
Barriers to Effective Biostatistical Learning in Medical Colleges and Strategies for Improvement

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Abstract

Background:

Biostatistics is a critical component of medical education, essential for evidence-based practice and clinical decision-making. However, many medical students face significant challenges in learning biostatistics, which impacts their ability to apply statistical reasoning effectively in clinical and research settings. This study aimed to explore the barriers to effective biostatistical learning and identify strategies for improvement among medical students at King Faisal University.

Methods:

A cross-sectional study was conducted among 563 medical students at King Faisal University. Data were collected using a structured, self-administered questionnaire that assessed demographic information, barriers to learning biostatistics, attitudes toward the subject, and preferred teaching strategies. Quantitative data were analyzed using descriptive and inferential statistics, while qualitative data from open-ended questions were analyzed thematically.

Results:

The most significant barriers identified were perceived irrelevance of biostatistics to clinical practice (62.5%), inadequate foundational knowledge in mathematics (58.8%), and ineffective teaching methods (54.7%). Anxiety and fear of the subject were reported by 32.1% of students. Preferred teaching strategies included problem-based learning (72.5%) and case-based teaching (68.6%). Despite access to statistical software, only 38.4% of students felt confident using these tools.

Conclusion:

The findings highlight the need for curriculum reforms, practical teaching approaches, and better integration of biostatistics into clinical contexts. Addressing these barriers and adopting student-centered strategies can enhance learning outcomes and equip students with essential analytical skills for evidence-based medicine.

Keywords:

Biostatistics, medical education, barriers, teaching strategies, evidence-based medicine

Introduction

Biostatistics is a cornerstone of evidence-based medicine and a critical tool for understanding, interpreting, and applying scientific data in healthcare. Its significance spans various areas, including clinical research, public health decision-making, and the evaluation of therapeutic interventions. Despite its pivotal role in modern medical education and practice, teaching and learning biostatistics in medical colleges often encounter significant challenges. Addressing these barriers is essential for preparing competent healthcare professionals capable of interpreting data critically and applying statistical reasoning to clinical and public health problems.

The increasing complexity of medical science and the shift toward evidence-based practice necessitate a solid understanding of biostatistics among medical professionals. Effective use of biostatistics enables clinicians and researchers to evaluate the validity of studies, assess the strength of evidence, and make informed decisions about patient care. This importance is reflected in global recommendations for integrating biostatistics into medical curricula as a foundational discipline [1]. However, despite these efforts, students often struggle to develop adequate competency in biostatistics due to various educational and systemic barriers.

One significant barrier is the perception of biostatistics as irrelevant or excessively abstract. Medical students, whose primary focus is clinical practice, frequently fail to see the connection between statistical concepts and their application in patient care [2]. This disconnect often results in a lack of motivation to engage with the subject, leading to superficial learning and limited retention of key concepts. Research has shown that integrating statistical education with practical clinical scenarios can help bridge this gap, yet such approaches are inconsistently implemented across medical colleges [3].

Another challenge stems from inadequate foundational knowledge in mathematics and statistics. Many

students entering medical schools have diverse academic backgrounds, and not all have prior exposure to mathematical concepts essential for understanding biostatistics. This variability in preparation creates a steep learning curve, particularly when students are introduced to advanced statistical methods without adequate scaffolding [4]. Addressing this issue requires targeted interventions, such as preparatory courses or supplementary resources, to strengthen students' foundational knowledge.

Teaching methods also play a critical role in shaping students' engagement and learning outcomes. Traditional approaches to teaching biostatistics often rely on lectures and theoretical explanations, with limited emphasis on practical applications or interactive learning. Such methods fail to capture students' interest and may contribute to the perception of biostatistics as a dry and difficult subject [5]. In contrast, active learning strategies, including problem-based learning, flipped classrooms, and group discussions, have been shown to improve students' understanding and attitudes toward biostatistics [6]. These methods not only enhance comprehension but also foster critical thinking and collaborative skills.

