
The Minnesota Heart Survey

Donna K. Arnett*, Paul G. McGovern†, David R. Jacobs, Jr., Eyal Shahar, Sue Duval, Henry Blackburn, and Russell V. Luepker

From the Division of Epidemiology, School of Public Health, University of Minnesota, Minneapolis, MN.

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MATERIALS AND METHODS

Samples were selected by a two-stage cluster design. In the first sampling stage in 1980–1981, the seven-county metropolitan area was divided into 704 clusters, each containing 1,000 households; 40 clusters were randomly selected. Cluster information was systematically supplemented with information from city and county planners about new construction and demolition, as well as census information from 1990. In 1995–1997, four additional clusters were randomly selected from 10 clusters with high growth. The survey samples reflected the age and ethnic distribution of the seven-county metropolitan area according to census information. In 1990–1992, the survey sample was 93 percent White and 47 percent male, while the metropolitan population was 92.3 percent White and 49 percent male according to the 1990 Census.

At each survey, in the second stage of sampling, a random sample of households was selected in each cluster to generate a sample size of about 5,000 adults aged 25–74 years. Only those households with at least one age-eligible person were included. After household enumeration, age-eligible individuals were interviewed in the home. In the 1980–1981 and 1995–1997 surveys, all age-eligible individuals in the household were invited to participate, whereas a randomly selected individual was interviewed in other survey years. The questionnaire solicited information regarding sociodemographic characteristics, health attitudes, medical history (hypertension, hypercholesterolemia, diabetes), medications for these conditions, and behaviors. Subjects in a nonfasting state were then invited to a survey center where detailed questions were asked regarding medical and reproductive history (women only), smoking behavior, leisure-time physical activity in the past year, and 24-hour dietary recall. Physiologic (blood pressure), anthropomorphic (height, weight, and waist/hip ratio), and biochemical (total and high density lipoprotein cholesterol, serum thiocyanate) measurements were obtained. Overall response rates for the complete survey (home interview and survey center) were 69 percent (1980–1982), 68 percent (1985–1987), 68 percent (1990–1992), and 65 percent (1995–1997), correcting for those refusing enumeration and noncontacts. The response rate for the home interview was 91 percent in 1980–1982, 88 percent in 1985–1987, 82 percent in 1990–1992, and 83 percent in 1995–1997.

**Measurements**

Blood pressure was measured in duplicate with a standardized protocol across the four surveys in seated participants following a 5-minute rest period using a random zero sphygmomanometer, with the correct cuff size selected on the basis of arm circumference measurements. The average of the two readings was used in analysis.

The Minnesota Heart Survey measured height in stocking feet with a rigid ruler attached to a wall and a wooden triangle. Weight was measured without a coat and shoes, on a balance-beam scale. The scale was calibrated daily using a 50-pound (22 kg) weight.

Current smoking was defined as smokers’ smoking more than 100 cigarettes in their lifetime and currently smoking. Analyses were also done to estimate trends in the number of cigarettes smoked per day among smokers.

Physical activity was measured with the Minnesota Leisure Time Physical Activity Questionnaire in a 50 percent systematic sample of participants (every other participant listed on the scheduling log) (11). The Leisure Time Physical Activity Questionnaire queried participants on about 63 leisure-time activities, the number of times each activity was performed per month, and the number of month(s) the activity was performed over the prior year. As part of the home interview, we asked participants whether they regularly engaged in exercise, and those who responded “no” were classified as sedentary.

The alternate participants on the scheduling log who did not complete the Leisure Time Physical Activity Questionnaire completed a 24-hour dietary recall, administered by trained, certified interviewers. From 1980–1982 to 1990–1992, a paper version of the 24-hour dietary recall was used. Because of innovations in data entry, we collected dietary information in 1995–1997 using computerized data entry. The same food database was used for all four surveys, although new foods were added so that the energy and nutrient composition of foods was accurately quantified according to the current food supply at each survey. To assess whether the paper and computer forms of the dietary information collected were comparable, we asked 107 participants to complete both during their visit in 1995–1997. The differences in total energy and fat intake between the two methods were small (<0.3 percent and <2.5 percent, respectively).

