Coronary Artery Disease

The Distribution of 10-Year Risk for Coronary Heart Disease Among U.S. Adults
Findings From the National Health and Nutrition Examination Survey III

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OBJECTIVES	We sought to establish the distribution of the 10-year risk for coronary heart disease (CHD) among U.S. adults.
BACKGROUND	Risk assessment for CHD was developed to provide clinicians with a tool to estimate the absolute risk of developing CHD. More recently, risk assessment is increasingly being incorporated into guidelines for diagnostic testing and treatment. Yet, little is known about the 10-year risk distribution for CHD among adults in the U.S. based on these risk assessment tools.
METHODS	We applied the risk prediction algorithm used by the National Cholesterol Education Program Adult Treatment Panel III guidelines to data from 13,769 participants (representing 157,366,716 U.S. adults) age 20 to 79 years in the Third National Health and Nutrition Examination Survey (1988 to 1994).
RESULTS	Among participants without self-reported CHD (heart attack and angina pectoris), stroke, peripheral vascular disease, and diabetes, 81.7% (140 million adults) had a 10-year risk for CHD of <10%, 15.5% (23 million adults) of 10% to 20%, and 2.9% (4 million adults) of >20%. The proportion of the participants with a 10-year risk for CHD of >20% increased with advancing age and was higher among men than among women but varied little with race or ethnicity.
CONCLUSIONS	Our results help to define the distribution of 10-year risk for CHD among U.S. adults. (J Am Coll Cardiol 2004;43:1791–6) © 2004 by the American College of Cardiology Foundation

Risk prediction for coronary heart disease (CHD) was developed to help clinicians in estimating a patient's absolute risk for developing CHD. The earliest such effort was done by Framingham Heart study investigators, and these risk equations have been periodically updated (1,2). The National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) (NCEP/ATP III) has incorporated the use of risk assessment to provide clinicians with guidelines to treat dyslipidemia (3).

The NCEP/ATP III adopted a modification of the risk prediction algorithm from the Framingham Heart study (2) that incorporates a patient's age, total cholesterol concentration, high-density lipoprotein cholesterol concentration, smoking status, and systolic blood pressure (BP) to estimate a person's 10-year risk for developing CHD. Three levels of risk were defined: <10%, 10% to 20%, and >20%. The NCEP/ATP III considered these levels of risk within a broader framework of risk assessment that included establishing the presence of CHD and risk equivalents for CHD as well as risk factor counting. Patients with CHD or a CHD risk equivalent are considered to be at very high risk for sustaining an acute cardiovascular event.

More recently, risk assessment has been used to guide clinicians in performing diagnostic testing (4). In addition, risk assessment may serve as a motivational tool. Thus, the use of CHD risk assessment in developing guidelines may be widening. Consequently, estimates of the numbers of people in each of the three categories of risk may be useful. To determine the distribution of 10-year risk for CHD among adults in the U.S. as proposed by NCEP/ATP III, we examined data from the Third National Health and Nutrition Examination Survey (NHANES III).

METHODS

Between 1988 and 1994, a representative sample of the civilian, non-institutionalized U.S. population was recruited into NHANES III using a multistage, stratified sampling design (5,6). After an interview in the home, participants were invited to attend a morning, afternoon, or evening examination. The survey received human subject approval from the Centers for Disease Control and Prevention.

The NCEP/ATP III risk prediction algorithm scoring approach has separate risk functions for men and for women. Total cholesterol concentration and high-density

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Abbreviations and Acronyms

BP	=	blood pressure
CHD	=	coronary heart disease
NCEP/ATP III	=	National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)
NHANES	=	National Health and Nutrition Examination Survey

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lipoprotein cholesterol, after the precipitation of other lipoproteins with a heparin-manganese chloride mixture, were measured using a Hitachi 704 Analyzer (Boehringer Mannheim Diagnostics, Indianapolis, Indiana). Three BP readings were obtained in the mobile examination center. The average of the second and third systolic BP and diastolic BP readings were used in the analyses. Participants were asked whether they were currently using antihypertensive medication. Participants were considered current smokers if they reported smoking at least 100 cigarettes during their life and were currently smoking.

To define CHD, we used self-reported heart attack and angina pectoris derived from a series of questions. To define CHD risk equivalents, we used self-reported stroke and diabetes; peripheral vascular disease was determined from a series of questions.