The availability of resources and access to modern tools for data analysis also significantly impact the learning experience. Many medical colleges lack adequate infrastructure, including statistical software and well-designed course materials, to support effective biostatistics education. In an era where data analysis tools like R, SPSS, and Excel are indispensable for research and practice, insufficient exposure to these tools can hinder students' ability to apply their statistical knowledge [7]. Additionally, outdated curricula that fail to address contemporary advancements in biostatistical methods further exacerbate the problem.

Time constraints within medical education are another factor that hinders effective biostatistics learning. Medical students are required to cover extensive curricula within limited timeframes, often prioritizing

clinically oriented subjects over foundational disciplines like biostatistics. This lack of dedicated time and focus on statistical education not only limits students' learning but also undermines the importance of biostatistics in medical practice [8]. Strategies to integrate statistical learning into clinical rotations and research projects can mitigate this issue by embedding biostatistics within the broader context of medical education.

Faculty expertise is another critical determinant of the quality of biostatistics education. Effective teaching requires instructors who not only possess a deep understanding of statistical methods but also the ability to contextualize these methods within medical applications. However, some medical colleges face challenges in recruiting or training faculty with adequate expertise in both biostatistics and pedagogy [9]. This gap underscores the need for continuous faculty development programs and interdisciplinary collaborations to enhance the teaching of biostatistics.

Students' attitudes and anxieties about biostatistics also play a significant role in shaping their learning experiences. Negative attitudes toward statistics, often rooted in fear of mathematics or prior negative experiences, can create a psychological barrier that prevents active engagement with the subject. These attitudes are often compounded by teaching methods that fail to address students' concerns or provide sufficient support [10]. Interventions such as mentorship, peer learning, and confidence-building exercises can help alleviate these anxieties and foster a positive learning environment.

To address these challenges, several strategies have been proposed and implemented with varying degrees of success. Integrating biostatistics into clinical practice and research activities, using case-based learning, and leveraging modern technology are among the most effective approaches. For example, the use of real-world datasets and case studies not only enhances students' understanding of statistical concepts but also highlights their relevance to clinical decision-making [11]. Similarly, training faculty to adopt innovative teaching methods and utilizing e-learning platforms

can significantly improve the accessibility and quality of biostatistics education [12].

Methodology

Study Design and Setting

This study employed a cross-sectional design to explore the barriers to effective biostatistical learning and identify potential strategies for improvement among medical students. The research was conducted at King Faisal University, one of the leading educational institutions in Saudi Arabia. The study took place over a three-month period, during the academic year 2024. A cross-sectional approach was chosen for its efficiency in capturing data from a large number of participants within a limited timeframe, enabling a comprehensive understanding of the current state of biostatistics education at the university.

Study Population

The target population for this study included all medical students currently enrolled in the undergraduate medical program at King Faisal University. A total of 563 students participated, representing a diverse cohort across various academic years. Participation in the study was entirely voluntary, and students were informed about the purpose and nature of the research before providing their consent. By including students from different years of study, the research aimed to capture a wide range of perspectives on biostatistical education, from those in their early years with limited exposure to the subject to those in advanced years with more experience.

Sampling Method

Participants were recruited using a convenience sampling method. Announcements about the study were made through official university communication channels, including emails, student forums, and learning management systems. Additionally, faculty members were encouraged to inform students during lectures and tutorials to maximize awareness and participation. This approach ensured that the study reached a broad audience, while still maintaining the voluntary nature of participation.

Inclusion and Exclusion Criteria

The study included all medical students currently enrolled in the undergraduate program at King Faisal University who consented to participate. Students who did not complete the questionnaire in full were excluded from the analysis. Additionally, non-medical students or students enrolled in other faculties were not eligible to participate.

Sample Size Justification

The sample size of 563 students was deemed sufficient to provide a reliable representation of the medical student population at King Faisal University. This large sample size enabled the detection of statistically significant differences and ensured the generalizability of the findings to the broader student body.

