

# Integrating Genomics into Psychiatry in India: A Narrative Review on Opportunities and Challenges

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## ABSTRACT

Genomic medicine is transforming psychiatry by revealing the genetic aetiology of mental illness. The diversity of India's population presents a singular opportunity to incorporate genomic information into psychiatric practice. This review discusses recent developments in psychiatric genomics, such as Genome-Wide Association Studies (GWAS), Polygenic Risk Scores (PRS), and pharmacogenomics, which facilitate more tailored mental health interventions. Pharmacogenomics promises to individualise treatments based on genetic profiles, whereas epigenetics and gene-environment interactions shed light on the biological underpinnings of mental health across various sociocultural settings. Genomic psychiatry in India has the potential to be applied in personalised medicine, early risk prediction, targeted therapies, and informing national mental health policy. Yet, the uptake of genomic psychiatry is hindered by infrastructure constraints, ethical as well as privacy issues, and the requirement of cultural competence. The proposed directions include increased research, combining genomic Learning Health Systems (gLHS), and use of Artificial Intelligence (AI) in predictive analytics. This review sums up with major recommendations for progressing genomic psychiatry in India through modifications in policy, funding for research, and public education efforts.

**Keywords:** Artificial Intelligence, Personalised medicine, Pharmacogenomics, Psychiatric genomics

## INTRODUCTION

Psychiatric disorders are complex by their very nature, resulting from a combination of genetic and environmental factors. Though genetic factors play a central role in the formation of the majority of mental health disorders, environmental factors, including stress, also take a significant role in triggering them. Evidence suggests that exposure to environmental stressors can induce long-lasting changes in gene expression, neural circuit function, and behaviour, with such maladaptive effects occurring along a continuum from developmental to adult exposures. [1]. Gene-environment interaction (G×E), the interplay between genetic predisposition and environmental influences, has been found in various mental disorders, such as depression, Attention-Deficit/Hyperactivity Disorder (ADHD), schizophrenia, and substance use disorders [2]. Genomic medicine, which is a new discipline, utilises a person's genetic data to inform medical decisions, including diagnosis, treatment choice, and prevention [3]. In psychiatry, genomic medicine promises much to facilitate patient care and outcomes [4]. Genomic disorders, caused by large rare deletions and duplications in regions of a specific chromosome, play important roles in several neurodevelopmental and psychiatric illnesses, including intellectual disability, autism spectrum disorder, and schizophrenia [5]. The use of genomic medicine within psychiatry focuses on using the genetic information to create more tailored treatments and ascertain patient groups with the highest chance of benefitting from certain interventions [4]. Incorporating psychiatric genomics into clinical settings presents unique challenges, particularly the potential for genetic essentialism to reinforce stigma, undermine patient autonomy, and overlook important socioeconomic and cultural factors influencing mental health [6]. In spite of these challenges, the incorporation of genomics into psychiatric practice may improve risk prediction, prevention, diagnosis, and treatment choice [7]. India which is characterised by a vast population exceeding 1.4 billion, diverse genetic backgrounds, and a relatively high prevalence of consanguinity (20-30% in certain demographics), the integration of genomic medicine presents a significant opportunity to enhance psychiatric care [8]. This potential is particularly pertinent given the substantial burden of psychiatric

disorders within the country. A meta-analysis indicates a prevalence of depression at approximately 12.4% and anxiety disorders at 11.6% [9]. Schizophrenia spectrum disorders exhibit a lifetime prevalence of 1.41% and a current prevalence of 0.42% [10]. Overall, any form of mental morbidity is estimated to affect 13.67% of the population over a lifetime and 10.56% currently [11]. These statistics highlight both the urgent need and the considerable potential for psychiatric genomics to inform more precise diagnostic, preventive, and therapeutic strategies within the Indian context. Genetic variants for psychiatric disorders have become an emerging area of focus for Indian research as a response to the heterogeneity of the Indian population's genes. Verma R et al., found novel mutations in the SYNGR1 and MLC1 genes in Indian patients with schizophrenia and bipolar disorder, which shed light on genetic mechanisms for the diseases [12]. India's distinctive genetic landscape, characterised by extensive diversity and relatively high rates of consanguinity, presents a unique opportunity for the application of genomic medicine in the field of psychiatry. However, this context also presents significant challenges, as the integration of genomic insights into clinical practice remains limited, resulting in a critical gap between research potential and practical application. This review aims to bridge this gap by critically analysing the current landscape, identifying key opportunities and barriers, and proposing culturally and contextually relevant strategies to foster the integration of genomics into Indian psychiatry

