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Review Article

An overview of the basic processes of biomedical research: A narrative review

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ABSTRACT

The role of scientific research in current medical practice is crucial, and engaging with research is vital for medical students right from the beginning of their professional journey. This early involvement in research brings numerous benefits that have a lasting impact on their academic years as students and their future careers as professionals. Research experience in undergraduate medical students will also have a positive influence on their future performance and will enable them to develop essential skills such as leadership and critical analysis, irrespective of their chosen professional path in research, academia, or clinical practice. However, there are various obstacles and challenges that make it difficult for undergraduate students to participate in research, resulting in fewer medicos who are interested in conducting studies. Therefore, it is important to execute suitable techniques and approaches to aid this method, aiming to encourage the early acquisition of crucial abilities that will improve ethical clinical practice. It is important to have a comprehensive understanding of the scientific data in the context before recommending academic proposals that are tailored to each specific context. This article aims to highlight the significance of doing biomedical research during undergraduate years and the step-by-step process involved, starting from generating an idea to disseminating the research through publication.

Keywords: Funding, Medical, Medical students, Publication, Research

INTRODUCTION

In many countries, training in medicine is now incorporating undergraduate research studies as one of the most important aspects. Regardless of whether professionals choose a research, academic, or clinical career, their participation in undergraduate research has had a positive impact on their future performance and has enabled them to acquire crucial skills such as leadership and critical analysis.[1] Undertaking a research project can address numerous questions and is highly valued by medical students as it enhances their learning experience.[2] Additionally, having research experience as a student is not only personally fulfilling but also advantageous for future endeavours such as writing a postgraduate thesis and job applications, as it adds value to their resumes.[1] However, despite growing acknowledgement of the value of research, medical students participation in research remains restricted, due to lack of finding time beyond academics, good mentors and funding. The majority of medical students lack understanding of relevance of research in science and its processes.[3] On the other hand, students who conduct research are far more inclined to make publications of their scientific works, produce higher-quality articles,

experience greater career satisfaction, and enjoy improved economic and educational stability.[1]

Through analysing various studies, it has been determined that initiating research at the beginning of one's medical career is considered optimal.[4] Furthermore, it has been noticed that undergraduate students who engage in writing articles are more inclined to continue writing and publishing manuscripts even after their graduation, in comparison to those who start writing after completing their studies.[5] The purpose of this article is to emphasise the significance of biomedical research and the step-by-step process involved, starting from generating an idea to publishing the research for wider distribution.

The different fundamental steps in a research process are outlined below - Figure 1.

Conceiving a research idea (Problem identification)

Conceiving a research idea involves a creative and systematic approach. The initial and most important element of the research process is the recognition and defining a research problem. In any research context, identifying problems may comprise analysing them, describing them from many aspects, studying them using diverse theoretical concepts, and generating different opinions and ideas about how to solve them.[6] Here are some steps to help you in the process:

Identify your interests

Start by exploring areas of interest within your field of study. Consider topics that intrigue you, problems you want to address, or gaps in current knowledge that you find compelling.

Figure 1: Steps in research process.

Review existing literature

Conduct a thorough survey of the available literature to gain insight into the present level of knowledge in the area of your interest. This will help you identify gaps, unanswered questions, or areas that need further exploration. The common resources include online repositories like PUBMED/MEDLINE and Google Scholar.

Brainstorm and generate ideas

Engage in brainstorming sessions to generate potential research ideas. This can involve discussing with peers, mentors, or experts in the field, attending conferences or seminars, or even exploring interdisciplinary connections.

Narrow down your focus

Once you have a list of potential ideas, narrow it down by considering factors such as feasibility, relevance, significance, and potential impact. Evaluate the resources, time, and expertise required to pursue each idea.

Define your research question/objective

Based on your narrowed-down ideas, develop a clear research question or objective that guides your study. Make sure it is specific, measurable, achievable, relevant, and time-bound (SMART). A clear research question is essential as it focuses the study, guides methodology, and ensures relevance, efficiency, and clarity in research findings.

Refine and align with the existing research

Ensure that your research idea aligns with the existing body of knowledge and complements or extends previous studies. It should contribute something new or provide a fresh perspective to the field.