**Laboratory measurements**

Serum total cholesterol was measured in nonfasting samples with an AutoAnalyzer II device (Technicon Corporation, Saskatoon, Saskatchewan, Canada) (a nonenzymatic method) between 1980–1982 and 1990–1992 and with an enzymatic method in 1995–1997. Between 1980–1982 and 1990–1992, laboratory drift assessment did not correctly adjust cholesterol levels. Therefore, we recalibrated by measuring 400 randomly selected samples from each of the first three surveys using the reference Abell-Kendall method (12). The Abell-Kendall method indicated that original measurements were low by 6.7 and 8.5 mg/dl in 1980–1982 and 1985–1987 (p < 0.001), respectively, and high by 4.1 mg/dl (p < 0.001) in 1990–1992, while enzymatic measurements were equivalent to the measures derived by the Abell-Kendall method in 1995–1997 (estimated bias < 0.5 mg/dl, n = 200, p > 0.25) (9). The Abell-Kendall method-adjusted cholesterol volumes were used in analysis.

High density lipoprotein cholesterol was measured using an enzymatic method after precipitation of non-high density lipoprotein cholesterol with magnesium dextran. Serum thiocyanate was measured using the method of Butts et al. (13).

**Statistical analysis**

Data were analyzed using SAS analytic software (SAS Institute, Inc., Cary, North Carolina) (14). All analyses were
sex specific. The means and frequencies of study variables were calculated. Analysis of covariance was used to test differences in age-adjusted means between 1980–1982, 1985–1987, 1990–1992, and 1995–1997. Ethnicity and educational level were initially included as covariates, but they were not significant predictors of the secular trends nor did they materially alter the estimates of the means of risk factors. Therefore, educational level and ethnicity were not included in further models. To compute unbiased variances of the sample means, we took into account the cluster design, adding the neighborhood cluster as a random effect term.

Results

Demographic characteristics
The number of participants and distribution of educational achievement and ethnicity are presented in table 1. Educational attainment and ethnic diversity increased between 1980–1982 and 1995–1997.

Trends in total and high density lipoprotein cholesterol and hypercholesterolemia
Serum total cholesterol levels declined significantly by 8.5 mg/dl in men and 7.6 mg/dl in women between 1980–1982 and 1990–1992 (table 2). Between 1990–1992 and 1995–1997, no further decline in serum cholesterol was found. There was no overall change in high density lipoprotein from 1980–1982 to 1995–1997. The prevalence of hypercholesterolemia (total cholesterol, ≥240 mg/dl, or taking lipid-lowering medications) decreased between 1980–1982 and 1990–1992 but increased between 1990–1992 and 1995–1997 in both men (p = 0.10) and women (p = 0.04). This upward trend largely reflected the increased prevalence of

| TABLE 1. Analysis of participants by survey, gender, age group, education, and ethnicity, Minnesota Heart Survey |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Age group (years)               | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   |
| 25–34                           | 630   | 34  | 863  | 31  | 705  | 25  | 967  | 31  | 910  | 29  | 973  | 31  |
| 35–44                           | 455   | 24  | 795  | 29  | 819  | 29  | 1,022| 34  | 842  | 27  |
| 45–54                           | 350   | 19  | 465  | 17  | 613  | 22  | 1,040| 37  | 842  | 27  |
| 55–64                           | 296   | 16  | 375  | 14  | 391  | 14  | 343  | 14  | 383  | 14  |
| 65–74                           | 143   | 7   | 215  | 8   | 240  | 9   | 343  | 14  | 383  | 14  |