## Promise of Genomic Medicine Pertaining to Psychiatry

The Psychiatric Genomics Consortium (PGC) has played a pivotal role in elucidating the genetic basis of common mental disorders. On a global scale, such initiatives have significantly accelerated the identification of risk loci and deepened the understanding of the biological mechanisms underlying psychiatric conditions [13]. In contrast, genomic research in psychiatry within India is still in its formative phase, with current endeavours aimed at closing the gap between genetic findings and their practical clinical applications. The domain of Indian psychiatric genomic research is characterised

by initiatives to understand the impact of Rare Genomic Disorders (RGDs) on neurodevelopmental psychiatric disorders. These RGDs are associated with numerous psychiatric disorders and affect a broad range of developmental and cognitive processes. The Genes to Mental Health Network (G2MH) is involved in the collection, collaboration, and evaluation of large datasets that integrate genomics with dimensional psychopathology measures, possibly including heterogeneous Indian populations [14]. Interestingly, as the genomic work continues, there has also been an accompanying debate about the influence of global mental health activities on India's indigenous healing systems and Modern Biomedical model of psychiatry is seen as the true way to treat mental health, which has changed how therapy is done in traditional healing places [15]. In India, balancing modern science with traditional healing is a challenge. It is important to respect cultural practices while also allowing scientific research.

Studies on the genomics of mental illnesses in the Indian population, which is underrepresented in the global literature on psychiatric genomics, are desperately needed. This entails a more thorough examination of the polygenic foundation of mental disorders and the ways in which these genetic predispositions impact engagement with India's unique sociocultural context.

## Current Landscape of Genomic Research in Psychiatry

- 1. Genome-Wide Association Studies (GWAS):** Latest innovations in genomic tools, such as GWAS and Next-Generation Sequencing (NGS), have led to the identification of many genetic variants associated with psychiatric illnesses. For example, GWAS has identified more than 100 genomic loci implicated in schizophrenia with variants in genes like *DRD2*, *COMT*, and *DISC1* [16]. Correspondingly, genes involved in bipolar disorder have also been discovered through GWAS such as *ANKK3*, *CACNA1C*, and *ODZ4* [17]. GWAS have enabled the identification of variants in *SLC6A4*, *HTR2A*, and *BDNF* associated with Major Depressive Disorder (MDD), advancing our understanding of its genetic basis [18]. The GWAS have found that psychiatric conditions are a complex polygenic condition in which many genetic variants play a role in the risk of psychiatric conditions [19]. This polygenicity is implicated by a wide number of ordinary variants, all having a moderate individual effect that together influence susceptibility to psychiatric disorder [20]. GWAS have managed to pinpoint numerous common genetic variants associated with mental disorders, the majority of which influence multiple disorders. Crucially, (GWAS) have revealed that psychiatric phenotypes are highly polygenic, with a multitude of pleiotropic variants affecting their heritability [21]. Such complex genetic architecture defies conventional diagnostic groups and emphasises that psychiatric disorders demand a more complicated understanding. In addition, GWAS findings have emphasised the importance of neuronal biology, system-wide mechanisms, and early neurodevelopment in the pathogenesis of these conditions [21]. The GWAS have revolutionised psychiatric genetics, providing essential information about the genetic basis of mental illness. These analyses possess the potential to guide new therapeutic strategies, refine risk prediction, and even redefine diagnostic categories in psychiatry [21,22]. While sample sizes keep getting larger and analysing techniques become even better, GWAS are set to shed greater light on the intricate world of psychiatric genetics [20].
- 2. Between potential and limitations: the role of polygenic Risk scores (PRS) in psychiatric genomics:** The GWAS have pinpointed numerous genetic variants linked to psychiatric disorders, while PRS integrate this data to evaluate an individual's comprehensive genetic risk. PRS have shown