Seek feedback

Share your research idea with mentors, professors, or colleagues and seek their feedback. Their input can help refine and strengthen your research idea, and they may offer valuable insights or suggestions.

Pilot study or feasibility assessment

Before undertaking a full-scale research project, consider doing a trial project or possibility analysis to determine viability and practicality of your research idea. This can help identify any potential challenges like methodological issues, resource constraints or modifications needed.

Remember that the process of conceiving a research idea is iterative, and it may take time and multiple iterations to develop a well-defined and promising research question. Be open to exploring new directions and adapting your idea as you progress through the research process.

Literature search and review

The process of finding and accessing current literature related to a specific topic or concern is referred to as a literature search, while the structured compilation of data from published studies is known as a literature review.[7] Literature searches serve various purposes, such as gathering data for evidence-based recommendations, as a phase in a research study, or as a component of academic evaluations.[8] Nevertheless, the major goal of an extensive literature review is to define the research hypothesis by analysing the current literature and identifying any gaps or deficiencies that may require further investigation or additional analysis. While literature searches might be tedious and exhausting, being focused and understanding the exact nature of the information sought can make the task easier. Two essential steps include formulating your research question and organising your search. PubMed is the most commonly used resource for literature searches, as many journals are indexed in PubMed and it is a freely accessible search engine. However, there are also other resources available for literature searches, although most of them require a subscription or payment. Detailed list of these resources and their website link are given in Table 1.

Formulating research hypothesis/question

Once the research topic has been chosen, the next step for the researcher is to develop a comprehensive research question or an overarching objective for the study, which can then be divided into more specific and focused research questions. Prior to formulating a research hypothesis, it is crucial to familiarise oneself with the chosen topic. This involves gathering sufficient information through reading articles, manuals, journals, or case studies, in order to narrow down and refine the topic into a research question. The study hypothesis is essentially the research question expressed in a concise single sentence.

Checking feasibility, novelty, ethical issues

Utilising the FINER architecture(feasible, interesting, novel, ethical, and relevant), research questions are created. When intending to address a research question, researchers must assess the immediate scientific and practical context. Researchers should also consider about the amount of money, time and effort they are ready to put in to a research project from conception through publication.

Table 1: List of resources and their websites for literature search.

Resource	Website link
Google	http://www.google.com
Google Scholar	http://www.scholar.google.com
Yahoo	http://www.yahoo.com
PubMed	https://www.nlm.nih.gov/pubmed
MeSH	http://www.ncbi.nlm.nih.gov/mesh
Medline (Medical literature analysis and retrieval system online)	https://www.nlm.nih.gov
CINAHL (The Cumulative Index to Nursing and Allied Health)	https://www.cinahl.com
Embase (ExcerptaMedica Database)	https://store.elsevier.com/embase
SCOPUS	https://www.scopus.com/
Ind Med: Indian Database	https://www.medind.nic.in
ERIC	https://www.eric.ed.gov
ProQuest	http://proquest.com
The Cochrane database of systematic reviews	http://www.cochranelibrary.com/
PubMed	http://www.ncbi.nlm.nih.gov/pubmed/
UpToDate	http://www.uptodate.com/online
Web of science	https://www.webofscience.com/

Deciding appropriate study design and methodology

Study design

When considering study design, it is important to recognize that there can be multiple suitable designs for the same research problem. The most relevant study design, however, is determined by how the research issue is phrased.[9] Generally, there are two broad categories of study designs: descriptive and analytical. Descriptive study methods are used to describe the distribution of variables, characteristics or traits of the population under investigation, such as through case studies or case series that examine unique cases or groups of cases. On the other hand, analytical study designs can be further divided into observational and experimental designs. Observational study methods (eg: Cohort, cross-sectional and case control studies) primarily observe and analyse changes occurring in the study participants without any experimental interventions. In contrast, analytical experimental study methods involve comparing two or more groups, where one group receives a new intervention and the other group receives a conventional treatment or serves as a control. Additionally, within the experimental design, samples are collected from the groups based on the specific comparison being made, such as comparing the same group before and after receiving the intervention or comparing different groups receiving different interventions. Detailed classification of study designs is depicted in Figure 2.

