg in 1961, an increase of only 7.5%. The chief source of dietary cholesterol is egg yolk and table II shows a slight increase in total calories provided by this food in both the United States and Ireland.

Carbohydrate

The amount of carbohydrate provided by the American diet is now about a fourth lower than at the beginning of the century, with about half of this decrease occurring since 1935–39. Approximately 436 g of carbohydrate were available *per capita* per day in 1935–39 compared with 374 g in 1960–62. The change has been less marked in Ireland where 512 g were available *per capita* per day in 1934–38 as contrasted to 489 g in 1960–62. The total percentage of calories provided by carbohydrate decreased 5.6% in the United States and 4.1% in Ireland (see table II).

The most marked change in carbohydrate consumption is the shift in the proportion of carbohydrate provided by sugars. FRIEND [19] reported

that at the beginning of the century two-thirds of the carbohydrate in the American diet was provided by starch and one-third by sugars. The amount of carbohydrate in the form of sugars increased to 43.2% in 1935–39 and to 51.2% in 1965. A similar trend in changes in type of carbohydrate available is noted in table II for Ireland. Potatoes and flour and cereal products contribute a total of 10.6% fewer calories in 1960–62 than in 1934–38 in the Irish diet while consumption of sugar and other sweeteners increased by 2.6%.

Magnesium

FRIEND [19] reported a decrease in magnesium available in the United States, decreasing from 380 mg *per capita* per day in the late 1930's to 340 mg in 1965. The implications of this have been reviewed [20]. The decreased use of grain products is primarily responsible for this change. A similar decrease would be expected in Ireland (see table II) with the decreased consumption of cereal products.

Food availability data must be viewed with caution. Food produced and available at retail is not the same as food consumption. No allowance is made for spoilage, waste, and food fed to domestic pets. In addition, they conceal variation in intake of individuals. At best, these data provide an estimate of trends in food consumption.

C. Mortality

1. Mortality from arteriosclerotic heart disease in Ireland and Massachusetts

Table III compares mortality rates per 100,000 male population in the United States and Ireland for the age groups 45–54 and 55–64. This shows that, for example, at age 55–64 deaths from 'all causes' were almost identical in the United States and Ireland in 1950. However, for the same year there were 300 more deaths per 100,000 from arteriosclerotic and myocardial heart disease (classification 420–422) in the United States than in Ireland.

Table III. Mortality rates per 100,000 males population (1950)

Age range	All causes		Classification 420–422	
	U.S.	Ireland	U.S.	Ireland
45–54	1067	922	348	199
55–64	2046	2044	896	596

Table IV. Deaths from arteriosclerotic heart disease (420) and other myocardial degeneration (421–422) as percentage of total deaths by age, sex and origin (1961)

	Males (age 45–64 years)		Females (age 55–64 years)	
	420	420–422	420	420–422
Ireland: total population	24	29	15	23
Massachusetts: Irish born	36	36	23	25
Massachusetts: U.S. born of Irish born parent	38	39	28	29
Massachusetts: U.S. born of U.S. born parent	40	42	26	27

Perhaps the most meaningful and clear comparison can be obtained by looking at the deaths due to these causes (classification 420–422) as a percentage of total deaths rather than by population. Table IV compares deaths in males aged 45–64. This shows that 29% of deaths in Ireland and 42% in second generation Americans in Massachusetts were due to this cause. The figures in this table suggest a definite trend in mortality from causes 420–422 in males. Irish born men living in Massachusetts have a higher rate than do men living in Ireland, and United States born men of Irish parentage have an even higher rate and closely approach the second generation Americans in Massachusetts in percentage of deaths from this cause. For women we have taken the upper of the two decades because the disease is much commoner in women between 55 and 64 than between 45 and 54 years of age. The table shows a trend in females similar to, though less marked than, that seen in males.

We realize that this type of comparison has disadvantages such as differences in age distribution, in prevalence of other causes of death, and in classification of death. Life expectation in the two countries has been shown to be very similar.

2. Assignment of cause of death

The International List of Classification of Death was revised in 1926 (3rd revision), in 1931 (4th revision), in 1940 (5th revision), and in 1950 (6th revision). All these have affected the classification of what is now 'arteriosclerotic heart disease' (420) and 'other myocardial degeneration' (421, 422). It is, however, possible to distinguish and separate these two conditions from other causes of death in all these classifications and therefore to make some comparison of death rates over a forty year period in Ireland.

When comparing deaths within a country the difficulties of assignment of deaths by cause arise not only because of changes in nomenclature but also because of changes in diagnosis. In the case of heart disease there have, over the period, been improvements in diagnostic technique, especially with the introduction and increased use of the electrocardiograph. There is also to be considered the question of what disease is 'fashionable' in any particular place and at any particular time in history. The assignment of cases of sudden death that do not come to autopsy will almost certainly be influenced by this factor. All these matters deserve serious consideration when looking at secular changes in mortality by cause taken from death certificates.

3. Secular change in mortality in Ireland

ACHESON and THORNTON [21] have reviewed the mortality from coronary artery disease in Ireland between 1926 and 1955. They mention that for every death in a man or a woman in the Republic of Ireland certified as due to angina pectoris in 1926 over 30 deaths were attributed to angina pectoris or coronary heart disease in 1956. They show that the secular increase in male and female death rates has been approximately equal and uniform. In contrast, comparative mortality indices for the group of diseases now classed as myocardial degeneration show little change for the period 1926–1956 for either sex.

Fig. 1 shows the mortality per 100,000 from arteriosclerotic heart disease in Ireland by sex in the age range 45–64. These data compiled by ACHESON and THORNTON [21] have been updated with our own more recent figures to 1965.

The rise in arteriosclerotic heart disease and the relatively minor changes in deaths due to myocardial degeneration are illustrated in fig. 2, which shows the comparative mortality indices for these two causes of death with 1938 as the base year. ACHESON and THORNTON showed that when these comparative mortality indices for arteriosclerotic heart disease are plotted using a logarithmic scale the rate of increase for females is rather similar to that for males.

When comparing mortality figures in the period since the last revision of classification of death and within the era of common use of the electrocardiograph we see a continuing rise in deaths attributed to arteriosclerotic heart disease. This is shown by sex in tables V and VI. It can be seen that in males below 65 years of age the death rate from arteriosclerotic heart disease has doubled between 1950 and 1965. In males above this age the rate has increased even more steeply. Similar trends are shown for females. It seems

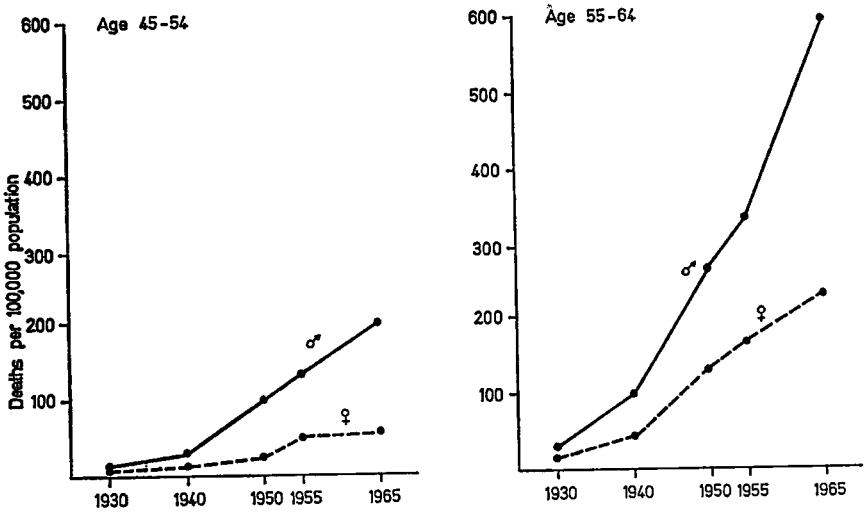

Fig. 1. Death rate per 100,000 from arteriosclerotic heart disease (420) in Ireland at ages 45–64 from 1930 to 1965. 1930 and 1940 figures taken from R.M. ACHESON and E.H. THORNTON: Brit. J. prev. soc. Med. *12:* 82 [1958]. 1930 rate is mean of 1926–1935 rate and 1940 rate is mean of 1936–1945 rate. Figures for ages by decade are a mean of the two five-year period figures given in their paper. Figures for 1950, 1955 and 1964 are from Irish Vital Statistics.