Data Collection Tool

Data were collected using a structured, self-administered questionnaire developed specifically for this study. The questionnaire was informed by an extensive review of existing literature on barriers to biostatistical learning and the recommendations for its improvement. To ensure content validity and relevance, the questionnaire was reviewed and refined by a panel of experts, including biostatistics educators and medical education specialists.

The questionnaire consisted of four sections. The first section gathered demographic information, including participants' age, gender, academic year, and prior exposure to biostatistics. The second section focused on barriers to biostatistical learning, such as perceived difficulty, attitudes toward the subject, challenges related to teaching methods, and availability of resources. The third section explored potential strategies for improving biostatistical education, including preferences for teaching methods and suggestions for integrating biostatistics into clinical practice. The final section featured open-ended questions, allowing participants to provide additional insights or suggestions. Both closed-ended and open-ended questions were included to collect comprehensive quantitative and qualitative data.

To ensure the clarity and feasibility of the questionnaire, a pilot test was conducted with a sample

of 20 students from the target population. Feedback from the pilot test was used to refine the language, structure, and content of the questionnaire. The final version was distributed electronically using Google Forms, a user-friendly platform that facilitated efficient data collection.

Data Collection Procedure

The data collection process was conducted entirely online to accommodate students' schedules and encourage higher response rates. A link to the questionnaire was distributed via email and shared on the university's online platforms. Participants were given three weeks to complete the survey, with weekly reminders sent to enhance participation. The electronic format allowed for automated data capture and storage, ensuring accuracy and efficiency in the collection process.

Ethical Considerations

Ethical approval for this study was obtained from the Institutional Review Board (IRB) at King Faisal University. All participants provided informed consent electronically before accessing the questionnaire. The consent form included details about the study's objectives, the voluntary nature of participation, and assurances of confidentiality and anonymity. No personally identifiable information was collected, and responses were securely stored in password-protected files accessible only to the research team. These measures were taken to uphold the ethical standards of research and protect the privacy of participants.

Data Analysis

The quantitative data collected from the closed-ended questions were analyzed using descriptive and inferential statistical methods. Data were exported from Google Forms to Microsoft Excel and then imported into IBM SPSS Statistics (version 25) for analysis. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize participants' responses. For categorical variables, such as perceived barriers and preferred strategies, frequency distributions were generated to identify common trends.

Inferential statistics were employed to explore associations between demographic variables (e.g., gender, academic year) and perceptions of barriers to biostatistical learning. Chi-square tests were used for categorical data, while independent t-tests or ANOVA were applied to continuous variables. These analyses provided insights into how perceptions and attitudes varied across different subgroups within the study population.

Qualitative data from open-ended questions were analyzed thematically. Responses were reviewed independently by two researchers to identify recurring themes and patterns. A coding framework was developed, and data were categorized into key themes, such as challenges in teaching methods or suggestions

for curriculum improvement. Discrepancies in coding were resolved through discussion to ensure consistency and reliability in the qualitative analysis.

Results

Participants' Demographic Characteristics

A total of 563 medical students participated in the study, representing various academic years. Table 1 provides an overview of the demographic characteristics of the participants, including age, gender, and year of study. The majority of participants were aged between 20 and 24 years, with a nearly equal distribution between male and female students. The highest representation was from students in their third and fourth years, reflecting the structure of the medical program at King Faisal University.

Table 1: Demographic Characteristics of Participants

Variable	Frequency (n)	Percentage (%)
Age		
<20 years	75	13.3
20–24 years	423	75.2
>24 years	65	11.5
Gender		
Male	287	51.0
Female	276	49.0
Year of Study		
First Year	82	14.6
Second Year	101	17.9
Third Year	152	27.0
Fourth Year	144	25.6
Fifth Year	84	14.9

Perceived Barriers to Learning Biostatistics

Table 2 illustrates the major barriers identified by participants in learning biostatistics. The most frequently reported barriers were a lack of perceived relevance of biostatistics to clinical practice (62.5%),

inadequate foundational knowledge in mathematics (58.8%), and ineffective teaching methods (54.7%). A considerable proportion of students (45.3%) also indicated that insufficient time within the curriculum posed a challenge to learning biostatistics effectively.

