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Basic Approach to Data Analysis and Writing of Results and Discussion Sections

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Abstract

A research paper or thesis writing is considered hard and very difficult process of intense concentration and brain work. Readers generally are first interested in new results of the paper. Writing results section contains new results from research investigation but is difficult in comparison to writing methods section as the latter section is already written at the proposal writing stage and requires only language change. Results section is heart of the paper and its completion with methods section already written; implies more than 50% of paper or thesis writing work and it become 70% paper writing work with writing of discussion section. Results writing section should be organized into different segments of text and visuals such as tables, figures, algorithms, etc. In order to start writing results section, we make a beginning with data analysis and its presentation of key findings as summarized results to yield an answer to the research question that study attempted. Answers to the questions and interpretations are presented in the discussion section. Data analysis is primarily linked with writing text part of the results and discussion of results. This is a desired sequence to work with in paper writing. The attempt of working in such a sequence provides a convenient approach to young researchers or post graduate/under graduate medical students to gain confidence in writing a research paper or thesis or a research report. While basic knowledge of study design and analysis is needed, the involvement of a qualified bio-statistician is recommended in various stages up to publication. In this communication, we describe the basic approach of data analysis required for initiating writing results and discussion while quoting the required rules for the purpose.

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Full Text

Introduction

Introduction, methods, results, and discussion (IMRAD) are sections of the format generally adopted in writing an original research article/paper.[1] Bio-medical post graduate (PG) or doctoral thesis[2],[3],[4] and other scientific reports are also basically and broadly written in IMRAD format with inclusion of some additional sections. There are number of articles available in literature[5],[6],[7],[8],[9],[10],[11],[12],[13],[14],[15],[16],[17],[18],[19] on writing of scientific manuscripts. A scientific manuscript tells the story of the study from framing of research question, data collection, statistical analysis, and discussion of results. Results are a text-based presentation of key findings with reference to tables and figures. Thus, data analysis is a primary work in this direction to prepare required tables and figures which serve as ingredients for paper writing. Research manuscripts are presented in IMRAD format, yet the order of writing work generally begins with results section. This section provides new information related to answering the research question. The desired answers to the research questions and interpretations of results are provided in the discussion section. Results section attempts to present the results of the analyses obtained on data collected on the medical investigation of interest after application of statistical analysis methods of descriptive and inferential types. Thus the data analysis and writing of results and discussion sections are interrelated. There is much literature and published guidelines available exclusively for writing results and discussion sections of a paper[20],[21],[22],[23],[24],[25],[26] but the presentation of their interrelationship with data analysis is attempted in this comprehension. Such a presentation along with gist of rules of writing is likely to provide a brief in sight of writing results and discussion sections of a paper to young researchers, under graduate (UG), and PG bio-medical students. We begin with some essential basics of handing data by summarization illustrations that help identifying the direction for generating required material for results section. In addition, we explain the rules as observed from literature for writing results and discussing the results.

Data

Data analysis has two broad approaches − obtaining descriptive features as estimates and performing tests of hypothesis to obtain inference on the data collected [Figure 1]. Data can be classified as either numerical or categorical. Numerical or quantitative data can be further classified as discrete or continuous and categorical data can be nominal or ordinal in nature [Figure 2]. For example, individual's height and weight, etc., are continuous. Categorical data are further classified as nominal or ordinal. In nominal, categories have no ordering (e.g., sex: male/female). In ordinal, categories are ordered (e.g., grade: A/B/C/D, rating: high/medium/low). Any measurement of quantitative type or categories of a quality observed from individual's measurements are called variables. Quantitative variables as against qualitative categories are those which are usually either measurements or counts in a discrete or continuous form. Continuous variable assumes uninterrupted range of values and on the other hand, counts are positive whole numbers. Quantitative variable such as age is numerical information and measured in years or months. Education and marital status will have non-numeric categories of qualities and whose categories are coded by assigning numerical numbers for the purpose of counting category responses. Quantities also can be converted sometimes into a qualitative variable by different groups of categories such as high and low blood pressure for a quantitative variable.{Figure 1}{Figure 2}