| Education                       | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   |
| Less than high school           | 255   | 14  | 235  | 9   | 182  | 6   | 225  | 8   | 190  | 6   | 144  | 4   |
| High school                     | 480   | 26  | 656  | 24  | 682  | 25  | 1,022| 34  | 842  | 27  | 1,051| 33  |
| Some college                    | 549   | 29  | 899  | 33  | 885  | 32  | 626  | 22  | 980  | 32  | 1,069| 33  | 1,051| 33  |
| College graduate                | 586   | 31  | 921  | 34  | 1,040| 37  | 1,145| 41  | 967  | 30  | 1,134| 36  |

| Ethnicity                       | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   | No.  | %   |
| White                           | 1,788 | 96  | 2,577| 95  | 2,592| 93  | 2,551| 92  | 2,853| 94.4| 2,997| 93.4| 2,898| 91.7|
| African American                | 49    | 3   | 70   | 3   | 99   | 3.5| 95   | 3.4| 90   | 3   | 122  | 4   | 130  | 4.1|
| Other                           | 26    | 1   | 64   | 2   | 97   | 3.5| 132  | 4.6| 78   | 2.6| 91   | 2.8| 132  | 4.2|
| Total                           | 1,863 | 2   | 2,713| 2   | 2,788| 2.7| 2,778| 2.7| 2,204| 2   | 3,021| 2   | 3,210| 2   |

TABLE 2. Age-adjusted mean levels† or prevalence of serum lipid variables by sex and year, Minnesota Heart Survey

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1,863</td>
<td>2,713</td>
</tr>
</tbody>
</table>

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TABLE 3. Age-adjusted prevalence or mean levels† of selected cigarette smoking variables by sex and year, Minnesota Heart Survey

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cigarette smoking (%)</td>
<td>34.2</td>
<td>29.6***</td>
</tr>
<tr>
<td>Cigar smoking (%)</td>
<td>8.1</td>
<td>3.8***</td>
</tr>
<tr>
<td>Serum thiocyanate (mg/dl)</td>
<td>78.1</td>
<td>70.7***</td>
</tr>
<tr>
<td>No. of cigarettes per day†</td>
<td>24.9</td>
<td>23.4*</td>
</tr>
</tbody>
</table>

† Among smokers.

TABLE 4. Age-adjusted mean levels† and prevalence† of selected blood pressure variables by sex and year, Minnesota Heart Survey

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP† (mmHg)</td>
<td>125.0</td>
<td>124.5*</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>78.0</td>
<td>76.9**</td>
</tr>
<tr>
<td>Hypertensive (%)§</td>
<td>29.6</td>
<td>26.5</td>
</tr>
<tr>
<td>Hypertensive (%)¶</td>
<td>23.9</td>
<td>21.2*</td>
</tr>
<tr>
<td>Antihypertensive medication use (%)</td>
<td>12.3</td>
<td>10.3*</td>
</tr>
</tbody>
</table>

† Adjusted for room temperature and pulse rate.
‡ BP, blood pressure.
§ Hypertensive defined by BP of ≥140/90 mmHg or taking antihypertensive medications.
¶ Systolic BP of ≥140 mmHg or diastolic BP of ≥90 mmHg; percentage defined on the basis of the entire clinic sample.

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1995–1997 in men (p = 0.06) and women (p = 0.07): In 1995–1997, 4.1 percent of men and 4.6 percent of women reported diabetes compared with 2.8 percent and 3.3 percent, respectively, in 1980–1982.

**Trends in other medication use**


**DISCUSSION**

The most recent data from the Minnesota Heart Survey indicate that downward trends in risk factors in Minneapolis-St. Paul are attenuating for several important cardiovascular disease risk factors. From 1990–1992 to 1995–1997, we detected flattening of declines in population levels of total cholesterol and hypercholesterolemia and increases in sedentary lifestyle, total caloric intake (women only), and body mass index. Favorable trends during this same period were noted for some risk factors, such as the prevalence of current smoking, hypertension, treatment for hypercholesterolemia and hypertension, and the percentage of intake from dietary fat.

