Concordance for Coronary Risk Factors Among Spouses

By DAVID L. SACKETT, M.D., GARY D. ANDERSON, Ph.D., RUTH MILNER, B.Sc., MANNING FEINLEIB, M.D., and WILLIAM B. KANNEL, M.D.

SUMMARY
Values for several coronary risk factors, including systolic and diastolic blood pressure, serum cholesterol, triglycerides, blood glucose, uric acid, hemoglobin, weight, vital capacity and cigarette smoking have been found to be similar among spouses in the Framingham Study. However, longitudinal analyses show that this spouse concordance does not increase over a twelve-year observation period, suggesting that it has arisen through the marriage of similar people rather than through the sharing of a common marital environment. Apparent conflicts between cross-sectional and longitudinal findings have been resolved by showing that spouses who were concordant at the beginning of the study are more likely to survive to later exams, while discordant spouse pairs tend to be dissolved through the death of one of their members.

CLINICIANS, epidemiologists, and other students of human biology share an interest in studies of family clusters of heart disease and its antecedents. The recent inclusion of husband and wife pairs (spouse pairs) has added a new dimension to earlier studies of first-degree relatives. Not only do spouse analyses assist in teasing out the relative contribution of genetic and environmental factors, but such studies, if a positive association is found, might provide a rationale both for case-finding and for environmental modification.

Previous studies of spouse concordance* for coronary risk factors have been summarized elsewhere.¹ In brief, the majority²-⁷ — but by no means all⁸-¹¹ — of these investigations have shown spouse concordance for blood pressure which is greater than chance; occasionally, this concordance approached or equalled that found among first-degree relatives. Furthermore, this spouse concordance was frequently observed to increase in direct proportion to the duration of marriage, suggesting a cumulative effect of the common marital environment.

Attempts to identify and measure spouse concordance for coronary risk factors face three difficult methodologic problems which warrant brief consideration here. First, because many coronary risk factors change with aging — /nd since spouse pairs tend to be of roughly similar ages — spurious spouse concordance results unless some statistical procedure is introduced to "correct" for this age-related change. However, the standard procedures used to "correct" for age differences in coronary risk factors may not accomplish this goal; we found persistent, statistically significant age differences in most coronary risk factors among Framingham subjects when we used the classic correction procedures.²,¹²

The second methodologic problem arises when tests for statistical significance are applied to these age-corrected coronary risk factor values in order to detect concordance. Because the age-corrected values are only rarely normally distributed, they violate a basic assumption of the significance tests.¹ Again, we have found that application of the classic age-correction procedures to Framingham data produce values which are seldom normally distributed.

Finally, cross-sectional studies which show increasing spouse concordance among spouse pairs married for longer periods can be used to support an environmental hypothesis (that sharing a marital environment causes progressive similarities in risk factors) only if one assumes that the same sort of pairs are studied throughout the succeeding marriage-duration categories. However, these same cross-sectional find-

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*We will use the term spouse concordance (rather than spouse aggregation) to describe the state where husbands and wives are found to have closely similar attributes (such as blood pressures and serum lipids).

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ings could arise if shorter married spouses were a mixture of both concordant and discordant pairs, but longer married spouses were a more homogeneous group of concordant pairs. In this case, the apparent increase in spouse concordance observed with increasing duration of marriage would be artifactual, leading to spurious support of the environmental hypothesis. Because the Framingham Heart Epidemiology Study permits both cross-sectional and longitudinal observations on large numbers of spouse pairs, it provides an opportunity to resolve discrepancies in these earlier findings and the resulting controversy about their interpretation.

This analysis of Framingham data was undertaken in order to answer the following questions:

1) Do statistically significant and biologically important similarities in coronary risk factors exist between husbands and wives in the Framingham Study population?

2) If present, does this spouse concordance increase over time in direct proportion to the duration of marriage, thus supporting an environmental explanation?

3) Finally, can the findings of cross-sectional and longitudinal analyses of spouse concordance be reconciled?