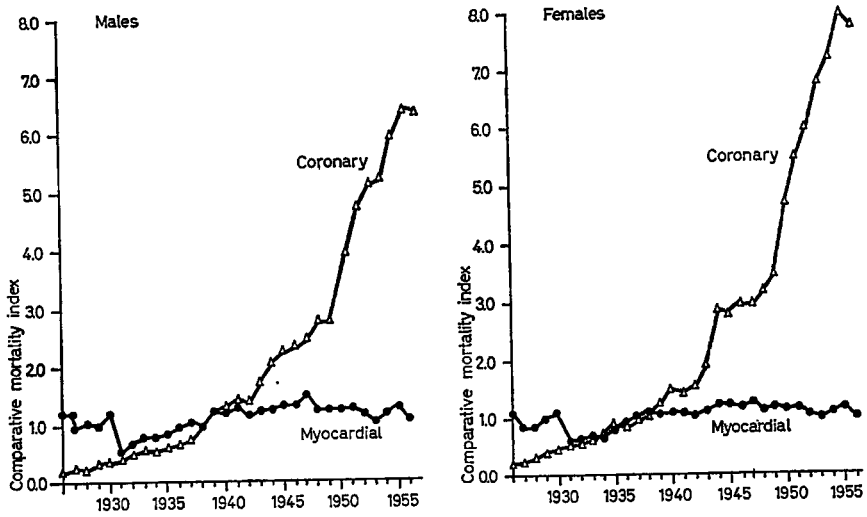

Fig. 2. Comparative mortality indices for coronary artery disease and myocardial degeneration in the Republic of Ireland from 1926 to 1956, by sex.

Table V. Death rate per 100,000 from arteriosclerotic heart disease (420) and from myocardial degeneration (422) for 1950, 1955, 1960, 1965; males

Year	Classification of cause of death	Age years 25–	35–	45–	55–	65–	75–	85+
1950	420	5.61	22.92	100.42	263.50	431.89	511.97	529.10
	422	4.51	10.18	62.91	243.72	1081.67	2713.27	4889.61
1955	420	9.39	22.94	139.23	338.32	770.80	1094.66	989.68
	422	1.17	6.0	34.04	161.35	800.67	2917.71	5979.92
1960	420	8.1	51.1	155.8	469.9	954.3	1440.9	
	422	1.4	6.6	24.6	111.2	560.6	3133.4	
1965	420	9.02	54.03	214.54	585.61	1228.86	1844.68	2750.0
	422	1.38	3.10	15.15	47.55	343.29	1527.65	5825.0

Table VI. Death rate per 100,000 from arteriosclerotic heart disease (420) and from myocardial degeneration (422) for 1950, 1955, 1960, 1965; females

Year	Classification of cause of death	Age years 25–	35–	45–	55–	65–	75–	85+
1950	420	3.09	5.40	27.11	137.31	220.31	305.18	358.79
	422	5.15	20.54	55.48	232.06	919.55	2502.49	4407.99
1955	420	1.14	15.80	49.01	164.64	409.84	574.58	486.61
	422	4.00	6.54	32.89	121.43	639.38	2674.87	6160.14
1960	420	2.0	13.5	55.9	164.8	492.9	837.4	
	422	2.7	7.0	25.5	93.9	451.4	2765.6	
1965	420	2.77	18.01	58.28	225.73	633.65	1201.78	2045.45
	422	—	2.48	10.42	36.02	226.92	1200.00	4672.72

likely that in those over 65 a substantial number of deaths previously assigned to 'senility' are now being assigned to the more fashionable coronary slot. The figures for the younger age groups are therefore likely to show more accurate trends in mortality rates from arteriosclerotic heart disease.

D. Dietary and physical findings in study subjects

Various epidemiological factors have been shown to be related to arteriosclerotic heart disease including dietary factors, cigarette smoking, activity and certain individual characteristics such as age, sex, serum lipid levels, obesity, body build, ECG abnormalities and blood pressure. This paper

reports some of the results obtained from dietary interviews, physical examination, electrocardiograph readings and serum cholesterol determinations of six groups of persons of Irish stock. It will be recalled that two groups resided in the United States, and the other groups in Ireland (see table I).

In all cases a careful dietary history was taken by a nutritionist. A dietary schedule which gave qualitative and quantitative information was used. The nutritionist also obtained information relative to cigarette smoking and alcohol consumption. A physician (cardiologist) obtained a personal and family history and performed a physical examination. Among others, measurements were made of height, weight, and skinfold thickness. Blood pressure was measured and a twelve lead electrocardiogram was obtained. Blood was taken for measurement of serum cholesterol. All cholesterol estimations for subjects both in Ireland and in Boston were performed in the same laboratory. The nutritionists and physicians on both sides of the Atlantic met on several occasions to standardize procedures and to work with each other in both Ireland and Boston.

In the results which follow, data in each case refer to findings on more or less the whole group. The only exception is with dietary information. Histories designed to describe eating patterns rather than actual nutrient composition of the dietaries were obtained on a number of subjects. Therefore, data comparative in terms of nutrients were available for about one-third of the Guinness, two-thirds of First Generation and three-quarters of subjects in the other four groups. In all groups dietary information was obtained from a sample of adequate size to allow meaningful comparisons to be made.

Table VII summarizes the intake of a number of dietary components of the six groups of men in this study. The major similarities noted are that fat provides approximately the same per cent of total calories (about 38%) and that a similar per cent of total calories is provided by saturated fatty acids for each of the six groups.

The chief differences between the diets of the Boston subjects and the men in Ireland are:

1. The men in Ireland eat more. As shown in table VII the Boston Brothers and the First Generation Irish consume an average of about 3000 calories daily. The caloric intake of the various groups in Ireland is between 700 to 1300 calories more per day.

2. Both the ratio of the polyunsaturated fatty acids to saturated fatty acids and the ratio of all unsaturated fatty acids (mono- and polyunsaturated fatty acids) to saturated fatty acids are slightly higher for the Boston sub-

Table VII. Mean values and standard deviation of certain dietary components of groups of subjects in Boston-Ireland heart study

	First Generation		Boston Brothers		Irish Brothers		Guinness		Transport		Rural	
Nutrient	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Calories	2984	880	3075	771	3768	1132	3936	863	4155	1200	4390	1151
Protein (g)	122	39	128	36	131	40	132	26	136	35	148	38
% animal	78	6	79	6	64	10	67	7	64	8	64	9
% of calories	17	3	17	3	14	2	14	2	13	2	14	2
Fat (g)	131	46	135	43	159	55	157	56	180	61	184	57
% animal	75	12	84	10	90	7	87	6	82	10	84	8
% of calories	39	6	39	6	38	6	36	8	39	6	38	5
SFA[1] (g)	54	20	59	20	77	28	75	29	86	30	87	29
% of calories	16	3	17	3	18	3	17	4	18	3	18	3
PFA[2]/SFA	2.18	1.27	1.59	0.92	1.18	0.43	1.22	0.42	1.33	0.54	1.31	0.52
PFA + MFA[3]/SFA	11.94	2.69	10.68	2.15	8.84	1.06	9.18	1.01	9.29	1.03	9.43	0.97
MFA (g)	52	17	52	17	58	21	59	21	68	23	70	22
% of calories	15	2	15	2	14	2	13	3	14	2	14	2
PFA (g)	11.3	6.9	8.6	4.7	9.2	4.1	9.1	3.2	11.4	5.0	11.8	3.9
% of calories	3.4	1.6	2.5	1.3	2.2	1.7	2.1	0.6	2.4	0.8	2.4	0.6
Carbohydrate (g)	291	98	293	80	436	150	425	95	461	126	501	143
% of calories	38	7	38	6	46	7	44	5	45	5	45	6
Carbohydrate as starch (g)	97	36	116	41	267	123	203	79	236	95	268	112
% of calories as starch	13	4	15	5	28	9	21	7	23	6	24	7
Carbohydrate as mono- and disaccharides (g)	137	60	133	45	134	55	171	82	162	61	161	60
% of calories	18	5	17	5	15	5	17	7	16	4	15	4
Fiber (g)	4.2	2.2	3.6	1.6	6.4	2.5	5.7	1.6	6.7	1.9	6.9	2.0
Cholesterol (mg)	696	261	844	312	894	345	730	279	776	261	825	257
Calcium (mg)	1203	673	1189	520	1644	672	1504	431	1656	646	1745	621
Phosphorus (mg)	1898	677	1963	557	2602	851	2479	482	2564	732	2829	812
Magnesium (mg)	274	98	255	81	404	137	438	128	432	129	472	145
Alcohol (g)	34	36	36	37	16	22	58	52	27	24	33	31
% of calories[4]	8	7	8	7	4	4	11	7	5	4	6	5

[1] Saturated fatty acids.
[2] Polyunsaturated fatty acids.
[3] Monounsaturated fatty acids.
[4] Value includes only subjects who consumed alcohol.

jects. The per cent of total calories provided by the polyunsaturated fatty acids is also slightly higher for these two groups.