Sample size calculation

The process of calculating the number of participants needed for a study to assure accurate representation of the target population is known as sample size estimation. Selecting an optimal sample size is a critical aspect of statistical analysis. Insufficient sample size can lead to reduced statistical power resulting in unreliable results and fail to accurately capture the characteristics of the population being studied. Conversely, an excessively large sample size can significantly escalate the costs and duration of the research.[10] Below formula can be used to compute sample size.

$$Sample\ size = \frac{(Z-score)^2 \times Standard\ deviation\,(SD) \times (1-Standard\ deviation\,(SD)}{(Confidence\ interval)^2}$$

Confidence intervals (margin of error) describe how certain or unsure a sampling technique is, as well as how uncertain each given statistic is. The standard deviation describes how much a collection of data deviates from the mean.

Sample size calculation requires careful consideration of various factors, such as the desired level of confidence, margin of error, and variability in responses, depending on the type of research technique. The confidence level and margin of error together determine the precision of the estimate; a higher confidence level or smaller margin of error requires a larger sample size. Sample size formulas differ by study objective—for example, estimating a proportion versus comparing two groups—and require careful consideration of factors such as variability and power. Among the most commonly used free software for sample size calculation are OpenEpi by Emory University, Rollins School of Public Health, StatCalc tool in Epi Info™ by Centre for Disease Control and Prevention (CDC), RStudio and EpiTools.

Sampling methods

Probability and non-probability sampling techniques are the two main categories of sampling techniques. The sampling techniques that use probability are those where likelihood of an eligible participant to take part in the study is already known or can be calculated, Whereas non-probability methods are the techniques where possibility of taking part in the study cannot be calculated. Probability methods are

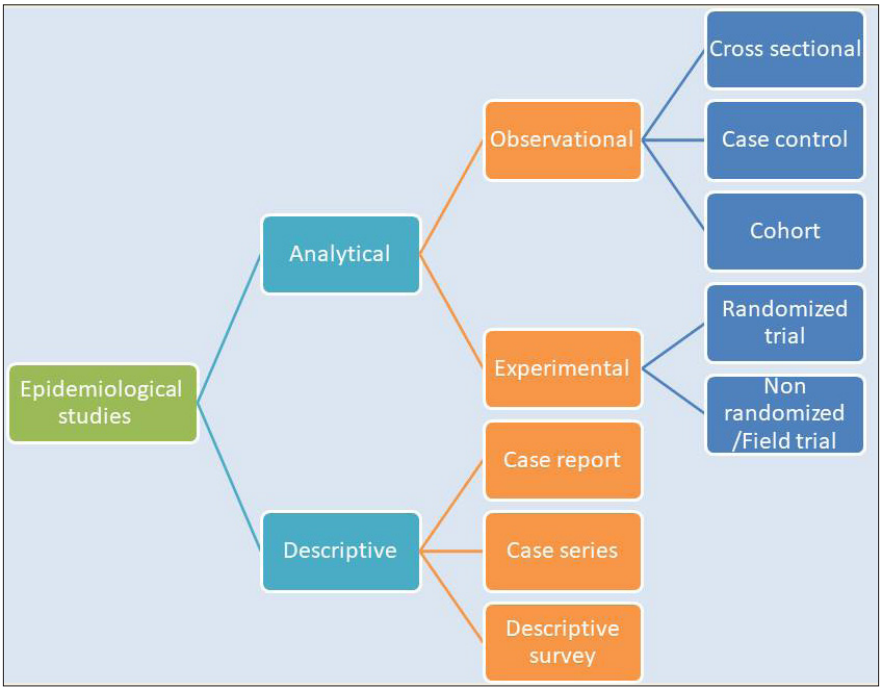

Figure 2: Classification of the study designs.

more chosen because the study's findings can be applied to the population under study, where as that extrapolating is not possible with non-probability sampling methods. In general, most of the community-based studies will be using probability sampling methods and hospital-based studies will use non-probability sampling methods.