potential in mental health research for predicting the likelihood of various psychiatric conditions and associated behaviours as these scores represent an individual's genetic susceptibility [23]. Studies have explored their use in conditions such as autism, schizophrenia, and bipolar disorder, as well as related conditions like substance abuse and smoking [24,25]. However, despite these research efforts, the clinical implementation of PRS in psychiatry remains limited. The primary reason for this limitation is the poor predictive accuracy of current PRS models, which typically explain less than 3% of the variance in psychiatric phenotypes [26]. An investigation into schizophrenia, for instance, showed that PRS did not improve outcome prediction over what could be accomplished with conventional clinical phenotypes alone [27]. The use of this strategy is also fraught with difficulties, including the possibility of misinterpreting the results and the lack of population diversity in the data that is currently available [26,28]. PRS in psychiatry present both potential and challenges due to their current limitations in predictive accuracy. Despite being promising tools for indicating genetic susceptibility to psychiatric disorders, PRS exhibit poor predictive power because they explain only a small fraction of the heritable variance of these complex conditions. The primary reason for this is that psychiatric disorders are influenced by a multitude of genetic and environmental factors, making it difficult for PRS to capture the full genetic contribution needed for accurate predictions [29,30]. Furthermore, the datasets used to derive PRS often lack diversity, which can result in lower applicability across different populations, further limiting their clinical utility [31]. For PRS to become clinically viable, research suggests that they need to be integrated with other factors, such as environmental influences and clinical measures, to improve their predictive accuracy [29,23]. This integration approach could help tailor preventative strategies and optimise treatment decisions, ultimately enhancing patient care [29]. In spite of the challenges, most scientists are optimistic about the role of PRS in the arena of psychiatry [29].

As we perform more complete and diverse genetic investigations and refine our techniques, PRS may be a valuable instrument for genetic counselling, risk assessment, and treatment tailoring [29,31]. In the future, PRS would likely have to be employed in combination with other clinical, environmental, and lifestyle variables in order to really succeed in psychiatric practice [23,30].

However, due to genetic differences, European population PRS models may not be usable as such in Indian populations, pointing towards the need for datasets that are Indian-specific [32].

- 3. Pharmacogenomics: an approach towards personalised psychiatry:** Shifting from risk prediction to optimisation of treatment, pharmacogenomics is a promising component of genomic medicine in psychiatry. It delves into the ways that gene variations shape an individual's response to different medications, efficacy, and toxicity, potentially leading to more personalised and effective treatments [33]. Pharmacogenomics is guiding the use of antidepressants, antipsychotics and other psychotropics, largely due to advancements in understanding genetic influences on drug response [34]. These tests focus on key cytochrome P450 enzymes like *CYP2D6* and *CYP2C19*, which are critical for the metabolism of several psychotropic medications, as well as genes relevant to mood stabilisers and other psychiatric drugs [33,34]. Similarly, variations in the *HLA-B* gene, particularly the *HLA-B\*1502* allele, have been strongly associated with an increased risk of developing Stevens-Johnson Syndrome (SJS) when taking carbamazepine, an antiepileptic medication. The underlying mechanism involves the presentation of drug antigens by the *HLA-B1502* molecule to T cells, triggering an immune response that can lead to

SJS, characterised by severe skin reactions and potentially life-threatening symptoms. The HLA-B1502 allele serves as a genetic marker that predisposes individuals to this adverse reaction [35,36]. Margoob et al., investigated the Serotonin Transporter (SERT) gene polymorphism and its effect on Selective Serotonin Reuptake inhibitor (SSRI) response in depression and found genotype-dependent differences that may direct the selection of antidepressants [37]. A systematic review further highlighted that individuals carrying the s/s genotype of the 5-HTTLPR polymorphism tend to exhibit poorer clinical outcomes with SSRI treatment, with this effect being particularly pronounced among Caucasian populations, while the GENDEP project demonstrated that SSRI response may also be moderated by factors such as gender, age, and additional serotonergic markers [38,39]. These findings emphasise the potential of genotype-dependent differences in guiding antidepressant selection.

Pharmacogenomic testing in psychiatry is currently practiced globally, with increasing uptake particularly in North America and Europe, although adoption remains limited across many other regions. However, the adoption of pharmacogenomics in clinical settings remains limited due to barriers such as a lack of standardisation of genetic testing panels and the need for more comprehensive evidence to support clinical decision-making [34].

For India, the potential integration of pharmacogenomic testing in psychiatry holds promise to enhance the precision and efficacy of psychiatric treatments. The Indian mental health landscape is currently undergoing significant reforms, including transforming psychiatric institutions into research and training centres [40]. These reforms aim to modernise mental health care practices and could serve as a foundation for integrating advanced genomic technologies, such as pharmacogenomic testing. Implementing such testing could be facilitated by India's efforts to increase access to mental health services and modernise psychiatric care, potentially addressing treatment gaps and promoting personalised medicine [40].

