Writing Up Your Research Results for Publication

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MaryAnn Foote has done an excellent job of presenting a guide to writing up research results for publication. [1] , [2] , [3] , [4] She has taken sections of a typical clinical trials research report one at a time and shown how it is done, focusing on ***CHEST*** requirements. Other very useful guides to scientific writing have also been published. [5] , [6] , [7] , [8] , [9] , [10] , [11] , [12] , [13] , [14] , [15] , [16] , [17] The brief dissertation that follows is similar but presents in one document all elements of a research paper that may be either basic or clinical. It is also intended to be broadly applicable beyond ***CHEST***. It does not address a variety of important associated issues such as who should be on the author list and in what position, which journal to submit to, or which ethical/conflict-of-interest issues to confront. At the outset, it must be recognized that there are literally thousands of scientific journals in existence. Each has its own list of instructions for authors that may to some extent conflict with, and therefore trump, the stereotypical approach of what now follows.

Typical Architecture of a Scientific Report

The most common report structure is presented in Table 1. Different journals may request different specific formats, sequencing, and emphasis, but it is hard to present a paper without each of the basic elements cited in Table 1, especially the following: introduction; methods; results; and discussion. In Table 2 are the attributes of a good paper. What follows is a set of principles for meeting the criteria set out in Table 2.

Table 1 -- Usual Elements of a Research Report

Title (on a title page encompassing authors, affiliation, contact information, and often a short running headline for the top of each page)
Abstract
Key words
Introduction
Methods
Results
In the text
In tables
In figures
Discussion
Conflict-of-interest disclosures; financial support for the research
References

Table 2 -- What Makes a Good Research Report

Text that throughout the paper
Is clear, concise, and not repetitive Flows well from section to section Is free of errors of spelling, syntax, and grammar
An introduction that is focused and leads naturally to a hypothesis A stated hypothesis that is novel and addresses an important problem Sound methods that have been validated Data that are presented by optimal combination of text, figures, and tables Figures and tables that can be understood without reading the text Correct statistical treatment and accurate reporting of the data Discussion that
Interprets, not repeats, the results Is divided into sections, with each one signposted with subheadings Is concise, balanced, and not selective Weaves the current results into the existing state of the art
Conclusions that are accurate and do not overreach what the data show References reflecting balance

Writing Principles for Each Section of the Report

Title

Most journals impose character limits, and so within those limits the title should do the following:

- Tell the story, including the outcome, and mechanisms when possible;
- Be unambiguous;
- Include reference to the experimental model;
- Begin with an important word;
- Be devoid of unnecessary words or cute quasi-scientific language; and
- Not have undefined abbreviations unless they are in very common usage.

Here is an example. Investigators are comparing the exercise capacity of normal rats in normoxia and hypoxia. A common title might be “Effect of Hypoxia on Exercise Capacity in the Rat.” However, a better title would be “Hypoxia Reduces Exercise Capacity in the Rat by Limiting O_2 Diffusion Within Muscle.” At 83 characters (including spaces), the latter title abides by many journal limits on total character count, but still manages to indicate the model (hypoxic exercise), the species (rat), the outcome (hypoxia reduces exercise capacity), and the mechanism (reduced diffusive transport of O_2 in muscle). The former title may have the virtue of brevity, but at the expense of failing to indicate the outcome and the underlying mechanism. The second title will probably catch more interest and a wider readership because of its richer content.

Abstract

The abstract is the entire paper reduced to its essence and may be all that many readers will see. It should contain all of the major elements listed in Table 1, especially introduction, hypothesis, methods, results, and conclusion. Obviously each of these has to be brief, and contain only essential, high-level information. To stay within word limits, and also to maintain reader attention, nonessential data should not be included. The introduction should in one to two sentences bring the reader to the point of expecting the next item (the hypothesis), which should fit within a single sentence. Next should be the overview of the experimental methods/strategy. It should include species and number of subjects (or cells or molecules, as appropriate) including control subjects, and give a high-level statement of the study design. Results should follow, limited to those that are key. If space permits, include data values and statistical outcomes. Finally, present the conclusion allowed by the data, referring back to the hypothesis and whether it is supported or not. In practical terms, it is common to write the first draft of the abstract without too much concern for word limits, just to set the major elements in place, and then refine the text to fit the allowed space in a second step.

Most journals ask for a list of 5 to 10 key words, which are used to facilitate reader searches for your paper. These are usually words not already in the formal title of the paper. They should identify key issues of interest to potential readers, and be chosen to try and help them find your paper once published. In the above example ("Hypoxia reduces exercise capacity in the rat by limiting O_2 diffusion within muscle"), one might consider as additional key words the following: altitude; maximum oxygen uptake; and oxygen transport. But, choose them carefully as this may well determine who does and does not see your paper.

Introduction

Most important is to keep in mind the purpose of the introduction, which is to provide background mostly for the nonexpert to give them enough information that they could predict your hypothesis before you state it. It should start by indicating the broad nature of the problem being addressed, continue with some references to specific articles that are key in the history of the area, state what is missing, and then lay out your hypothesis. Ending with just one to two sentences that lay out the study design and even the outcome from a high level is often useful as a bridge to the methods and results that will follow. However, this is optional.