Methods

The Framingham Heart Epidemiology Study, which has included the surveillance and biennial examination of over 5,209 inhabitants of Framingham, Massachusetts, U.S.A., began in 1948 and has been described in detail elsewhere. For the analyses reported here, marital histories and details of family composition were extracted from microfilm records of the biennial exams, and coronary risk factor measurements were taken directly from tapes developed in the Biometrics Branch of the National Heart and Lung Institute.

In order to generate a study population capable of demonstrating the effect of a shared marital environment, the analyses performed here were confined to the 1,259 Framingham spouse pairs (out of a total of 1,644) who had single, continuous marriages. Since the duration of marriage was not routinely ascertained at entry to the Framingham Study, it had to be estimated for each spouse pair by one of three alternative strategies. First, 328 pairs could be assigned directly to a five-year marriage-duration group on the basis of interviews performed several years later on a subset of the study population under the direction of Drs. Norman Scotch and Sol Levine of The Johns Hopkins University. A second batch of 874 spouse pairs were assigned to marriage-duration groups on the basis of the year of birth of their first offspring. Finally, 57 childless spouse pairs were assigned to marriage-duration groups by matching them with other spouse pairs of similar ages who had borne children.

In order to compare the relative levels of coronary risk factors between the members of individual spouse pairs, it was necessary to select a method of age- and sex-adjustment for individual measurements. After considering a number of potential approaches, we opted for one which both avoided the methodologic pitfalls noted at the beginning of this paper and minimized the likelihood of concluding that concordance existed when, in fact, it was absent.

An example of our approach is illustrated in figures 1 and 2, and is analogous to the Ordac method of Priore. For each coronary risk factor, the values were divided into sextiles for each sex and for each five-year age group: in the case of the husband shown in figure 1, sextiles of systolic blood pressures for men ages 35 to 39 at Exam 1.

Because of the preponderance of blood pressure readings ending in 5, 0 and 2, large numbers of identical readings occurred at some cut-off points between two sextiles (these are enumerated in the columns titled "number of ties" in figure 1. In these cases we adopted the conservative approach of randomly allocating tied measurements to the two sextiles in order to achieve a numerical balance for each. In the example shown in figure 1, the husband is assigned to the 5th sextile and the wife to the 3rd.

The subsequent testing for concordance within individual spouse pairs was performed in contingency tables as shown...

<table>
<thead>
<tr>
<th>Sextile</th>
<th>Range</th>
<th>No. Ties</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st.</td>
<td>94-116</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2nd.</td>
<td>118-124</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>3rd.</td>
<td>124-130</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>4th.</td>
<td>130-136</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>5th.</td>
<td>136-145</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sextile</th>
<th>Range</th>
<th>No. Ties</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st.</td>
<td>94-108</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2nd.</td>
<td>110-112</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>3rd.</td>
<td>112-120</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4th.</td>
<td>120-124</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>5th.</td>
<td>124-130</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>6th.</td>
<td>130-160</td>
<td>20</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure 1
An example of the method used to adjust blood pressures.
in figure 2, in which the columns represented, from left to right, ascending age-specific sextiles of the risk factor among wives and the rows, from top to bottom, ascending sextiles among husbands. Each spouse pair was then assigned to that cell which corresponded to the sextile locations of its two members, and the couple in our example is seen to reside in cell 3, 5.

A number of measures of ordinal association have produced similar results when applied to these contingency tables. For purposes of clarity, the test statistic used in this communication will be Kendall's Tau-A, a nonparametric statistic which measures order association. In this case Tau-A compares the occurrence of concordant spouse pairs, shown along the main diagonal of figure 2, with that of pairs who are discordant and lie to either side of the main diagonal. The statistic tells us whether the former occur more frequently than would be expected by chance. In assessing these Tau-A values, it should be borne in mind that they are numerically much lower than corresponding product-moment correlation coefficients calculated from identical data sets. The resulting Tau-A values have been assessed in two different ways. In the first assessment, spouse concordance for coronary risk factors was determined cross-sectionally at Exam 1 (or the earliest exam at which the risk factor was determined), subdividing the spouse pairs by their duration of marriage at Exam 1. The second assessment was a longitudinal one and followed spouse concordance as it progressed from Exam 1 to Exam 7 for those spouse pairs who were present throughout this interval. In this longitudinal assessment, spouse pairs were also subdivided by their duration of marriage at Exam 1.