Statistical analyses. The NCEP/ATP III risk prediction algorithm was proposed for people age 20 to 79 years; consequently, only participants in this age range were included in the analyses. Analyses were limited to participants who attended the examination. We calculated estimates using the sampling weights so that the estimates were

representative of the civilian, non-institutionalized U.S. population. Age-adjustment was done using the direct method and the age-distribution for the year 2000. To account for the complex sampling design, all analyses were conducted by using Software for the Statistical Analysis of Correlated Data (SUDAAN, Research Triangle Institute, Research Triangle Park, North Carolina) to obtain proper variance estimates.

RESULTS

A total of 13,769 participants (6,433 men and 7,336 women) had complete information to calculate their 10-year risk for CHD. An additional 289 participants without complete information reported having CHD or a CHD risk equivalent (diabetes, peripheral vascular disease, or stroke). Compared with women, men were younger, had lower concentrations of total cholesterol and high-density lipoprotein cholesterol, had higher systolic BP, were less likely to use antihypertensive medication, and were more likely to smoke (Table 1).

Among participants without CHD (self-reported myocardial infarction or angina pectoris) or a CHD risk equivalent (diabetes, peripheral vascular disease, or stroke), 81.7% had a 10-year risk for CHD of <10%, 15.5% of 10% to 20%, and 2.9% of >20% (Table 2). The risk increased strongly with advancing age, was greater among men than women, and did not differ much among the four racial or ethnic groups. We also calculated the risk distribution after assigning participants with CHD or a CHD risk equivalent to the highest risk category (Table 3, Fig. 1). After adjusting for age, 72.6% of participants had a 10-year risk for CHD of <10%, 11.9% of 10% to 20%, and 15.6% of >20%.

Although the NCEP/ATP III report defined intermediate

Table 1. Age-Adjusted Descriptive Information for Variables Included in the 10-Year Risk Estimates for Coronary Heart Disease, National Health and Nutrition Examination Survey III, 1988 to 1994

	Men (n = 6,433; Weighted n = 75,960,017)	Women (n = 7,336; Weighted n = 81,406,699)	
	Mean or % (SE)	Mean or % (SE)	p Value
Age (yrs)	42.8 (0.4)	44.0 (0.4)	0.001
Total cholesterol (mg/dl)	203.6 (1.0)	205.6 (0.7)	0.037
High-density lipoprotein cholesterol (mg/dl)	45.5 (0.4)	55.3 (0.4)	<0.001
Systolic blood pressure (mm Hg)	122.7 (0.4)	116.9 (0.3)	<0.001
Hypertension treatment, %	11.0 (0.6)	13.3 (0.5)	<0.001
Current smoking, %	32.1 (1.0)	25.3 (0.7)	<0.001
Risk factors for cardiovascular disease not used to estimate risk*			
Diastolic blood pressure (mm Hg)	76.4 (0.3)	70.7 (0.3)	<0.001
Body mass index (kg/m^2)	26.7 (0.1)	26.6 (0.2)	0.457
Waist circumference (cm)	95.8 (0.2)	88.9 (0.4)	<0.001
Triglycerides (mg/dl)	147.6 (3.8)	125.0 (2.3)	<0.001
Self-reported diabetes, %	5.0 (0.3)	5.7 (0.5)	0.254
C-reactive protein >3 mg/l, %	20.2 (1.0)	31.1 (1.3)	<0.001
Self-reported use of cholesterol-lowering medications, %	3.0 (0.3)	3.3 (0.3)	0.525

*Sample sizes may vary.

Table 2. Age-Specific and Age-Adjusted Distribution Risk for Coronary Heart Disease Among United States Adults Age ≥20 Years Without Self-Reported Coronary Heart Disease or a Coronary Heart Disease Equivalent,* National Health and Nutrition Examination Survey III, 1988 to 1994