Inclusion and exclusion criteria

The target population's eligibility to take part in a research study is determined by inclusion and exclusion criteria, which are also known as eligibility criteria.[11] The qualities that potential research participants must have in order to be taken into account for the study are referred to as inclusion criteria. Common inclusion criteria include geographic, clinical, and demographic factors. Exclusion criteria comprise qualities used to identify possible research subjects who shouldn't be enrolled in a project as they can potentially affect the outcome of the study. Common exclusion criteria include participants who do not give consent to participate, properties of eligible individuals that make them more likely to be lost to follow up, miss scheduled data collection appointments, submit erroneous data, possess comorbid confounding factors that could skew the research outcome.[11]

Methodology

A method of systematically addressing the research question is known as research methodology. The methods you followed for gathering and analysing data are detailed in the research methodology. It can be considered as a field of study that emphasises on how scientific research is undertaken.[12]

Data collection

The process of gathering, assessing, and interpreting specific research-related information using accepted, established methods is known as data collection. Regardless of the research field, gathering data is generally the initial and most critical step. Depending on proposed research issue, the investigator will select which methods to use for collecting data. Surveys, interviews, focus groups, textual and content analysis, observations, record reviews, and biological samples are a few ways to collect data.[13]

Selection of appropriate statistical methods

Choosing the correct statistical test is a key component of a well-designed research proposal, as inappropriate methods can compromise data interpretation and study conclusions. The selection should be guided by the study objectives, the type and distribution of data, and whether observations are paired or unpaired. Descriptive statistics are used to summarize data, while inferential statistics apply appropriate tests of significance to draw conclusions.[14] Although statistical software has simplified analysis, careful selection of suitable tests remains essential, highlighting the need for basic biostatistical knowledge or early expert consultation.

Writing research proposal

The proposal serves as a “proper outline” or "template" for the planned analysis, therefore once it is finalised, the proposed research should continue ahead without any difficulties. A research proposal's format and content are often provided by the institution or the review committee, depending on their specifications.[15] A title page should typically include the following data- the title of the project, the names of the first author and co-authors, the degrees of the investigators, and the name of the institution where the research will be carried out and communication details such as contact numbers, mail address. The major body of the research proposal may be divided into the following sections: background and rationale, review of related literature, research question or hypothesis, aims and objectives, research methodology, ethical issues, plan of work and timeline, funding, and bibliography.

Applying for funding

Research funding is a subsidy granted for doing a research, frequently secured through process of contest. The ability to undertake the research study successfully depends on both the researcher's work and the infrastructure that is accessible. If the researcher or institution has the required infrastructure, many research initiatives can be carried out without the need for additional funding.[16] It may not be possible to undertake the study within the resources of the department or institution when projects like multi-centric studies, randomised controlled trials, experimental studies, or observational studies with high sample sizes are planned, and a source of outside financing is required. Ordering tests for study purpose that do not truly benefit patients or are not part of standard treatment is unprofessional. For the successful completion of research initiatives as well as to cover these costs, funding is required.[16] Due to a lack of funds, many brilliant ideas never become successful research projects. Currently there are multiple funding opportunities available for Medical Researchers beginning from Medical Students onwards. To promote the research aptitude among Indian Medical students (MBBS & BDS students), Indian Council of Medical Research has been offering the stipend in the form of Short Term Studentship (STS) since 1979.

Obtaining IRC approval

Proposal in the prescribed format has to be sent to Institute Research Committee (IRC) and will be checked for scientific rigor of the article. If the methodology is appropriate to the research question, IRC approval will be obtained and then the proposal should be processed for IEC approval. If any corrections are needed, the committee will suggest the corrections and after the corrections approval will be obtained.

ETHICS IN BIOMEDICAL RESEARCH

Ethical principles form the foundation of biomedical research and are essential for safeguarding the rights, dignity, and welfare of research participants. Core ethical principles like autonomy, beneficence, non-maleficence, and justice guide the design, conduct, and reporting of research. All studies involving human participants should receive prior approval from an Institutional Ethics Committee and adhere to national and international ethical guidelines. Informed consent, confidentiality of participant data, and protection of vulnerable populations are critical ethical requirements. Researchers must ensure transparency in methodology, disclose potential conflicts of interest, and maintain integrity throughout the research process. Ethical conduct not only protects participants but also enhances the credibility and societal trust in biomedical research.