3. In Ireland a greater per cent of total calories is supplied by carbohydrate; slightly less by protein; and, with the exception of the Guinness Workers, less by alcohol. The Guinness Workers receive about 11% of their total calories from alcohol compared with 4 to 6% for the other groups in Ireland and 8% for the two Boston groups. Most of the alcohol consumed by the groups in Ireland is stout and beer while more gin and whisky is used by the Irish in Boston.

4. The diets of the men living in Ireland contain a greater proportion of the carbohydrate as complex and less as simple carbohydrates. The Guinness group had about 48% of their carbohydrate as starch, Transport Workers 51%, Rural 53% and the Irish Brothers 61%. The two groups in the United States received much less of their carbohydrate as starch with the Boston Brothers having 40% and the First Generation the lowest per cent, 33.

5. Calcium intake is greater by about 50% in the diets of the men living in Ireland, chiefly because of a greater consumption of milk. The ratio of calcium to phosphorus, however, is similar for all groups ranging from 0.60 for the Boston Brothers, Guinness and Rural groups to 0.65 for the Transport Workers.

6. The men living in Ireland have a higher magnesium intake, ranging from 404 to 472 mg per day as compared with an intake of 255 mg daily by the Boston Brothers and 274 mg daily for the First Generation Irish. This difference in magnesium intake is due mainly to a greater consumption of whole grain cereals and breads in Ireland. The greater consumption of these whole grain products is also reflected in a larger amount of fiber and starch in the diets of the men in Ireland. As shown in table VII, the intake of both fiber and starch by the groups in Ireland is about double that of the Boston groups.

7. The men in Ireland drink more tea and less coffee than the Boston subjects (table VIII). An average of 40 to 45 cups of tea and only 1½ to 3 cups of coffee are consumed weekly by the men in Ireland. The Boston Brothers drink an average of about 15 to 16 cups of tea and a similar amount of coffee each week. The First Generation group have the highest coffee consumption of all groups (24 cups per week) and the lowest tea consumption (about 9 cups per week).

Selected physical findings are summarized in table IX. A number of other anthropometric measurements are reported later in the paper.

Table VIII. Consumption of tea and coffee

	Coffee cups/week		Tea cups/week	
	Mean	S.D.	Mean	S.D.
First Generation	24.0	18.1	9.3	13.4
Boston Brothers	15.6	12.3	15.7	12.5
Irish Brothers	1.4	4.2	43.5	14.5
Guinness	3.1	6.8	40.5	14.6
Transport	1.8	3.9	43.3	15.3
Rural	1.6	2.9	45.3	16.6

In looking at the parameters in table IX, the mean age of the groups as mentioned earlier should be considered. The Irish and Boston brothers' groups are older with a mean age of about 50 years, which is 5 to 10 years higher than for the other four groups and as is reported later in this paper, the First Generation Irish are about one inch taller, on the average, than the older groups.

The Boston Brothers, First Generation, and Guinness Workers were found to have similar mean weights (172, 176 and 174 pounds respectively) and to be from 10 to 20 pounds heavier than the other three groups. The Irish Brothers' mean weight is 162 pounds; Transport Workers and the Rural groups average 159 and 156 pounds respectively. These weight differences are reflected in the relative weights of the groups with the Boston Brothers, First Generation, and the Guinness groups having a relative weight of 107 to 108 and the other three groups being very close to their desirable weight with relative weights between 99 and 101. The ponderal index also points up the fact that the Boston Brothers, First Generation and Guinness groups are heavier in relation to their height than the other three groups of men.

The triceps skinfold measurement, considered the best single predictive parameter in estimating obesity, shows some interesting differences between groups. As expected from their lower mean actual weight, relative weight, and ponderal index, the Irish Brothers, Transport and Rural groups all have mean triceps measurements (7.3, 7.7 and 7.1 mm respectively) less than the Boston Brothers (9.8 mm), the First Generation (13.1 mm) and the Guinness group (8.0 mm).

In comparing the First Generation and Guinness Workers, the mean actual weights (176 pounds and 174 pounds respectively), mean relative weights (107 vs. 108), and mean ponderal indices (12.56 vs. 12.53) are similar.

Table IX. Mean values and standard deviation of certain physical parameters by age of subjects in Boston-Ireland heart study

		in Boston				in Ireland							
		First Generation		Boston Brothers		Irish Brothers		Guinness		Transport		Rural	
	Age	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Blood pressure systolic (mm Hg)	20–39	129	14	129	17	129	14	130	14	137	10	135	12
	40–49	132	20	132	19	130	16	135	16	142	23	139	17
	50–59	140	22	140	21	136	18	141	24	146	18	150	24
	60+	146	28	147	23	145	24	—	—	154	30	158	32
	Average	135	21	137	21	135	19	133	16	141	19	141	19
Blood pressure diastolic (mm Hg)	20–39	83	10	82	13	82	9	84	10	80	8	82	9
	40–49	85	13	84	13	82	10	86	10	86	12	86	10
	50–59	88	13	88	12	83	11	87	10	88	11	88	11
	60+	87	13	87	13	85	12	—	—	90	16	92	14
	Average	85	12	86	13	83	11	85	10	84	11	86	10
Serum cholesterol mg/100 ml	20–39	206	41	210	39	199	37	227	42	208	36	246	48
	40–49	217	39	218	39	219	40	243	41	209	41	243	48
	50–59	220	45	225	39	214	47	217	42	219	44	242	42
	60+	221	41	220	38	216	47	—	—	221	35	247	61
	Average	215	42	219	39	213	44	232	43	211	39	244	43

But, a marked difference in mean triceps skinfold measurements was observed (13.1 mm for the First Generation vs. 8.0 mm for Guinness Workers) which indicates a greater incidence of obesity in the First Generation Irish.

Cigarette smoking was investigated. The mean number of cigarettes smoked per day was higher in the two groups of men in Boston than in the four groups in Ireland. The differences were, however, not large. The heaviest smokers were the Boston Brothers. Oddly, the Guinness Workers, who as a group had the highest consumption of alcohol, smoked the least number of cigarettes.

Table IX shows the systolic and diastolic blood pressure readings by age in the various groups. Table X shows the number and per cent of men in various groups at different ages in each of three categories relative to blood pressure, i.e., normal, borderline and hypertensive. In this table the rural groups (Irish Brothers and Rural) were combined to compare against the urban groups (Transport and Guinness). No important differences were observed between groups.

Table XI shows the results of the readings of the 12 lead electrocardiogram. It is important to remember that the mean age of the two brother samples was very close at about 50.5 years, and the mean age of the other four groups was almost six years younger. ECG abnormalities can be expected to increase with age. Comparing the Irish and the Boston Brothers there were 575 ECG's read in each group, yet evidence of coronary disease was twice as common, left ventricular hypertrophy six times as common, and all other abnormalities twice as common in the Boston as compared with the Irish Brothers. In the same way the First Generation men, who have lived their whole life in the United States and who are a younger group than the Brothers, show many more abnormal ECG findings than do equivalent rural or urban subjects living in Ireland.

E. Anthropometric characteristics of the subjects

In the present study, the anthropometric data include four measurements (height, weight, triceps and subscapular skinfolds), and two derived indices (relative weight and ponderal index). These data are available on six Irish or Irish-American groups, two from the United States, the First Generation and Boston Brothers, and four from Ireland, the Irish Brothers, the Guinness, Transport and Rural groups (see table I).