Continuing the example of hypoxic exercise, the introduction might be structured something like this (somewhat abbreviated), as follows: "It has been known for many years that ascent to altitude, causing hypoxia, results in reduced ability to exercise (refs). It has always been assumed (refs) that this is explained by reduced inspired Po_2 leading to reduction in arterial O_2 content, which in turn causes the exercising muscle circulation to be undersupplied with O_2, a condition termed reduced O_2 delivery. However, there is a final step in O_2 transport to the muscle metabolic machinery that has not been explored, yet which could play a major role in limiting O_2 availability in hypoxia. That step is diffusive transport of O_2 from the muscle microcirculation to the muscle mitochondria. We hypothesize that this final step is as important as reduced O_2 delivery in limiting exercise. To test this idea, we exercised rats maximally in both normoxia and hypoxia, and measured the diffusive conductance for O_2 between the RBCs and mitochondria within muscle. The results showed that impaired delivery alone could not account for the degree to which exercise was reduced by hypoxia, and that limited O_2 diffusion within muscle was as important as reduced delivery in impairing hypoxic exercise."

Methods

This section usually begins with a statement about study subjects, providing assurances of animal/human use committee approvals. Such a statement is required by most journals, so refer to their instructions and comply. Of course, theoretical studies or bench studies of instruments, for example, may not require this.

Next should come a study design section (indicated as such by a subheading) that lays out the high level experimental plans but without going into details. In the rest of the methods section, which lays out each specific technique, it is a good idea to also use subheadings for each method applied. This separates the methods so that readers know where to read and where to skip depending on their interest in the details. When methods reflect very common analyses, it is usually sufficient to reference the method and keep the details to a minimum, perhaps indicating only any modifications you have inserted. When methods are not widely known, you will have to provide enough detail to convince the reader that your methods are reliable.

Most methods sections end with a description of the statistical procedures applied. Very often the wrong test is used, or the test is not adjusted for such issues as multiple comparisons/use of data, or normalcy of the data distribution. When in doubt, it is best to consult a statistician about which tests are best suited to your particular data set. Parenthetically, one should seek this advice prior to initiating the study as such a discussion may well change the study design. The question often arises whether to express data variance by SD or SEM. The former describes variance within a cohort, the latter describes variance of the cohort means. Both have their place and are easily derived from one another knowing the number of members in the cohort (SEM = SD/[square root of the cohort number]). Journal rules and reviewers are often specific on which to use.

Results

Decisions in presenting the results stem from the following questions: which data should be presented (and which omitted)?; in what sequence should the data be presented?; and what should be stated in the text vs tables and figures?

In general, the most important results should be shown first, the least important last. One exception may be simple descriptive statistics concerning the cohorts themselves (*eg*, age, height, weight, and gender), which are often put first, especially in human studies, to put the reader's mind to rest about the possibility of confounding anthropometric factors. As with the methods section, it is suggested that the results be separated by subheadings according to methods or thematic categories. Under each subheading, all included cohorts are normally compared. Being concise is as important here as elsewhere in the paper. Finally, not all data collected may need to be reported. A rule of thumb is to present only those data that have a bearing on the interpretation of the study and that would therefore surface somewhere in the discussion.

Presenting data within the text is space efficient but often hard for the reader to assimilate. It works best for simple outcomes, especially those that are not central to the study, where the data can be presented as mean or median values, and where only two cohorts are being compared.

Using tables is good when many variables need to be compared individually among cohorts at the same time, where there are several cohorts, and where you want the reader to have access to the actual numbers. It is also usually space efficient. In using tables, it is important to define all abbreviations, to include units of measurement, and to provide statistical outcomes. Considerable thought should be given to the table layout, with the objective being ease of understanding by the reader.

Figures are usually space intensive and should be used when relationships among different variables are being explored, when a time course is important to describe, and obviously for images of, for example, tissue or blots. Relationships are very hard to extract from a data table. Keep in mind that it is generally not appropriate to try and clean up images that have odd spots and dirt, or otherwise enhance such images, by digital editing. When in doubt, contact the journal editor first. In preparing figures, ensure that text and symbol size are large enough to survive substantial size reduction.

No matter which format combination is used, it is important to avoid duplicating the same data in text, tables, and/or figures. It is also important that both figures and tables stand alone; that they can be understood without reference to the text. Finally, if re-presenting data from prior published work is essential (usually to compare specific findings across time or cohorts), one must be completely open about acknowledging prior publication, and it may well benefit you to contact the journal editor prior to submission to explain the situation and get advice.

Discussion

The discussion section is usually where most revision is required after peer review. The most common concerns include the following: it is too long, rambling, and unfocused; it is of little or no relevance to the present study; the literature review is selective, and is biased in support of the paper; there is too much re-presentation of the data; it fails to interpret the data and place them in the context of prior work; it fails to reconcile divergent findings of other investigators; its limitations are not adequately discussed; and it overly extrapolates findings, concluding more than the data allow.

These criticisms can be largely prevented by directly thinking about each as you construct the discussion. Using subheadings for each topic discussed, keeping the text concise and focused on the main issues, striving for balance in quoting the literature, avoiding re-presenting the results, trying to really interpret your data and reconcile findings different from those of others, acknowledging study limitations, and, especially, not overextrapolating the conclusions, are the key strategies for building a good discussion. The discussion is no place to show arrogance or to be dismissive of the work of others.

References

Common concerns in the reference list include the following: not using the right format for the particular journal; citation/spelling errors in the references; being lazy by referencing reviews by other authors rather than the primary articles on the topic; attributing a prior finding not to the original discoverer but to someone who later rediscovered it; being selective and choosing just those references that support your viewpoint; using particular references erroneously; and missing citing of references of importance through ignorance. Each of these problems has obvious solutions that all boil down to fastidious attention to detail.

Summary

If you have read through this entire dissertation, what will be evident is that composing a good paper is truly a matter of common sense. If you combine a fastidious approach, concise writing, clarity of data presentation, logical sequencing and linkage from section to section, and remember that the term “discussion” means just that, you will end up with a good paper, provided of course you had good data to start with.

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