	n	Weighted, n	10-Year Risk for Coronary Heart Disease			p†
			<10%, % (SE)	10% to 20%, % (SE)	>20%, % (SE)	
Total	11,611	138,463,213	81.7 (0.5)	15.5 (0.5)	2.9 (0.2)	—
Gender						<0.001
Men	5,481	67,159,469	66.0 (0.6)	28.7 (0.8)	5.3 (0.4)	
Women	6,130	71,303,744	94.8 (0.3)	4.3 (0.3)	0.9 (0.1)	
Age (yrs)						
Total						<0.001
20–29	2,951	34,410,851	99.9 (0.1)	0.1 (0.1)‡	0.0 (0.0)	
30–39	2,778	36,429,134	95.7 (0.8)	3.7 (0.8)	0.6 (0.2)‡	
40–49	2,022	27,827,102	89.7 (0.8)	8.5 (0.8)	1.8 (0.5)	
50–59	1,345	17,152,023	70.9 (1.7)	25.3 (1.7)	3.8 (0.6)	
60–69	1,486	13,884,733	55.0 (1.2)	40.1 (1.3)	5.0 (0.6)	
70–79	1,029	8,759,370	34.5 (1.6)	51.5 (1.5)	14.0 (1.4)	
Men						<0.001
20–29	1,388	17,394,942	99.8 (0.2)	0.2 (0.2)‡	0.0 (0.0)	
30–39	1,256	18,193,189	91.4 (1.5)	7.4 (1.6)	1.2 (0.4)	
40–49	988	13,843,244	80.2 (1.7)	16.2 (1.6)	3.6 (0.9)	
50–59	614	8,120,105	40.6 (2.4)	52.0 (2.6)	7.4 (1.3)	
60–69	767	6,101,047	8.4 (1.4)	80.8 (1.7)	10.8 (1.4)	
70–79	468	3,506,943	2.5 (0.7)	75.5 (2.4)	22.0 (2.5)	
Women						<0.001
20–29	1,563	17,015,909	100.0 (0.0)	0.0 (0.0)	0.0 (0.0)	
30–39	1,522	18,235,945	99.9 (0.1)	0.1 (0.1)†	0.0 (0.0)	
40–49	1,034	13,983,858	99.1 (0.4)	0.8 (0.4)†	0.1 (0.0)‡	
50–59	731	9,031,919	98.2 (0.6)	1.4 (0.5)†	0.4 (0.2)‡	
60–69	719	7,783,687	91.5 (1.2)	8.2 (1.2)	0.3 (0.2)‡	
70–79	561	5,252,426	55.9 (2.5)	35.5 (2.1)	8.6 (1.5)	
Race or ethnicity						
Total						0.289
White	4,573	106,562,092	81.6 (0.5)	15.6 (0.5)	2.8 (0.3)	
African American	3,290	13,978,761	80.5 (0.6)	16.1 (0.6)	3.5 (0.3)	
Mexican American	3,249	6,937,452	80.6 (0.8)	16.7 (0.7)	2.8 (0.3)	
Other	499	10,984,907	83.1 (1.4)	14.0 (2.0)	2.9 (1.2)‡	
Men						0.275
White	2,077	51,612,956	65.6 (0.8)	29.2 (0.8)	5.2 (0.4)	
African American	1,527	6,480,578	66.0 (1.3)	28.2 (1.2)	5.8 (0.6)	
Mexican American	1,658	3,727,827	67.0 (1.1)	28.2 (1.2)	4.8 (0.5)	
Other	219	5,338,108	69.7 (2.4)	24.0 (3.6)	6.3 (2.7)‡	
Women						0.002
White	2,496	54,949,136	95.1 (0.3)	4.1 (0.3)	0.8 (0.1)	
African American	1,763	7,498,183	92.7 (0.6)	5.8 (0.6)	1.5 (0.3)	
Mexican American	1,591	3,209,625	94.3 (0.7)	5.1 (0.7)	0.6 (0.3)‡	
Other	280	5,646,799	94.5 (1.1)	5.2 (1.1)	0.3 (0.2)‡	

*Self-reported myocardial infarction, angina pectoris, history of stroke, peripheral vascular disease, or diabetes mellitus; †p value is for chi-square test for unadjusted results and for Cochran-Mantel-Haenszel chi-square test for age-adjusted data; ‡estimate may be unstable and should be interpreted cautiously.

risk as 10% to 20%, a range of 6% to 20% has also been used. Therefore, we recalculated the estimates in Tables 2 and 3 using the following categories: <6%, 6% to 20%, and >20%. Among participants without CHD or a CHD risk equivalent, 72.8% (men: 55.0%; women: 88.4%) had a 10-year risk of <6%, 24.4% (men: 39.7%; women: 10.8%) had a risk of 6% to 20%, and 2.9% (men: 5.3%; women: 0.9%) had a risk of >20%. When participants with CHD or a CHD risk equivalent were assigned to the highest risk category, 65.4% (men: 51.7%; women: 77.8%) had a 10-year risk of <6%, 19.1% (men: 31.0%; women: 8.1%) had a risk of 6% to 20%, and 15.6% (men: 17.3%; women: 14.1%) had a risk of >20%.

