RESEARCH ARTICLE

Awareness about pharmacogenomics among medical students in a tertiary care institute of western Rajasthan

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ABSTRACT

Introduction: Pharmacogenomics, the study of genetic variations that influence drug responses, is a crucial component of personalised medicine. Despite its growing importance, integration into healthcare in India faces challenges, including limited awareness, restricted access to genetic testing, and inadequate infrastructure. This study aimed to assess knowledge and awareness of pharmacogenomics among undergraduate MBBS students at AIIMS Jodhpur. *Methods*: A cross-sectional survey was conducted in December 2024 using a self-administered, pre-validated questionnaire. The tool assessed sociodemographic details and pharmacogenomics knowledge. Descriptive statistics were performed using SPSS version 21. *Results*: Of 358 students approached, 324 completed the survey (response rate: 90.5%). The mean age was 19.6 years, and 71.9% of the participants were male. Most participants were aware of the basic concept (85.8%) and professional relevance (85.2%) of pharmacogenomics. However, knowledge gaps were evident: only 60.8% were aware of the USFDA pharmacogenomic labelling requirements, and 59% believed it could reduce drug development costs. While 80.9% supported its role in diagnosis and treatment, just 71.3% favoured its inclusion in the MBBS curriculum. *Discussion*: The findings indicate that students possess a strong foundational understanding of pharmacogenomics but have limited awareness of its clinical, regulatory, and economic implications. Similar studies from India and abroad highlight comparable gaps, underscoring the need for structured education. Integrating pharmacogenomics into undergraduate curricula through case-based modules and CME sessions could bridge deficiencies and enhance preparedness for precision medicine. Medical students demonstrated good baseline knowledge but lacked deeper insights. Strengthening curricular integration is crucial for equipping future clinicians to effectively apply pharmacogenomics in practice.

Keywords: Drug Safety, Pharmacogenomics, Personalised Medicine, Medical Education.

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INTRODUCTION

Genetic factors were initially identified as influencing pharmacological responses over a century ago. Some people had unexpected and occasionally severe adverse drug reactions (ADRs) to medications like isoniazid and primaquine.[1,2] These unconventional reactions resulted in the development of what is now referred to as pharmacogenomics. Drug therapy is typically intended for the entire population. However, pharmacogenomics concerns how an individual responds to a specific medication, which is influenced by genetic diversity.[3]

Over time, pharmacogenomics has developed into a crucial element of personalised treatment.[4] It offers a more thorough account of inter-individual variability in medication response by fusing genomic science with knowledge from pharmacokinetics and pharmacodynamics.[4,5] Based on genetic variations that affect medication absorption, metabolism, distribution, and target receptor sensitivity, it allows physicians to customise pharmacological therapy.[6,7] This method enhances therapeutic interventions' efficacy and safety while possibly reducing the trial-and-error component of medication prescription.

The clinical relevance of pharmacogenomics is increasingly recognised in modern medicine. Today, the United States Food and Drug Administration (USFDA) includes pharmacogenetic information on the labelling of approximately 100 drugs.[8] This information can be found in various sections of the medicine labels, including Indications and Usage, Dosage and Administration, and Warnings and Precautions, and will assist clinicians in making informed decisions.[9] For certain drugs, such as trastuzumab, cetuximab, and maraviroc, pharmacogenomic testing is not only recommended but also required prior to prescribing to ensure optimal patient outcomes and minimise the risk of ADRs.[10] These regulatory measures reflect a growing trend toward precision medicine,

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which seeks to deliver the right treatment to the right patient at the appropriate dose.

India, with its immense sociocultural and genetic diversity, offers a unique opportunity for exploring population-specific pharmacogenomic variations. Numerous regional and ethnic genetic variations have been demonstrated to influence the pharmacokinetics and pharmacodynamics of frequently prescribed medications.[11] These results highlight the need for tailored implementation techniques and studies specific to a given region. Despite its potential, pharmacogenomics has not yet been fully incorporated into Indian healthcare. Obstacles, including restricted access to genetic testing, limited infrastructure, and low awareness among healthcare professionals, continue to impede its advancement. [12]

Educating future healthcare providers is essential for bridging this gap. Pharmacogenomics has been incorporated into the curricula of medical, pharmacy, and public health programs by numerous academic and professional organisations worldwide. The International Society of Pharmacogenomics (ISP), for example, issued guidelines as early as 2005, advocating for the inclusion of pharmacogenomic principles in undergraduate medical education.[13] These initiatives are crucial to ensuring that the next generation of medical professionals has the knowledge and skills necessary to integrate genetic findings into their standard clinical judgment.

MATERIAL AND METHODS

A cross-sectional survey was conducted among all current undergraduate MBBS students at the All India Institute of Medical Sciences (AIIMS), Jodhpur. Students who were not present during data collection were excluded from the study. The study was conducted in the month of December 2024. The study was approved by the Institutional Ethics Committee (Ref. No. AIIMS/IEC/2024/5282). Confidentiality of participant identity was strictly maintained.