Table X. Blood pressure. Number and percentages of subjects in three blood pressure categories by age and group

	First Generation							Boston Brothers							Rural (Irish Brothers and Rural)							Urban (Transport and Guinness)						
BP	N[1]		B[2]		H[3]			N[1]		B[2]		H[3]			N[1]		B[2]		H[3]			N[1]		B[2]		H[3]		
Age	No.	%	No.	%	No.	%	T	No.	%	No.	%	No.	%	T	No.	%	No.	%	No.	%	T	No.	%	No.	%	No.	%	T
20–29															15	70	5	20	2	9	22	10	53	9	47	0	0	19
30–39	77	66	24	21	16	14	117	72	63	21	18	22	19	115	74	59	37	30	14	11	125	71	55	40	31	19	15	130
40–49	67	55	33	27	21	17	121	71	63	22	20	19	17	112	130	57	66	29	34	15	230	52	49	27	25	27	25	106
50–59	44	42	26	25	34	33	104	92	61	75	50	76	50	243	99	50	66	33	34	17	199	18	39	12	26	16	35	46
60+	14	41	6	18	14	41	34	34	31	34	31	41	38	109	59	39	38	25	54	36	151	3	27	2	18	6	55	11
Totals	202	54	89	24	85	22	376	269	47	152	26	158	27	579	377	52	212	29	138	19	727	154	49	90	29	68	22	312

[1] Normal 139/89 or lower.
[2] Borderline 140–159/90–94.
[3] Hypertensive 160+/95+.

Table XI. Numbers and percentages of ECG findings in each group

	in Boston				in Ireland							
	First Generation		Boston Brothers		Irish Brothers		Guinness		Transport		Rural	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Normal	259	79.6	356	61.8	501	87.2	91	90	138	91	141	92.7
Probably and presumably normal	51	13.7	71	12.4	11	1.9	1	1	0	0	0	0
Coronary disease[1]	9	2.4	23	4.0	12	2.1	2	2	1	1	0	0
Left ventricular hypertrophy[1]	8	2.2	36	6.3	6	1.0	1	1	0	0	1	0.7
All other abnormalities[1]	45	12.1	89	15.5	45	7.8	7	6	12	8	10	6.6
Total	372	100	575	100	575	100	102	100	151	100	152	100

[1] Coronary disease was defined on electrocardiogram by the presence of a classic abnormal Q wave pattern of previous infarction of the myocardium. Left ventricular hypertrophy was interpreted generally on the application of the voltage criterion of SOKOLOW and LYON [Amer. Heart J. *37:* 161, 1949], realizing that exceptions to this criterion are possible particularly in the younger age groups. In addition to voltage changes, characteristic ST-T wave forms for hypertrophy were included in the diagnosis. All other abnormalities were grouped together to include non-diagnostic ST and T wave change and left bundle branch block of the complete or incomplete variety.

The groups in the present study should, first of all, be briefly compared with similar national populations in order to obtain some idea of where they fall in the existing range of general body size. The average stature of a nationwide probability sample of adult males measured in the United States in 1960–62 was 68.2 inches [22]. In the present study the American-born First Generation group is 0.7 inch taller than this standard (see table XII), a fairly marked difference, while the Ireland-born, Boston-living Brothers are 0.3 inch shorter. In Ireland, an extensive anthropometric survey made in the 1930's showed a mean stature of 67.7 inches [23]. As compared with this older Irish standard, the Irish Brothers from the present study are 0.3 inch taller, Guinness Workers 0.8 inch taller, Transport Workers 0.2 inch taller and the Rural group 0.2 inch shorter. If the continuing, apparently worldwide tendency towards an increase in stature is taken into account, the statures of the Irish groups in the present study would seem to be fairly representative of the Irish population today.

With regard to weight, both groups in the present study who live in the United States are heavier than the general U.S. population, the First Generation group by 10 pounds and the Boston Brothers by 6 pounds. The present Irish groups, when compared with the Irish measured in the 1930's, are with one exception heavier, as would be expected since they are generally taller, the Guinness Workers by 17 pounds, the Irish Brothers by 5 pounds, and the Transport Workers by 2 pounds. The Irish Rural group is lighter by 1 pound than the mean of 157 pounds found in this earlier survey. With the exception of the Guinness Workers, who are apparently somewhat atypical, the groups in this study appear to be reasonably representative of the present Irish population in regard to weight.

Since body dimensions vary with age, sometimes rather considerably, it is important to note that the age composition of the six groups in the present study differs somewhat. The youngest group is the Irish Guinness Workers with an average age of 40.2 years, while the oldest group is the Irish Brothers living in Ireland with an average age of 50.7 years. This 10-year difference in mean ages will have some effect on intergroup comparisons. On the basis of the general U.S. population, differences in height between populations with mean ages of 40 and 50 years would be expected to be about 0.3 inch, the older group being the shorter, but virtually no difference should be found in weight. The large series of males measured in Ireland in the 1930's showed a stature decline, also in cross sectional data, of about 0.4 inch from 40 to 50 years, but again almost no weight change. Differences in skinfold measurements as a result of age changes between 40 and 50 years are small,

Table XII. Mean values and standard deviation of certain physical parameters and relative caloric intake by age of subjects in Boston-Ireland heart study

		in Boston				in Ireland							
		First Generation		Boston Brothers		Irish Brothers		Guinness		Transport		Rural	
	Age	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Height (inches)	20–39	69.3	2.6	68.7	2.3	68.0	2.7	69.1	2.0	68.4	2.5	67.5	2.8
	40–49	69.1	2.1	68.0	2.0	68.3	2.2	68.0	2.1	68.0	2.1	67.6	2.4
	50–59	68.6	2.7	68.0	2.3	67.8	2.4	67.1	2.1	66.6	2.4	66.9	2.7
	60+	67.6	2.3	67.1	2.4	67.9	2.4	—	—	68.3	3.0	68.8	2.1
	Total	68.9	2.5	67.9	2.3	68.0	2.4	68.5	2.2	67.9	2.5	67.5	2.6
Weight (lbs)	20–39	175	25	174	21	165	26	176	24	161	23	157	23
	40–49	180	28	173	23	166	22	173	21	161	24	157	27
	50–59	176	26	173	22	161	26	162	28	152	22	150	22
	60+	162	21	167	26	159	28	—	—	160	22	168	24
	Total	176	26	172	23	162	26	174	24	159	23	156	25
Relative weight	20–39	108	15	109	13	107	17	110	13	104	13	102	15
	40–49	109	15	108	12	102	13	108	12	100	13	98	14
	50–59	105	13	106	12	98	14	102	15	97	11	95	10
	60+	99	12	104	15	97	22	—	—	96	10	99	11
	Total	107	15	107	13	101	17	108	13	101	13	99	14
Ponderal index (ht/wt)	20–39	12.65	.58	12.55	.52	12.60	.67	12.57	.54	12.83	.56	12.79	.66
	40–49	12.49	.60	12.45	.47	12.67	.55	12.43	.46	12.77	.57	12.82	.61
	50–59	12.50	.57	12.44	.48	12.74	.61	12.57	.67	12.72	.50	12.82	.42
	60+	12.64	.58	12.45	.65	12.84	.61	—	—	12.81	.48	12.72	.50
	Total	12.56	.59	12.47	.52	12.73	.61	12.53	.52	12.80	.54	12.80	.57
Triceps skinfolds (mm)	20–39	14.2	9.2	10.0	4.2	7.5	3.5	7.7	2.5	7.4	2.2	7.7	2.0
	40–49	13.9	6.5	9.7	3.9	7.2	3.3	8.4	2.9	7.6	3.5	6.9	2.3
	50–59	12.3	5.8	9.8	4.1	7.2	6.0	7.9	3.4	6.8	1.2	6.7	2.2
	60+	11.9	6.6	9.5	4.3	7.7	5.7	—	—	7.9	2.4	5.8	1.5
	Total	13.1	7.0	9.8	4.1	7.3	4.6	8.0	2.5	7.4	3.7	7.1	2.5
Subscapular and triceps (mm)	20–39	3.3	1.2	2.6	1.0	2.1	1.0	2.4	1.0	2.1	1.0	2.2	1.0
	40–49	3.6	1.3	2.5	1.0	2.0	1.0	2.7	1.0	2.3	1.0	2.0	1.0
	50–59	3.2	1.3	2.6	1.0	2.0	1.0	2.3	1.1	2.1	1.0	2.1	1.0
	60+	3.0	1.4	2.7	1.0	2.0	1.0	—	—	2.4	1.0	2.6	1.0
	Total	3.3	1.3	2.6	1.0	2.0	1.0	2.5	1.0	2.2	1.0	2.1	1.0
Relative caloric intake[1]	20–39	78	52	96	44	134	66	114	40	175	78	172	75
	40–49	70	44	91	55	142	66	142	71	135	63	177	74
	50–59	71	55	82	44	152	79	—	—	144	65	181	76
	60+	71	54	90	52	116	62	—	—	136	71	173	105
	Total	72	51	87	48	138	71	123	52	154	73	176	76

[1] Relative caloric intake = $\frac{\text{Total daily calories} - \text{basal metabolic calories}}{\text{Basal metabolic calories}}$

probably of the order of 1 to 2 mm at most, with the older being the smaller.