Figure 2
An example of a contingency table for determining spouse concordance for systolic blood pressure.

Figure 3
Cross-sectional analysis of spouse concordance for blood pressure among different marriage-duration groups: Exam 1.
Table 1

Blood Pressure Concordance Among True and "Random" Spouse Pairs, Exam 1

<table>
<thead>
<tr>
<th></th>
<th>True spouse pairs</th>
<th>&quot;Random&quot; spouse pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tau-A</td>
<td>F*</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>0.0850</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>0.0543</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

(Based upon 1026 spouse pairs in which both members were present at Exams 1 and 7).

*One-tailed.

BP = blood pressure.

Results

Cross-Sectional Analyses

Figure 3 shows Tau-A values for systolic and diastolic blood pressures at Exam 1, among spouse pairs married 0–9 years, 10–19 years, and 20–29 years at the time that these measurements were made. Statistically significant* spouse concordance was observed for both systolic and diastolic blood pressure, and the latter demonstrated a clear trend toward greater concordance as we looked at spouses married for longer periods of time.

At this point in the analysis we considered the possibility that our analytic strategy itself, plus the fact that the members of individual spouse pairs tend to be examined at about the same point in the calendar year, might result in spurious spouse concordance. Accordingly, we performed a "spouse-swapping" experiment in which each husband was randomly assigned someone else's wife who had been examined within the same three-month period. As shown in table 1, these random pairs failed to exhibit the concordance for systolic or diastolic blood pressures found among true spouse pairs, and it was concluded that the spouse concordance shown in figure 3 was real.

The cross-sectional analysis of spouse concordance for other coronary risk factors is summarized in table 2. As with blood pressure, greater concordance among longer married spouse pairs was observed for hemoglobin, cholesterol, and uric acid. On the other hand, spouse concordance was high and constant throughout all marriage-duration groups for phospholipids and blood sugar, and was highly variable for weight and vital capacity.

The concordance of coronary risk factors of specific clinical interest was determined after they had been dichotomized into clinically relevant subgroups. The results for risk factors measured at Exam 1 are shown in table 3, in terms of both the degree of concordance and the likelihood that this concordance is due to chance (as indicated by Chi-square). We want to stress that no age-correction has been carried out in this subsection of the analysis, and these results

Table 2

Cross-sectional Analyses of Spouse Concordance for Coronary Risk Factors

<table>
<thead>
<tr>
<th></th>
<th>Length of marriage at exam 1</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-9 yr (N = 327)</td>
<td>10-19 yr (N = 509)</td>
<td>20-29 yr (N = 345)</td>
<td>30-39 yr (N = 78)</td>
<td>All spouse pairs (N = 1259)</td>
</tr>
<tr>
<td></td>
<td>*</td>
<td>**</td>
<td>*</td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>SBP</td>
<td>0.0570 ± 0.0324</td>
<td>0.0785 ± 0.0258</td>
<td>0.0602 ± 0.0310</td>
<td>0.1038 ± 0.0666</td>
<td>0.0682 ± 0.0163</td>
</tr>
<tr>
<td>DBP</td>
<td>-0.0388 ± 0.0329</td>
<td>0.0667 ± 0.0254</td>
<td>0.0735 ± 0.0322</td>
<td>0.0912 ± 0.0689</td>
<td>0.0430 ± 0.0166</td>
</tr>
<tr>
<td>Hg</td>
<td>0.0070 ± 0.0430</td>
<td>0.0748 ± 0.0373</td>
<td>0.1735 ± 0.0434</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chol</td>
<td>0.0509 ± 0.0425</td>
<td>0.0429 ± 0.0366</td>
<td>0.1653 ± 0.0423</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phos</td>
<td>0.1764 ± 0.0417</td>
<td>0.1453 ± 0.0349</td>
<td>0.1367 ± 0.0439</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluc</td>
<td>0.1024 ± 0.0302</td>
<td>0.1374 ± 0.0306</td>
<td>0.1013 ± 0.0391</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uric acid</td>
<td>0.0257 ± 0.0446</td>
<td>0.1609 ± 0.0345</td>
<td>0.1062 ± 0.0441</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wt</td>
<td>0.1231 ± 0.0334</td>
<td>0.0697 ± 0.0261</td>
<td>0.0973 ± 0.0313</td>
<td>0.0635 ± 0.0699</td>
<td>0.0808 ± 0.0167</td>
</tr>
<tr>
<td>VC</td>
<td>0.1430 ± 0.0315</td>
<td>0.0562 ± 0.0260</td>
<td>0.1487 ± 0.0314</td>
<td>0.1318 ± 0.0650</td>
<td>0.1098 ± 0.0164</td>
</tr>
</tbody>
</table>

