CEPP Guidelines for the Use and Presentation of Statistics

These guidelines are intended to supplement the Section on *Methods of Statistical Analysis* in the *Instructions for Authors* (http://www.blackwellpublishing.com/submit.asp?ref=0305-1870&site=1). They extend and expand the Instructions and are accompanied by references that support and explain these guidelines. The Guidelines are presented as bullet points. References are given at the end, including some useful preliminary reading.[1–3]

We wish to emphasise that these guidelines are advisory and are not prescriptive; however, if authors follow them, they will find it much easier to negotiate the editorial process.

- **Statistical analysis or Data analysis, at the end of the Methods section of a manuscript**
  - (a) Describe in detail how you quantified your results.
  - (b) Describe in detail, if necessary with references, the statistical procedures you used to analyse your data.
  - (c) Explain <u>why</u> you used these procedures, especially if they are unusual.
  - (d) State what outcomes from the statistical procedures you used to test what hypotheses. For example, a complex analysis of variance can result in many terms; it is important to nominate those that test your hypotheses.
  - (e) State what statistical computer software you used (e.g. SPSS v. 16.0; SPSS Inc., Chicago, IL, USA).
  - (f) State what level of *P* you regard as 'statistically significant' (e.g. $P \leq 0.05$) and state whether *P* is one or two sided (the norm is two sided).
  - (g) If you also present confidence intervals (CI), state what range (e.g. 95% CI) and indicate how they were estimated. A useful reference source is the book by Altman *et al*.[4]

- Under the above heading, state how you estimated minimal group (sample) size. This is essential in the case of clinical studies, but optional in the case of laboratory studies. The purpose is to ensure that the risk of Type II error is controlled (e.g. that the power was 80 or 90%, for a Type I error rate corresponding to your critical value of *P*, usually two-sided $P = 0.05$).

- Pay special attention to the risks of making false statistical inferences if multiple comparisons have been made. State what procedure you used to control the family wise Type I error rate.[5,6] Note that it is not only multiple *P* values, but also multiple CIs that require correction.[7]

- The statistical symbols and abbreviations that conform to the style of *CEPP* are listed in the Appendix.

- When presenting the results of statistical analyses as *P* values, whenever possible give actual *P* values (rather than, for instance, $P < 0.05$).[1,2] This practice provides an indication of the strength of evidence against the null hypothesis.

- When selecting statistical tests, distinguish between <u>independent</u> and <u>related or serial</u> observations. The latter require procedures such as repeated-measures analysis of variance.[8]

- In your Figures, independent observations can be presented properly as bars indicating group means and corresponding standard error (SE) bars. However, this is unsuitable for related or serial observations, which are best presented by connecting the values for

individual experimental units in the case of paired observations or the group means in the case of multiple serial observations.[9]

- Do not use a correlation coefficient (r) unless it is accompanied by the outcomes of the corresponding regression analysis, designed to estimate a dependent variable by one or more independent variables. The Pearson correlation coefficient (or, strictly, the coefficient of determination, r^2) merely indicates goodness of fit.

- Note that ordinary least-squares (OLS) regression analysis is applicable only if the x values are fixed in advance (Model I regression). If both x and y values are free to vary, Model II regression analysis should be used, for example, ordinary least products (OLP) regression analysis.[10]

- Great care should be taken when selecting a statistical procedure to analyse categorical data. In the case of two-way tables of frequencies, exact methods of analysis are preferred.[11] In more complex situations, you should consider using binomial logistic regression analysis.[12]

References

1. Curran-Everett D, Benos DJ. Guidelines for reporting statistics in journals published by the American Physiological Society. *Am. J. Physiol. Regul. Integr. Physiol.* 2004; **287**: R247–9.

2. Ludbrook J. Comments on journal guidelines for reporting statistics. *Clin. Exp. Pharmacol. Physiol.* 2005; **32**: 324–6.

3. Ludbrook J. The presentation of statistics in *Clinical and Experimental Pharmacology and Physiology*. *Clin. Exp. Pharmacol. Physiol.* 2008; **35**: 1271–4.

4. Altman DG, Machin D, Bryant TN, Gardner MJ (eds). *Statistics with Confidence*, 2nd edn. BMJ Books, London. 2000.

5. Ludbrook J. On making multiple comparisons in clinical and experimental pharmacology and physiology. *Clin. Exp. Pharmacol. Physiol.* 1991; **18**: 379–92.