However, mean age differences between most of the six groups are less than 10 years. Two of the primary groups, for example, show quite similar mean ages, the Irish Brothers with 50.7 years and the Boston Brothers with 50.3 years. Again, where comparisons are made between the same age subgroups of two different groups, e.g., 40–49 years, the effect of age difference in the distributions will be slight. For the most part, therefore, age differences should not contribute substantially to differences in the values of the anthropometric variables from group to group.

All measurements were taken according to standard anthropometric techniques as follows:

1. Height: except under field conditions when the subjects were measured standing against a flat, upright surface with a standard tape measure, all subjects were measured with an anthropometer with subject standing free and erect, looking straight ahead, shoes removed, feet flat on the floor. The maximum vertical dimension to the highest point on the top of the head, firm pressure with the horizontal bar of the anthropometer to compress the hair.

2. Weight: taken with a standard balance-scale to the nearest pound, subject wearing light indoor clothing without shoes.

3. Triceps skinfold: taken at the back of the right arm over the triceps muscle, midway between the most lateral point on the acromion process of the scapula and the tip of the elbow when at right angles using a Lange Caliper.

4. Subscapular skinfold: taken over the inferior angle of the right scapula using a Lange Caliper.

5. Subscapular and triceps: the sum of the two skinfolds as measured above.

The two indices were calculated as follows:

1. Relative weight: weight as measured, expressed as a percentage of standard weights for age, sex and height determined from the Medico-Actuarial Investigation of the Metropolitan Life Insurance Company [24].

2. Ponderal index: height, in inches, divided by the cube root of weight, in pounds.

Means and standard deviations for those six anthropometric variables on the six groups are given in table XII. The data for each of the groups are further subdivided by age as follows: 20–39, 40–49, 50–59 and 60 years and over.

The tallest of any of the groups measured was the First Generation, the only one born in the United States. All others, including all of the Boston Brothers, were born in Ireland. The taller stature of this American-born group might have been expected in view of the often observed increase in body size of descendents of immigrants to this country [25–27]. In the present context it is interesting to note that improved nutrition following immigration has usually been offered as one of the major reasons for this increase in gross body size. In the present study the Boston Brothers and the Irish Brothers have virtually identical statures, 67.9 and 68.0 inches, respectively. Since all of the Boston Brothers were born in Ireland, and most came to this country after the age of 20, they would have achieved their full linear growth before immigration, hence the stature increase observed in the First Generation group would not be expected in the Boston Brothers, and, in fact, it is not found. They are almost an inch shorter than those born in this country of Irish descent. On the other hand, the virtual identity in stature between the two groups of brothers would be expected in view of the common genetic ancestry of each pair of brothers, most of whom achieved full growth under similar environmental conditions in Ireland.

The next tallest group is the Guinness Workers in Ireland who have a mean stature of 68.5 inches; they are an urban group and the youngest in the study. The Transport Workers, also urban, are 67.9 inches, the same as the Boston Brothers. The shortest of the six groups is the Rural one at 67.5 inches. The overall stature range for the six groups is from 68.9 (First Generation, U.S.) to 67.5 inches (Rural, Ireland).

The American-born, First Generation group has the highest mean weight. In addition to being the tallest, they are also the heaviest of any of the six groups measured, though at 176 pounds they are only two pounds heavier than the Irish Guinness Workers, the next heaviest. The Boston and Irish Brothers, though virtually identical in stature, differ by 10 pounds in weight, with the U.S. group the heavier of the two at 172 pounds. The Irish Brothers at 162 pounds are heavier than their countrymen, the Transport Workers, 159 pounds, and the Rural group, 156 pounds. The latter are the lightest as well as the shortest of any of the groups measured.

When comparing all six groups the progression from heaviest to lightest follows generally the same pattern as stature. Those who are tallest tend also to be the heaviest, and vice versa. The single exception is the above noted fairly marked difference between the Boston and the Irish Brothers. Though the latter are (insignificantly) taller, the former are markedly heavier.

In relative weight, the highest value, 108, is found among the Irish Guinness Workers, with the two American groups, the First Generation and the Boston Brothers, having a similar mean value of 107. As in the case of weight, the Irish Brothers differ significantly from their American kin with a lower mean relative weight of 101, the same as that for the Irish Transport Workers. The group with the lowest value, 99, is again the Irish Rurals. Within each group there is a generally consistent drop in relative weight with advancing age for each of the age subgroups. The only exceptions are for the First Generation group where there is a very small increase from 20–39 to 40–49, and the Rural group where an increase at age 60 and above is based on only eight subjects.

In considering the ponderal index, it must be remembered that high values in this index tend to be associated with ectomorphy, or relative absence of weight for height, while low values are associated with endomorphy and/or mesomorphy, or a relatively larger body bulk with reference to stature, whether due primarily to fat in the case of endomorphy, or muscle and bone in the case of mesomorphy. The ponderal index does not effectively distinguish between these two components, except at very low values where extreme endomorphy is indicated. This index has been related to differences in mortality by SELTZER [28], but he found no appreciable differences until values of about 12.3 or lower were reached, and not until values of 11.6 or lower were attained, i.e., the frankly obese, was there any significant rise in mortality.

The Boston Brothers have the lowest ponderal index, 12.47, though only slightly lower than that of the Irish Guinness Workers at 12.53, and the U.S. First Generation group at 12.56. The Irish Brothers have a mean ponderal index 12.73, or 0.26 units above their American relations. The two groups with the highest values, i.e. those most linear in body build, are the Irish Transport Workers and Rural group, both with a mean of 12.80. Intragroup age changes in this index show no uniformity or pattern whatever.

The triceps skinfold is the one measurement or index that shows a clear cut division between the two U.S.-living groups and the four Ireland-living groups. The First Generation group has by far the largest mean value for this measurement, 13.1 mm; the next largest value, 9.8 mm, is displayed by the Boston Brothers. The First Generation group, in fact, has a mean value fully 5.1 mm larger than any of the four groups presently living in Ireland, none of whom have values exceeding 8 mm. These values are, in descending order, Guinness, 8.0, Transport, 7.4, Irish Brothers, 7.3, and Rural, 7.1. There are no very consistent or striking age changes in body fat

as measured by triceps skinfold within or between any of the groups with the exception of the First Generation, U.S.-born group where there is a consistent and substantial decline with age. Even at their lowest values in the 60 and above age group, however, these Irish-Americans are still a full 2 mm larger than the largest subgroup of any age, in any of the other five groups.

Since the most marked between-group differences in any of the anthropometric variables in the present study appear to be those dealing with fat, it would be well to examine the significance of these differences. The First Generation group have triceps skinfolds significantly larger than the Boston Brothers, the next largest, at age groups 30–39, 40–49 and 50–59 years, all at levels of $p < 0.001$. These Boston Brothers, in turn, have significantly larger skinfolds than their Irish Brothers at these same age groups, also at levels of $p < 0.001$. The four groups presently living in Ireland were relatively homogeneous with few differences of any statistical significance; when the Irish Brothers were compared with the other three groups, no t values exceeded levels of $p < 0.2$, while most were about 0.5.

When subscapular skinfold values are added to those of the triceps for each subject a similar pattern emerges. The First Generation group is again by far the largest, with a mean value of 33.4 mm. The next largest is again the Boston Brothers at 26.0, but from here the gap to the Ireland born and living groups is slight, 25.0 mm for the Guinness Workers. The other three Irish groups are somewhat lower, 21.7 for the Transport Workers, 20.9 for the Rural group, and 20.1 for the Irish Brothers who have the lowest combined subscapular and triceps skinfold values of any of the six groups measured. Internal changes in this combined measurement with age within the groups show no clear pattern, and those that do occur are fairly small.

The most striking observation here, as in the case of the triceps skinfold (which of course comprises one part of the present values) is the substantially greater amount of body fat, at least as indicated by the measurements taken at these two sites, found on men of Irish ancestry who were born and raised in this country. Their mean value is fully 8.4 mm larger than the next 'fattest' group.

F. Body fat, caloric intake and activity

It is interesting to speculate on the relationships between body fat, as evidenced by skinfold measurements, caloric intake and activity. A common finding among obese persons is a decreased tendency for muscular activity.