Data Collection Tool

A self-administered questionnaire in Google Forms was used, comprising two sections. Section I included sociodemographic details such as age, gender, and year of study, while Section II comprised a semi-structured questionnaire to assess awareness of pharmacogenomics. This questionnaire was adapted, with prior permission, from the Department of Pharmacology, Pt. JNM Medical College, Raipur, Chhattisgarh. The final version was prepared after making minor modifications to the original tool. The purpose of the study was clearly explained to the participants, and they were encouraged to respond sincerely. A link to the questionnaire was provided, and students were requested to complete it. Participation was entirely voluntary, and since the study aimed to include the entire population, no sample size calculation was necessary. Confidentiality was assured, and the assessment tool was completed in the presence of departmental faculty.

Statistical Analysis

Descriptive statistics were used to calculate the frequencies of categorical variables, and measures of central tendency and dispersion were applied to describe continuous variables. A *p-value* of <0.05 was considered statistically significant. Data were analysed using IBM SPSS version 21 for Windows (IBM Inc., Armonk, New York, USA).

RESULTS

Out of 358 questionnaires distributed, 324 students completed the survey, yielding a response rate of 90.5%. The mean age of participants was 19.58 ± 1.53 years. The majority of the respondents were male (Figure 1). A majority (69.8%) of participants had previously heard about pharmacogenomics (Figure 2).

Most students were aware of the definition (85.8%) and aims (85.5%) of pharmacogenomics. However, a considerable proportion lacked awareness regarding its key aspects. While 81.5% recognised that genetic variations in drug targets, metabolising enzymes, and transporters can affect drug therapy, 18.5% either disagreed or were unsure, indicating a notable gap in understanding the broader implications and applications of pharmacogenomics. A majority of students (73.8%) were aware that genetic variations influence the occurrence of haemolytic anaemia in individuals with G6PD deficiency, while 4.6% disagreed and 21.6% had no idea. Additionally, 71% agreed that pharmacogenomics could help decrease the number of ADRs, yet 29% remained unsure

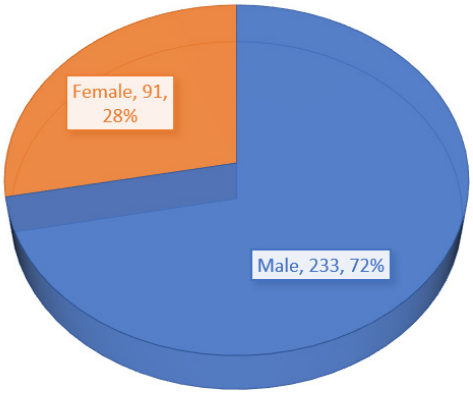

Figure 1: Gender-wise distribution of study participants

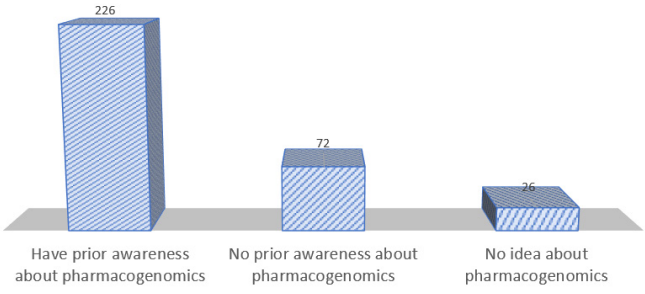

Figure 2: Prior awareness of pharmacogenomics among participants

or disagreed. Only 59% believed that pharmacogenomic knowledge could help reduce drug development costs, while 41% either disagreed or were unsure. Awareness of its regulatory relevance was also limited, with only 60.8% knew that the US FDA now requires genetic information on some drug labels, whereas 35.8% were unaware, and 3.4% were unsure. Furthermore, although 85.2% considered pharmacogenomics relevant to their profession and 80.9% believed it should be part of diagnosis and treatment, only 71.3% supported its inclusion in the MBBS curriculum, suggesting a potential gap in enthusiasm for formal education in this field (Table 1).

DISCUSSION

The study demonstrated a high response rate among participants of a relatively young cohort. A majority of students had prior awareness of pharmacogenomics and showed a good understanding of its basic definition and aims. However, deeper insights into its practical applications appeared limited. While many students recognised the role of genetic variations in drug response and disease susceptibility, there were noticeable gaps in understanding their broader clinical and economic implications. For instance, a significant portion of respondents were uncertain about the potential of pharmacogenomics to reduce adverse drug reactions and the costs associated with drug development. Awareness of regulatory aspects, such as the inclusion of genetic information on drug labels, was also suboptimal. Although most students acknowledged the relevance of pharmacogenomics to their future profession and its role in diagnosis and treatment, there was comparatively less support for its integration into the formal medical curriculum, indicating a need for enhanced educational efforts in this area.

