CORRESPONDENCE

SAS program for testing the difference between two correlated correlation coefficients

Sir,—Sometimes we need to statistically compare two product-moment correlation coefficients (r) that are correlated—that is, not statistically independent. We might, for example, wish to determine whether the correlation of urinary cadmium (X_1) on β_2 microglobulin (Y) is statistically different from the correlation of blood cadmium (X_2) on β_2 microglobulin (Y) in the same group of subjects. In a methodological study to validate two methods, say machine (X_1) v ascultatory (X_2), against a reliable invasive method (Y), for measuring blood pressure, we might compare the correlation of X_1 on Y with the correlation of X_2 on Y .

These correlation coefficients are correlated because they share the common variable Y measured from the same group of subjects, and any test of significance that ignores this non-independence will be inappropriate. Actually the problem has long been recognised and the test for comparing correlated correlation coefficients was first described by Hotelling in 1940.¹ Hotelling's t test has been used for many years and is still being used, even though the method has serious drawbacks.^{2,3} Improvements to the Hotelling test have been considered by several authors.²⁻⁶

Here I describe an SAS program⁷ to compare two correlated correlation coefficients. The program uses the statistical procedure given by Meng *et al*⁶ and it outputs the Z value (standard normal deviate) and the two sided significance probability pertaining to the statistical difference of the two correlated correlation coefficients. To enhance user friendliness, the program is packaged as an SAS macro named %MACRO CCORR (appendix). The macro requires four user supplied parameters: rxly (correlation of X_1 on Y), rx2y (correlation of X_2 on Y), rx1x2 (correlation of X_1 on X_2), and n (number of subjects in the sample). If you stored the macro with filename and extension as "ccorr.mac" in C:/MYSAS, then the entire SAS program will consist of as few as two statements, one to invoke the macro and the other to supply the four parameters to the macro. Here is an example of a complete SAS program:

```
%INCLUDE 'C:/MYSAS/CCORR.MAC';
%CCORR (0.72, 0.55, 0.22, 50)
%CCORR (0.25, -0.14, 0.18, 60)
```

The first test gives $Z = 1.4282$ with the two sided probability value = 0.15319; the second test gives $Z = 2.3085$ with the two sided probability value = 0.02097.

Appendix: listing of the SAS codes

```
%MACRO CCORR (rxly, rx2y, rx1x2, n);
*% stored as 'CCORR.MAC';
OPTIONS nocenter nodate;
DATA _null_;
  z1 = 0.5*log((1 + &rxly)/(1 - &rxly));
  z2 = 0.5*log((1 + &rx2y)/(1 - &rx2y));
  rs = (&rxly*&rxly + &rx2y*&rx2y)/2;
  f = (1 - &rx1x2)/(2*(1 - rs));
  if f > 1 then f = 1;
  h = (rs*(1 - f)/(1 - rs)) + 1;
  zdif = z1 - z2;
  den = 2*h*(1 - &rx1x2);
  Z = zdif*((&n - 3)/den)*0.5;
  prob = (1 - probnorm(abs(Z)))*2;
  put @5 'Z' = 'Z 8.4' 2-sided p value =
    'prob 7.5';
  *Note: output is shown on the 'LOG
  WINDOW';
run;
%MEND CCORR;
```

JAMES LEE

Division of Biostatistics and Health Informatics,
Department of Community,
Occupational and Family Medicine,
National University of Singapore, NUS
Lower Kent Ridge Road,
Singapore 0511

- Hotelling H. The selection of variates for use in prediction, with some comments on the general problem of nuisance parameters. *Annals of Mathematical Statistics* 1940;11: 271-83.
- Williams EJ. The comparison of regression variables. *Journal of the Royal Statistical Society B* 1959;21:396-9.
- Steiger JH. Tests for comparing elements of a correlation matrix. *Psychol Bull* 1980;87: 245-51.
- Dunn OJ, Clarke VA. Comparison of tests of the equality of dependent correlation coefficients. *Journal of the American Statistical Association* 1971;66:904-8.
- Neill JJ, Dunn OJ. Equality of dependent correlation coefficients. *Biometrics* 1975;31: 531-43.
- Meng XL, Rosenthal R, Rubin DB. Comparing correlated correlation coefficients. *Psychol Bull* 1992;111:172-5.
- SAS Language guide, release 6.03. Cary, North Carolina: SAS Institute, 1988.