**Total and high density lipoprotein cholesterol, hypercholesterolemia, and lipid-lowering medication use**

Several population-based studies suggest that the population mean serum cholesterol level has decreased consistently since 1960 (5, 6, 8–10, 16–20). The National Health and Nutrition Examination Survey reported that serum cholesterol decreased from 1960–1962 to 1988–1991 (20). Results from other studies are consistent with previously published reports from the Minnesota Heart Survey, which demonstrated sizeable and consistent declines in serum cholesterol from 1980 to 1992 (8, 18). Our recent data suggest no further reduction in the population level of serum cholesterol. To our knowledge, this is the first study to report attenuation of temporal declines in population levels of serum cholesterol. Previous reports from the Minnesota Heart Survey demonstrated that changes in cardiovascular risk preceded patterns observed nationally (5, 9); if this observation holds true for cholesterol, it could signify an increase in cholesterol in the US population as a whole in the future.

The Minnesota Heart Survey showed consistent reductions in hypercholesterolemia (defined as total cholesterol of ≥240 mg/dl or current use of lipid-lowering medication) prevalence between 1980–1982 and 1990–1992. Minnesota Heart Survey prevalence estimates during this period were nearly identical to the 20 percent prevalence reported by the Third National Health and Nutrition Examination Survey in 1991 but lower than those observed in the Atherosclerosis Risk in Communities Study (from 30 percent in 1986 to 25.3 percent in 1989) (16). In the Minnesota Heart Survey, hypercholesterolemia prevalence increased (p > 0.10) between 1990–1992 and 1995–1997. Although the increase may be due to an increased serum cholesterol level in the population, a portion may result from greater utilization of lipid-lowering medication, the latter of which contributes to the hypercholesterolemia definitions. Moreover, there is a decreasing threshold for placing persons on such drugs, which may reflect changing prescribing patterns rather than real changes in hypercholesterolemia. Nonetheless, when medication use was removed from the definition, the prevalence trend was flat between 1990–1992 and 1995–1997, suggesting true attenuation of the decline in hypercholesterolemia in the population.
Diet, physical activity, and body mass index

Lipid-lowering medication use more than doubled in men and increased in women between 1990–1992 and 1995–1997. This trend is comparable with the pattern described in US retail pharmacies: The number of lipid-lowering medications dispensed nearly doubled, from 22.5 million in 1991 to 39.9 million in 1997 (21).

Smoking

The Minnesota Heart Survey showed substantial declines in smoking prevalence between 1980–1982 and 1995–1997. Downward smoking trends in the Minnesota Heart Survey are reflective of the US decline in smoking during the 1980s and 1990s, although the prevalence is lower in Minneapolis-St. Paul (21–24). The number of cigarettes smoked by smokers also decreased to fewer than a pack a day in 1995–1997, comparable with national trends where the number of cigarettes smoked per day decreased from 19 in 1987 to 15 in 1996 in women (24). These reductions were supported by a decline in serum thiocyanate, a biochemical marker of cigarette consumption (25). Despite this improvement in smoking prevalence and smoking behavior in adults aged 25–74 years, there is concern that the declining trend will not continue. Smoking initiation and prevalence increased among high school students by about 50 percent between 1988 and 1996 and by about 30 percent among college students between 1993 and 1997 (26, 27). Cigar smoking was promoted heavily in recent years, and the Minnesota Heart Survey noted an increasing trend in cigar smoking. This trend mimics the trend observed in California: Daily or occasional cigar smoking doubled in California between 1990 and 1996, from 2.5 percent to 4.9 percent, an area for future concern if the trend continues (28).

Hypertension

The Minnesota Heart Survey noted improvements in blood pressure levels and hypertension prevalence. Limited data are available from national samples during the 1990s. Results from the first half of the Third National Health and Nutrition Examination Survey (1988 and 1991) indicate significant reductions in systolic and diastolic blood pressure levels and hypertension prevalence compared with those from the Second National Health and Nutrition Examination Survey (1976 and 1980), although hypertension prevalence (defined by systolic and/or diastolic blood pressure of ≥140/90 and/or use of antihypertension medication) in the Third National Health and Nutrition Examination Survey was slightly lower than in St. Paul-Minneapolis in 1990–1992 (29). Even greater reductions in hypertension prevalence in the Minnesota Heart Survey were observed when medication use was ignored in the definition. Lower treatment levels in the community suggest that blood pressure itself is declining in Minneapolis-St. Paul despite the observed increasing trends in obesity, physical inactivity, and alcohol intake.

