A simple procedure for investigating differences in sexual dimorphism between populations

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Abstract

Although sexual dimorphism has a strong genetic component in many animals, external factors may alter its expression - enhancing or diminishing it depending on the parameter measured and the type of influence experienced. A measure of sexual dimorphism may be used, therefore, to characterise a whole population and the factors acting upon it. Differences between populations for such factors may then be investigated by comparing sexual dimorphisms and may be more informative than merely comparing population means.

A quick and relatively simple technique which provides a coefficient of the relationship between a continuous variable and another which is dichotomous, such as sex, is the point biserial correlation. This is a less frequently described extension of the commonly used Pearson product-moment correlation. The point-biserial correlation coefficients can be calculated for a given parameter and compared to determine whether the same sexual dimorphism is evident in different samples. If it is not, some factor influencing one or other population, as a whole, may require further investigation.

The full procedure, which can be performed without the need for statistical tables, and the necessary formulae are described. This method, in its generalised form, may also be applied to the study of bilateral asymmetry.

Introduction

Although sexual dimorphism has a strong genetic component in many animals, external factors may alter its expression - enhancing or diminishing it depending on the parameter measured and the type of influence experienced. Under optimal nutritional conditions, for example, both males and females may be expected to achieve their full genetic height potential (Gray and Wolfe 1980). Sexual dimorphism demonstrated under such conditions would reflect genetic rather than environmental factors. Where nutrition is less than optimal, males usually fare worse and failure to reach full genetic potential in parameters such as height is by a greater margin than in females. Accordingly, the degree of sexual dimorphism is reduced (Figure 1). A measure of sexual dimorphism may be used, therefore, to characterise a whole population and the factors acting upon it. Furthermore, differences in sexual dimorphism between populations may be more informative about factors acting on each population as a whole than simply comparing the separate sample means for males and females (Relethford and Hodges 1985).

A quick and relatively simple technique which provides a coefficient of the relationship between a continuous variable, such as height, and another which is dichotomous, such as sex, is point-biserial correlation (Bruning and Kintz 1987). This is a less frequently described extension of the commonly used Pearson product-moment correlation. The point-biserial correlation coefficients for two samples may be calculated for a given parameter and compared to determine whether the same correlation - here, indicative of sexual dimorphism - is evident in both populations. If it is not, some factor influencing one or other population, as a whole, may require further elucidation.

Procedure

Firstly, the point-biserial correlation coefficient for each mixed sex population is determined using the equation:

$$r_{pb} = \frac{\bar{x}_1 - \bar{x}_0}{s_x}\sqrt{\frac{n_1 n_0}{N(N-1)}}$$

... Eq. 1

Where

$\bar{x}_1$ is the mean of the values of the continuous variable in category 1 — males

$\bar{x}_0$ is the mean of the values of the continuous variable in category 0 — females

n_1 is the number of males in the sample

n_0 is the number of the females in the sample

s_x is the standard deviation of the continuous variable, all subjects – male and female – taken together (Eq. 2) and

N is the total number of subjects in the sample ($n_1 + n_0$).

(Males and females were allotted the categories 1 and 0 respectively so that ($\bar{x}_1 - \bar{x}_0$) would yield a positive result where male values are larger.)

The estimated standard deviation of the population (S_x) is determined by:

$$s_x = \sqrt{\left(\frac{\sum x^2}{N-1} - \frac{\left(\sum x\right)^2}{N(N-1)}\right)}$$

... Eq. 2

(It is important that the standard deviation is derived from raw data. Pooling separate standard deviations from two samples gives false results.)

Given two point-biserial correlation coefficients (r_{pb}) from different populations, they may then be compared using the equation:

$$Test\ Statistic = \frac{(z_1 - z_2)}{\sqrt{\frac{1}{(N_1 - 3)} + \frac{1}{(N_2 - 3)}}}$$

... **Eq**. 3

Where
N_1 and N_2 are the population sizes of the two groups compared and
Z_1 and Z_2 are determined, given r_{pb} for each population, using the equation:

$$z = \tfrac{1}{2}\ln\left\{(1 + r_{pb})/(1 - r_{pb})\right\}$$

... **Eq**. 4

Where **In** indicates the natural (base e) logarithm.

The statistical significance of the test statistic (sometimes denoted: Z) in Eq. 3 indicates whether the two correlation coefficients are describing populations which have the same internal relationship between the sexes for the chosen parameter. A significant result indicates that the two point-biserial correlation coefficients characterise populations where sexual dimorphism, at least for the parameter in question, is different. This may suggest that some factor affecting one or other population as a whole is being manifested in the way the physical differences between the sexes is expressed.

It is not necessary to use statistical tables to ascertain the significance of the test statistic. If its value is greater than 1.96, the result is significant at the 5% level; if greater than 2.576, then significant at 1% and if greater than 3.291, then significant at 0.1%. (These values are derived from the normal distribution curve).

Note:
The significance of r_{pb} may be determined, in the usual way for a correlation coefficient, by:

$$r_{pb}\sqrt{\frac{N-2}{1-r_{pb}^2}}$$

(*dof*: N-2))

… Eq. 5

Parameters found consistently to show a significant point-biserial correlation with sex within populations are those most appropriate for population comparisons as it is these which are more likely to have a genetic component which may be modified by environmental factors.

Corollary
This method, in its generalised form, may also be applied to the study of differences in bilateral asymmetry between groups - left and right taking the place of male and female.

References
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Gray, J. P. and Wolfe, L. B. 1980 'Height and sexual dimorphism of stature among human societies', *American Journal of Physical Anthropology* 53, 441-56.
Relethford, J. H. and Hodges, D. C. 1985 'A statistical test for differences in sexual dimorphism between populations', *American Journal of Physical Anthropology* 66, 55-61.

Figure 1 – Differential response to stress leading to a diminution of sexual dimorphism