Data are summarized in the form of tables, graphs or numbers. The tables can be one dimension or two dimensions depending on the type of objective of analysis on a set of observed variables. Data are basically collected on a tool. Data collection tools include questionnaire, schedule or a proforma [Table 1]. Data from a questionnaire can be entered in a computer on an Excel spreadsheet, for example, as un-coded [Table 2] and coded [Table 3] form for further use. Sometimes information on a particular variable may be missing. The missing information of an item may be coded as "9" or "99" instead of leaving cell blank. Excel spreadsheet with information of each individual in a row may be formed as a data file for several individuals data. Such data files can be transferred to or made on statistical software such as SPSS or SAS or STATA or EPI. Statistical packages are widely available for tasks such as one-way tabulation or two-way tabulations. For data summarization, apart from tabular method, the other important methods are graphical and numerical.{Table 1}{Table 2}{Table 3}

By using data, tabular presentations may be in one dimension or two dimensions. For example, a one-dimensional or one-way classification of information on menstrual history of woman may have categories such as regular, irregular, and menopause may be performed by counting the codes corresponding to each response. Then codes are decoded and present the results. Similarly, a two-dimensional or a two-way table would have various headings of categories in horizontal rows and vertical columns. Such a cross tabulation is done when the interest is in assessing relationship between two variables. The values or numbers related to a combination of row and column is called a cell in a two-way table. If there are only two rows and two columns in a two-way table, such a table is called 2 × 2 table.

Consider the hypothetical data on cervical cancer screening shown in [Table 2] as it is entered in the Excel sheet. The coding for different variables is performed to make statistical analyses easier. Post coding for the above hypothetical example is illustrated in [Table 3].

Data Analysis

There are different methods of summarizing data depending on the type of data and the dimension (univariate, paired, etc.) of the variable. Univariate is one measurement or variable taken at a time for analysis, for example, height. Multivariables or multiple measurements are taken two or more at a time, for example, height, weight, sex. A Summarization can be in the form of graphs, as histograms which is a visual summary of the sample distribution, quantile–quantile plot which compares a sample to a known distribution, or scatter plot which compares a pair of points in (X, Y) axis.

The three broad steps to summarize data are:

Classify categorical data types into different tabular forms − one-way or two-way, etc. Use the appropriate numerical summaries for quantitative type of data − mean, standard deviation (SD), etc. Use appropriate visual summaries for different types of data − for categorical, bar, pie, etc., and for qualitative − histogram, scatter plot, box plot, etc.

For categorical data, frequency or counts are used to know how frequent different categories are. Tables are used to count the frequency or proportions from the total. Examples of tables are given in [Table 4],[Table 5],[Table 6]. One-way tables may be manually computed for variables such as menstrual history and clinical signs as shown in [Table 4] and [Table 5] by counting the frequency of codes for menstrual history (code 1 or 2 or 3) and clinical signs (code 1, 2, 3 or 4) given in columns 4 and 6 of [Table 3]. Two variables such as menstrual history and clinical signs were used as an example for studying relationship between two variables with the help of a two-way table [Table 6]. Then relevant percent for each category will be calculated and presented in the tables. The data can then be exported to statistical software such as SPSS for data analysis. These tables can also be generated in the computer using a statistical package for any sample size easily after a data file is created for the purpose.{Table 4}{Table 5}{Table 6}

For numerical data, the center or location measures the “center” of the data, for example, sample mean and sample median. For quantitative variable such as age [2nd column of [Table 3], mean and SD or other locations can be computed. Similarly, the other commonly used presentations for various other locations are percentiles, deciles, tertiles, etc. Percentiles divide data and present in one hundred while deciles and tertiles are ten and three parts, respectively. The spread or dispersion measures the “spread” of the data, for example, sample variance, inter-quartile range. In multiple variable numerical data, each dimension is uni-variate. Hence, numerical summaries from uni-variate data can be used for two-group comparison for a characteristic under study [e.g., hemoglobin (Hb) levels in diabetic and non-diabetics in terms of sample mean and SD]. To study two measurements or variables at a time to assess their relationship for example mother’s Hb level and newborn’s birth weight, numerical summaries such as sample correlation and regressions are used. Sample correlations and regressions measure the linear relationship between two variables.