Furthermore, it is generally assumed that the relationship of food intake to exercise is one of direct proportionality above the basal level corresponding to inactivity. That this concept is an oversimplification at variance with the facts has been shown by a number of investigators. This is true only within certain limits of 'normal' activity. Below these levels, levels which correspond to what can be termed 'sedentary', a further decrease in activity may not be followed by a decreased food intake but by a slight, but significant increase [29]. Furthermore, several researches [30–32] have reported that obese individuals do not necessarily eat more than nonobese persons (in fact may eat less), but a striking difference in activity has been observed.

Earlier in this paper it was noted that the two groups of men living in the United States ate the least, their intakes ranging from 700 to 1400 calories less than the groups living in Ireland. In spite of the lower intake, however, these two groups were the 'fattest' as indicated by skinfold measurements. The lower intakes would be expected since both the observations of the investigators and a crude assessment of activity levels of the subjects indicated that the least active of the groups were the two American-Irish groups with the First Generation being the least active.

Since our assessment of activity was limited, an indirect method for approximating the calorie expenditure of physical activity in relation to basal metabolic needs was devised. Basal metabolic calories were determined using the formula of HARRIS and BENEDICT [33], $H = 66.473 + 13.752\,W + 5.003\,S - 6.755\,A.$, where H equals total heat production in 24 h, W equals weight in kg, S = height in cm and A = age in years. Using the daily total caloric intake (estimated from a research dietary history) and the basal metabolic calories, an index was derived, Relative Calorie Intake (RCI), using the following formula:

$$\text{RCI} = \frac{\text{Total daily calories} - \text{Basal metabolic calories}}{\text{Basal metabolic calories.}}$$

The RCI for the six groups by age are shown in table XII. The First Generation had the lowest RCI, 72, and the Boston Brothers' RCI was next lowest, 87. All groups in Ireland had higher RCI's, 123, 138, 154, and 176, for Guinness, Irish Brothers, Transport and Rural respectively.

The First Generation group, the tallest, the heaviest, and the 'fattest' had significantly lower RCI's than the Irish Brothers, Transport Workers, Guinness Workers, or the Rural group, usually at levels of $p < 0.001$. They also have lower values than their countrymen, the Boston Brothers, at $p < 0.25$ for 20–39 years and $p < 0.01$ at 40–49 years. Differences between

the Irish Brothers and the other three Ireland-dwelling groups showed no significant differences except for the Rurals who had significantly higher RCI's ($p < 0.005$) for the two youngest age groups, 20–39 and 40–49 years, perhaps not surprising in view of their environment and occupation. The Boston Brothers, though fatter than their Irish kin as measured by the triceps skinfold, had much lower RCI's ($p < 0.001$) throughout the age ranges. Thus, in the present study it would appear that increases in body fat are not necessarily related to higher relative calorie intakes. There is, in fact, an inverse relationship between these two variables for these groups. .

Table XIII. Number and percentage of subjects by age by triceps skinfold measurements and relative caloric intake (RCI)[1]

	Thin (triceps skinfold 7 mm or less)		Medium (triceps skinfold 8–16 mm)		Obese (triceps skinfold 17 mm +)	
	No.	%	No.	%	No.	%
Age 20–39						
RCI						
<100	49	33	83	49	15	60
100–149	44	29	56	33	5	20
150+	56	38	31	18	5	20
Total	149	100	170	100	25	100
	$X^2 = 19.124$ $p < .001$					
Age 40–49						
RCI						
<100	38	23	93	53	18	86
100–149	51	30	46	26	3	14
150+	80	47	37	21	0	0
Total	169	100	176	100	21	100
	$X^2 = 57.14$ $p < .001$					
Age 50–59						
RCI						
<100	74	38	133	60	20	87
100–149	47	24	53	24	2	9
150+	74	38	35	16	1	4
Total	195	100	221	100	23	100
	$X^2 = 41.88$ $p < .001$					

[1] $\text{RCI} = \dfrac{\text{Total daily calories} - \text{Basal metabolic calories}}{\text{Basal metabolic calories}}$

This inverse relationship between body fat and calorie intake was also evident when the subjects from all six groups were combined by age levels. Table XIII shows the number and percentage of subjects by age who were 'thin', 'medium', or 'obese' as determined by triceps skinfold measurements in relation to their relative caloric intake. The inverse relationship between caloric intake and body fat is clearly evident. Chi square was highly significant ($p < 0.001$) in each of three age levels, 20–39, 40–49, and 50–59. The same trend was noted in the 60+ age range, but the number of subjects in some cells was too small to determine chi square. Thus, it is evident that obese individuals overeat in a relative sense in that their energy expenditure is below their intake.

G. Pathological findings in aorta and coronaries

1. Autopsies of subjects in Boston, Dublin and Galway

The main part of the Ireland-Boston heart study consisted of the investigation of epidemiological and other factors related to arteriosclerotic heart disease in six groups of subjects. A pathology study was conducted in order to supplement these findings and the comparative mortality statistics which had been gathered. This was designed to ascertain the relative amounts of arterial atherosclerosis in persons dying in Ireland and in Irish subjects dying in Boston.

It was clear that even 1994 middle aged men would not have a high enough mortality rate during the period of the study to yield sufficient autopsy material for a comparative study of this kind. It was also realised that collection of specimens from study subjects who did die, would present an almost impossible problem. Instead, then, random routine autopsies in two Irish cities and in persons of Irish origin dying in Boston were used for this part of the investigation.

A comparison was made of the extent and type of atheromatous involvement of the aorta and of one branch of the coronary vessels. These were taken from subjects, of both sexes and at any age, coming to autopsy in Boston, Dublin and Galway. The results that follow are taken therefore from examination of the arteries of random subjects and not of those who were examined during life as participants in the Ireland-Boston Heart Study.

The anterior descending ramus of the left coronary artery and the aorta were obtained from unselected routine autopsies in Dublin and Galway. Similar specimens were collected in Boston from autopsies on subjects who themselves, or whose parents, had been born in Ireland. For a previous

comparative study specimens had been collected from mixed Boston subjects. In all cases the coronary artery and the aorta were opened longitudinally, flattened, fixed in 10% formalin and preserved in transparent plastic bags for review at a later date.

Atherosclerosis was assayed by the method of GORE and TEJADA [34], an objective assay method which has been used in previous comparative studies [35, 36]. Using this method the per cent of the surface of the intima involved by all types of atheromatous lesions was estimated and recorded for each vessel examined. The relative proportion of the intimal surface involved in four types of lesions, namely, lipid streaks, plaques, ulcerative and calcific lesions, was then determined and expressed as a per cent of the total intimal surface of the artery being examined.

These estimates were all made by one observer (Dr. GORE). In order to be as objective as possible the cause of death, the sex and the age of the subject were not known by the examiner at the time of examination.

2. Findings in aorta and coronaries

All the data are broken down into age groups by decade, but include both male and female subjects. In Dublin and Galway approximately two-thirds of the specimens were from males and one-third from females, whereas in Boston almost exactly half were males and half females. The Boston data are divided into two parts: those from persons of Irish origin, collected for this Boston-Ireland study, and those from mixed specimens of undetermined national origin, collected for a previous study. Total number of aortic specimens studied were Galway 250, Dublin 304, Boston Irish 403, and Boston Mixed 379.

The results of the findings in the aorta are given in table XIV. The graph in fig. 3 compares the mean extent of intimal atheromatous involvement of the aorta in the four groups of subjects. It can be seen that in every decade there is a higher percentage of the intima involved in the Boston than in the Irish subjects. A way of contrasting the extent of involvement is to note from this graph the age at which 50% of the intimal surface of the aorta is involved with atheromatous lesions. This occurs at a mean age of 46 years in the Boston Irish, 61.5 in the Dublin and 69 in the Galway subjects. Sixty per cent of the intima is involved at a mean age of 52 years in the Boston Irish, at age 72 in the Dublin and at age 80 in the Galway subjects. Thus, taking the mean aortic intimal involvement it can be seen that subjects in Ireland have the same amount of involvement 15 to 28 years later than their countrymen or descendents in Boston.

