PROBABILITY OF DEVELOPING CORONARY HEART DISEASE

BY

ERICA BRITTAI

TECHNICAL REPORT NO. 54
MARCH 1980

PREPARED UNDER THE AUSPICES
OF
PUBLIC HEALTH SERVICE GRANT 5 RO1 GM21215-05

DIVISION OF BIOSTATISTICS
STANFORD UNIVERSITY
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Based on multiple logistic functions estimated from the Framingham Study data, charts are compiled for calculating the probability of developing coronary heart disease in six years by men and women.

Key Words and Phrases: Multiple logistic function; Coronary heart disease.
1. **Background**

The Framingham Study has followed a sample of adults since 1948, in order to investigate the development of cardiovascular disease in individuals. The sample is composed of several thousand men and women who reside in Framingham, Massachusetts. Biennial clinical examinations provide information about the characteristics of persons in the study both before and after the onset of cardiovascular disease. The Framingham Study has sought to determine those characteristics which are associated with subsequent development of heart disease.

The data collected provided the basis for estimating parameters in multiple logistic functions using the Duncan-Walker method. A multiple logistic function yields an individual's estimated risk of disease given his or her values on certain characteristics, called risk factors.

In 1973, the American Heart Association published the **Coronary Risk Handbook** based on a particular set of these multiple logistic functions. This pamphlet was designed for easy physician use and consists of nearly 100 tables. A physician can obtain a patient's risk of developing heart disease in the next six years by locating the pertinent table, given the patient's age, sex, systolic blood pressure, serum cholesterol, cigarette smoking, presence or absence of glucose intolerance, and presence or absence of left ventricular hypertrophy by ECG.

The enclosed charts were designed to be used in place of the tables in the **Coronary Risk Handbook**. They are less cumbersome to use and also provide an intuition as to the relative importance of the factors. The charts and the handbook are mathematically equivalent as they are both derived from the same set of multiple logistic functions. However, the chart probabilities may be slightly less accurate than those in the handbook.
2. Definition of Risk Factors

The following definitions of the risk factors are taken from the Coronary Risk Handbook.

SYSTOLIC BLOOD PRESSURE - in mm Hg. Casual pressure taken with the subject seated.

SERUM CHOLESTEROL - in mg/100 ml as measured by the Abell-Kendall method. Correction will be necessary if another laboratory method is used.

LEFT VENTRICULAR HYPERTROPHY - as evaluated by electrocardiogram (ECG) consists in finding tall R-waves in leads reflecting potentials from the left ventricle accompanied by S-T depression or T-wave inversion. Other ECG abnormalities (including intraventricular conduction disturbance, non-specific S-T depression, and T-wave inversion abnormalities) also carry an excess risk of a similar magnitude.

SMOKING - refers to current cigarette smoking habit. The charts do not take into account intensity of smoking habit and contrast only smokers versus non-smokers.

GLUCOSE INTOXERANCE - as evidenced by: diabetes, trace or more of sugar in the urine, a casual (non-fasting) whole blood glucose level of 120 mg% or greater.

3. Construction of Charts

The following discussion uses the chart for men as an example.
Multiple Logistic Function for Men:

\[
\text{Estimated Risk} = \frac{1}{e^{(\hat{\alpha} + \hat{\beta}_1 x_1)}}
\]

where

\[
\hat{\alpha} = -22.227532 \quad \text{INTERCEPT}
\]

\[
\hat{\beta}_1 = 0.460575 \quad x_1 = \text{AGE}
\]

\[
\hat{\beta}_2 = -0.002882 \quad x_2 = \text{AGE} \times \text{AGE}
\]

\[
\hat{\beta}_3 = 0.028590 \quad x_3 = \text{SERUM CHOLESTEROL}
\]

\[
\hat{\beta}_4 = 0.012444 \quad x_4 = \text{SYSTOLIC BLOOD PRESSURE}
\]

\[
\hat{\beta}_5 = 0.447815 \quad x_5 = \text{SMOKING (0-no 1-yes)}
\]

\[
\hat{\beta}_6 = 0.743158 \quad x_6 = \text{LVH-ECG (0-no 1-yes)}
\]

\[
\hat{\beta}_7 = 0.265016 \quad x_7 = \text{GLUCOSE INTOLERANCE (0-no 1-yes)}
\]

\[
\hat{\beta}_8 = -0.000416 \quad x_8 = \text{AGE} \times \text{CHOLESTEROL}
\]

The above multiple logistic function determines the estimated probability
of developing coronary heart disease in six years as established by the
Framingham Study (see Gordon, Sorlie, and Kannel, 1971).

Method of Construction:

The estimated risk is a function of \( \Sigma \hat{\beta}_1 x_1 \) and the objective of
the charts is to reproduce \( \Sigma \hat{\beta}_1 x_1 \) with a simple scoring system.