By applying the age-specific proportions of participants in each risk stratum to the year 2000 U.S. population age 20 to 79 years without CHD or a CHD equivalent, as we defined it, we estimated that about 140 million people had a 10-year risk for CHD of <10%, 23 million of 10% to 20%, and 4 million of >20%. In addition, another 24 million people had CHD or a CHD equivalent.

Among participants who had a CHD risk equivalent or >20% 10-year risk for developing CHD or sustaining a cardiovascular event, 59.2% had self-reported diabetes, 14.8% had a stroke, 5.3% had peripheral vascular disease, and 36.1% had a 10-year risk for CHD >20% (Table 4). When the analysis was limited to participants who had fasted ≥8 h and had a plasma glucose measurement, 65.8%

Table 3. Age-Specific and Age-Adjusted Distribution of Risk for Coronary Heart Disease Among U.S. Adults Age ≥20 Years After Including People With Self-Reported Coronary Heart Disease or Coronary Heart Disease Risk Equivalents* in the Highest Risk Category, National Health and Nutrition Examination Survey III, 1988 to 1994

| | n | Weighted, n | 10-Year Risk for Coronary Heart Disease | | | p† |
			<10%, % (SE)	10% to 20%, % (SE)	>20%, % (SE)	
Total	14,058	159,308,285	72.6 (0.7)	11.9 (0.4)	15.6 (0.6)	
Gender						<0.001
Men	6,563	76,748,866	61.0 (0.7)	21.7 (0.7)	17.3 (0.6)	
Women	7,495	82,559,418	82.8 (0.8)	3.1 (0.2)	14.1 (0.8)	
Race or ethnicity						
Total						<0.001
White	5,487	122,096,537	73.3 (0.8)	12.1 (0.4)	14.6 (0.7)	
African American	4,020	16,761,822	68.0 (0.6)	10.8 (0.6)	21.2 (0.8)	
Mexican American	3,970	8,039,538	68.4 (0.8)	11.3 (0.5)	20.3 (0.6)	
Other	581	12,410,388	73.8 (1.6)	11.0 (1.3)	15.2 (1.3)	
Men						0.044
White	2,541	59,255,039	60.8 (0.9)	22.1 (0.8)	17.0 (0.7)	
African American	1,814	7,473,158	59.8 (1.2)	20.5 (1.0)	19.7 (0.9)	
Mexican American	1,965	4,179,034	60.3 (1.0)	20.5 (1.0)	19.2 (0.7)	
Other	243	5,841,635	65.9 (2.4)	19.0 (2.7)	15.1 (2.5)	
Women						<0.001
White	2,946	62,841,498	84.5 (1.0)	3.0 (0.2)	12.5 (1.0)	
African American	2,206	9,288,664	74.2 (1.2)	3.4 (0.4)	22.4 (1.3)	
Mexican American	2,005	3,860,504	75.7 (0.8)	2.8 (0.4)	21.5 (0.8)	
Other	338	6,568,753	80.8 (1.8)	4.0 (0.7)	15.2 (1.8)	

*Self-reported myocardial infarction, angina pectoris, history of stroke, peripheral vascular disease, or diabetes mellitus; †p value is for chi-square test for unadjusted results and for Cochran-Mantel-Haenszel chi-square test for age-adjusted data.

of participants had diabetes (self-report or ≥126 mg/dl), 12.2% had stroke, 4.6% had peripheral vascular disease, and 32.8% had a 10-year risk for CHD >20%.

DISCUSSION

The results from our analyses may help to better define the percentages and numbers of U.S. adults at three levels of risk for CHD during a 10-year interval. Such information may be helpful to those developing diagnostic and treatment guidelines for topics related to CHD. These findings may also help in estimating costs associated with such guidelines. In addition, this information may hold promise for surveillance purposes. Health care organizations use prediction models for various purposes including identifying members at increased risk for incurring high costs and planning care delivery (7,8). Although risk prediction using information from their own memberships is of greater practical use to those organizations, results such as ours may still be useful for making comparisons with national data.