Values shown are Kendall's Tau-A ± standard error.

*P < 0.05 (one-tailed).

**P < 0.01 (one-tailed).

***P < 0.001 (one-tailed).

Abbreviations: SBP = systolic blood pressure; DBP = diastolic blood pressure; Hg = hemoglobin; Chol = cholesterol; Phos = phospholipid; Gluc = blood glucose; Wt = weight; VC = vital capacity.
therefore exaggerate the true degree of spouse concordance.

Longitudinal Analyses

Longitudinal analyses of spouse concordance for systolic and diastolic blood pressures are shown in figures 4 and 5, respectively. Two features are striking: First, spouse concordance for blood pressure does not increase over the 12-year period between Exams 1 and 7; at best, it remains at approximately the Exam 1 level throughout the ensuing 12 years. Second, longer married spouse pairs tend to show more concordance, both at Exam 1 and throughout the 12-year follow-up.

The results of longitudinal analyses for other coronary risk factors are summarized in table 4. With the exception of weight, concordance for these risk factors either declines slightly with time or remains roughly constant. Furthermore, successively longer married spouses exhibit greater concordance throughout the 12-year follow-up and there is little or no tendency for spouse concordance to increase over calendar time.

This failure of spouse concordance to increase over calendar time has been studied in greater detail by identifying subsets of concordant and discordant spouse pairs at Exam 1 and determining their degree of concordance at Exam 7; for the sake of space, these analyses are omitted from this communication. They indicate that these trends of concordance and discordance over time are closely balanced; for example, the net increase in concordance for systolic blood pressure over this 12-year follow-up is only 11 spouse pairs.

Discussion

Returning to the questions posed at the beginning of this paper:

1) Do statistically significant and biologically important similarities in coronary risk factors exist between husbands and wives in the Framingham Study population?9

Both cross-sectional and longitudinal analyses have demonstrated statistically significant spouse concordance for the coronary risk factors identified in the Framingham Heart Epidemiology Study. Not only do these findings confirm the results of some earlier studies of spouse concordance;6 7 they extend these earlier findings, which were restricted to considerations of blood pressure and cholesterol, to a broad array of additional physiologic and biochemical predictors of coronary risk. Thus, spouse concordance for coronary risk factors is real.

The biologic and clinical significance of this finding is much less clear. The degree of spouse concordance, while real, is not great, and only parallel analyses of both spouses and first-degree relatives will reveal the comparative strengths of these two relationships. At any rate, the degree of spouse concordance shown here is not great enough to be useful in case-finding.1

2) If present, does this spouse concordance increase over time in direct proportion to the duration of marriage?2

Cross-sectional analyses of most risk factors showed

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Table 3
Cross-sectional Analyses of Spouse Concordance for Clinical Entities

<table>
<thead>
<tr>
<th>Clinical category</th>
<th>N pairs</th>
<th>% Concordant</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic hypertension</td>
<td>1259</td>
<td>80</td>
<td>0.07</td>
</tr>
<tr>
<td>(&gt; 160 mm Hg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diastolic hypertension</td>
<td>1259</td>
<td>71</td>
<td>0.19</td>
</tr>
<tr>
<td>(&gt; 95 mm Hg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypercholesteremia</td>
<td>671</td>
<td>75</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(&gt; 260 mg %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity</td>
<td>1242</td>
<td>84</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>(&gt; 120 % FRW)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cigarette use</td>
<td>1259</td>
<td>66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>(&gt; 1 pack)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Derived from Chi-square test.
FRW = Framingham Relative Weight.

