# BIOMETRICS INFORMATION

(You're 95% likely to need this information)

SUBJECT:      On the presentation of statistical results: a synthesis

One of the final steps of a study is to communicate its findings to others via a report or journal publication. This pamphlet provides guidelines for presenting statistical analysis in a report or journal paper. It is a synthesis of the main ideas presented by Warren (1986), Fowler (1990), Mills (1993), and Railey (1994).

First and foremost, the report should describe clearly the background of the experiment, the objectives and the experimental design (e.g., randomized complete block design; split-plot design; Latin square) so that the readers can appreciate the design of the study and judge the efficiency of the data analysis (Railey, 1994). Sit (1993) provides a check list of the essential elements that must be addressed when presenting an experimental or sampling design. Next, the report should describe in detail the method of analysis. Use standard statistical terminology instead of software acronyms (e.g., "general linear model was used" instead of "Proc GLM was used"). In the report be sure to:

- State the model on which the analysis was based.
- State the assumptions made in the analysis.
- Describe the method of analysis used to address each objective. The analysis method should match the study design.
- Identify the variables used in the analysis. Provide reasons if a transformation was performed on a variable.
- Justify the exclusion of any data from the analysis (e.g., outliers). Provide reasons for doing subgroup analysis.

The report should provide sufficient quantitative information to allow readers to evaluate the appropriateness of the analysis and to draw their own interpretations. The report should also include summary statistics (e.g., mean, standard error, and sample size) to show the data structure and to justify subsequent analyses. Be sure that the standard error calculation matches the study design. For example, in a completely randomized design with subsamples, the correct standard errors for the levels of the main factor should be based on the experimental units, not the subsamples. Standard errors calculated using the subsamples tend to underestimate the true variations. Where the data are not normally distributed, other summary statistics such as median, mode, or frequency counts should be reported instead.

The remainder of this pamphlet details the type of information required for some of the commonly used analysis methods. Where appropriate, an example statement for use in a report is included within parentheses.

ANOVA type of analysis

      For ANOVA, ANCOVA, and MANOVA types of analysis, the following information should be included in a report.

- State the statistical model and the nature of the factors (random or fixed; nested or crossed).
- Provide an ANOVA table[1] that includes the sources of variation, degrees of freedom, sum of squares, appropriate error terms for the relevant tests, and P-values.
- Report results of diagnostic checks on ANOVA assumptions.
  ("a probability plot of the residuals indicated that the normality assumption was reasonable"; "a plot of the residuals versus predicted values showed no obvious pattern, suggesting that the assumptions of independence and equal variance were reasonable")
- For factorial designs, intepret the interaction term first, followed by the main factors.
- If appropriate, state the multiple comparison test used, and give reasons for the chosen test. ("The least significant difference method with a Bonferroni correction was used to make pair-wise comparisons between treatments, and to control the overall Type I error rate.")
- Present the statistical power of the test for all non-significant results using a biological meaningful effect size. The power of the test allows readers to judge whether the non-significant results were real or only a consequence of small sample size.

Regression analysis

- Report the adjusted $R^2$ value and sample size.
- Justify any pooling of data from different populations (e.g., data from different sites).
- Provide results of regression diagnostics.
- Explain why a particular equation was chosen for the final regression.
- Interpret the form of the regression equation.
- Give the range of the x-variable where predictions using the regression equation are valid. Do not extrapolate regression results beyond the range exhibited in the original data.
- Provide estimates of standard error for all predictions.
- Plot raw data and fitted equation on the same graph to demonstrate the fit of the regression model.

Contingency table tests

- Include contingency table with both observed and expected counts.
- State the test used according to the study objective (e.g., chi-squared goodness of fit test; chi-squared test of independence; chi-squared test of homogeneity; log-linear model).
- Address the issue of low cell counts.
  ("Lichen score classes 0 and 1 were combined to eliminate cells with expected counts of zero.")
- Discuss the biological implications of combining data classes.

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[1] Refer to Sit (1995) for sample ANOVA tables for various experimental designs.

Estimation of means, totals, or other population parameters

- State sampling method used for data collection. (e.g., simple random sampling; cluster sampling; stratified sampling; multistage sampling.)
- Report standard errors for all estimates.  Be sure that the formulae used to calculate standard errors match the sampling design.
- Include confidence interval for the estimates if appropriate.

Repeated measures

- Explain the repeated nature of the data.
- State the analysis method used (split-plot in time; MANOVA; response curve analysis) and the reason for the chosen method.
- See discussions on "ANOVA type of analysis" for reporting the results from the ANOVA component of the repeated measures analysis.

In presenting and discussing results, keep in mind the limitations of the study.  Do not generalize the results beyond its scope.  For example, a study that examines the effect of aspect on tree growth can only conclude that aspect might be associated with tree growth.  It cannot establish cause and effect because aspect was not randomly assigned to individual areas.

Warren (1986) stated that "statistical analyses provide objective criteria to aid in the decision-making process; they do not, in themselves provide the decision."  Statistical significance *alone* can be misleading.  With a sufficiently large sample, any difference, no matter how small can be found statistically significant.  Therefore we must use our experience and knowledge when interpreting statistical results.  Finally, we must distinguish between testing and generating hypotheses.  It is tempting to examine the data from all possible angles to search for "significant" findings.  As stated by Mills (1993), "If the fishing expedition catches a boot, the fishermen should throw it back, not claim that they were fishing for boots." — though, another expedition might be planned to properly check if the fishing pond is a good place for boots.

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