Diet, physical activity, and body mass index

The Minnesota Heart Survey found substantial downward trends in the percentage of calories from fat, the polyunsaturated/saturated fat ratio, and the Keys score, while total caloric intake remained constant in men but rose slightly in women (p < 0.05). Declining trends in dietary fat consumption are consistent with ecologic trends in consumption of low-fat foods (e.g., fruits and vegetables and low-fat dairy products), indicating success of the public health campaign to reduce fat. However, recent reports from national surveys suggest an increase in caloric intake (30, 31). That dietary fat intake decreased during the same period while serum cholesterol remained constant or increased is interesting. The Keys score, which predicts the change in serum cholesterol based on the dietary intake of cholesterol and saturated fat, changed by 8 mg/dl in men and 7 mg/dl in women through 1990–1992 compared with the total cholesterol change of 9 mg/dl and 7 mg/dl, respectively. Although the Keys score continued to decline through 1995–1997, serum cholesterol increased in men and did not change in women. Because weight is an important determinant of cholesterol, the rapid increase in body mass index in the Minneapolis-St. Paul population might have offset the expected reduction in serum cholesterol predicted by the Keys score. Alternatively, other changes in dietary composition besides type and amount of fat may have contributed to the trend in serum cholesterol.

During the past two decades there have been few gains in leisure-time physical activity in the United States despite the widespread recognition of the positive association between regular physical activity and health (32). In 1996, 29 percent of adults reported no regular physical activity outside work (32). Although the Minnesota Heart Survey noted significant increases in physical activity in the 1980s, no further increases were observed in the 1990s, and our data suggest that physical activity declined between 1990–1992 and 1995–1997. Population strategies to encourage more leisure-time physical activity are needed.

Body mass index reflects the balance of dietary intake and energy expenditure. The prevalence of obesity (body mass index of >30 kg/m²) increased rapidly in the United States between 1991 and 1998 (33). The Minnesota Heart Survey mirrored this national trend: Body mass index increased substantially in a relatively short period (1980–1982 through 1995–1997). Increased body mass index strongly influences other risk factors, such as diabetes, hypertension, and hypercholesterolemia. The rapid body mass index change implicates secular trends in the social environment that create energy imbalance since the trends in self-reported caloric intake and the Leisure Time Physical Activity Questionnaire do not fully explain the trend. In the United States, nonleisure physical activity decreased (e.g., energy expenditure for work, transportation, and home maintenance) while portion sizes increased. These data suggest an urgent need for effective population strategies for weight maintenance and weight reduction.

The Minnesota Heart Survey has several limitations. We collected a single measure of cholesterol. We assessed blood pressure on one occasion, although readings were taken in duplicate and averaged to reduce measurement error. Cigarette smoking information is based on self-report; however, the levels of thiocyanate, the biochemical marker of tobacco consumption, support the observed reductions in cigarette smoking prevalence and consumption. Dietary intake is estimated from one 24-hour recall using the same set of food...
models for each survey. Participants may not accurately report their intakes or may report only those intakes considered socially acceptable.

In summary, the Minnesota Heart Survey found favorable trends in blood pressure, hypertension, smoking, dietary fat consumption, and use of antihypertensive and cholesterol-lowering drugs in Minneapolis-St. Paul from 1980–1982 and 1995–1997. However, these favorable trends were counterbalanced by less favorable trends in serum cholesterol, hypercholesterolemia, obesity, and physical inactivity. These findings suggest that the population burden of cardiovascular disease may increase in the near future. Programs or strategies targeted to increased physical activity, reductions in body weight, and improved diet and eating patterns are urgently needed.

ACKNOWLEDGMENTS

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REFERENCES