Reproductive risks associated with diving

Sir,—Raymond (1993;50:1055-6) considers the risks to reproduction from convective heat exposure among divers who use hyperbaric chambers. It is worth noting that they may be presumed to be at risk not only from the heat, but also from the pressure.

Röckert *et al*¹ reported that the plasma testosterone concentrations of rats exposed to a hyperbaric environment of air were significantly and substantially (about 50%) reduced. Röckert and Haglid² reported that preliminary results from the determination of plasma testosterone in human divers showed it to decrease after diving.

I have hypothesised that the sex ratio (proportion of males) of mammalian (including human) offspring is affected by the hormone concentrations of both parents at the time of conception; high concentrations of testosterone being associated with subsequent births of boys and high concentrations of gonadotrophin with subsequent births of girls.³ This suggestion is supported by the findings of Lyster⁴ and Röckert⁵ who reported highly significant low sex ratios in the offspring of Australian abalone divers and Swedish navy divers. It is also supported by the finding of a significantly low sex ratio in the offspring of men who were exposed to the nematocide DBCP: such men have been reported to have high

gonadotrophin but normal testosterone concentrations.⁷

Workers in industrial medicine might consider using the sex ratios of offspring as a criterion of reproductive risk. Unusual sex ratios of offspring are characteristic of a number of diseases—for example, prostatic cancer,⁸ hepatitis B,⁹ multiple sclerosis,¹⁰ otosclerosis,¹¹ and non-Hodgkin's lymphoma.¹²

Meanwhile it might be prudent to re-examine the testicular function and sex ratios of offspring of further samples of divers.

W H JAMES

Galton Laboratories,
Department of Genetics and Biometry,
University College, London,
Wolfson House,
4 Stevenson Way,
London NW1

- Röckert HOE, Damber J-E, Janson PO. Testicular blood flow and plasma testosterone concentrations in anesthetized rats previously exposed to 6 ATA. *Undersea Biomedical Research* 1978;5:355-61.
- Röckert HOE, Haglid K. Reversible changes in the rate of DNA synthesis in the testes of rats after daily exposure to a hyperbaric environment of air. *IRCS Journal of Medical Science* 1983;11:531.
- James WH. The human sex ratio. Part 2: a hypothesis and a program of research. *Hum Biol* 1987;59:873-900.
- Lyster WR. Altered sex ratios in children of divers. *Lancet* 1982;ii:152.
- Röckert HOE. Changes in the vascular bed of testes of rats exposed to air at 6 atmospheres absolute pressure. *IRCS Journal of Medical Science* 1977;5:107.
- Potashnik G, Yanai-Inbar I. Dibromochloropropane (DBCP): an 8-year re-evaluation of testicular function and reproductive performance. *Fertil Steril* 1987;47:317-23.
- Whorton D, Milby TH, Krauss RM, Stubbs HA. Testicular function in DBCP exposed pesticide workers. *J Occup Med* 1979;21: 161-6.
- James WH. The hypothesized hormonal control of human sex ratio at birth—an update. *J Theor Biol* 1990;143:555-64.
- Chahnazarian A, Blumberg BS, London WT. Hepatitis B and the sex ratio at birth: a comparative analysis of four populations. *J Biosoc Sci* 1988;20:357-70.
- Verdoer-Taillefer MH, Alperovitch A. Do male patients with multiple sclerosis have an excess of female offspring? *Neuroepidemiology* 1991;10:18-23.
- James WH. Sex ratios in otosclerotic families. *J Laryngol Otol* 1989;103:1036-9.
- Olsson H, Brandt L. Sex ratio in offspring of patients with non-Hodgkin's lymphoma. *N Engl J Med* 1982;306:367.

Occupational exposure to dust and lung disease among sheet metal workers

Sir,—The study *Occupational exposure to dust and lung disease among sheet metal workers* by Hunting and Welch (1993;50: 432-42) was an ambitious undertaking. This correspondence considers the modelling and selection techniques employed, the validity of the work history and exposure modelling, the potential impact of possible selection bias, and the appropriateness of the industrial hygiene evaluation on the fibreglass insulation findings.

In terms of the modelling and variable selection techniques, the final analyses of exposure v chronic bronchitis were not age adjusted even though the confounding effects of age are ubiquitous and universally recognised in epidemiological research. Age should have been included in the regression equation "regardless of statistical significance if such inclusion changes the estimated coefficients of the risk variables by any appreciable degree."¹ Without such an adjustment, the statistical significance of the association between chronic bronchitis and high level fibreglass exposure (ripout) may