Table 2: Perceived Barriers to Learning Biostatistics

Barrier	Frequency (n)	Percentage (%)
Lack of perceived relevance	352	62.5
Inadequate foundational knowledge	331	58.8
Ineffective teaching methods	308	54.7
Limited access to resources	224	39.8
Insufficient time in the curriculum	255	45.3

Anxiety or fear of statistics	181	32.1
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Attitudes Toward Biostatistics

Table 3 presents students' attitudes toward biostatistics. More than half of the participants (56.1%) reported that they found biostatistics moderately to very difficult. A significant proportion of students (47.8%) expressed a

neutral attitude toward the subject, suggesting ambivalence about its importance and utility. Only 18.1% of respondents indicated a positive attitude toward biostatistics.

Table 3: Attitudes Toward Biostatistics

Attitude/Perception	Frequency (n)	Percentage (%)
Perceived Difficulty		
Very easy	32	5.7
Easy	84	14.9
Moderate	142	25.2
Difficult	183	32.5
Very difficult	122	21.7
Overall Attitude		
Positive	102	18.1
Neutral	269	47.8
Negative	192	34.1

Preferences for Teaching Methods

Participants expressed preferences for various teaching methods to improve their learning experience in biostatistics. Table 4 shows that problem-based learning (PBL) and case-based teaching were the most

preferred methods (72.5% and 68.6%, respectively). Flipped classrooms and the use of statistical software for hands-on learning were also favored by a substantial number of participants (59.5% and 52.4%, respectively).

Table 4: Preferences for Teaching Methods

Teaching Method	Frequency (n)	Percentage (%)
Problem-based learning (PBL)	408	72.5
Case-based teaching	386	68.6
Flipped classrooms	335	59.5
Hands-on learning with software	295	52.4
Traditional lectures	181	32.1
Online tutorials	192	34.1

Accessibility of Resources

Table 5 outlines the availability and use of resources for learning biostatistics. While the majority of students (63.2%) reported access to statistical software

like SPSS and Excel, only 38.4% felt confident in using these tools effectively. This highlights a gap between resource availability and students' proficiency in utilizing them for practical applications.

Table 5: Accessibility and Use of Resources

Resource	Frequency (n)	Percentage (%)
Access to statistical software	356	63.2
Confidence in using software	216	38.4
Availability of study materials	289	51.3
Availability of workshops/training	178	31.6

Suggested Strategies for Improvement

Figure 1 shows that Students provided several suggestions for improving biostatistics education, summarized in Table 6. The most commonly suggested strategies were integrating biostatistics into clinical

practice (74.1%) and providing workshops to enhance foundational knowledge (68.2%). Many students also emphasized the importance of updating curricula to include relevant and engaging content (63.8%).