Given the considerable genetic heterogeneity within the Indian population, pharmacogenomic research is increasingly recognised as a promising approach to reduce adverse drug reactions and optimise treatment response, reduce the trial-and-error approach common in psychiatric prescribing in highly prevalent psychiatric disorders such as depression and schizophrenia. Unlike phenotypic approaches, including Therapeutic Drug Monitoring (TDM) or clinical observation, which are dynamic and influenced by co-morbidities, dietary factors, and concurrent medications, genotyping offers stable and predictive insights into an individual's metabolic capacity and susceptibility to drug response or toxicity [41].

#### 4. Epigenetics and gene-environment interactions:

In addition to genetic variations, epigenetic factors add another level of sophistication to our comprehension of psychiatric disorders and treatment. Epigenetics deals with changes that influence gene expression but not the fundamental genetic code [42]. Environmental pressures such as stress, nutrition, early life experience, and exposure to toxic substances can introduce epigenetic modifications that increase the risk for the progression of various psychiatric disorders [43]. Studying gene-environment interactions in Indian populations can be helpful in uncovering the biological substrates of psychiatric disorders in heterogeneous sociocultural environments [44]. Heritable epigenetic changes can indeed influence the methylation of certain genes like NR3C1 and SLC6A4, which are stress-sensitive [45]. These epigenetic modifications, such as DNA methylation, are known to play a role in complex diseases by potentially mediating the effects of environmental factors. The methylation of these genes is related to psychiatric disorders, including schizophrenia, which is known to have both genetic and environmental components contributing to its pathogenesis [46].

In the context of schizophrenia, Deoxyribonucleic Acid (DNA) methylation changes have been associated with neural development and the disorder itself. Specific genes such as RELN (for Reelin, which is important for neuronal migration and synaptogenesis) have been highlighted, where hypomethylation is linked to decreased expression in schizophrenia [47]. Similarly, Catechol-O-methyltransferase (COMT), which is involved in the degradation of neurotransmitters, is another gene where DNA methylation may contribute to schizophrenia risk. Studies have shown that modulations in DNA methylation at specific CpG sites can impact treatment responses in psychiatric conditions, indicating a complex interplay between genetics, epigenetics, and environmental factors [47]. The integration of epigenetic studies with genomic knowledge can significantly contribute to the identification of DNA methylation patterns that serve as diagnostic markers, thus facilitating early intervention strategies. Additionally, DNA methylation provides insights into the epigenetic modifications that map onto biological pathways implicated in psychiatric conditions. This includes genes involved in neurotransmitter systems and responses to environmental and genetic risk factors [48]. By combining these advancements with 'Big Data' and analytical approaches, researchers anticipate creating biomarker panels that can be evaluated in real-life cohorts, leading to tailored treatment strategies for psychiatric disorders [47]. Hence, the collaboration of these scientific endeavours holds the potential to be transformative in the diagnosis, treatment, and early intervention of mental health disorders within the Indian context and beyond.

Pharmacoepigenetic therapies in psychiatry offer promise but face challenges in ensuring specificity of DNA methylation effects. Precision strategies, including nanoparticle/exosome-based delivery systems and genome-editing tools like CRISPR-Cas9, aim to enhance targeted action while minimising off-target risks [49]. However, rigorous research and clinical validation are essential to balance efficacy with safety.

### Potential Applications: An Indian Perspective

#### 1. Personalised medicine: a new era of treatment:

Genomic medicine is an attractive solution for improving psychiatric treatment in India, with the potential to enhance diagnosis, tailor treatment, and achieve better outcomes. The application of genomic technologies to psychiatry can revolutionise current diagnostic and treatment approaches. Methods like NGS and microarray technologies have made it easier to identify genetic variants associated with psychiatric disorders, which may result in more accurate diagnoses and personalised treatment plans for patients [50]. Personalised psychiatry aims to individualise treatment strategies according to the distinct traits of every patient, departing from the traditional one-size-fits-all model. This approach integrates a range of biomarkers, such as genetic, neuroimaging, and electrophysiology data, for improved diagnosis, treatment choice, and outcome projection. The goal is to improve the effectiveness of therapies while minimising adverse effects, and ultimately morbidity and mortality for psychiatric disorders [51,52]

Nonetheless, while there is the promise of personalised medicine in psychiatry, it faces certain challenges. The current psychiatric classification, which is marked by wide diagnostic categories and considerable biological heterogeneity within each category, generates a disconnection between sophisticated research possibilities and clinical practice [53]. In addition, concentrating on biologic factors only might prove insufficient, since psychiatric disorders encompass dynamic processes that have to be weighed in terms of phenomenological, psychological, behavioural, social, and cultural considerations [54]. As much as genomic medicine promises bright horizons, it presents certain challenges in India

as well.