1) A scale factor was chosen. It can be chosen in order to create cer-
tain interval lengths of a particular variable.

\[
\text{Scale Factor} = \frac{1}{\hat{\beta}_1 \times \text{Interval Length}}
\]

Since 10 points was a desirable interval length for SYSTOLIC BLOOD
PRESSURE, 8.036 was chosen as the scale factor because
\[
\frac{1}{0.012444 \times 10} = 8.036.
\]

8.036 is then the scale factor for all variables.

2) Point values were computed for certain values of the variables.

\[
\text{Point}(i) = \text{Value}(i) \times \hat{\beta}_1 \times 8.036
\]

Example

No Smoking \(0 \times 0.447815 \times 8.036 = 0\) \(\Rightarrow 0\) points

Smoking \(1 \times 0.447815 \times 8.036 = 3.6 \Rightarrow 4\) points

Due to the interaction, points for age and cholesterol were calculated jointly for specified values.

Example

Cholesterol = 240, Age = 50

\[
[(0.460575)(50) - (0.002882)(50)(50) + (0.028590)(240)
- (0.000416)(50)(240)] \times 8.036 = 142.2 \Rightarrow 142\ points
\]

3) 10 points were subtracted from all SBP points and 118 points were subtracted for all AGE \times CHOL points, for ease of computation and simple chart making.

4) \(\sum \hat{\beta}_1 x_i\) is estimated by

\[
\frac{10 + 118 + \text{SCORE}}{8.036}
\]

where \(\text{SCORE}\) is the sum of points on the chart for specified values of the characteristics. The risk is then estimated by

\[
\frac{1}{1 + e^{-(-22.227532 + [(128+\text{SCORE})/8.036])}}.
\]

Multiple Logistic Function for Women:

The estimated parameters in the multiple logistic function for women from Gordon, Sorlie, and Kannel (1971) are
\[
\hat{\alpha} = -19.066572 \quad \text{INTERCEPT}
\]
\[
\hat{\beta}_1 = .311558 \quad x_1 = \text{AGE}
\]
\[
\hat{\beta}_2 = -.001724 \quad x_2 = \text{AGE} \times \text{AGE}
\]
\[
\hat{\beta}_3 = .016802 \quad x_3 = \text{SERUM CHOLESTEROL}
\]
\[
\hat{\beta}_4 = .015278 \quad x_4 = \text{SYSTOLIC BLOOD PRESSURE}
\]
\[
\hat{\beta}_5 = .049966 \quad x_5 = \text{SMOKING (0-no 1-yes)}
\]
\[
\hat{\beta}_6 = .441707 \quad x_6 = \text{LVH-ECG (0-no 1-yes)}
\]
\[
\hat{\beta}_7 = .416906 \quad x_7 = \text{GLUCOSE INTOLERANCE (0-no 1-yes)}
\]
\[
\hat{\beta}_8 = -.000190 \quad x_8 = \text{AGE} \times \text{CHOLESTEROL}
\]

A method similar to that given above for men was used to construct the chart for women.

4. Charts

The charts for calculating the probability of developing coronary heart disease in 6 years for men and women are given after the References. Copies of the charts which are 6\(\frac{1}{2}\)\(\times\)8 inches and laminated in plastic are also available.

5. Examples

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<thead>
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<th>Characteristic</th>
<th>Value</th>
<th>Point Value</th>
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<tr>
<td>LVH</td>
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</tr>
<tr>
<td>GLU</td>
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<td>0</td>
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<tr>
<td>AGE/CHOL</td>
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Total: 36 \(\Rightarrow\) Probability: .14

Coronary Risk Handbook Probability: .134
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<th>Point Value</th>
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<tr>
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<td>14</td>
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</table>

Total: 16  ⇒  Probability: .012

Coronary Risk Handbook Probability: .012 (Smoker)
.012 (Non-Smoker)

6. References


Probability of Developing Coronary Heart Disease in 6 years. 
Men (Aged 35-70)

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</table>

Calculation of Probability

Enter Points (in red) for

- Systolic Blood Pressure
- Cigarette Smoking
- Left Ventricular Hypertrophy
- Glucose Intolerance
- Age/Serum Cholesterol

Total Points → Probability

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<tr>
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<th>Age 36</th>
<th>Age 38</th>
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Probability of Developing Coronary Heart Disease in 6 years. Women (Aged 35-70)

<table>
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</table>

Note: No points added for Smoking

### Calculation of Probability

Enter Points (in red) for

- **TP**
- **Prob**

**Systolic Blood Pressure**

**Left Ventricular Hypertrophy**

**Glucose Intolerance**

**Age/Serum Cholesterol**

**Total Points → Probability**

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<td>.32</td>
</tr>
</tbody>
</table>

Left Ventricular Hypertrophy — as evaluated by electrocardiogram (ECG).
Glucose Intolerance — as manifested by diabetes, or a trace or more of sugar in the urine, or a non-fasting whole blood glucose level of 120 mg% or greater.