Obtaining IEC approval

Proposals will be submitted to the Institute Ethics Committee (IEC) in the appropriate format for consideration of their scientific quality and to ensure that subjects are protected from unneeded research hazards, the IEC will assess all subject recruiting protocols, with a focus on women, children, and healthy volunteers who will serve as controls. A thorough proposal must be submitted along with the appropriate Participant Information Sheet (PIS) and Participant Informed Consent Form (PICF) in both English and the local language. Generally, scheduled IEC meetings will happen every 1 to 2 months with a panel comprising of both Medical and Non-Medical personnel and Principal Investigator (PI). The proposal will be discussed and will be given approval certificate/review for corrections. If given for review, the proposal after the necessary corrections will be discussed in the next meeting and approval certificate will be given. After receiving the IEC approval only the data collection should be started.

Data collection

It is the process of gathering and evaluating information on relevant parameters in a defined and planned manner that makes it possible to address given research problems, test hypotheses, and assess results.[17] Data gathering is a difficult task that requires meticulous planning, determination, dedication, and a many other abilities in order to be efficiently executed. The first step in data collection is defining the type of data that is needed, that is followed by the choosing of a sample from a specified group. The data from the chosen

Table 2: Different types of techniques for collecting data used in Biomedical research.

Primary data gathering techniques	Secondary data gathering methods
Questionnaires	Books
Interviews	Journals/e- Journals
Observation	Magazines/Newspapers
Survey	Published printed/electronic sources
Focus group interviews	Letters
In-depth interviews	Data from government sources like national level surveys, Eg: NFHS data

sample must then be collected using a specific tool. The unpublished information that is collected directly from a source without being altered by anyone is the primary data, whereas the information taken from published sources is the secondary data, which means it has already been collected for another purpose and may be used for other scientific reasons.[17] Different types of Primary and secondary data collection methods are detailed in Table 2.

Performing statistical analysis and interpretation of data

The field of science that deals with acquiring, compiling, interpreting, and extrapolating data from samples to the entire population is statistics. Statistical analysis involves choosing of a suitable research sample, an appropriate research methodology, and acceptable statistical test. Using erroneous analytical techniques might lead to incorrect findings and malpractice. Data are summarised using descriptive statistics as mean, median, and mode which are the indices of central tendency.[18] The central tendency defines how closely the data cluster around a centre. Inferential statistics use a random data sample from a group of people to characterise and draw conclusions about the entire population. The term 'null hypothesis' in inferential statistics represents that there exists no association between the population variables being analysed. An assertion between the variables is said to be substantiated by an alternative hypothesis. The P value represents the likelihood of the circumstance occurring randomly if null hypothesis is correct. Parametric tests are used to evaluate numerical data (quantitative variables) which are distributed normally.[18] The Student's t-test, analysis of variance (ANOVA), repeated measures analysis of variance are among the most frequently utilised parametric tests. To assess whether there is a disparity between the means of two separate groups, the Student's t-test is carried out. ANOVA is utilised to assess if there is a substantial difference between the means of two or more groups. Non-parametric tests are used when the sample means do not follow normal distribution. Depending on how the variables are distributed, the Pearson or Spearman correlation test is used to assess the correlation between the variables. The association between variables in a sample or population is calculated using methods of Regression analysis. If the outcome or dependent variable is a quantitative variable, Linear regression analysis will be done and if the outcome variable is categorical, logistic regression analysis will be done. Different types of plots like histogram, bar chart, scatter plot, forest plot, etc., can be used for depicting the results of the study, depending on the distribution of variable, type of analysis, etc.,

Submitting report

Once the study is over, a detailed report is to be submitted to the funding agency, IRC and IEC in the stipulated time. Generally a period of three to six months will be given for the submission of report after the completion of the study.

Poster/paper presentation in conference

A research paper presentation at a conference can be intimidating for a beginner. You must select a suitable and genuine conference to write and present an abstract. The procedure for making a poster or paper begins with submission of abstract and getting approved by the conference research committee.[18] After that, they will segregate the submissions into those accepted for conventional poster presentations or oral paper presentations based on the significance of the topics.