Genomics-based prediction and risk stratification are difficult to implement because psychiatric genetics is highly polygenic and pleiotropic in nature [4]. Furthermore, based on genomic findings, the existing practice of Indian psychiatry depending so heavily on syndromic diagnosis might have to be re-evaluated.

The future of personalised psychiatry relies on the integration of clinical information with data from other sources of data, including proteomics, metabolomics, neuroimaging, and genomics [3]. However, a global approach is needed to truly advance personalised psychiatry, addressing the current bias against rich countries and combining studies for a variety of populations with diverse genomic profiles [55].

2. **Shaping national mental health policies:** For the proper use of genomics in psychiatric treatment, national health policies must address some key issues. These involve enhancing training of mental health practitioners in genomics, developing practice guidelines that include clinical, psychological, and social determinants, encouraging integrated models of care, and placing a high emphasis on patient engagement and informed consent [7]. Furthermore, policies must consider ethical implications, such as the risk of enhancing stigma through genetic essentialism, effects on patient autonomy, and the danger of distracting from social determinants of mental health [6]. National health policies regarding genomic medicine in psychiatry need to walk the line between the promise of personalised care and the need for responsible application. This may include supporting research to develop multivariable diagnostic or prognostic algorithms that combine genomic information with other predictors [4], as well as addressing structural and clinical issues to provide equitable access and ethical use of genomic technologies in mental health treatment [7].
3. **Community involvement for integrating genomic medicine in psychiatry:** Community involvement is important in enhancing psychiatric genetic testing acceptance in rural India because it tackles cultural, ethical, and practical issues involved in the provision of such services. Successful community involvement is important in carrying out field trials of genetic interventions because such studies have the potential to affect communities [56]. In rural India, with its cultural asymmetry between health workers and the general society, community involvement is even more essential to close this gap and promote acceptance of psychiatric genetic testing. Culturally sensitive psychiatric theory and clinical services are crucial to enhance the mental well-being of rural citizens who put their faith in India's biomedical network [57]. Notably, even though community engagement is becoming a part of different projects, it has questions about its genuineness and impact. In order to enhance psychiatric genetic testing acceptance in rural India, an effective community engagement strategy is required. Such a strategy must fulfil broadly accepted standards like timeliness, consent, information sharing, transparency, understanding, responsiveness, mutual understanding, inclusiveness, and respectfulness [56]. Furthermore, genetic counselling in the form of a discussion about genetic and environmental factors leading to disease aetiology and encouraging people to probe their ideas and phobias might prove to be an effective intervention to cut stigma and misunderstanding towards psychiatric disorder among rural dwellers [58].

## Challenges and Ethical Considerations

India's genetic diversity offers a unique opportunity for psychiatric

genomics research, with potential for significant global implications. The country's population structure, characterised by multiple endogamous groups and prevalent consanguineous marriages, has amplified founder effects and contributed to a high prevalence of recessive alleles [59]. This genetic isolation has resulted in a considerable burden of rare genetic diseases, including those with psychiatric manifestations.

Although the potential in India for applying genomic psychiatry is encouraging, there are certain challenges that have to be resolved for its proper implementation.