Table XIV. Percentage of intima of aorta involved in different types of atheromatous lesions

Age		20–30				30–40				40–50				50–60				60–70				70–80				80–			
		Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed
No. of subjects		17	9	1	0	12	9	1	5	30	15	1	21	46	36	7	39	79	65	23	56	43	41	23	73	10	27	21	49
Streaks	%	9	17	14	—	14	15	10	26	13	14	11	22	11	12	11	16	12	10	9	14	12	11	9	11	9	11	7	8
Plaques	%	0	5	6	—	4	5	25	14	12	19	28	22	15	26	28	36	26	30	35	31	26	35	37	33	27	33	34	35
Ulcerated	%	0	0	0	—	0	2	0	2	1	4	5	2	2	3	9	5	5	5	10	13	5	8	12	13	8	8	15	14
Calcific	%	0	0	0	—	0	0	0	2	0	1	11	3	1	1	15	5	5	9	16	12	10	8	15	18	23	12	31	22
Total	%	9	22	20	—	18	22	35	44	26	38	55	49	29	42	63	62	48	54	70	70	53	62	73	75	67	64	87	79

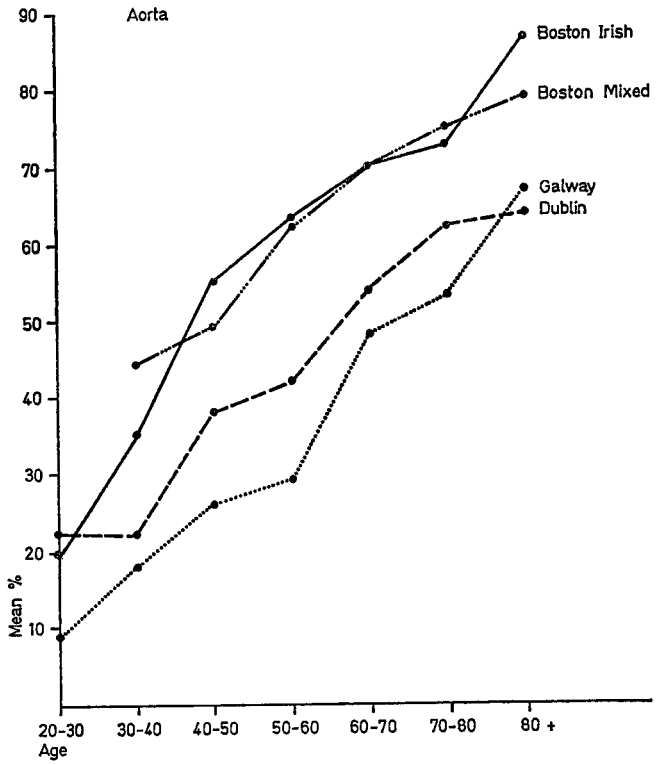

Fig. 3. Comparison of autopsies of Boston Irish, Boston Mixed, Dublin and Galway subjects.

In the histograms (fig. 4) the different types of lesion found in the aorta in the Boston Irish and Galway subjects are shown. This shows that the extent of the early lesion, the lipid streaks, is not too different in Galway and Boston, nor is there much variation with age. However, the more serious or advanced lesions, the plaques, the ulcerative and the calcific lesions, are much more extensive in the Boston Irish than in the Galwegians and in both groups they tend to increase with age. Thus, at age 50 to 60 years both the Boston Irish and Galway aortas have a mean of 11% of their intima involved with lipid streaks. At this same age, only 15% of the aorta in the Galway subjects compared with 28% of the Boston Irish subjects is involved in plaque. However, taking advanced atheromatous changes, there is over four times as much area involved in ulcerated and 12 times as much in calcified lesions in the Boston Irish as in the Galway subjects at this age. It can be

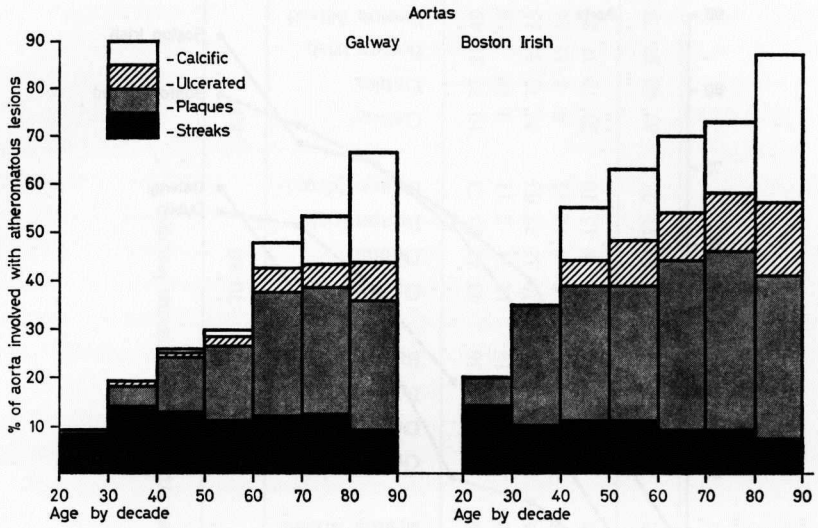

Fig. 4. Comparison of extent of involvement of aortas with four types of atherosclerotic lesions in Galway and Boston subjects.

seen from table XIV that this is also true in general for the Dublin subjects although the contrast is not quite as marked.

In the case of the coronary specimens, there were unfortunately relatively few collected in the Boston Irish group and none in the earlier decades. The number of coronary specimens studied were Galway 176, Dublin 166, Boston Irish 22, and Boston Mixed 233. The results of all the findings are shown in table XV. The same trends can be seen as in the aortas, but the differences between subjects dying in Boston and in Ireland are less marked. In the graph in fig. 5 the data from Boston Irish and Boston Mixed subjects have been pooled and compared with those from the Galway and Dublin subjects pooled in the same way. From this it can be seen that a Boston subject has a mean of 40% of his coronary involved in atheromatous lesions if he dies at age 42, and in Ireland this amount of involvement is seen only at 59 years of age. A Boston subject has 50% involvement at age 55 and an Irish subject at age 73. The coronary artery of the Bostonian therefore has the appearance of that of an Irish subject 17 or 18 years older.

3. Discussion of pathology findings

The autopsy findings confirm the mortality statistics and clearly show much more atherosclerotic involvement of the aorta and of the anterior descending

Table XV. Percentage of intima of coronary arteries involved in different types of atheromatous lesions

Age		20–30				30–40				40–50				50–60				60–70				70–80				80–			
		Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed	Galway	Dublin	Boston Irish	Boston Mixed
No. of subjects		13	8	—	—	8	8	—	5	21	10	—	22	32	35	—	34	58	37	5	57	34	40	3	67	10	28	14	48
Streaks	%	7	10	—	—	12	12	—	17	10	13	—	13	15	10	—	12	12	9	7	10	10	8	12	8	4	11	12	7
Plaques	%	3	5	—	—	9	5	—	17	6	13	—	28	12	30	—	30	31	28	45	37	36	34	44	36	36	33	44	39
Ulcerated	%	0	0	—	—	0	0	—	0	0	3	—	1	1	1	—	0	1	1	0	2	1	1	0	1	2	0	3	2
Calcific	%	0	0	—	—	0	0	—	0	0	0	—	1	1	3	—	6	3	6	5	9	3	9	14	12	18	12	11	15
Total	%	10	15	—	—	21	17	—	34	16	29	—	43	29	44	—	48	47	44	57	58	50	52	70	57	60	56	70	63

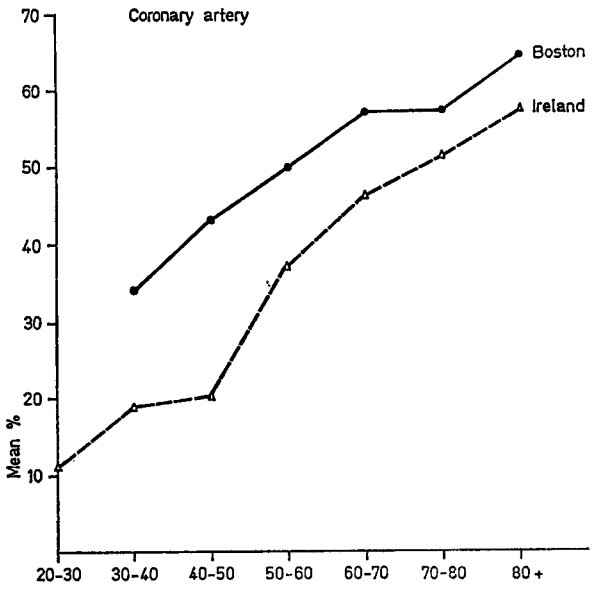

Fig. 5. Comparison of autopsies of subjects in Ireland and Boston and showing mean percentage of coronary involved with atheromatous lesions at different ages by decade. Points on graph indicate percent of arterial involvement and are a mean of subjects falling in each decade of age.

ramus of the left coronary artery at a similar age in subjects in Boston than in Ireland. Equivalent extent and types of atheroma occur at a younger age in Boston than in Ireland. The results also indicate greater arterial involvement in Dublin than in Galway, a fact which probably reflects urban-rural differences. Dublin is a much larger city and is more industrialized than Galway. It is also likely that more of the subjects who died in Galway than in Dublin had lived most of their lives in rural areas.