Pharmacogenomics, an emerging field within precision medicine, examines how genetic variations affect individual responses to drug therapy. Most of the students in our study showed a solid grasp of pharmacogenomics and its practical applications. Nonetheless, certain knowledge gaps were identified, underscoring the need for enhanced educational initiatives in this area. This conclusion is consistent with earlier research that has found comparable deficiencies in pharmacogenomic understanding among students and healthcare professionals, underscoring the need for all-encompassing training initiatives. [14,15]

The majority of participants acknowledged the usefulness of pharmacogenomics in reducing ADRs, consistent with Malaysian research showing that 95% of students understood the importance of pharmacogenomics for medication safety. This widespread student recognition demonstrates the growing recognition of its importance in medical practice.[16] Several international organisations have emphasised the importance of integrating pharmacogenomics into health science curricula.[17-19] Evidence indicates that integrating pharmacogenomics into health science curricula significantly enhances students' understanding of its clinical implications. A scoping review of educational interventions in pharmacogenomics found that such programs are beneficial for healthcare students, as they improved knowledge acquisition and confidence in pharmacogenomic data interpretation by 21 and 37%, respectively. [20] Despite these recommendations, many academic institutions still lack structured education in pharmacogenomics. Notably, the ISP recommended in 2005 that medical schools should include at least four hours of pharmacogenomics in their core curriculum.[13] In contrast, most UK medical schools currently allocate only 1 to 2 hours to the subject.[21] Our findings support the inclusion of comprehensive pharmacogenomics education in the Indian MBBS curriculum to bridge existing knowledge gaps.

Recent analyses of UK-based pharmacovigilance data have emphasised the potential of pharmacogenomic prescribing

Table 1: Responses to pharmacogenomics awareness questions

Questions	*Responses*		
	Yes, n (%)	*No, n (%)*	*No idea, n (%)*
Pharmacogenomics is the study of drug response in relation to human genetic variations	278 (85.8)	10 (3.1)	36 (11.1)
Pharmacogenomics aims at understanding the role of human genetic variations in drug safety	277 (85.5)	10 (3.1)	37 (11.4)
Genetic variations in drug targets, metabolizing enzymes, and transporters affect drug therapy	264 (81.5)	13 (4)	47 (14.5)
Genetic variations influence the occurrence of hemolytic anaemia in G6PD-deficient	239 (73.8)	15 (4.6)	70 (21.6)
Is the knowledge of Pharmacogenomics likely to decrease the number of ADRs?	230 (71)	22 (6.8)	72 (22.2)
Is the knowledge of Pharmacogenomics likely to decrease the cost of developing drugs?	191 (59)	71 (21.9)	62 (19.1)
Is Pharmacogenomics relevant to your profession?	276 (85.2)	9 (2.8)	39 (12)
Should Pharmacogenomics information be included in your MBBS curriculum?	231 (71.3)	50 (15.4)	43 (13.3)
Should Pharmacogenomics be part of diagnosis and treatment?	262 (80.9)	16 (4.9)	46 (14.2)
Genetic information is now a requirement for some drug labels, according to the Food and Drug Administration (FDA)	197 (60.8)	116 (35.8)	11 (3.4)

guidelines in significantly reducing ADRs. Of the more than 1.3 million ADR reports submitted to the UK's Yellow Card Scheme between 1963 and 2024, approximately 9% (115,789 cases) were associated with drugs for which pharmacogenomic guidance could have mitigated the risk of ADRs.[22] By tailoring drug therapies to individual genetic profiles, pharmacogenomics offers a promising approach to enhancing both drug safety and therapeutic efficacy.[22] In our study, the majority of participants expressed strong confidence in the role of pharmacogenomic information in reducing ADRs. Additionally, there was considerable support for integrating pharmacogenomic data into pharmacovigilance systems to improve clinical decision-making and patient outcomes.

Furthermore, most students believed that pharmacogenomics could help lower drug development costs, suggesting awareness of its broader economic implications. This perspective is reinforced by approximately 60% of participants who correctly identified that the USFDA mandates the inclusion of genetic information on the labels of certain medications. This reflects a solid understanding of the importance of genetic data in advancing personalised medicine.

Overall, these findings underscore the crucial role of pharmacogenomics in contemporary healthcare. Incorporating this field into medical education will not only improve students' preparedness for clinical practice but also promote safer, more effective, and economically sustainable therapeutic strategies.

CONCLUSION

According to this study, medical students have a strong basic understanding of pharmacogenomics, particularly its fundamental concepts. While they acknowledge its role in clinical practice, a clear gap is evident in their understanding of its practical, clinical, and regulatory implications. The limited support for its inclusion in the medical curriculum further underscores the need for targeted educational initiatives. To address this, pharmacogenomics must be systematically incorporated into medical education at all levels. Incorporating case-based learning modules is advised to improve clinical applicability. Regular continuing medical education (CME) sessions should also be instituted to ensure that current and future healthcare professionals stay up to date on the latest developments in this rapidly evolving field.

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CONTRIBUTION OF AUTHORS: CONCEPTUALIZATION

TK, GD, PA, VR, SA, SBV, RK, PT, JC; Study design - TK, GD, PA, VR, SA, SBV, RK, PT, JC; Data collection - TK, PA, SA, SBV, RK, PT, JC; Data analysis - VR, SA, SBV, RK, PT, JC; Manuscript drafting - TK, GD, PA, JC.

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PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.