### 1. Infrastructure and resource limitations:

In India, genomic medicine integration in psychiatry faces significant challenges because of the lack of adequate genomic research infrastructure. Though there is a growing recognition of the revolutionary value of genomic and personalised medicine for healthcare systems to reduce morbidity, mortality, and healthcare costs [60], its implementation in psychiatric treatment in India is hindered by various factors. One major hurdle is the large-scale genomic research lacking advanced sequencing technologies and bioinformatics infrastructure [61]. Integrating clinical information with genomic data requires massive computing power and sophisticated AI algorithms. Yet, India's existing infrastructure might not be developed enough to handle the immense medical data volume and images required to design intelligent psychiatric diagnostic tools. Interestingly, even though there are efforts to revamp mental healthcare in India, e.g., transforming public psychiatric hospitals into "Centres of Excellence" to meet workforce demands [40], such reforms may not adequately address the demand for genomic research infrastructure. The focus on promoting greater access to mental healthcare through community-oriented approaches could inadvertently draw resources away from building up the technological infrastructure necessary for genomic work. In short, to overcome this challenge and maximise the promise of genomic medicine in psychiatry, India needs to invest in setting up an overall genomic research infrastructure. This would involve not just the procurement of advanced sequencing technologies but also the establishment of bioinformatics capacity, uniformly structured data representation, centralised knowledge repositories, and a strong clinical decision support system [62]. In addition, resolution of challenges like the scarcity of clinical and genomic data, diversity in datasets, and ethics will be critical to the effective use of genomic medicine in Indian psychiatry [61].

- **Educational Gaps Inadequate Training for Clinicians:** Most healthcare professionals are not trained in genomics and its clinical applications in psychiatry, causing confusion regarding the interpretation of genetic tests and integrating them into clinical work. There is an urgent need for education programs to enhance clinician knowledge of genomic medicine. **Public Awareness:** There is a lack of awareness amongst the public about the benefits and constraints of genomic medicine that can restrict patient participation and acceptability for genomic testing [63].

### 2. Ethical and privacy concerns

Genetic testing raises significant concerns about confidentiality, potential misuse of genetic information, and genetic discrimination [64].

- **Ethical and Social Issues: Stigma and Discrimination** Genomic medicine and Indian psychiatry are confronted with a range of ethical and privacy issues: The integration of genomic studies into psychiatric practice presents novel ethical issues. These involve informed consent, confidentiality, privacy, and the possibility that genetic essentialism may increase stigma against individuals with mental illness. There are also concerns regarding how genetic information would affect the clinician-patient relationship and therapy strategies [6]. Specifically

in the Indian context, there is a lack of ethical regulations regarding psychiatric studies [65]. This absence of well-defined regulations, combined with the swift development of technology, poses ethical challenges to researchers' responsibility to track unwanted effects, collect fully informed consent, maintain participant confidentiality, and provide clarity of machine learning models. Privacy and data security are significant issues, particularly with the growing application of large genetic databases and telemedicine in psychiatry [66]. Collection and utilisation of genetic data in large public data banks have the potential to redefine the conditions of entry into research and undercut long-standing ethical norms such as privacy and consent [66]. Cultural issues specific to India are also involved. The asymmetry of culture between broader society and health professionals and the bureaucratic character of Indian community psychiatry can result in rural community voices being "edited out" of mental health policies and practices. This poses ethical concerns regarding equal access and appropriate care in a culturally responsive fashion. Formulating mature, culturally-suitable ethical codes and promoting level playing fields towards access to mental health care needs to be placed on the priority agenda as such technologies are launched in the Indian scenario [67].

To accommodate diverse cultural perspectives, ethical frameworks should incorporate principle of inclusivity, adaptation, sensitivity, safety, and reciprocity [68]. This approach would ensure that genetic testing practices respect cultural traditions and beliefs while providing benefits to participants from various backgrounds. Additionally, integrating cultural neuroscience perspectives into psychiatric theory and practice can help address the complex interplay between culture, genetics, and mental health [69]. By embracing explanatory pluralism and considering multiple paradigms in psychiatric genetics ethical frameworks can better accommodate the diverse cultural perspectives on genetic testing and its implications for mental health care [68].

- **Other Barriers to Practice of Genomics in Psychiatry in India:** Despite the global momentum toward integrating genomics into psychiatric practice, there remains a significant dearth of region-specific literature addressing how this integration unfolds within the Indian context [7]. Most existing studies focus predominantly on Western populations, whose genetic diversity, healthcare infrastructure, and sociocultural frameworks differ markedly from those in India [70]. This geographical skew limits the generalisability of findings and overlooks the unique genetic architecture of the Indian population, which includes high endogamy, population stratification, and a wide array of ethnolinguistic groups [70]. Furthermore, while India's increasing investment in genomic research-exemplified by initiatives like the *GenomeIndia Project*- hints at untapped potential, there is little exploration of how these genomic datasets are being translated into psychiatric care [71]. There is also a lack of interdisciplinary discourse between psychiatrists, geneticists, policymakers, and bioethicists in India, hindering the development of actionable frameworks for genomic integration into mental health services. The challenges posed by limited awareness, resource constraints, and cultural perceptions of both mental health and genetic testing are underexplored in the current literature. Additionally, there is insufficient empirical research on the Ethical, Legal, and Social Implications (ELSI) of psychiatric genomics in the Indian context, especially in rural and marginalised communities [72].