III. Discussion and Conclusions

In this study several interesting differences between the diets of the men in the United States and the subjects in Ireland were observed. The men in Ireland eat more total calories, yet, with the exception of the Guinness group, weigh less than the Irish in Boston. The obvious reason for these findings is that the men in Ireland are much more active. The Guinness

group, although having nearly the same actual and relative weight as the Boston groups, is clearly less obese, as is reflected in their triceps skinfold measurements.

The serum cholesterol of the six groups does not differ markedly; however, there is a trend toward higher levels of serum cholesterol in the Guinness and Rural groups. This might be expected since there is little difference in the per cent of total calories provided by fat, in the per cent of calories from saturated fatty acids, and in intake of dietary cholesterol between groups. Interestingly, the lowest intake of dietary cholesterol is in the First Generation Irish (696 mg daily) and the Guinness Workers (730 mg daily). The two Boston groups have a higher proportion of total unsaturated and polyunsaturated fatty acids than all other groups.

The slight differences in the levels of serum cholesterol in the groups in Ireland do not seem to be related to any differences in the fat or cholesterol composition of the diet.

A higher proportion of the carbohydrate in the diet in Ireland was starch, ranging from an estimated 48% (Guinness Workers) to 61% (Irish Brothers), compared with 33% (First Generation) to 40% (Boston Brothers). Previous studies have shown that the level of serum cholesterol can be altered when starch is the principal dietary carbohydrate; however, only small changes have been observed and these only when starch constituted 75 to 80% of the dietary carbohydrate [37].

A smaller proportion of the carbohydrate in the diet in Ireland was in the form of mono- and disaccharides, ranging from 31% for the Irish Brothers to 40% for the Guinness group. The Boston Brothers had 45% of the carbohydrate as simple sugars and the First Generation had the highest per cent, 47. Whether these differences in sugar consumption are of any significance is unknown.

A low magnesium diet in animals has been shown to be associated with soft tissue calcification [38–40]. The magnesium intake of the Boston Brothers (255 mg daily) and the First Generation Irish (274 mg daily) compared with the more generous magnesium intake of the Irish groups (404–472 mg) may perhaps explain in part the pathological findings already described.

The pathology findings show both more disease and more extensive disease in Irish-born Bostonians than in men in Ireland.

As was shown in table VIII, the groups in Ireland drink more tea and less coffee, both of which have been shown to correlate with the level of cholesterol and other fats in the serum. LITTLE *et al.* have shown a positive correlation between amounts of coffee consumed and levels of

serum cholesterol in patients with coronary heart disease [41]. They also found a negative correlation between tea drinking and serum cholesterol levels in subjects with coronary heart disease. PAUL *et al.* [42] have also reported a correlation between coffee drinking and the later development of coronary heart disease. In our study, the number of subjects with overt coronary heart disease is too small for evaluation of the effects of tea and coffee drinking on levels of serum cholesterol. However, although no significant differences were observed in cholesterol levels of the subjects in Ireland and Boston, as we have already mentioned, there is evidence of more coronary heart disease in the Boston groups.

Tea contains fluoride in the ionized state, at a concentrate of about 1 ppm [43, 44]. It has been shown by BERNSTEIN *et al.* [3] that residents of areas with a high level of fluoride in their water supply (4.0 to 5.8 ppm) had a lower incidence of calcification of the aorta than residents living in areas where the water contained low levels of fluoride (0.15 to 0.30 ppm). Moreover, fluoride seems to have a protective effect in animals fed a low magnesium diet [45, 46]. However, more research will have to be done before either magnesium or fluoride deficiency can with confidence be incriminated as important dietary factors in human arteriosclerosis.

With the marked differences in mortality and pathology, it is perhaps surprising to find that the dietary intake and the physical and related findings of the groups living in Ireland and in Boston do not show even greater differences than those discussed.

Perhaps of greatest significance is the fact that the Irish brother, although consuming more calories, has an average weight (and relative weight) lower than that of his Boston brother. The Irish brother is clearly more active and is burning up his calories. He is storing fewer of his calories as fat and this is corroborated by the differences in the measurements of triceps skinfold thickness now generally regarded as the most reliable, simple means of estimating body fat. Another significant difference between the brothers is the much higher rate of abnormal electrocardiographs in the Boston brothers. Therefore, besides the greater amount of magnesium and fluoride (from tea) in the diets in Ireland, greater physical activity, less obesity, a greater intake of complex carbohydrates, and a lower amount of cigarette smoking are all in favor of the Irish subject.

It must be remembered that the autopsy findings and the mortality statistics are not those of the 1994 study subjects. The relative lack of differences in the physical findings other than electrocardiographs and the marked differences in autopsy and mortality data may, in part, be explained

by the recent rapid increase in arteriosclerotic heart disease in Ireland. In the 1920's and 1930's Ireland had a predominantly rural population which had not yet been greatly influenced by the industrial revolution. Our mortality figures for the 1950's and 1960's are a reflection of life during that period in Ireland. In contrast, the middle aged men of today, who were our study subjects, have changed their way of life considerably. People have become more prosperous and even the farms have become somewhat mechanized. People are performing less hard physical work, they are smoking more cigarettes and the many factors which a generation earlier increased the risk factors in England and the United States are now beginning to affect men in Ireland. It seems likely that, had this study been carried out in 1930, marked physical differences would have been found between men in Ireland and in the United States and that if the study were repeated in 1990, assuming that present trends continue, probably no differences would be detectable. Done in the intervening period, the present study has shown marked differences in mortality and autopsy findings and much smaller differences in the physical factors related to arteriosclerotic heart disease.

We do not conclude that these data are necessarily contrary to or invalidate previous studies which strongly implicate the consumption of saturated fats and cholesterol and elevated levels of serum cholesterol as important factors in the etiology of coronary heart disease. In studies on the relationship between the composition of dietary fat and serum cholesterol HEGSTED *et al.* [47] found that the amount of fat was less important than the composition of the dietary fat. Diets which contained the same kind of fat produced similar levels of serum cholesterol whether the fat supplied 25 or 40% of the total calorie intake. Thus the higher total fat intake in Ireland is not necessarily expected to produce higher levels of serum cholesterol. The overall percentage of total calories supplied by fat and the composition of the dietary fat in Ireland and Boston is not greatly dissimilar. As in the Framingham studies [48] dietary differences by themselves are probably insufficient to demonstrate their etiologic role. In any event, the roles of the many various etiologic factors are probably interdependent and the significance of any one may depend upon a number of environmental or genetic conditions. Although it is uncertain how current dietary and environmental conditions in Ireland related to the development of atherosclerotic heart disease which has undoubtedly been influenced by events and conditions over a considerable period of years, the implications of this study are that food intake is of less importance when the subjects are active and extra calories consumed are expended in physical activity

as was the case with the Irish brothers in Ireland. In a future paper the data upon caloric intake, physical activity, body size and skinfold measurements will be discussed in more detail.

Summary

There is a higher mortality rate from arteriosclerotic heart disease in Massachusetts than in Ireland. A comparative epidemiological study of possibly related factors was made using 1994 middle aged men, including over 500 pairs of brothers, one of whom lives in Ireland and the other in Boston. The intake of calories, complex carbohydrates, magnesium and fluoride (from tea) was higher in Ireland. The proportion of calories derived from fat and saturated fat, the serum cholesterol, the blood pressure levels and the amount of cigarette smoking did not differ markedly. The weight, skinfold thickness and number of abnormal electrocardiograms were higher in the Boston subjects. A study of the pathology of coronaries and aortas from autopsies revealed much earlier serious atheromatous involvement in the Boston than in the Irish specimens. Increased physical activity appears to be important in reducing the risk of coronary heart disease in Ireland.

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Author's address: Dr. FREDRICK J. STARE, M.D., Department of Nutrition, Harvard School of Public Health, 665 Huntington Avenue, *Boston, MA 02115* (USA).