The third type of summarization is graphical for both numerical and categorical type of data. Histograms are for numerical data, histogram is a method to show the “shape” of the data by using frequencies of the measurements in the sample. The distribution of the variable under study can be assessed whether it is symmetric (no skew) or bell shape, right or positive-skewed, or left or negative-skewed. Graphical presentations are commonly used in almost all disciplines. Graphical are used for displaying trends and contrasts hidden in the statistical information, and this method is often used in the presentation of statistical data in scientific articles and reports. There are various types of diagrams for displaying of different types of data. The frequently used types of diagrams are bar, pie, line, scatter diagram, etc. It is assumed that the reader is familiar with such presentations and advised to use Excel spreadsheet or any package for preparing good graphs.

Inferential summaries of results presentation have the components of estimation and test of hypothesis. The basis of estimation of measures is dependent on whether the data are qualitative or quantitative. The quantitative measures such as mean, SD, etc., and qualitative measures in frequency or proportion or rate or ratio etc., are computed to summarize data. These measures on sample (small group) of observations are called estimates of the population (larger group). A measure of sampling variability called standard error (SE) is used in estimating the confidence intervals (CIs). CI is measure of certainty as an interval estimate of the population summary measures such as mean and proportion. For example, suppose we have data on cholesterol level in 200 children of 4–10 years of age with mean 130 and SD 25, then what is the 95% CI of mean? The 95% CI is (mean + 2 SE), (mean−2 SE) or (130 ± 2 × 25 × SQRT 300) (130 + 2 × 1.45), (130−2 × 1.45) or (127, 133). The interpretation that there is 95% chance of population mean of cholesterol level in children of 4–10 years of age to be included in the interval (127, 133). A threshold of 95% confidence statement indicates that there remains an uncertainty of 5% which could result into a critical region that becomes the basis for hypothesis testing. The probability of wrongly rejecting a true null hypothesis (no difference between groups − proposition) is an error in statistical decision-making. This is also referred to as P value. The value of this error is generally kept at 0.05. This threshold of 5% is also called the level of significance. A result is called as “statistically significant” when $P < 0.05$. The approach of analysis of quantitative data and qualitative data are shown in [Figure 3] and [Figure 4], respectively. There are situations for comparison of means in hypothesis testing. This could be a comparison of means in two independent groups such as the comparison of mean Hb levels in a random sample of well-nourished and undernourished categories or groups. The situations where more than two means are to be compared, the procedure is called analysis of variance with F-test for assessing overall significance. When data on a group of the same patients are obtained at two different time points such as blood pressure or heart rate before and after a therapy, it is said to be in a dependent or paired set-up. Both these settings of unpaired and paired could be present with qualitative setting too.

When groups of comparison are more than two procedures, other than t-test are used. Along with results of estimates, CIs and tests of hypothesis, assessing strength of relationship between two qualitative and two quantitative variables, evaluators of diagnostic or screening test performances, etc., along with multiple regressions considering and evaluating the joint effect of several variables are also used in the presentation of results section. The analysis and presentation of results from such methods is out of scope of this introductory communication. Reader may refer to other material[27],[28],[29],[30] for more details on methods of analysis that obtain results that are presented in results section. The computation of tables or quantities and their estimates in terms of CIs or tests of hypotheses are summarized further to form crisp information for inclusion as contents in the results section. Such contents in the form of comprehensive tables and figures that have potential to answer the research question are part of results section. As a part of the team member of the investigation, authors must have some basic knowledge or training in research methodology, else it is advised to involve a qualified bio-statistician as a team member.{Figure 3}{Figure 4}

Involvement of a qualified bio-statistician as a team member

It is advised that preparing to begin writing for publication of research work begins with the data analysis that is required for results section of research paper. Data analysis is performed the investigators who are trained to that requirement themselves or by a qualified bio-statistician, this depends on the depth of exploration of data needed. It is a well known fact that if the quality of data collected by following a research design suited for the research question being investigated or objective being achieved is not met, the writing however best will not yield desired results for publication. Therefore, it demands either efforts of the investigators trained on these aspects or involvement of a biostatistician from the design stage of the research study (methodology section) through the subsequent stages of analysis and interpretation of results. In all such stages, involvement of a bio-statistician as a team member would reflect definite fulfillment of the felt need in the sections of results and discussion of the publication. Key messages on data analysis and data presentation are given in [Table 7].{Table 7}