Several issues may have affected the accuracy of our numbers. The definitions used in this study for CHD and CHD equivalent were based on self-reported data provided by the participants. Such data may underestimate the true prevalence of these conditions. If we had been able to detect these conditions more accurately, our estimates of the percentage of participants in each risk stratum would likely have been lower. For example, if the prevalence of CHD or CHD equivalent were twice as large as our estimates, about 123 million people would have had a 10-year risk for CHD of <10%, 16.5 million of 10% to 20%, and 3 million of

>20%. Smoking was self-reported, which likely underestimated the true prevalence of smoking. This, in turn, may have resulted in an underestimate of the percentage of participants who had a 10-year risk for CHD of 10% to 20% or >20%.

The Framingham coronary disease prediction algorithm that formed the basis for the NCEP/ATP III risk scoring algorithm used age, low-density lipoprotein cholesterol concentration, total cholesterol concentration, high-density lipoprotein cholesterol concentration, BP, diabetes, and smoking status and was developed for people age 30 to 74 years (2). Several changes to this algorithm were adopted by NCEP/ATP III. The age range was broadened to include people age 20 to 79 years. Low-density lipoprotein cholesterol was not included. Different high-density lipoprotein cholesterol categories were used. Points assigned for BP depended on treatment status, which was not considered by the Framingham algorithm. Finally, points assigned for smoking status were dependent on age, whereas in Framingham age was not a factor. Because diabetes was considered a risk equivalent by the NCEP/ATP III, it was not incorporated in the risk-scoring algorithm.

The NCEP/ATP III describes two approaches to risk assessment in persons without CHD or CHD risk equivalents. The principal approach consists of first counting the number of risk factors using five factors: cigarette smoking, hypertension, low-, high-density lipoprotein cholesterol concentration, family history of premature CHD, and age. For people with ≥2 risk factors, NCEP/ATP III recommends calculating the 10-year risk for CHD. The second
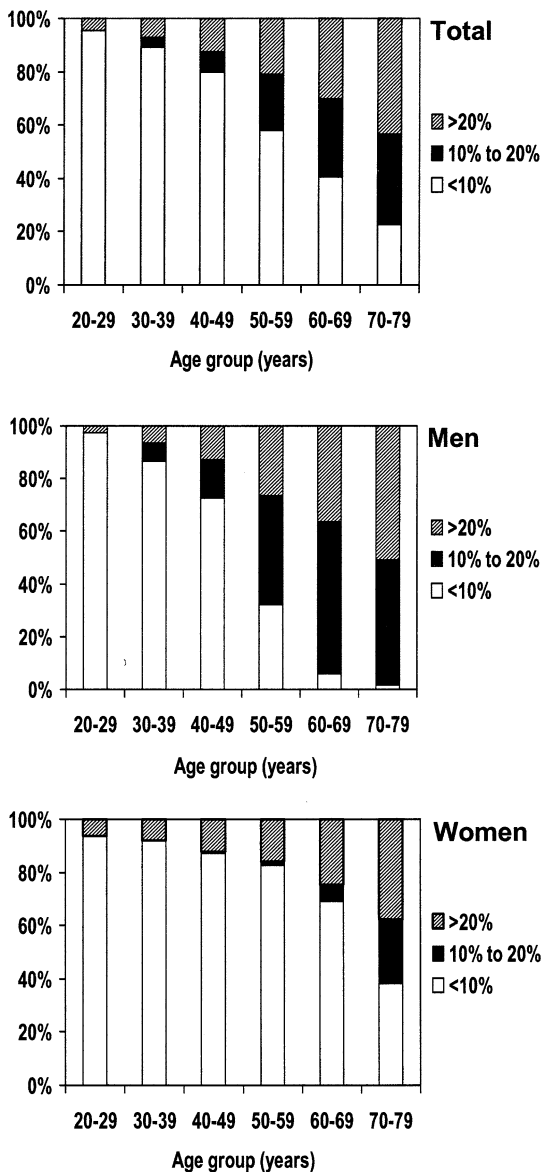
Figure 1. Age-specific distribution of risk for coronary heart disease (CHD) among U.S. adults age ≥20 years after including people with self-reported CHD or CHD risk equivalents (history of diabetes mellitus, peripheral vascular disease, or stroke) in the highest risk category, National Health and Nutrition Examination Survey III, 1988 to 1994. **Hatched bars** = >20%; **solid bars** = 10% to 20%; **open bars** = <10%.

approach consists of first calculating the 10-year risk score for CHD and, in people with a 10-year risk <10%, count the number of risk factors. People with CHD or a CHD risk equivalent are automatically considered to be at highest risk under either approach. We followed the latter approach but did not count risk factors in participants with a 10-year risk for CHD of <10%, primarily because of difficulty in defining a family history of CHD as described by NCEP/ATP III.