6. Ludbrook J. Multiple comparison procedures updated. *Clin. Exp. Pharmacol. Physiol.* 1998; **25**: 1032–7.

7. Ludbrook J. Multiple inferences using confidence intervals. *Clin. Exp. Pharmacol. Physiol.* 2000; **27**: 212–15.

8. Ludbrook J. Repeated measurements and multiple comparisons in cardiovascular research. *Cardiovasc. Res.* 1994; **28**: 303–11.

9. Cumming G, Fidler F, Vaux DL. Error bars in experimental biology. *J. Cell Biol.* 2007; **177**: 7–11.

10. Ludbrook J. Statistical techniques for comparing measurers and methods of measurement: A critical review. *Clin. Exp. Pharmacol. Physiol.* 2002; **29**: 527–36.

11. Ludbrook J. Analysis of 2×2 tables of frequencies: Matching test to experimental design. *Int. J. Epidemiol*. 2008; 18 Aug 2008 [Epub ahead of print].

12. Hosmer DW, Lemeshow S. *Applied Logistic Regression*, 2nd edn. John Wiley & Sons, New York. 2000.

APPENDIX

MATHEMATICAL OPERATORS AND STATISTICAL SYMBOLS

Unless indicated by †, the symbols are those recommended by the Council of Science Editors (CSE) and should be regarded as the benchmark for all scientific publications. The reference is Council of Science Editors, Style Manual Subcommittee. *Scientific Style and Format: The CSE Manual for Authors, Editors and Publishers*, 7th edn. Rockefeller University Press, Reston, VA. 2006.

Mathematical operators

+	Plus
-	Minus
×	Multiplied by
/ or ÷	Divided by
Δ	Increment of
∫	Integral of
=	Equal to
≡	Exactly equal to
≅	Approximately equal to
≠	Unequal to
≥	Equal to or greater than
≤	Equal to or less than
α	Proportional to
x^2	x squared
$\sqrt{x}$ or $x^{0.5}$	Square root of x
$\sqrt[3]{x}$ or $x^{0.333}$	Cube root of x
$x!$	x factorial (e.g. $4! = 4 \times 3 \times 2 \times 1 = 24$)
$\|x\|$ or abs x	Absolute value of x (no sign; e.g. –9 becomes 9)
$\log_{10}$	Logarithm to base 10
10^x	Anti-$\log_{10}x$
ln or $\log_e$	Natural logarithm, log to base e
e^x or exp x	Exponential of x
{[( )]}	Hierarchy of enclosures for mathematical equations

Statistical symbols

Descriptive statistics

N	Population size
n	Sample size
X, Y etc.	Population variables
x, y etc	Sample variables
Σ	The sum of (e.g. $s = \sum(x - \overline{x})^2 / (n-1)$)
μ	Population mean
$\overline{x}, \overline{y}$ etc.	Sample mean of x, y etc.
σ	Population standard deviation
s or SD	Sample standard deviation (use SD if there is a chance of confusion with s for seconds)
σ^2	Population variance
s^2	Sample variance
SEM† or $s_{\overline{x}}$	Sample standard error of the mean (i.e. SD/$\sqrt{n}$)
CI	Confidence interval (usually 95% CI)
r, c	Rows and columns in an r × c table of frequencies
π	Population proportion
p	Sample proportion
%	Percentage ($100 \times p$)
odds†	Ratio of two frequencies
OR†	Odds ratio (ratio of two odds)
RR†	Relative risk (ratio of two proportions; i.e. p_1/p_2)
logit†	Logit (corresponds to $\ln(p/(1-p))$ or ln(odds))

Statistical tests

F	Variance ratio (Fisher), usually with d.f. (e.g. $F_{1,23}$)
t	Student's t statistic, usually with d.f. (e.g. t_{13})
χ^2	Chi-squared statistic, usually with d.f. (e.g. χ^2_4)
$U^\dagger$	Mann–Whitney statistic
T_1,† T_2; T_+, T_-	Wilcoxon rank sum statistics
υ or d.f.	Degrees of freedom
H_0	Null hypothesis
H_1 or H_A	Alternative hypothesis
α	Probability of Type I error
β	Probability of Type II error
$1-\beta$	Power to reject H_0
P	Probability of false rejection of H_0

Regression analysis

b_0, b_1, b_2 etc	Regression coefficients
b_0 or a	Constant in regression (e.g. $y = a + bx$ or $y = b_0 + b_1x_1 + b_2x_2$ etc.)
$\hat{Y}$	Estimate of population value of Y
ε	Random error in regression model (e.g. $\hat{Y} = b_0 + b_1x_1 + \varepsilon$)
r	Product–moment correlation coefficient
r^2	Coefficient of determination

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