Writing of Results Section

Suppose a testable hypothesis that can be answered experimentally, or a question that can be answered by collecting samples, we accumulate observations about those organisms or phenomena. Those observations are then analyzed to yield an answer to the question called key result. In the results section, it is required to present data that supports the results of research question. Data analysis and summarization becomes the first step and especially presentation of data in terms of tables, graphs, and computation of numerical values of central location and dispersion such as mean, median, and SD. The second step is summarization using inferential statistics results in terms of significance and exact P values.

Generally, the order of presentation followed in methods section will be adopted for writing results section. For example, if the sequence in methods section is about − study subjects, measurements, and statistical analysis, then the results section should include − presentation of characteristics in terms of one-way or two-way tabular form, this follows and further analysis of the summarizations both descriptive and inferential done on data based on objectives. Detailed data is presented as tables and figures to keep written data to a minimum. Some data descriptions are directly presented in the text. Generally, tables are used for large or complicated data sets that would be difficult to fully explain in the text. A textual presentation of key findings that emerge or reveal from figures and tables must be included in the results section. The tables or figures must always be referred in text.

The results section should be organized based on the sequence of tables and figures included. The tables and figures should be prepared as soon as all the data is analyzed. It is a good practice to note one or two key results from each table or figure to be addressed in the text portion of the results.

Numbers should be assigned to tables and figures in the sequence to be referred in the text as [Table 1], [Table 2], etc. and [Figure 1], [Figure 2], and so forth. Table is referred in the text as (e.g., [Table 1]), whereas figure is abbreviated as Fig. (e.g., [Figure 1]). The table and figure legends should include the brief description of the results being presented and any other necessary essential information. Results are a text-based presentation of the key findings with reference to the tables and figures. The key results should be stressed clearly providing the answers to the questions investigated. The tables should be mentioned sequentially clearly indicating the key results that they convey.[31],[32]

The results section objectively explains the key results in an orderly and logical sequence without interpretation, using both text and illustrative materials (tables and figures). The results section always begins with key results in the form of text followed by reference to figures and tables. The summaries of the statistical analyses can be done either in text (usually parenthetically) or in relevant tables or figures (in the legend or as footnotes to the table or figure). The results section should highlight the evidence needed to answer the questions/hypotheses investigated, reporting the negative results as well. The text of the results section should be concise and objectively written. Past tense should be used as the writing style. Repetitive paragraph structures should be avoided and data should not be interpreted in this section. Some points to remember while writing results are given in [Table 8].{Table 8}

The results of the experiment should be presented in logical sequence to support (or provide evidence against) the hypotheses, or answer to the question, stated in the introduction. It is important to report negative results. The hypothesis needs to reformulated if the anticipated results are not obtained or there is absence of an effect. Even though the results do not support the hypothesis, they may be of importance to others. Results obtained contrary to that expected should not be considered as “bad data”, as many important discoveries can be traced from it. Appropriate units should be used while reporting data or summary statistics. For an individual value, units should be written as “the mean age was 30 years.” On the other hand, for a series of numbers all having the same unit, the unit should be placed after the last value (e.g., height of 156, 154, 157, and 172 cm).

The use of the word, “significant” in scientific studies implies the statistical test indicated a larger difference in the particular variable in the study than expected to get by chance alone. If P-value in the statistical information indicates significance (usually when $P < 0.05$), it is unnecessary to use the word “significant” as the P-value is interpreted in the same way. Similarly, when the difference in means is reported, it is understood that it is tested and the difference is found to be statistically significant, especially if P-value <0.05 is reported.