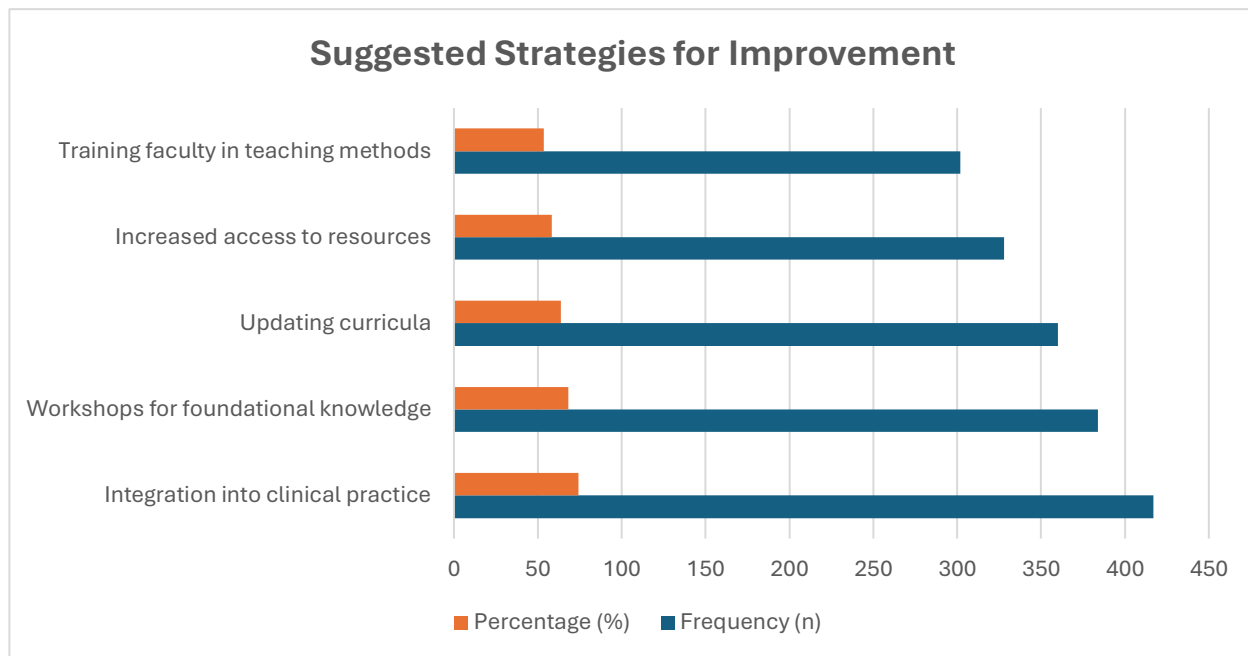


Figure 1. Suggested Strategies for Improvement

Discussion

This study explored the barriers to effective biostatistical learning among medical students at King Faisal University and identified potential strategies for improvement. The findings reveal significant challenges in the teaching and learning of biostatistics, consistent with prior research. These challenges encompass perceived irrelevance to clinical practice, inadequate foundational knowledge, ineffective teaching methods, and limited access to resources. In addition, students expressed a strong preference for more practical and interactive teaching strategies. Addressing these barriers is critical to fostering a positive learning experience and equipping students

with the skills necessary for evidence-based medical practice.

A major finding of this study was the perception of biostatistics as irrelevant to clinical practice, reported by 62.5% of students. This aligns with previous studies that highlight the disconnect between theoretical statistical concepts and their practical applications in medicine [13,14]. Students often struggle to see the relevance of statistical methods to clinical decision-making and research, which diminishes their motivation to engage with the subject. Integrating biostatistics into clinical case studies and research projects may help bridge this gap, as such approaches contextualize statistical concepts within real-world

medical scenarios [15]. For example, teaching students how to interpret statistical results in clinical trials or epidemiological studies can demonstrate the practical value of biostatistics in improving patient care.

Another prominent barrier was inadequate foundational knowledge in mathematics, reported by 58.8% of participants. This issue has been widely documented in the literature, particularly among medical students who often lack prior exposure to quantitative disciplines [16,17]. Without a strong mathematical foundation, students may find it difficult to grasp complex statistical methods, leading to frustration and disengagement. Providing preparatory courses or workshops that focus on essential mathematical skills could mitigate this barrier. Additionally, adopting incremental teaching approaches that gradually introduce advanced concepts can help students build confidence and competence in biostatistics [18].