Drafting manuscript

The most essential component of the article, is the abstract, is often missed and drafted improperly. A short, self - contained abstract provides a synopsis for the article and enables viewers in assessing if it is related to their project.[19] The abstract includes background and objectives, that must express the significance of the research, materials and methods to provide a short outline of the settings, design, variables to be measured, data analysis, the study results which should be brief, with an emphasis on the important findings and conclusions which should be concise but impactful.[20] The general structure of manuscript should include Introduction which should be brief, avoiding lengthy summaries of the research topic, better to follow the funnel pattern, i.e., begin with the less important aspects of the study topic, then the important aspect and finally emphasizing on the prevailing information gap, the research hypothesis, methods section details on the study's overall design, settings, sample size, inclusion and exclusion criteria, data collection, and analysis of data, statistical tests and software used, the results which

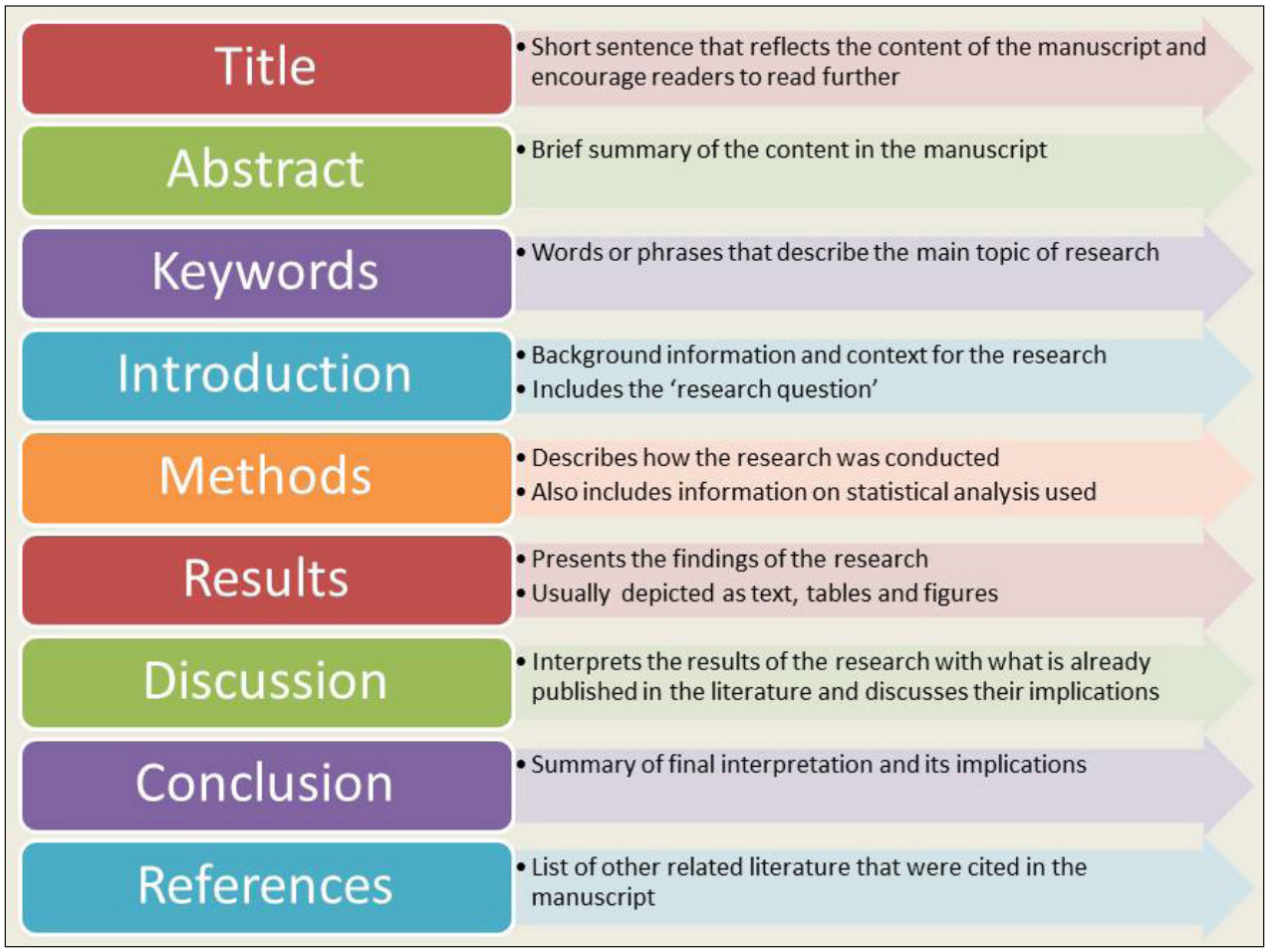

Figure 3: Picture representing general structure of manuscript.