Discussing Results of Research Study

In manuscript writing, one of the faltering blocks is preparation of a write-up on discussion on results. Discussion writing is a concern and a scary one even for many young faculty and students attempting to write their PG thesis. Discussion section presents the findings in a research context and explains the meaning of findings in its main purpose. The section provides answers to the questions posed in the introduction section and follows results section where new information related to findings on research question or questions presented. The sequence is that in the introduction, we arrive at a research question from a background of the research topic while in the discussion we begin with summary of findings and arrive at discussing the results by presenting interpretations, discrepancies, unexpected findings, weaknesses, and limitations.[20],[21],[22]

Checklists of guidelines for writing various sections of an original research article in IMRAD are available freely on internet sites such as STROBE[33] for observational studies, CONSORT[34] for clinical trials, and journal instructions on writing various sections of a research article. Yet the presentation of discussion section by authors in their research articles has wide variations. Authors adopt writing approach by reiterating the aim of the study or by specifying the major findings or a few start comparing the findings in the beginning. Even some authors view this section as if it is a review of literature and describe without relating to the findings of the study. Re-writing of most results again in discussion section is also a deviation from guidelines. The order of presentation by some authors is quite haphazard and not as dictated by the importance of the results presented in results section of the research article. Since every research paper has its unique results and findings, the order of discussion requires certain rules and guidelines following which the section is written to improve the quality of the manuscript. The narration and demonstration of available rules and guidelines of writing discussion in the light of published papers are helpful. Some important guidelines of writing discussion section are given in [Table 9].{Table 9}

Citing of references in discussion section

The work of others is used as citation primarily in the introduction section to develop back-group and rationale on the topic of research question and in the discussion section of the article or a thesis. No referencing of others work is cited in the results section while in methods section if necessary have some citations of others or standard methodology. Discussion of our results by comparing and contrasting the findings of other studies is of importance by citing and referencing of those studies. Whenever other studies’ findings are used, we must refer and cite the sources from which such information is drawn. Citing means acknowledging within our own text the related document from which information is obtained. References are the details of document included in a separate section at the end of our text. As against reference, the term bibliography is used in thesis/dissertation document which includes the total publications consulted. We generally look at the aspects in others studies for inclusion in our discussion of our results such as their objectives, findings and conclusions. We must take the information of other studies and put it in our own words to avoid plagiarism. This is related to use of others’ work or ideas or words without proper citing of their reference. In writing or reporting research, credit must be given for others’ ideas or writing or research.

There are standardized systems for referring to materials used in our writing with the help of a citation style or a reference system. Most biomedical journals including Maulana Azad Medical College Journal of Medical Sciences today use Vancouver style. In this style, a number is allocated to a source in the order in which it is cited in the text beginning from introduction to discussion sections. In case if the source is referred to again, the same number is used and the references are listed in numerical order in the reference list at the end of the paper. Academic institutions use, including for the purpose of thesis and dissertations, the other famous style of referencing called Harvard style. This is an author-date referencing style which varies in some features between institutions/journals such as punctuation, capitalization, abbreviations, and the use of italics.

Check list for observational and clinical trials

According to the checklist STROBE statement,[33] observational studies the number of individuals at each stage of study should be reported (e.g., potentially eligible participants, eligibility confirmed, those included in the study, those who came for follow up, and finally those who were analyzed). The reasons for non-participation at each stage should be given. Flow diagram showing the different stages of study should be considered. The demographic, clinical, and social characteristics of the participants should be given with information on exposures and potential confounders. The number of participants should be mentioned with mention about the missing data for each variable of interest. For a cohort study, the average and total follow-up time should be summarized. The number of outcome events or summary measures over time for a cohort study should be reported. In a case–control study, the numbers in each exposure category, or summary measures of exposure should be reported. For a cross-sectional study, the numbers of outcome events or summary measures should be reported. While reporting the main results, the unadjusted estimates should be given along with the confounder-adjusted estimates and their precision (e.g., 95% CI), if applicable. Explanation for including the confounders and how they were adjusted should be given. If the quantitative data is categorized, the category boundaries should be reported. For a time period, the relative risk and absolute risk should be translated into meaningful data. If any other analyses are done such as, analyses of subgroups and interactions, and sensitivity analyses should also be reported.