**Future Directions:** Despite these challenges, the field of genomic psychiatry in India continues to evolve. Looking ahead, several key directions will shape its future development.

## Research Expansion

Conducting massive studies across Indian populations is crucial for the identification of novel genetic markers and enhancing predictive models. Multicentre efforts, such as the PGC, offer a platform for this purpose. The integration of gLHS in psychiatry presents an auspicious avenue for personalised medicine by integrating genomic data with clinical information to enhance patient care and outcomes. These systems are based on Electronic Health Records (EHRs), machine learning, and data analytics to provide personalised decision support for care delivery and management [70]. In psychiatry, gLHS can integrate pharmacogenomic data to support treatment decisions. Research has discovered several Single Nucleotide Polymorphisms (SNPs) associated with responses to treatments using antidepressants and mood stabilisers, which have the potential to guide medication selection. Application of gLHS in psychiatry could be through procedures like genetic testing for candidate gene variants, integrative analysis of multi-omics data, and creation of multivariable prognostic algorithms integrating genomic data with other clinical predictors [4,67]. But the application of gLHS in psychiatry is faced with challenges. Ethical considerations such as data privacy, transparency, and fair distribution of care must be met [73]. There are also challenges to be addressed in model validation, uncertainty quantification, and evidence of better patient outcomes [74].

To realise the complete potential of gLHS in psychiatry, one needs an integrated strategy, which combines biological indicators with psychological, behavioural, and social aspects of mental illness [75]. While gLHS possess high potential to contribute to precision psychiatry, application is dependent on resolving technical, ethical, and clinical challenges. Future research should emphasise future clinical trials, inter-disciplinary cooperation, and the development of clinically relevant management platforms that can be translated to practical healthcare settings [74,76].

## AI and Big Data: Transforming Research Potential

Leveraging AI and big data analytics can potentially and dramatically improve the impact of genomic studies in psychiatry. AI application to predictive analytics in genomic psychiatry is a growing area with potential to transform the treatment of mental illness in India. By identifying trends and risk factors in genomic data, AI-based predictive analytics helps prevent and diagnose diseases early, improving patient outcomes and lowering healthcare costs [77]. To improve treatment outcomes for conditions like MDD and bipolar disorder, AI technologies like machine learning and natural language processing analyse vast genomic data sets to identify genetic markers associated with psychiatric disorders [78]. However, there are many challenges facing the real-world implementation of AI in this field, such as data privacy, ethical concerns, and the need for thorough clinical validation [78]. The key elements of AI use in genomic psychiatry are its diagnostic accuracy, ability to handle intricate genomic data and enhanced risk prediction and diagnosis. Tailored treatment regimens are useful as they support tailored therapeutic strategies, aligning with individual drug responses [79]. Clinical decision support systems powered by AI are able to enhance drug management by considering genetic, clinical, and demographic information [78]. The application of AI for predictive analytics in genomic psychiatry has the potential to revolutionise mental health care in India by enabling early diagnosis, personalised treatment, and improved patient outcomes. As the discipline develops, it will be necessary to foster interdisciplinary research, enhance education among healthcare professionals, and increase research and development to maximise the benefits of AI in genomic psychiatry for the Indian population. To fully benefit from AI in genomic psychiatry for the Indian population, it will be crucial to advance research and development, enhance healthcare professional education, and promote interdisciplinary collaboration as the field continues to grow [79,80].

## CONCLUSION(S)

Genomic medicine in psychiatry offers significant potential to advance mental healthcare in India through personalised treatments, early risk prediction, and targeted therapies. The country's vast genetic diversity provides opportunities for discovering population-specific markers but also demands India-specific datasets and models. Key challenges include limited infrastructure, ethical and privacy concerns, and the risk of stigma and genetic essentialism. Moving forward, success will depend on expanding research, leveraging AI for predictive analytics, building clinician and public awareness, and ensuring culturally sensitive and ethically responsible implementation.

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