express clearly and thoroughly the primary outcomes of the research, the discussion which gives a quick summary of the key findings with major emphasis on addressing the research problem. The subsequent sentences should focus on combining the results with existing knowledge from the literature. Citing the relevant prior original publications and similar studies that put the outcomes in context can help provide a fair categorisation of results of present study.[21] If there are any discrepancies between our observations and earlier research that has already been published, such resemblance and distinctions must be mentioned, the conclusion that outlines the information that the research has contributed, and the citations, which are often in the Vancouver format in scientific publications. Many freely and paid-for software applications like EndNote, Zotero, Mendeley, etc., exist that make it easier to cite sources and create bibliographies by providing information for various citation formats.[20] The best time to draft the manuscript is within 15 to 20 days of completion of the report/thesis. The more is the delay, the less are the chances of acceptance of manuscript by a good journal. General structure of the manuscript is given in Figure 3.

Submitting to journal for publication

Reading the criteria and limitations of journals in your chosen research subject is the next step, once the manuscript is written. Choosing the right journal for your paper can greatly enhance your likelihood of approval and make sure that it will be viewed by your intended users. The manuscript should be accompanied by a strong cover letter which should emphasise three key points the fundamental concept of the article, its uniqueness or innovation, and the suitability of manuscript to the selected journal.

AUTHORSHIP AND CONTRIBUTION

Authorship in biomedical research should be based on substantial intellectual contribution and accountability for the work. According to the International Committee of Medical Journal Editors (ICMJE), authorship credit should

be granted only to individuals who meet all four criteria: (1) significant contribution to the conception or design of the work, or acquisition, analysis, or interpretation of data; (2) drafting the article or critically revising it for important intellectual content; (3) final approval of the version to be published; and (4) agreement to be accountable for all aspects of the work, ensuring accuracy and integrity.[22] Individuals who contribute in a limited manner, such as providing technical support, funding, or general supervision, should be acknowledged but not listed as authors. Adherence to transparent authorship criteria helps prevent disputes, gift authorship, and ghost authorship, thereby upholding research integrity.

PLAGIARISM AND RESEARCH INTEGRITY

Plagiarism represents a serious breach of research integrity and undermines the credibility of scientific scholarship. It includes the unauthorised use of another individual's ideas, text, data, or images without appropriate acknowledgment, as well as self-plagiarism through redundant or duplicate publication. In biomedical research, plagiarism can distort the scientific record and erode public trust. Researchers are responsible for ensuring originality in their work, appropriately citing all sources, and adhering to journal and institutional policies on academic integrity. The use of plagiarism detection tools, proper paraphrasing, and accurate referencing are essential preventive measures. Promoting awareness and education on ethical writing practices is crucial for fostering a culture of honesty and accountability in biomedical research.

CONCLUSION

Biomedical research is inherently a collaborative endeavour, and successful completion of research projects requires effective teamwork, strong interpersonal skills, and sustained commitment. Although research during undergraduate medical training may initially appear challenging, it offers a valuable and intellectually rewarding complement to routine academic learning. When undertaken with adequate time, genuine interest, and perseverance, undergraduate research can significantly enhance professional development. Historically, contributions by medical students have played a meaningful role in advancing medical knowledge, underscoring the importance of early exposure to research. A clear understanding of research methodology and the tangible benefits of scholarly engagement is therefore essential for motivating students.

The biomedical research process spans from the conception of an idea to the dissemination of findings through publication in reputable journals. While this journey may be demanding and time-intensive, its educational and professional rewards are substantial. Participation in research under the guidance of experienced mentors and within supportive teams fosters critical thinking, ethical practice, and lifelong learning skills. Despite initiatives by government, institutions, and medical schools to promote research, enthusiasm among medical students and healthcare professionals remains limited. Identifying and addressing the underlying barriers to engagement is crucial for cultivating a robust research culture and ensuring the continued advancement of evidence-based medical practice.

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