For a clinical trial, the CONSORT 2010 checklist[34] provides the necessary information to be included while reporting. It is strongly recommended that the participant flow should be explained in the form of flow diagram. The numbers of participants who were randomly assigned into each group should be mentioned, along with those who received treatment and who were analyzed for the primary outcome. After randomization, those participants who were lost or excluded for each group should also be mentioned. The recruitment period and follow up date should be stated. The reason for ending or stopping the trial should be declared. The baseline demographic and clinical characteristics should be illustrated in the form of table. The number of participants (denominator) for each group included in each analysis should be mentioned and whether the analysis was by original assigned groups. The results report the primary and secondary outcomes for each group with the estimated effect size and its precision (e.g., 95% CI). The absolute and relative effect size should be presented for binary outcomes. The subgroup analyses and adjusted analyses for pre-specified and exploratory analyses should be stated. As per the specific guidelines under ethics for harms, it is necessary to report all important harms or unintended effects in each group. The above description is on checklists for observational and clinical trial studies and there are checklists for other kinds of studies too in the literature.For discussion section, the desired checklist is to ensure whether the following are included − (i) key results summarized with reference to objectives, (ii) limitations with reference to source of bias along with magnitude and direction, (iii) interpretation of results in the light of objectives, limitations and results of other similar studies, and (iv) generalization of study results in terms of external validity.

There are many statistical terms[27],[28] used while writing the results section. Some commonly used statistical terms are given in [Table 10].{Table 10}

Summary

Writing a manuscript of a research article or a thesis on public health or any scientific subject is a stupendous process for learning writers. An original research article should follow the format of IMRAD following the sections in the sequence of Introduction, Methods, Results, and Discussion. Even though the IMRAD format is followed, the results section is written first that provides new information related to answering the research question. Sometimes first in the order of writing manuscript, methods section is preferred to results section as the former is already written section at the protocol level and only requires to be re-written in past tense. To make a beginning of results section writing, it is essential to understand its association with data summaries expected to give answers to the research questions attempted to answer. Results section attempts to present the results of the analysis obtained on data collected on the investigation of interest after application of appropriate statistical tools. This communication attempts to present the link between data summarization and writing text part of the results section. This attempt provides tips to young researchers in writing paper and PG/UG medical students in the thesis writing. The completion of results section along with methods section constitutes 50% of the paper writing work and the young researcher or student who is attempting first research paper or thesis writing can gain confidence in the process of research document.

Questionnaire, schedule or proformae are the commonly used data collection tools. Data can be either numerical (or quantitative) or categorical. Numerical or quantitative data can be further classified as discrete or continuous. Categorical data can be nominal or ordinal. Various methods of summarization of data include tables, graphs or numbers. Depending on the type of analysis the tables can be one-dimension (or one-way) or two-dimension (two-way). Excel sheet is used for data entry and data analyses are done using statistical packages.

Data summaries are generally prepared and presented through tables and graphs. Trends are displayed using graphs such as bar,

pie, line, and scatter diagram. Data summarization can be descriptive or inferential. Descriptive summarization can be performed in the form of graphs, as histograms, quantile–quantile plot or scatter plot. The data needs to be classified into different types and then depending on the type of data, appropriate numerical and visual summaries are used. The estimation and test of hypothesis are the components of inferential summarization. This is dependent on whether the data are qualitative or quantitative. Mean, SD, etc. are quantitative measures whereas frequency, proportion, rate or ratios are qualitative measures. Involvement of a qualified bio-statistician is recommended as a team member for contribution in study design, statistical analysis and publication.

The text part of results is presented in the past tense and all the contents of what is presented in tables and figures should not be repeated in the text results. As this section provides new information in the related research question attempted to answer, key consideration and rules of writing this section help to produce a good text part of the results section. Following data summarization based on the objectives, the results section is written. The text part of all the contents of what is presented in tables and graphs should not be repeated in the text results. In this section, each paragraph begins with a result. Most of the data is presented in the form of tables and figures and its use is mentioned in the text. Results section objectively explains the key results in an orderly manner and logical sequence without interpretation. The evidence needed to answer the questions/hypotheses investigated should be highlighted in this section. It is important to highlight the negative results as well. As compared to other sections of the manuscript, discussion is considered hard to define. It describes virtues; interpret results, state limitations and future recommendations. It is focused to answer the research question raised in the introduction section of the manuscript. It includes statements on important results and compares study results reported previously. The approach of working on data summarization and begin the writing of text part of the results and discussion of results together is expected to help the young researchers or UG and PG medical students to make a good beginning in writing research paper or thesis writing.

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Conflicts of interest

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