The NHANES III provided the most recent national data to estimate risk, but newer data for some of the risk factors needed for risk estimation is becoming available. The U.S. population has grown older. Cholesterol concentrations have changed little from the 1988 to 1994 period to the 1999 to 2000 period (9). National trends in high-density lipoprotein cholesterol concentration remain unknown. A significant increase in hypertension has occurred during this time, and the percentage of people with hypertension who are using antihypertensive medications has increased (10). Cigarette smoking decreased during the early part of the 1990s before leveling off (11). Thus, the net effect of the trends of risk factors on the population risk distribution of cardiovascular disease is difficult to predict.

The use of risk categories instead of equations may yield less accurate estimates of absolute risk. Newer analytical techniques may provide more accurate risk estimates in the future (12). In addition, most risk equations and the NCEP/ATP III risk prediction algorithm are based on a limited set of variables. Factors—such as obesity, physical activity, diabetes, triglyceride concentration, family history of CHD, and so on—are not included in the NCEP/ATP III risk calculation. Furthermore, emerging risk factors for CHD, such as C-reactive protein concentration, may improve risk prediction. In the future, risk algorithms may be refined and incorporate additional risk factors.

The generalizability of the NCEP/ATP III risk prediction algorithm has not been tested directly. However, the Framingham risk equation that was used to develop the algorithm had been tested in several U.S. as well as European populations (13–20). In the U.S., the Framingham risk prediction algorithm appears to predict risk reasonably well among various populations but not Native Americans (17).

Table 4. Distribution of CHD Risk Equivalents Among 3,026* U.S. Adults Age ≥20 Years With Any Such Risk Equivalent, National Health and Nutrition Examination Survey III, 1988 to 1994

	Total	Men	Women
Self-reported myocardial infarction and angina pectoris	45.3 (1.1)	42.9 (1.8)	47.9 (1.6)
Stroke	10.9 (0.9)	10.5 (1.5)	11.3 (1.3)
Peripheral vascular disease	3.8 (0.6)	3.6 (0.7)	4.1 (0.9)
Diabetes (self-report or plasma glucose ≥126 mg/dl among those fasting ≥8 h)	58.0 (1.4)	52.3 (1.9)	63.4 (1.9)
10-year risk for CHD >20% among participants without CHD or a CHD risk equivalent	11.8 (1.0)	19.3 (1.5)	4.1 (0.6)

Values represent percentage (SE). Conditions are not mutually exclusive. *Represents 25,785,513 U.S. adults.
CHD = coronary heart disease.

Few studies have provided estimates of the distribution of risk for CHD in populations. In a British study of 126 hypertensive men, 50% had a risk of ≥2% per year, and 28% had a risk of ≥3% per year based on the risk function of the Prospective Cardiovascular Münster study (21). In a study of 691 British participants age 30 to 70 years recruited from primary care practices, 8.5% had a 10-year projected risk for CHD of ≥30%, and 42.1% had a projected risk of ≥15% (22). In a study of 1,102 British men and women, the 10-year risk for CHD of ≥30% was 6.5% among men and 0.8% among women (19). The 10-year risk for 15% to 29% was 34.8% for men and 19.4% for women. In an analysis of data from the Prospective Cardiovascular Münster study, 3.9% to 8.4% of men age 35 to 65 years had a 10-year risk of >20% (12). The variability of estimates occurred because of the different approaches used for calculating risk. Our analysis of NHANES III data of participants age 20 to 79 years showed that 5.3% of men and 0.9% of women had a 10-year risk for CHD of >20%, and 28.7% of men and 4.3% of women had a 10-year risk for CHD of 10% to 20%. The large difference between the sexes in our analyses was consistent with findings by Rabindranath et al. (19).

In conclusion, we have provided estimates of the distribution of 10-year CHD risk among U.S. adults and have estimated the numbers of U.S. adults in each risk stratum. The risk distribution differed significantly among age groups and among men and women. Relatively little racial or ethnic variation was found. As the various risk stratification schemes evolve, new estimates will be needed. Hopefully, our estimates will provide useful information to researchers and clinicians who develop guidelines for diagnostic testing and treatment as well as policy makers.

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