The study also found that ineffective teaching methods significantly hinder students' learning. Over half of the respondents (54.7%) reported dissatisfaction with traditional lecture-based teaching, which they perceived as overly theoretical and unengaging. Similar findings have been reported in other contexts, where passive learning methods fail to capture students' interest or promote deep understanding [19]. Active learning strategies, such as problem-based learning (PBL) and case-based teaching, were identified as preferred alternatives. These methods have been shown to enhance comprehension and critical thinking skills by encouraging students to apply statistical concepts to real-world problems [20]. For instance, a study by Sullivan et al. demonstrated that incorporating PBL into biostatistics courses significantly improved students' attitudes and performance [21].

Limited access to resources, including statistical software and training materials, was another barrier identified by students. Although 63.2% of respondents reported access to tools like SPSS and Excel, only 38.4% felt confident in using them effectively. This finding underscores the importance of not only providing resources but also ensuring that students are

adequately trained to use them. Hands-on training sessions and workshops can help students develop proficiency in data analysis, which is essential for both academic research and clinical practice [22]. Furthermore, integrating software training into the curriculum can ensure that students gain practical skills alongside theoretical knowledge.

Anxiety and fear of biostatistics, reported by 32.1% of students, further complicate the learning process. Such negative attitudes are often rooted in prior experiences with mathematics or statistics, leading to a lack of confidence and a mental block toward the subject [23]. Addressing this issue requires a supportive learning environment that encourages students to overcome their fears. Mentorship programs, peer-assisted learning, and personalized feedback can help students build confidence and reduce anxiety [24]. Additionally, simplifying the language used in teaching and avoiding unnecessary jargon can make the subject more accessible and less intimidating.

Students' preferences for teaching methods provide valuable insights into potential strategies for improving biostatistical education. The majority of respondents favored PBL (72.5%) and case-based teaching (68.6%), highlighting the demand for more interactive and application-focused approaches. These findings are consistent with evidence suggesting that active learning methods promote higher engagement and better retention of knowledge compared to traditional lectures [25,26]. Flipped classrooms, where students review materials independently before engaging in group discussions and problem-solving activities, were also well-received, with 59.5% of students expressing a preference for this approach. Such methods can maximize classroom time for interactive learning and ensure that students arrive prepared for in-depth discussions [27].

Interestingly, the study found that traditional lectures remain a preferred method for 32.1% of students, indicating that a one-size-fits-all approach may not be suitable for biostatistics education. Blended learning models, which combine traditional lectures with active learning components, may offer a balanced solution that caters to diverse learning preferences [28]. For

example, foundational concepts can be introduced through lectures, while practical applications are explored through PBL or case studies.

The study's findings also emphasize the importance of integrating biostatistics into clinical practice. Nearly three-quarters of respondents (74.1%) suggested that linking statistical education with clinical applications would enhance its relevance and utility. This recommendation aligns with calls for a more integrated medical curriculum that embeds biostatistics within clinical rotations and research activities [29]. For instance, teaching students how to calculate and interpret confidence intervals or p-values during clinical discussions can reinforce the practical importance of statistical reasoning.

Faculty expertise emerged as a critical factor influencing the quality of biostatistics education. Effective teaching requires not only a strong understanding of statistical methods but also the ability to contextualize these methods within medical practice. Faculty development programs that focus on both content knowledge and pedagogical skills can enhance teaching effectiveness [30]. Additionally, interdisciplinary collaborations between statisticians and clinicians can enrich the learning experience by providing diverse perspectives and expertise.

Despite its strengths, this study has limitations. The use of convenience sampling may introduce selection bias, as participants who are more interested in biostatistics might have been more likely to respond. Additionally, the cross-sectional design captures perceptions at a single point in time, limiting the ability to explore changes over the course of students' education. Future research could address these limitations by using longitudinal designs and random sampling methods to obtain more representative data.

In conclusion, this study highlights significant barriers to biostatistical learning among medical students, including perceptions of irrelevance, inadequate foundational knowledge, and ineffective teaching methods. It also underscores the need for practical, interactive teaching strategies and better integration of biostatistics into clinical practice. By addressing these

challenges, medical colleges can enhance the quality of biostatistical education and equip students with the critical skills needed for evidence-based medicine.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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