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Figure 4
Longitudinal analysis of spouse concordance for systolic blood pressure among different marriage-duration groups: Exams 1–7.
increasing concordance among longer married spouse pairs, suggesting that spouses become more similar as they continue to share a common environment. However, longitudinal analyses performed upon these same people showed that the degree of spouse concordance for most coronary risk factors remains constant over a 12-year follow-up, indicating that a shared, common environment does not, in fact, result in detectable increments in spouse concordance for these predictors of coronary heart disease. Indeed, these longitudinal analyses are far more consistent with the suggestion that the spouse concordance observed here has resulted from marriages between persons with similar coronary risk factors (i.e., assortative marriage).

While it is beyond the scope of this communication to deal definitively with the issue of assortative marriage on the basis of coronary risk, it should be noted that some of the risk factors studied here, such as height and weight, have previously been shown to directly affect the choice of a marital partner. Furthermore, other coronary risk factors are known to be influenced by one or more traits which determine the selection of a mate; these traits include ethnic background and race, socio-economic status, residential nearness, health status, and a series of psychologic traits and personality characteristics. Thus, assortative marriage on the basis of coronary risk factors is plausible.

At any rate, we hope that this observation will encourage other investigators with access to longitudinal data to perform similar investigations.

3) Finally, can the findings of cross-sectional and longitudinal analyses of spouse concordance be reconciled?

The explanation of assortative marriage does not resolve the apparent paradox that, whereas the cross-sectional analyses frequently show increasing concordance among progressively longer married spouses, longitudinal analyses fail to reveal increasing spouse concordance over the 12-year follow-up.

We think that this apparent paradox can be resolved. Utilizing a property of Kendall’s Tau-A which permits the “partialling out” of the test statistic (the principle is analogous to “partialling out” a correlation coefficient), we have divided the spouse pairs from the cross-sectional analysis at Exam 1 into two groups: the 981 spouse pairs who survived to Exam 7, and the 119 spouse pairs destined to be dissolved before Exam 7, the latter almost always because of the death of one of the members of the pair. The result is shown for systolic blood pressure in figure 6. Spouse pairs destined to be dissolved prior to Exam 7 are either discordant (Tau-A values are negative) or only slightly concordant. Their inclusion in the earlier
cross-sectional analyses of spouse concordance (fig. 3 and table 2) has decreased the over-all degree of concordance among spouses married for shorter durations. Thus, the increase in spouse concordance observed with increasing duration of marriage in other cross-sectional studies4-7 may also be due simply to the “uncovering” of previously concordant, surviving spouse pairs through the dissolution of spouse pairs discordant for systolic blood pressure.

“Partialling out” analyses for diastolic blood pressure, cholesterol, and other risk factors produced generally similar results, but also occasionally showed concordance for high levels of the risk factor among spouse pairs destined to be dissolved prior to Exam 7, a finding which is in agreement with a recent Evans County investigation.7

In conclusion, cross-sectional and longitudinal analyses of Framingham spouse pairs have consistently revealed statistically significant spouse concordance for coronary risk factors. However, among spouse pairs present throughout a 12-year follow-up, concordance did not increase with calendar time, suggesting assortative marriage (“like marries like”) as a probable mechanism for the observed concordance. Apparent increases in concordance noted in cross-sectional studies among longer married spouse pairs are largely the result of the “uncovering” of previously concordant spouse pairs through the dissolution of spouse pairs who are discordant for these predictors of coronary heart disease.

References
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